International Journal of Food, Agriculture and Veterinary Sciences ISSN: 2277-209X (Online)
An Online International Journal Available at http://www.cibtech.org/jfav.htm
2012 Vol. 2 (2) May-July, pp.106-114/Das et al.
Research Article

EFFECT OF BAKING CONDITIONS ON THE PHYSICAL PROPERTIES OF HERBAL BREAD USING RSM

Lipi Das, Utpal Raychaudhuri and *Runu Chakraborty
Deptartment of Food Technology and Biochemical Engineering Jadavpur University
Kolkata – 700032 India
**Author for Correspondence*

ABSTRACT
The use of composite coriander-wheat flour for commercial bread making purposes and consumption of coriander leaf fortified bread are relatively new. Response surface methodology was used to study the effects of baking conditions on various baking parameters and thus the optimum conditions selected for further studies. Time and temperature are the two important baking conditions on which the quality and acceptability of the breads depend. In this study, baking temperature and time were the predictor variables and loaf specific volume, crumb moisture and crumb hardness were the dependent variables (responses). Baking temperature and time ranged from 200 to 240°C and 10 to 30 min respectively. Loaf weight, volume, and the color of the crumb and crust of the bread samples varied significantly with the baking time and temperature. Quadratic model fitted with the experimental data of specific volume, crumb moisture and hardness obtained. The baking conditions of the herbal bread have been optimized with the help of RSM.

Key Words: *Coriander Leaf, Response Surface Methodology, Brownness Index, Crumb Moisture, Specific Loaf Volume, Crumb Hardness*

INTRODUCTION
Bread has become one of the most widely consumed non-indigenous food item in India. Fresh bread is characterized by a soft and elastic crumb, a brownish crust, a pleasant aroma and a moist mouth feel (Giannou *et al.*, 2003). Baking is an important step of bread preparation. During this process, the raw dough piece gets transformed into a light, porous, flavorful and readily digestible product under the influence of heat (Therdthai, 2002). The quality of the final product mainly depends on the rate and amount of heat applied the type of baking chamber and the baking time. Some of the physical, chemical and biochemical changes during bread baking include volume expansion, evaporation of water, crust formation, inactivation of yeast and enzymatic activities, protein coagulation and starch gelatinization (Pyler, 1988).

The control of the baking parameters like temperature and time combination during baking is an engineering problem that is critical to the successful implementation of commercial flour baking technology (Shittu *et al.*, 2007). Till now, few studies have been conducted on the effect of baking time-temperature on the quality of bread from 100% wheat flour (Bloksma, 1990; Singh & Bhattacharya, 2005; Therdthai *et al*., 2002; Zhang & Datta, 2006; Jusoh et al., 2007), very few on the composite wheat flour (Shittu *et al*., 2007) and virtually none has been reported on composite coriander-wheat bread.

Response surface methodology (RSM) is a collection of statistical and mathematical techniques used for development, improvement and optimization of processes or formulations (Malcolmson *et al*., 1993; Bas & Boyaci, 2007; Turabi, 2008). It is used to examine the relative significance between a set of quantitative experimental factors and the response variables. In food research studies, response surface methodology (RSM) is very frequently used to optimize the efficiency of the ingredients such as fibres, improvers (Collar *et al*., 1999; Collar *et al.*, 2007; Clarke *et al.*, 2003; Sabanis *et al.*, 2009), composite flours (Shittu *et al.*, 2007), optimization in food processes like product development, functional food preparation etc (Seog *et al.*, 2008; Gupta *et al.*, 2007; Flander *et al.*, 2007) as well as in optimizing processing conditions (Ghodke *et al.*, 2009; Mondal & Datta, 2010).

The aim of the present study was to observe the effect of various baking time-temperature combinations on bread loaf size, crust color, crumb moisture and hardness of the bread samples made from composite wheat flour consisting of 5% coriander leaf powder, and further to optimize the baking conditions using RSM technique.

MATERIALS AND METHODS

Raw Materials

Fresh coriander leaves were procured from the local market of Jadavpur, Kolkata. White refined flour, granulated sugar, salt, refined oil as shortening agent were purchased from the local grocery stores of Jadavpur, Kolkata, India. Compressed Baker's yeast (Saf Yeast Company Pvt. Ltd., Mumbai, India) was used as the leavening agent in bread preparation.

