Korean J. Food & Nutr. Vol. 17. No. 3, 278～285 (2004)

THE KOREAN JOURNAL OF
FOOD AND NUTRITION
한국식품영양학회

The Optimized Formulas of Rye Bread on the Sensory Properties using RSM

†Kyung-Soohn Kwon

Department of Hotel Culinary Art and Nutrition, Sohae College

RSM을 적용한 관능 특성에 따른 Rye Bread의 최적 Formulas에 대한 연구

†권 경 순

서해대학 호텔조리영양과

Abstract

The effects of water, rye flour and vital gluten on the sensory properties of bread were studied by response surface methodology and sensory evaluations.

A response surface model was used to evaluate the effects observed and to determine the optimum variations for rye bread. The study included 12 combinations of the following independent variables : Water(57, 62, 67%), Rye flour(0, 10, 30, 50%), and Vital gluten(0, 1, 3, 5%). Bread quality attributes determined were specific volume, color, texture, appearance, taste, chewiness, moisture, overall. Rye bread specific volume, sensory evaluation values and Instrumental testing results were significantly affected by variety (water, rye flour and vital gluten).

Rye bread with a high specific volume was produced using water 67%, rye flour 10% and vital gluten 3%. Whereas, rye breads with a high overall sensory evaluation were water 62 %, rye flour 10 % and vital gluten 5%. And Specific volume predicted and overall preference also was shown high.

It was shown that the experimental design used provided information about the rye bread of variation of water, rye flour and vital gluten and can be a useful supplement to standardized and optimized formulas in rye bread making.

The results suggest that water, rye flour, vital gluten can be combined in rye bread making at various levels, contributing to optimize the functional properties of rye bread. These result represents that breads loaf volume related to directly consumer preference.

Key words: rye bread, water, rye flour, vital gluten, response surface methodology.

INTRODUCTION

Rye is used in bread making for sourdough bread, crisp bread, and mixed with wheat in the northern part of Europe[1,2]. In north American, rye bread is produced in many different forms to meet the demands of consumers[3]. There are both round and elongated loaves, baked with or without pans. North America rye bread recipes use a variety of minor ingredients in addition to the basic components of flour, yeast, salt, and water. There are four basic types of rye bread (for example : America rye bread, Sour rye bread, Pumper-nickel, and

† Corresponding author : Kyung-Soohn Kwon, Department of Hotel Culinary Arts and Nutrition, Sohae College, 832-1 Oryongdong, Kunsan, Jeonbuk 573-717, Korea.
Tel : 82-63-460-9240, Fax : 82-63-460-9316, E-mail : rachel@sohae.ac.kr

Sweet or pan rye) are produced in the united states[4]. Among these rye breads, American rye bread is a light rye bread with good grain and soft texture. It is usually made from a blend of 60~85% first or second clear wheat flour and 15~40% rye flour.

Especially in overall nutritional value, rye bread has some advantages over wheat bread[5]. Rye bread is higher in mineral and fiber content. A the protein is somewhat better in nutritional quality because of its higher lysine content. Rye is known as the cereal richest in pentosan content. Furthermore, rye has an advantage over wheat because of its higher content of dietary fiber, β-glucan, lignin, vitamines and minerals which are mixed into the dark flour and enrich the bread. Therefore, baking products made from the whole kernel contribute to the health of the consumers. Recently, awareness of the healthiness of rye bakery products has been increased by taking into account the presence of lignans and phytoestrogens defined as matairesinol secoisolariciresinol. Thus, it can be expected that rye bread will become more accepted as a healthy part of a daily diet. In general, baking tests can be classified as standard baking tests[6] or optimized baking tests[7]. The test baking procedure can also be designed to be optimized by response surface methodology and sensory evaluation. This technique has been applied to baking experiments to study the effects of varieties[8]. The present study was designed to examine the effects of varying of absorption, rye flour, and vital gluten on the sensory properties and specific volume and to determine the optimum variety for rye bread.

