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Full Length Research Paper

Optimisation of wheat-sprouted soybean flour bread using response surface methodology

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The effect of sprouted soybean flour on wheat bread was studied. Sprouting significantly increased the vitamin C content of soybean flour from 2.0 mg kg^{-1} to 3.25 mg kg^{-1}. The sprouted soybean flour resulted in increased loaf volume, a firmer, spongy and more elastic loaf. However, increasing the sprouted soybean flour beyond 10% adversely affected these qualities. The loaf with 4% yeast and 5% sprouted soybean was significantly rated better in taste and general acceptability than the control. Significant differences existed ($p < 0.05$) in the proximate composition between the wheat-sprouted loaves and their respective controls. The addition of the 5% sprouted soybean resulted in a significant increase in protein, fibre and ash content of white bread. The quadratic polynomial regression model was adequate and acceptable at 0.05% for predicting the specific loaf volume and apparent yield stress. Response surface was saddle shaped for specific loaf volume where a maximum or minimum response is found at various combinations of the independent variables, corresponding to the optimal yeast (2.15%) and sprouted soybean flour (11.8%). Apparent yield stress value of 120 kN/m^2 can be obtained from baking with yeast (2.4%) and sprouted soybean flour (10.6%).

Key words: Sprouted soybean flour, wheat, bread, response surface, loaf volume, loaf firmness, fibre.

INTRODUCTION

Bread is one of the major products of baked foods and is consumed worldwide (Bakke and Vickers, 2007). Bread products and its production techniques vary from country to country. Basic ingredients are wheat flour, water, yeast and salt (Martin, 2004; Sluimer, 2005). Other ingredients which may be added include flours of other cereals, fat, malt flour, soya flour, yeast foods, emulsifiers, milk and milk products, fruit and gluten (Kent, 1983; Sluimer, 2005). With appropriate process optimization, breads with acceptable quality can be made with the addition of non-traditional ingredients (Siddiq et al, 2009).

Wheat is a good source of calories and other nutrients but its protein is of lower nutritional quality than milk, soy, pea and lupin proteins as its protein is deficient in essential amino acids such as lysine and threonine (Mariotti et al., 2002; Morens et al., 2003; Dewettinck et al., 2008). It is known that legumes contribute significantly towards protein, mineral and B-complex vitamin needs of people in developing countries. Hence, supplementation of wheat flour with inexpensive staples, such as cereals and pulses, helps in improving the nutritional quality of wheat products (Sharma et al., 1999). Dhingra and Jood (2001) reported that development and consumption of such functional foods not only improves the nutritional status of the general population but also helps those suffering from degenerative diseases associated with today's changing life styles and environment.

Sprouted grains are seen in a number of baked goods at natural health food stores. Sprouting is the practice of soaking, draining and leaving seeds or grains until they germinate or begin to sprout. The concept behind the use of such grains and legumes is that the enzymes produced during sprouting convert starch into more digestible maltose and the vitamins and mineral content available for digestion increases. In effect the sprouting process 'predigests' grains (Misty, 2004). It is known that germination induces increase in free limiting amino acid and available vitamins with modified functional properties

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Table 1. Independent variables and levels used for the 3^2 factorial design and factorial design arrangement for bread production[a,b,c].

		Coded variable level (x_i)		
Variable	Symbol	-1	0	1
Yeast (%)	X_1	1	2.5	4
Sprouted soybean	X_2	5	10	15
Design point	**Yeast (X_1)**	**Sprouted soybean flour (X_2)**		
1	-1	-1		
2	0	-1		
3	1	-1		
4	-1	0		
5	0	0		
6	1	0		
7	-1	1		
8	0	1		
9	1	1		

[a]Transformation of coded variable (x_i) to uncoded variable (X_i) levels cold be obtained from $X_1 = 1.5x_1 + 2.5$; $X_2 = 5x_2 + 10$.
[b]Coded levels of yeast (-1, 0 1) correspond to 1, 2.5 and 4 % respectively; that unsprounted soybean correspond to 5, 10 and 15 % respectively.
[c]Control samples were baked with only yeast at 1, 2.5 and 4 % without sprouted soybean added.

of seed components (Hallén et al., 2004; Wai et al., 1946). Germination also decreases anti-nutritional factors such as trypsin-inhibitor (Uwaegbute et al., 2000).

Furthermore, most bread in Nigeria is of poor quality being gummy rather than spongy and loaded with starch. Chemical improvers are all compounds which exhibit a powerful effect on bread when they are added in amount of the order of ten parts in each million parts of flour. A few of these chemical improvers are ascorbic acid, potassium bromate, cysteine, to mention a few (Pyke, 1981). There is a limitation to production of bread. The use of potassium bromate as a dough improver is a problem, because of its carcinogenic property. National Agency for Food and Drug Administration and Control (NAFDAC) banned the use of potassium bromate by bakers in Nigeria. Therefore, there is a need to source for bread improvers from local raw materials. It is thought that the nutrients released in the sprouted soybeans will play an important role in baked products.

Our objective was to produce wheat-sprouted soybean flour bread, assess the effect of yeast and sprouted soybean on the loaf qualities, establish sensory qualities of the loaves and determine the optimal levels of yeast and sprouted soybean sprout for acceptable loaf.

MATERIALS AND METHODS

Source of materials

All the equipment used in this work was obtained from the Department of Food Science and Technology, Federal Polytechnic, Bauchi, Nigeria. Soybean, wheat flour, sugar, and yeast were purchased from Wunti market in Bauchi metropolis, Nigeria.