Preparation of The Raw Material

The coriander leaves were washed in tap water to remove the adhering dirt. They were then de-rooted, blanched in lukewarm water (approx. 50ºC) for about 1min. They were next dried in a Tray Dryer (Reliance Enterprise, Kolkata, India) at 60°C for approximately three and half an hour. Finally, the dried leaves were ground in a Grinder ($GX_{7,}$ Bajaj Electricals Ltd, India), sifted to less than 150µm (BSS 100) and then stored in air-tight polythene packets to obtain the coriander leaf powder.

Bread Preparation

The ingredients and their proportions required for the preparation of bread samples were wheat 3.0%, sugar 5.0%, salt 2.0%, compressed wet yeast 2.5%, refined oil 5.0%, glycerol monostearate 1.5% and water 60.0%. The flour blend was prepared by mixing 100g wheat flour with 3.0% w/w of coriander leaf powder. The dry mix was prepared by mixing flour, sugar, salt and the chemicals. Baker's compressed yeast was dissolved in water (10 ml) and kept at the 37ºC for the activation of the yeast cells. Small amount of flour (approx. 1g) and same amount of sugar were added to the warm water for activation of the yeast cells. Mixing is an important step for achieving homogenous as well as soft dough. Here, mixing was carried out manually according to the straight dough method. The dry ingredients, shortening and the activated yeast were added in a bowl and water added and then kneaded until the dough was elastic and the required consistency was reached. After this, the dough was rounded and kept in a bowl for the first proofing at the room temperature (30°C) for about 40 min. The bowl was covered with a wet cloth to maintain a relative humidity of 80-90%. After the first proofing, the dough was punched and worked lightly so that the excess gas could escape and the gas cells are redistributed. The dough was then shaped to fit lightly in greased bread molds. The dough was again kept for the final proofing for about 1 hour at 40±1°C. Finally, after second proofing, the breads in molds were baked in rotary oven (CM HS108, Chanmag Bakery Machine Co. Ltd., Taiwan) at different experimental temperatures and time. After baking, the prepared bread samples were cooled for about 1 hour at room temperature and then analyses carried out.

Analysis for Bread

Loaf weight, volume and specific volume

Bread samples were weighed after cooling and the volumes of the loaves were measured by the seed displacement method (Dhingra and Jood, 2004; Smith and Johansson, 2004). From these, the specific volume of the loaf was calculated as:

$$\text{Specific volume (ml/g)} = \frac{\text{Loaf volume}}{\text{Loaf weight}} \tag{1}$$

Crumb Moisture

Bread crumb moisture was determined by taking 2g of the bread crumb, grinding it to small pieces and then drying for 2 hours at 130±2°C (AACC, 2000; McCarthy *et al.*, 2005). After drying, the samples were cooled in a desiccator. Moisture content was determined as follows:

$$\% \text{ moisture content} = \frac{\text{Initial weight of the sample (w1)} - \text{Final weight of the sample (w2)}}{\text{Initial weight of the sample (w1)}} \times 100$$

(2)

Color

The crust color of the bread samples were measured sing the Hunter Lab color measurement system, ColorFlex 45/0, D65, 10° observer (Hunter Associates Laboratory Inc., Reston, VA, USA). A 3.5 cm thick layer was covered with the white standard plate (X=79.22; Y=84.10; Z=88.76) for measurement of diffused reflected light from the cell bottom using a 1.25 inch diaphragm aperture. Color of the bread samples were measured according to the CIELAB system of color measurement as *L**-whiteness/darkness (100-0), *a**-redness/greenness (+ to -) and *b**-yellowness/blueness (+ to -). The 'brownness index' (BI) was calculated as follows: (Maskan, 2001; Torregiani & Bertolo, 2001; Yan *et al.*, 2008).

$$BI = \frac{[100\,(x-0.31)]}{0.17} \qquad (3)$$

$$\text{Where, } x = \frac{(a+1.75\,L)}{(5.645\,L+a-3.012\,b)} \qquad (4)$$

Crumb Hardness

The hardness of the bread crumb was measured the by Instron Universal Testing Machine, Table Model 4301 (Instron Ltd., High Wycombe, Bucks, UK) in the compression mode fitted with a 100N load cell. The bread samples were sliced and the middle slices having a width of 25mm were taken for measurement. A two-cycle crumb compression test was performed by compressing axially each sample with a 40mm diameter flat plate probe attached to the moving crosshead. The testing conditions were: compression ratio of 50% deformation from the initial height of the sample; 20mm/min crosshead speed and 20mm/min chart speed. The force-distance curve obtained was used to derive the various textural properties (Bandyopadhyay *et al.*, 2005; Bourne, 1978).