Response surface methodology and sensory evaluations were used to study the relationships between processing varieties, bread specific volume, and loaf characteristics.

MATERIALS AND METHODS

1. Materials

A commercial brand of light rye flour containing 8.8% moisture (Mennel Milling Co., Fostoria, OH), wheat flour 11% moisture and vital gluten(American Ingredients Co., Kansas City, Mo) were used for all samples.

2. Experimental Design[9]

The Sample experimental design shown in Fig. 1 shows how 11 experimental run(R) can cover the 48

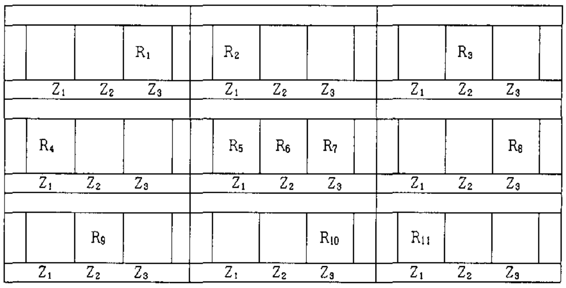

Fig. 1. Sample experimental design, showing how 11 experimental run(R) can cover the 27 possible combinations represented by three levels (1, 2, 3) of three different independent variables (X, Y, Z). The actual order of performing the 11 experimental run(R1~11) should be randomized.

Table 1. Experimental plots and compositions of materials for rye bread

Sample number	% rye flour	% gluten	% water
1	10	1	57
2	30	1	67
3	50	1	62
4	10	3	67
5	30	3	57
6	30	3	62
7	30	3	67
8	50	3	57
9	10	5	62
10	30	5	57
11	50	5	67
12	0	0	57

possible combinations represented by three levels (rye flour % : 0, 10, 30, 50 / vital gluten % : 0, 1, 3, 5 / water % : 57, 62, 67) of three different independent variables (rye flour, vital gluten, and water) is shown in Table 1. The actual order of performing the 11 experimental run (R1~11) should be randomized.

3. Experimental Methods

All breads were prepared by the optimized straight-dough bread- making method (AACC Method 10-10B)[10] as a Fig. 2.

Ingredients were mixed in a Hobart model A-200 mixer (Hobart Manufacturing Co., Troy, OH) to develop the dough(dough temperature, 27°C[80±1°F]).

Ingredients
↓
Dough(27±1℃)
↓
First fermentation (30℃, 85% RH, 90 min.)
↓
Dividing of dough
↓
Rounding
↓
Bench time (room temperature, 10 min.)
↓
Molding
↓
Second fermentation (40.6℃, 92% RH, 60m)
↓
Baking (215℃, 24min.)
↓
Cooling at room temperature

Fig. 2. Bread making processes by the optimized straight-dough.

The dough was fermented for 1hr 30min(30℃: 86°F, 85% RH), divided into two pieces, Sheet for punching and sheeting before molding(National Manufacturing Co), molded into loaves through a Pillsbury Moline bread molder (Pillsbury Co., Duluth, MN), proofed for 1hr (40.6℃ : 105°F, 92% RH), and baked for 24min at 215 ℃(419°F) in a reel oven (Reed Oven Co., Kansas City, MO).

Breads were removed from the pan, and cooled on a rack for at least 1hr at room temperature. Loaf volume was measured by the rape seed displacement method, and the specific volume was calculated as loaf volume / baked weight.

4. Analysis of the Physics and Chemistry

The experimental results analysed through RSM analysis, crumb firmness, crumb and crust color and pH of the rye bread.

1) RSM Analysis

A simple response surface methodology(RSM-plus) program was used to analyze all data. A pc compatible computer was used, and three independent variables could be analyzed, depending upon the data. Predicted responses and contour maps were obtained for all data sets[9].

Loaf volume was measured by the rape seed displacement method, and final volume was determined at this time. Specific volume was calculated as loaf volume / baked weight. Using RSM, predicted results are shown in Table 2.

Table 2. Effect of rye flour, gluten & water concentration on rye bread volume

Actual data volume by rye bread	% rye flour	% gluten	% water	Predicted data volume by RSM program
4.0750	10	1	57	4.4357
5.3460	30	1	67	5.4581
4.1800	50	1	62	4.3017
6.0950	10	3	67	6.1934
3.6260	30	3	57	3.7103
4.4490	30	3	62	4.5984
4.8200	30	3	67	4.8738
3.6800	50	3	57	3.4243
5.9080	10	5	62	5.8744
4.2300	30	5	57	4.2617
3.8760	50	5	67	3.9607
5.7800	0	0	57	5.1715

2) Crumb Firmness of the Rye Bread

Crumb character was determined according to American Institute of Baking Devore Systems, Inc., using Crumb Scan Software. Crumb firmness was measured with a consistometer (LFRA Texture Analyser, Stevens & Son Ltd, St. Albans, England). The small bread loaf size necessitated modifications in the sampling procedure for texture analysis. The top of the bread loaves was sliced off 2.5cm from the bottom and resistance to compression was measured on the bottom part of the loaves.

3) Crumb and Crust Color of the Rye Bread

Crumb and Crust color were determined by a Chroma Meter CR-200 (Minolta, Osaka,Japan) and L = lightness, a = redness, and b = yellowness were recorded.

4) pH of the Rye Bread

The pH was determined by AACC Method 02-52(Electrometric Method).

5. Sensory Evaluation of the Rye Bread

Breads for the sensory and instrument evaluation were wrapped in plastic bags and stored overnight at room temperature. Sensory evaluation of the bread was performed by 12 trained panelists(Kansas State University : Dept. of Grain Science, Graduate students) The samples (triplicates) were labeled with 3-digit random numbers. Quality of the bread was predicted by specific volume and by subjective appraisal of its grain, texture, taste and overall appearance. These numbers were used for statistical evaluation. For sensory evaluation, before serving, cuts were removed and each loaf was sliced into samples. To prevent drying, the samples were covered with plastic material until served. They were rated on a hedonic Scale ranging from 7(like extremely) to 1(dislike extremely).

6. Analysis of the Statistics

The results of experiment analysed using SAS Program and the Duncan's multiple range test. Crumb firmness, Sensory evaluation, crumb & crust color, and pH value are shown Table 3, 4, 5 and 6 respectively.

RESULTS AND DISCUSSION

A response surface model was used to evaluate the effects observed and to determine the optimum variations for rye bread. The relationships between the independent variables (water, rye flour, vital gluten) and response in volume of rye bread were described adequately with Instruments testing and sensory evaluations.

1. Analysis of Water, Rye Flour and Vital Gluten for Rye bread

The optimum variations for rye bread was obtained by RSM program are shown in Table 2 and Fig. 3∼5.

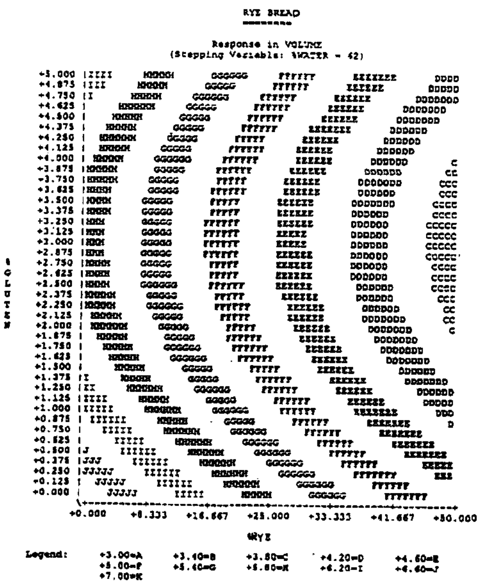

Fig. 4. Three-way RSM analysis. Contour Printout, showing the percentage of water, rye flour and vital gluten on the rye bread response in volume(%water:62).