Experimental Design and Statistical Analysis

The experimental design was done by RSM comprising of a central composite design with two-factors and five-levels (Table 1). The two independent variables (factors) used here were: baking time (X_1) and baking temperature (X_2) and the three dependent variables (responses) studied were loaf specific volume (Y_1), crumb moisture (Y_2) and crumb hardness (Y_3). 13 baking trials were performed with five centre points. The combination of the two factors (baking time and temperature), their actual and coded values are given in Table 1. For each response variable, model selection for linear, quadratic or cubic models were made on the basis of sequential model sum of squares (SMSS), lack-of-fit tests and the multiple correlation coefficients (R^2). The cubic model was aliased because there were not enough points for this type of model. From this information, the most accurate model was chosen which in all cases appears to be quadratic model. The second-order response functions for the experiments were fitted to the following quadratic regression equation:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_{11}X_1^2 + b_{22}X_2^2 + b_{12}X_1X_2 \qquad (5)$$

where X_1 is the baking time; X_2 is the baking temperature; b_0 is the value of the fitted response at the centre point (0, 0) of the design; b_1 and b_2 are the linear regression terms; b_{11} and b_{22} are the quadratic terms and b_{12} is the interaction term.

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

Independent variables	Unit	Symbol	Coded levels				
			-2	-1	0	+1	+2
Baking time	min	X_1	10	15	20	25	30
Baking temperature	°C	X_2	200	210	220	230	240

Statistical analysis of variance (ANOVA) and multiple regression were performed using the software, Design Expert® Version 7.1.6 (Stat-Ease, Inc., Minneapolis,USA) to fit the equation. The results included the estimated model coefficients, the regression coefficients and the lack-of-fit test.

RESULTS AND DISCUSSION

Loaf Size

The effects of baking time and temperature on coriander fortified bread size are shown in Table 2. Loaf volume and weight ranged from 294.15 ml to 346.5 ml and 147g to 159g respectively. Higher loaf weight and volume are desirable to the bakers as consumers often get attracted to these factors over other factors. Specific volume, a ratio of loaf volume to loaf weight is a more precise measurement of loaf size. Loaf volume is mainly affected by the protein content of the flour (Ragaee & Abdel-Aal, 2006) as well as the proofing time and temperature (Zghal *et al*., 2002). On the other hand, loaf weight is mainly influenced by the amount of dough baked and the percent of moisture and carbon dioxide diffused out during baking (Shittu *et al*., 2007). In this study, increase in temperature and baking time has decreased the loaf weight (Table 2), while the reverse occurred in case of loaf volume. Since the formulation of the bread samples are same in all cases, the variation in loaf volumes is mainly because of the differences in the rate of gas evolution and starch gelatinization as baking time and temperature are varied.

Crust Color

Color in baked products is an inevitable quality, because the product color can be influenced by the ingredients, processing factors, quality and shelf-life of the produced bread as is evident from the previous works (Jusoh *et al*., 2007; Erkan *et al*., 2006; Gallagher *et al*., 2003a; Gallagher *et al*., 2003b). Therdthai *et al*., in 2002 reported that baking conditions affect the *color* of the crust technically. As the bread formulation remains same in all the samples, it can be assumed that the crumb color characteristics are not liable to differ significantly (Shittu *et al*., 2007).