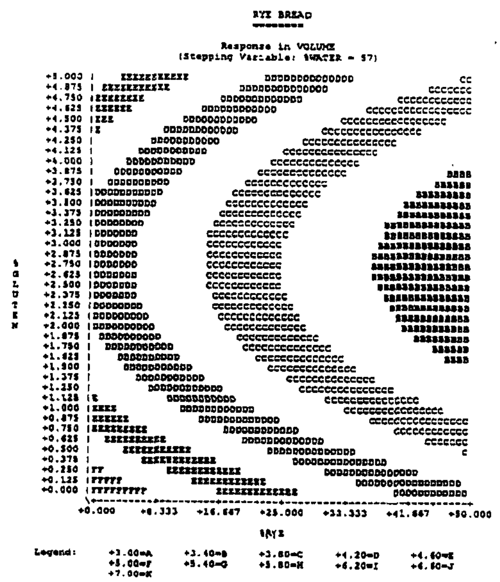

Fig. 3. Three-way RSM analysis. Contour Printout, showing the percentage of water, rye flour and vital gluten on the rye bread response in volume(%water:57).

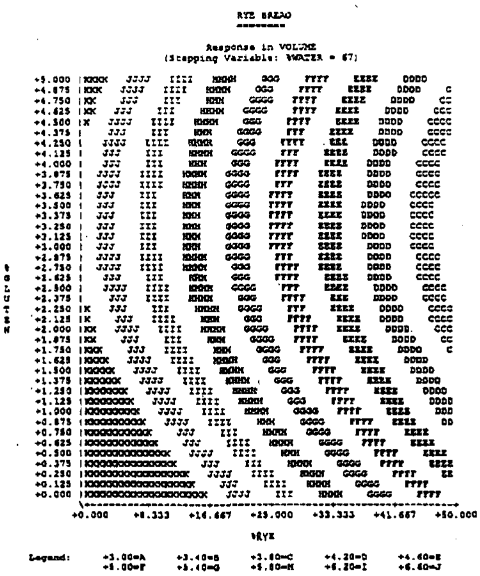

Fig. 5. Three-way RSM analysis. Contour Printout, showing the percentage of water, rye flour and vital gluten on the rye bread response in volume(%water:67).

In general, response in volume(4.435) of rye bread represented highly in rye flour 10%, vital gluten 1% at constant water 57%(Fig. 3). At the 62% water, rye flour 10% and vital gluten 5% shows highly in volume 5.874 (Fig. 4). Volume predicted (6.193) highly in Fig. 5 shows rye flour 10%, and vital gluten 3% at constant 67% water.

These results also indicates that volume predicted in variations (water, rye flour and vital gluten) of rye bread affected loaf volume, each other.

According to the Contour maps, reducing rye flour level increased the loaf volume. Furthermore, increasing the vital gluten and water levels increased the loaf volume(Fig. 3～5).

It appears that a rye bread with a good loaf volume can be produced by a little rye flour(10%) with higher water(62～67%) and vital gluten(3～5%).

Especially, the highest volumes for loaves from these varieties were obtained when water 67%, rye flour 10%, and vital gluten 3% were used.

2. Correlation between Mechanical and Sensory Measurements

Mechanical crumb firmness values results are shown in Table 3. Generally, The bread of same percentage rye flour with high percentage gluten represented more firmmer, because water absorption affected by vital gluten[6]. The rye bread with rye flour(10%), vital

Table 3. Crumb firmness values of the independent variables (rye flour, vital gluten & water) for rye breads

Sample	1	2	3	4	5	6
pH	167.33±20.65[1)de]	151.33±17.50[ef]	219.67±46.05[b]	118.33±22.85[f]	349.00±27.00[b]	199.33±10.26[cd]
Sample	7	8	9	10	11	12
pH	142.00±12.17[ef]	415.00±34.39[a]	136.33±27.79[ef]	209.33±8.33[cd]	198.67±15.01[cd]	178.33±9.61[cde]

[1)] Determined in triplicate (mean±SD).