In this study, the values of the color parameters L^*, a^* and b^* of the bread crust are affected by the baking time-temperature combinations as is shown in Table 2. The values of L^*, a^* and b^* ranged from 26.903 to 34.287, 2.737 to 7.503 and 8.713 to 14.433 respectively. Table 2 suggests that baking time and temperature were inversely proportional with the L^* value of the crust. Breads baked at higher temperature had lower L^* value. This is mainly due to the fact that the rate of brown pigment formation increases with time and temperature. This browning is mainly due to the Maillard reaction rather than

Table 2: Loaf size and crust *color* characteristics of the coriander breads in different baking conditions

		Loaf size		**Crust *color***			
Temp (°C)	**Time (min)**	**Loaf wt. (g)**	**Loaf volume (ml)**	***L****	***a****	***b****	**BI**
230	25	150 ± 0.677^{r}	345.9 ± 1.081^{i}	28.917 ± 0.398^{a}	6.83 ± 0.183^{m}	13.687 ± 0.238^{e}	79.804 ± 1.359^{c}
220	20	154 ± 0.74^{t}	338.8 ± 1.31^{j}	32.283 ± 0.732^{b}	5.61 ± 0.118^{n}	11.723 ± 0.3^{f}	57.255 ± 2.902^{a}
230	15	157 ± 0.959^{s}	332.84 ± 1.617^{k}	30.66 ± 0.07^{ab}	5.37 ± 0.046^{mn}	11.36 ± 0.026^{f}	58.413 ± 0.34^{a}
220	10	159 ± 0.902^{rs}	294.15 ± 1.166^{kl}	33.137 ± 0.136^{d}	2.737 ± 0.111^{p}	9.373 ± 0.064^{g}	38.628 ± 0.339^{d}
200	20	156 ± 0.416^{pq}	312.465 ± 0.882^{m}	34.287 ± 0.131^{e}	4.817 ± 0.07^{op}	8.713 ± 0.093^{h}	39.216 ± 0.679^{b}
220	20	155 ± 1.465^{t}	346.5 ± 1.191^{n}	31.077 ± 0.458^{c}	5.86 ± 0.252^{q}	10.743 ± 0.945^{ij}	55.294 ± 4.669^{a}
220	20	154 ± 1.008^{t}	338.13 ± 1.293^{j}	30.183 ± 0.133^{f}	5.53 ± 0.095^{n}	12.087 ± 0.072^{f}	63.725 ± 0.34^{ad}
240	20	147 ± 1.52^{q}	341.481 ± 0.904^{l}	26.903 ± 0.228^{g}	7.503 ± 0.057^{r}	14.11 ± 0.887^{kl}	92.353 ± 5.228^{ac}
210	25	151 ± 0.444^{st}	324.65 ± 1.44^{ij}	30.19 ± 0.809^{cd}	5.997 ± 0.096^{s}	11.013 ± 0.99^{f}	59.216 ± 3.781^{a}
220	30	147 ± 1.059^{p}	342.51 ± 1.076^{mn}	28.67 ± 0.74^{ad}	7.113 ± 0.05^{pq}	14.433 ± 0.137^{i}	86.275 ± 2.066^{bc}
210	15	158 ± 1.361^{op}	303.044 ± 1.294^{p}	31.267 ± 0.085^{h}	4.507 ± 0.07^{rs}	12.813 ± 0.311^{j}	62.353 ± 1.765^{ab}
220	20	155 ± 0.514^{t}	341.0 ± 0.63^{pq}	29.867 ± 0.567^{ef}	5.917 ± 0.09^{t}	10.67 ± 0.44^{gh}	58.039 ± 2.716^{a}
220	20	153 ± 0.576^{t}	345.65 ± 0.80^{op}	31.533 ± 0.086^{bc}	5.497 ± 0.41^{n}	11.487 ± 0.137^{f}	57.451 ± 0.339^{a}

Data represents means of three samples (n=3) ± s.d.
Means with different superscripts within the same row are significantly different ($p \leq 0.05$)
caramelization (Mondal & Datta, 2010). The brown color formation in the crust may be measured by the 'brownness index' (BI) of the loaf crust, which ranged from 38.824 to 92.353 for the bread samples.
The other color components a^* and b^* reacted oppositely in contrast to L^*. a^* values are directly proportional to baking time and temperature. Table 2 also shows that lower baking time and temperature produced breads of lower a^* and b^* values, or rather lower in redness and yellowness intensity.

Response Surface Models

Estimated regression coefficients for the dependent variables were obtained from responses by the multiple regression analysis (Table 3) and the mathematical models obtained from these are shown below:

$$\text{Specific volume } (Y_1) = 2.22 + 0.084X_1 + 0.11X_2 - 0.019X_1^2 - 0.037X_2^2 - 0.0009X_1X_2 \quad (6)$$

$$\text{Crumb moisture } (Y_2) = 39.86 - 1.17X_1 - 1.33X_2 - 3.73X_1^2 - 3.04X_2^2 - 3.75X_1X_2 \quad (7)$$

$$\text{Crumb hardness } (Y_3) = 9.93 + 1.08X_1 + 1.42X_2 + 2.18X_1^2 + 1.81X_2^2 + 2.75X_1X_2 \quad (8)$$

Analysis of variance (ANOVA) of the effect of baking time and temperature to produce the breads in the form of linear, quadratic and interaction terms on the response variables, the lack-of-fit test and the regression coefficients are depicted in the Tables 4. F-test values of 25.49, 44.75 and 108.12 for specific volume, crumb moisture and crumb hardness obtained from ANOVA of the quadratic regression models demonstrate that the models are significant. The P-value checked the significance of each of the coefficients to understand the interaction between the independent variables. The lower the P-values, the more significant are the model terms. Values of P less than 0.05 indicate that the model term is significant (Ghodke *et al.*, 2009). The regression coefficient (R^2) checks the goodness of fit of the models. The closer the R^2 values to 1.0, the more fit are the models.

Table 3: Estimated coefficients of the fitted quadratic equation for different responses such as Y_1 (specific volume), Y_2 (crumb moisture) and Y_3 (hardness)

Coefficients	Y_1	Y_2	Y_3
b_0	2.22	39.86	9.93
b_1	0.084	-1.17	1.08
b_2	0.11	-1.33	1.42
b_1^2	-0.019	-3.73	2.18
b_2^2	-0.037	-3.04	1.81
b_1b_2	-0.0009	-3.75	2.75

Table 4: Analysis of variance of the responses by quadratic regression model

Source	**Degrees of Freedom**	**P value**		
		Specific volume	**Crumb moisture**	**Crumb firmness**
Model	5	0.0002*	<0.0001*	<0.0001*
A	1	0.0004*	0.0317*	0.0006*
B	1	<0.0001*	0.0184*	0.0001*
A^2	1	0.0938**	<0.0001*	<0.0001*
B^2	1	0.0065*	<0.0001*	<0.0001*
AB	1	0.7094**	0.0016*	<0.0001*
Lack of Fit	3	0.1269**	0.3664**	0.3444**
R^2		0.9479	0.9697	0.9872

*Significant, **Not significant

The 3D response plots (Fig 1-3) are the graphical representation of the regression equations from where the values of the responses can be predicted with respect to the variable factors. The contour plots show multiple asymmetric saddling indicating a rather complex relationship between the dependent and the independent variables. The dependence of the baking levels, the response surfaces for specific volume, crumb moisture and hardness are shown in Figs 1 to 3.

Specific Loaf Volume

The specific volume of the bread samples ranged from 1.85 to 2.32 ml/g. Specific volume depended both upon baking time and temperature as it had positive linear effect (Table 3). The linear baking time and temperature terms and quadratic temperature term has significant P values (Table 4). The R^2 value of this model is 0.9479 which means that 94.795 of the variability in the response data fitted the model. Fig. 1 depicts the combined effect of baking time and temperature on loaf specific volume 3D surface. It shows that with increase in baking time and temperature the specific volume has increased almost linearly.