[a~f] Mean followed by different letters within columns are significantly different at p=0.05 by Duncan's multiple test.

Table 4. Sensory evaluations score of the independent variables(rye flour, vital gluten & water) for rye breads

Sample	Appearance	Color	Cell uniformity	Flavor	Manual springiness	Chewiness	Moistness	Overall
1	4.6[c1)]	5.4[b]	5.4[a]	5.3[a]	5.8[a]	5.7[a]	5.4[a]	5.6[a]
2	4.4[d]	5.0[d]	4.8[c]	4.8[c]	4.9[cd]	4.9[bc]	5.1[b]	4.9[d]
3	3.4[e]	4.3[e]	3.9[e]	4.1[e]	3.9[g]	4.0[d]	4.3[e]	3.8[g]
4	3.1[f]	4.1[f]	3.1[g]	4.3[d]	4.6[e]	4.8[c]	4.7[c]	4.5[e]
5	1.8[j]	3.4[h]	3.1[g]	3.4[f]	2.8[h]	3.1[e]	2.7[f]	2.8[h]
6	4.7[c]	5.1[cd]	4.5[d]	4.4[d]	5.0[c]	4.8[c]	4.8[c]	4.6[e]
7	2.8[g]	5.0[d]	3.9[e]	4.1[e]	4.4[f]	4.1[d]	4.4[de]	4.2[f]
8	2.0[i]	3.4[h]	3.2[g]	3.2[g]	2.4[i]	2.9[f]	2.8[f]	2.7[h]
9	5.4[b]	5.2[c]	5.2[b]	4.8[c]	5.4[b]	5.0[b]	5.4[a]	5.3[b]
10	5.7[a]	5.0[d]	5.4[a]	4.1[e]	5.0[c]	4.9[bc]	4.7[c]	5.0[cd]
11	2.4[h]	3.8[g]	3.6[f]	4.7[c]	4.8[d]	5.0[b]	4.5[d]	4.3[f]
12	5.7[a]	5.6[a]	4.8[c]	5.0[b]	5.3[b]	5.0[b]	5.2[b]	5.1[c]

[1)] Rating scale : 1(bad) to 7(excellent).

[a~j] Means followed by different letters within columns are significantly different at p=0.05 by Duncan's multiple test.

Table 5. Crumb and crust Color values of the independent variables (rye flour, vital gluten & water) for Rye breads

Hunter's value	Crumb			Crust		
	a	b	L	a	b	L2
1	75.80±1.45[1)b]	- 0.02±0.32[c]	17.25±0.97[c]	49.30±5.81[a]	13.58±1.81[abc]	25.18±3.20[a]
2	71.07±0.88[c]	1.13±0.56[b]	17.32±0.22[bc]	45.78±3.03[a]	13.68±0.16[abc]	24.51±1.56[a]
3	66.10±0.12[d]	1.96±0.24[a]	18.39±0.39[ab]	47.88±5.95[a]	12.36±1.74[abc]	23.95±2.89[a]
4	76.11±1.38[b]	- 0.03±0.31[c]	17.69±0.91[abc]	45.88±4.39[a]	14.31±0.28[ab]	25.52±2.29[a]
5	70.51±0.54[c]	1.37±0.13[b]	18.33±0.31[ab]	50.55±4.15[a]	11.61±2.08[bc]	26.44±0.68[a]
6	71.07±0.66[c]	1.19±0.16[b]	18.03±0.53[abc]	47.31±2.39[a]	14.25±0.70[ab]	26.34±0.91[a]
7	71.71±1.30[c]	1.07±0.29[b]	18.06±0.71[abc]	45.23±6.01[a]	13.07±1.67[abc]	24.10±2.73[a]
8	66.49±0.52[d]	2.23±0.21[a]	18.42±0.22[a]	52.79±4.21[a]	11.23±2.03[c]	27.16±2.82[a]
9	76.90±1.15[b]	0.08±0.13[c]	17.75±0.16[abc]	45.92±6.14[a]	14.76±0.45[a]	26.13±4.44[a]
10	71.89±1.10[c]	1.22±0.29[b]	18.19±0.68[abc]	46.54±5.60[a]	13.64±1.42[abc]	26.15±2.86[a]
11	66.87±1.39[d]	2.01±0.35[a]	18.44±0.47[a]	49.06±7.59[a]	12.91±1.66[abc]	25.87±3.22[a]
12	79.38±0.61[a]	- 0.82±0.15[d]	17.46±0.26[abc]	45.16±2.29[a]	13.93±1.07[abc]	25.39±2.30[a]