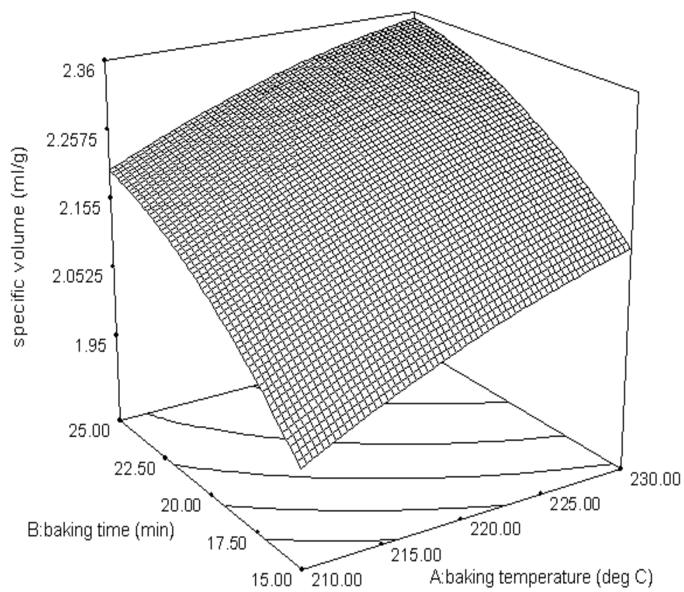

Figure 1: Response Surface Plot for the Effect of Baking Time and Temperature on Loaf Specific Volume

Crumb Moisture

Here, the linear, quadratic and interaction model terms are found to have significant P-values (Table 4). Thus crumb moisture depended upon baking time and temperature; the linear and quadratic effect of both the variables is negative. The R^2 value of 0.9697 suggests that the raw data had a good fit to the model. The crumb moisture content ranged from 23.0 to 42.0%. As evident from Fig. 2, with the increase in baking time and temperature, the crumb moisture content decreases. The combination of medium levels of both the factors resulted in higher crumb moisture content (Fig. 2). The moisture content of the bread crumbs may be governed by the extent of gelatinization of starch in dough during baking. The crumb moisture content has some implication on the mechanical (Zghal *et al.*, 2002) and keeping qualities (Defloor *et al.*, 1993).

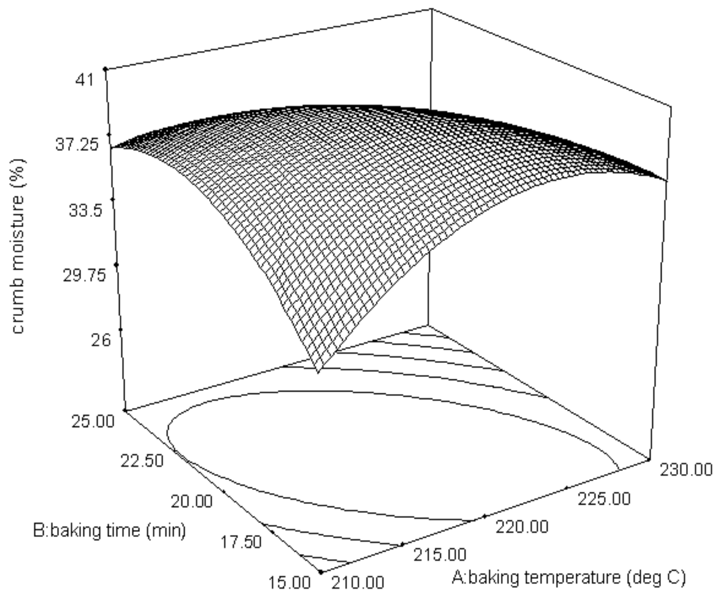

Figure 2: Response Surface Plot for the Effect of Baking Time and Temperature on Crumb Moisture

Crumb Hardness

Hardness is an important factor in bakery products and is strongly related with the consumer's perception of bread freshness (Ahlborn *et al.*, 2005). Table 4 shows that all the linear and quadratic model terms have significant P values. Crumb hardness depends both on baking time and temperature and the linear and quadratic effects being positive in this case (Table 3). The R^2 value is 0.9872 stating that 98.72% of the data fits with the model. The crumb hardness values ranged between 9N to 21N. Fig 3 defines the 3D plot of crumb hardness with respect to baking time and temperature. Hardness of the breads increased with increasing baking time and temperature (Fig 3). An optimum of crumb hardness has been reached at the middle points of baking time and temperature. On a whole, Fig 3 is just the inverse nature of Fig 2. Thus from the two figures it can be inferred that crumb moisture and hardness here are inversely proportional to each other.