[1)] Determined in triplicate (mean±SD).

[a~e] Mean followed by different letters within columns are significantly different at p=0.05 by Duncan's multiple test.

[2)] L=lightness, a=redness, and b=yellowness.

Table 6. pH values of the independent variables (rye flour, vital gluten & water) for rye breads

Sample	1	2	3	4	5	6
pH	7.37±0.39[1)]	7.16±0.07	7.21±0.08	7.28±0.15	7.22±0.14	7.24±0.13
Sample	7	8	9	10	11	12
pH	7.20±0.13	7.20±0.14	7.29±0.17	7.26±0.14	7.16±0.09	7.25±0.14

[1)] Determined in triplicate (mean±SD).

gluten(3%) and water(67%) were the lest firm. And the rye bread with rye flour(50%), gluten(3%) and water (57%) were the most firm. But, there is a little difference depending on the vital gluten, water. For example, crumb firmness values of rye flour, gluten and water (10% : 1% : 57% / 10% : 5% : 62% / 10%: 3% : 67%) were 167.3, 136.3 and 118.3 respectively.

Similar phenomena were observed in the analyses of manual springiness, chewiness, cell uniformity and moistness etc. in Table 4. Breads with high firmness were less springy, chewiness, cell uniformity, and moistness. Breads with 50% rye flour had a tight, small cell structure, resulting in a dense and firm texture, whereas breads with 10% rye flour had an open, bigger cell structure, resulting in a spongy, soft, and springy texture. The values of the sensory evaluation is in Table 4. The sensory evaluation value of the water 62%, rye flour 10% and vital gluten 5% is the approximate 5, and that of the water 57%, rye flour 50% and vital gluten 3% is the approximate 3. I consider that this results depend on the quantity(%) of the rye flour. The water 62%, rye flour 10% and vital gluten 5% evaluated the best variation of rye bread and I supposed that the rye bread made by water 62%, rye flour 10% and vital gluten 5% is reasonable in sensory evaluation. The correlation of the evaluations between mechanical analysis and sensory evaluation was significant.

The crumb and crust color of the rye bread measured by a Chroma Meter showed highly significant correlation with consumer color sensory evaluation. In this study, regardless the water, breads with 10 % rye flour had a higher crumb color a than the other rye flour(30%, 50%), whereas breads with 50% rye flour had the most crumb color b. And then, crust color b had a high in 30 % rye flour(Table 5).

This indicates that rye breads color measurement with colorimeter is an efficient method, it that can be used to predict consumer acceptance of rye bread color, but no significant relationship was found between pH and favor(Table 6). And Specific volume predicted and overall preference also was shown high. These result represents that breads loaf volume related to directly consumer preference.

요 약

본 논문은 rye bread 제조에 있어서, water, rye flour 그리고 vital gluten이 rye bread 의 관능 특성에 미치는 영향에 대하여 response surface methodology, 관능검사 및 통계적 분석을 통하여 연구하였다.