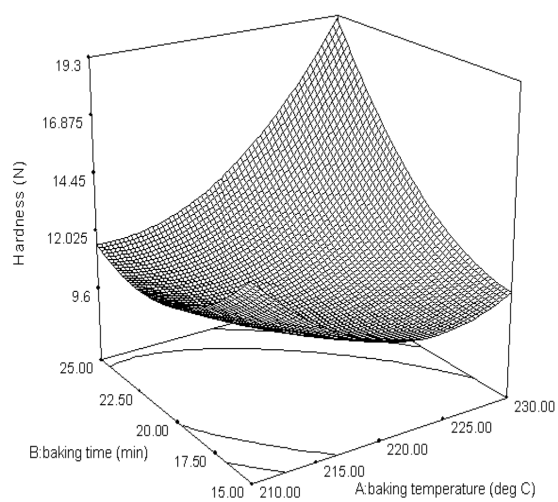

Figure 3: Response surface plot for the effect of baking time and temperature on crumb hardness

Optimization

The next step involved the detection of the best combination of factors that are able to produce the expected characteristics in the final product. The optimization of the baking conditions arises from compromises among the different responses (Sabanis *et al.*, 2009). Each variable response may either be maximized or minimized. The widely accepted bread quality criteria are large volume, soft crumb and optimum crumb moisture content. Thus, to obtain such product, loaf specific volume should be maximized, crumb hardness minimized and moisture content to be controlled. As a result of optimization, the best baking conditions that were attained for the expected responses were a baking temperature of 220±2°C and baking time of 20±2 min.

CONCLUSIONS

This study showed that varying temperature-time combination during baking leads to significant changes in the physical characteristics of coriander fortified wheat breads. All the responses were significantly affected by the varying factors. Bread specific volume, crumb moisture and hardness fitted well with the quadratic model. The baking conditions obtained from optimization were 220±2°C and a baking time of 20±2 min. From this optimization, bread loafs having desired loaf weights, volume, crumb softness and crust color were obtained. Thus, the study is useful in interpreting the basic baking conditions of wheat breads fortified with herbal constituents.

ACKNOWLEDGEMENTS

This research work is financially supported by the Centre for Advanced Studies (CAS I) programme under University Grants Commission (UGC), India.

REFERENCES

AACC (2000). Approved Method of the American Association of Cereal Chemists. St Paul MN USA.

Ahlborn GJ, Pike OA, Hendrix SB, Hess WM and Huber CS (2005). Sensory mechanical and microscopic evaluation of staling in low-protein and gluten-free breads. *Cereal Chemistry* **82** 328-335.

Bandopadhyay M, Chakraborty R and Raychaudhuri U (2005). The effect of coagulants on the texture of chhana (an acid and heat coagulated product made from milk). *International Journal of Food Science and Technology* **40**(8) 799-810.

Bas D and Boyaci IH (2007). Modeling and optimisation I: Usability of response surface methodology. *Journal of Food Engineering* **78** 836-845.

Bloksma AH (1990). Rheology of the bread making process. *Cereals Foods World* **35** 226–236.

Bourne MC (1978). Texture profile analysis. *Food Technology* **32** 62-66, 72.

Clarke CI, Schober TJ, Angst E and Arendt EK (2003). Use of response surface methodology to investigate the effects of processing conditions on sourdough wheat bread quality. *European Food Research Technology* **217** 23-33.

Collar C, Andreu P, Martinez JC and Armero E (1999). Optimization of hydrocolloid addition to improve wheat bread dough functionality: A response surface methodology study. *Food Hydrocolloids* **13** 467–475.

Collar C, Santos E and Rosell CM (2007). Assessment of the rheological profile of fibre-enriched bread doughs by response surface methodology. *Journal of Food Engineering* **78** 820–826.

Defloor I, Nys M and Delcour JA (1993). Wheat starch, cassava starch, and cassava flour impairment of the bread making potential of wheat flour. *Cereal Chemistry* **78** 525–530.

Dhingra S and Jood S (2004). Effect of flour blending on functional, baking and organoleptic characteristics of bread. *International Journal of Food Science and Technology* **39** 213-222.

Erkan H, Celik S, Bilgi B and Koskel H (2006). A new approach for the utilization of barley in food products: barley tarhana. *Food Chemistry* **97** 12–18.

Flander L, Salmenkallio-Marttila M, Suortti T and Autio K (2007). Optimization of ingredients and baking process for improved wholemeal oat bread quality. *Lebensm.-Wiss. Technology* **40** 860–870.

Gallagher E, Gormley TR and Arendt EK (2003a). Crust and crumb characteristics of gluten free breads. *Journal of Food Engineering* **56** 153–163.

Gallagher E, Kunkel A, Gormley TR and Arendt EK (2003). The effect of dairy powder addition on loaf and crumb characteristics, and on shelf life (intermediate and long term) of gluten-free breads stored in a modified atmosphere. *European Food Research Technology* **218** 44–48.

Ghodke SK, Ananthanarayan L and Rodrigues L (2009). Use of response surface methodology to investigate the effects of milling conditions on damaged starch dough stickiness and chapatti quality. *Food Chemistry* **112** 1010–1015.

Giannou V, Kessoglou V and Tzia C (2003). Quality and safety characteristics of bread made from frozen dough. *Trends in Food Science and Technology* **14** 99–108.

Gupta RK, Sharma A and Sharma R (2007). Instrumental texture profile analysis (TPA) of shelled sunflower seed caramel snack using response surface methodology. *Food Science and Technology International* **13** 455-460.

Jusoh YM, Chin NL, Rahman RA and Yusof YA (2007). Bread crust thikness estimation using L A B *color* system. *World Engineering Congress* 2001 Penang Malaysia 5-9 August 2007.

Malcolmson LJ, Matsuo RR and Balshaw R (1993). Textural optimisation of spaghetti using response surface methodology: effects of drying temperature and durum protein level. *Cereal Chemistry* **70** 417 - 423.

Maskan M (2001). Kinetics of color change of kiwi fruit during hot air and microwave drying. *Journal of Food Engineering* **48** 169–176.

Mccarthy DF, Gallagher E, Gormley TR, Schober TJ and Arendt EK (2005). Application of Response Surface Methodology in the optimisation of gluten-free breads. *Cereal Chemistry* **82** 609-615.

Mondal A and Datta AK (2011). Investigation of the process parameters using response surface methodology on the quality of crustless bread baked in a water-spraying oven. *Journal of Food Process Engineering* **34**(6) 1819-1837.

Ragaee S and Abdel-Aal ESM (2006). Pasting properties of starch and protein in selected cereals and quality of their products. *Food Chemistry* **95** 9–18.

Sabanis D, Lebesi D and Tzia C (2009). Development of fibre-enriched gluten-free bread: a response surface methodology study. *International Journal of Food Science and Nutrition* **60** 174-190.

Seog EJ, Kim HR and Lee JH (2008). Optimization of onion cookie baking process using response surface methodology. *Journal of Food Quality* **31** 306-322.

Shittu T, Raji AO and Sanni LO (2007). Bread from composite cassava-wheat flour: I. Effect of baking time and temperature on some physical properties of bread loaf. *Food Research International* **40** 280–290.

Singh AP and Bhattacharya M (2005). Development of dynamic modulus and cell opening of dough during baking. *Journal of Texture Studies* **36** 44–56.

Smith PR and Johansson J (2004). Influences of the proportion of solid fat in a shortening on loaf volume and staling of bread. *Journal of Food Processing and Preservation* **28** 359-367.

Therdthai N, Zhou Wand Adamczak T (2002). Optimisation of the temperature profile in bread baking. *Journal of Food Engineering* **55**:41–48.

Torreggiani D and Bertolo G (2001). Osmotic pre-treatments in fruit processing: chemical, physical and structural effects. *Journal of Food Engineering* **49** 247–253.

Turabi E, Sumnu G and Sahin S (2008). Optimization of baking of rice cakes in infrared-microwave combination oven by response surface methodology. *Food Bioprocess Technology* **1** 64-73.

Yan Z, Sousa-Gallagher MJ and Oliveira FAR (2007). Identification of critical quality parameters and optimal environment conditions of intermediate moisture content banana during storage. *Journal of Food Engineering* **85** 163-172.

Zghal MC, Scanlon MG and Sapirstein HD (2002). Cellular structure of bread crumb and its influence on mechanical properties. *Journal of Cereal Chemistry* **36** 167–176.

Zhang J and Datta AK (2006). Mathematical modeling of bread baking process. *Journal of Food Engineering* **75** 78–89.