Response surface model은 rye bread의 최적 variation을 결정하고 관찰되어진 결과를 평가하기 위하여 사용되었으며, 본 실험은 water 57, 62, 67%, rye flour 0, 10, 30, 50% 그리고 vital gluten 0, 1, 3, 5%의 12가지 조합을 하여 실험하였다. 실험 결과 water 67%, rye flour 10% 그리고 vital gluten 3%일 때 높은 specific volume의 rye bread가 생산되었으며, water 62%, rye flour 10% 그리고 vital gluten 5%일 때 전체적인 관능치가 높은 rye bread가 생산되었다. 또한 specific volume과 전체적인 기호도도 높은 것으로 나타났으며, 이러한 결과는 bread loaf volume과 소비자의 기호도가 직접적인 관계가 있음을 보여준다.

본 논문은 rye bread의 생산에서 다양한 water, rye flour 그리고 vital gluten의 배합에 대한 정보를 제시하였으며, 표준화 최적화 방법에 대한 기초 정보를 제공하는데 큰 의의를 두었다.

또한 이 결과는 water, rye flour 그리고 vital gluten이 rye bread의 생산에서 다양한 방법으로 배합될 수 있으며, 제빵의 기능적 특성을 최적화 하는데 기여할 것으로 기대된다.

REFERENCES

1. Gunnarsson, E. Cultivar Variation and breeding goals for rye in the Nordic countries. pp. 26-32 in : Int. Rye Symp. Technol. Prod. VTT Technical Research Centre of Finland : Espoo. 1995
2. Weipert, D. Processing performance of rye as influenced by sprouting by resistance and pentosan contents. Pages 39-48 in : Int. Rye Symp. Technol. Prod. K. poutanen and K. Autio, eds. VTT Technical Research Centre of Finland : Helsinki. 1995
3. Gordon, J. Basic production aspects of rye bread. *Baker's Dig.* 44:38-39,67. 1970
4. Weberpals, F. Fundamentals of rye bread production. *Baker's Dig.* 1950
5. Walter Bushuk. Rye: Production, Chemistry, and Technology. Inc. Published. 2nd edition. pp. 115-118. 2001
6. Pyler, EJ. Baking Science & Technology. Published by Sosland Publishing Co. Third edition. page 393-396. 1988
7. Finney, KF. An optimized, straight-dough, breadmaking method after 44 years. *Cereal Chem.* 61(1): 20-27. 1984
8. Box, GEP and Wilson, KB. On the experimental attainment of optimum conditions. *J. Royal Statistical Soc.* (*Series B*) 13: 1-34. 1951
9. Walker, CE and Parkhurst, AM. Response surface analysis of Bake-Lab Data with a personal computer. *Cereal Chem.* 29(10):663-666. 1984
10. American Association of Cereal Chemists. Approved Methods of the AACC, 9th ed. Method 10-10B. The Association : St. Paul, MN. 1995
11. Ebeler, SE and Walker, CE. Wheat and composite flour chapatis : effect of soy flour and sucrose ester emulsifiers. *Cereal Chem.* 60(4):270-275. 1983
12. Myers, RH. Response Surface Methodology. Virginia Polytechnic Institute and State University. Blacksburg. 1976
13. Lin Carson and Xiuzhi S. Sun. Creep-recovery of bread and correlation to sensory measurements of textural attributes. *Cereal Chem.* 78(1):101-104. 2001
14. Mettler, E and Seibel, W. Effects of emulsifiers and hydrocolloids on whole wheat bread quality : A response surface methodology study. *Cereal Chem.* 70(4):373-377. 1993
15. Lai, CS, Davis, AB and Hoseney, RC. Production of whole wheat bread with good loaf volume. *Cereal Chem.* 66(3):224-227. 1989

16. Aboubacar, A, Kirleist, AW and Oumarou, M. Important sensory affecting consumer acceptance of sorghum porridge in West Africa as related to quality tests. *Journal of Cereal Science* 30:217-225. 1999
17. Magnus, EM, Brathen, E, Sahlstrom, S, Mosleth Fargestad, E and Ellekjar, MR. Effects of wheat variety and processing conditions in experimental bread baking studied by univariate and multivariate analyses. *Journal of Cereal Science* 25:289-301. 1997

(2004년 8월 2일 접수)