Production of sprouted soybean flour

Soybean (3 kg) were cleaned by sorting and soaked in water at room temperature (25 ± 3°C) for 3 h. The soaked beans were drained and spread on a rack of four plastic baskets. Black polyethylene bags were used to cover the beans leaving the sides for ventilation. The plastic rack containing the soybeans was kept in a cupboard away from light.

The soybeans were watered every 6 h for 48 h. The sprouted soybeans were washed, drained and dried at 50°C for 2 days in a cabinet dryer and milled into sprouted soybean flour (SSF) using a hammer mill. The SSF was packaged in low density polyethylene bag, stored in the refrigerator until required.

Determination of vitamin C content of the unsprouted and sprouted soybean flours

Ascorbic acid (vitamin C) was estimated by visual titration method of reduction of 2, 6-dicholorophenol-indophenol dye (Gupta et al., 2005). An aliquot of the sample (10 ml) with 25 ml of 20% orthophosphoric acid in a 50 ml conical flask was mixed with 2.5 ml acetone. The mixture was titrated against 0.05% 2, 6-dichloropheno-indophenol solution until a faint colour which persisted for 15 sec was obtained. The experiment was carried out in duplicate. The Vitamin C content in mg/100 g was estimated using the relationship:

Vitamin C (mg/100 g) = Titre value × dilution factor × mg of dye × 10 mg/100 g.

Experimental design

A 3^2 factorial experiment (Gacula and Singh, 1984) was used to study the effects of yeast (X_1) and SSF (X_2) on the specific loaf volume (Y_1) and yield stress (Y_2) of wheat bread. Each of the factors was at three levels (Table 1). Each design point consisted of three replicates. For the statistical analysis the numerical levels were standardized to -1 0 1. Experiments were carried out in randomized order.

To optimize the wheat-sprouted soybean bread, the specific loaf volume (cm^3/g) and the apparent yield stress (kN/m^2) were normalized by transforming the data to standardized scores ($z = \frac{x - \bar{x}}{s}$ where x = independent variable of interest; $\bar{x}$ = mean of independent variable of interest and s = standard deviation). The standardized scores were fitted to a quadratic polynomial regression model for predicting individual Y responses by employing a least square technique (Gacula and Singh, 1984; Wanasundara and Shahidi, 1996; SPSS, 2007). The model proposed for each response of Y was

$$Y = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + \sum_{i<j=1}^{3} \beta_{ij} X_i X_j \qquad (1)$$

where β_0, β_i, β_{ii} and β_{ij} are intercepts, linear, quadratic and interaction regression coefficient terms, respectively, X_i and X_j are independent variables, yeast and sprouted soybean flour, respectively. Response surface plots were developed using the fitted quadratic polynomial equations using MATLAB (2005).

Production of wheat-sprouted soybean bread

The straight dough procedure reported by Irvine and Mcmulan (1960) was adopted for producing the wheat-sprouted soybean bread with slight modification. The standard recipe consisted of wheat flour (100%), salt (1.5%), fat (1%), sugar (7.3%) and water (57%). Varying quantities of yeast and SSF were added as determined by the 3^2 factorial design arrangements. The dough was mixed for 15 min and allowed to ferment for 1½ hr at room temperature (25 ± 3°C). The dough was knocked back and 200 g of the dough was moulded in triplicates into baking pans (30.7 × 15.5 × 6.0 cm) and allowed to proof for 1 h. The proofed panned dough was baked at 180°C for 35 min. The dough was allowed to cool and loaf volume, sensory evaluation and loaf firmness of the bread were measured after 24 h.

Following this method, nine different formulations of wheat-sprouted soybean bread in triplicate varying yeast and sprouted soybean concentration. Also produced for comparison was bread from wheat flour only.

Proximate analysis

The unsprouted and sprouted soybean flours, wheat-sprouted soybean loaves and the best overall assessed loaves were assessed for their proximate composition. Moisture, crude protein and fat contents were determined using the method of AOAC (1984). The carbohydrate content was by difference. All determinations were in three replicates.

Loaf volume determination

The acha seed displacement method of Jideani et al. (2008) was used to determine the loaf volume of the wheat-sprouted soybean bread. A 2 L measuring cup box was filled with acha grain and the surface leveled with a ruler. The loaf whose volume was to be determined was weighed and the loaf placed in the 2 L cup. The acha grain from the measuring cylinder was poured over the loaf in the box and leveled. The volume of the spilled acha grain was noted as the volume of the loaf. The specific loaf volume (SLV) of the loaf was calculated as the loaf volume per weight of the loaf (cm^3/g). All determination was in three replicate.

Determination of loaf firmness

The cone penetrometer was used to measure the apparent yield stress [AYS] (firmness) of the bread samples. The method of Lewis (1990) was used to calculate the apparent yield stress (N/m^2) using the relationship in equation 2.

$$\tau_0 = \frac{gm}{P^2 \tan^2\left(\frac{1}{2}\alpha_c\right)} \qquad (2)$$

where P = penetration in metres after 5 seconds; m = mass (kg) of the cone (0.08 kg); α_c = cone angle in degree (30°); τ_0 = apparent yield stress (N/m^2) and g = acceleration due to gravity (9.8 m/s^2).

Sensory evaluation

A 20-member consumer panel was used to access the loaves for taste, crust texture, flavour, appearance and general acceptability. The loaves were presented in sets of four to the panelists as follows: set with 1% yeast (coded DBE, GFT, EMM and control IYK), set with 2.5% yeast (coded KRE, EDS, GLR and control VTR) and set with 4% yeast (coded KME, ADB, OGE and control KYD). A thin slice of each loaf (3 mm thick) in a white plastic plate indicate their preference on a four-point hedonic scale of 5 best, 4 better, 3 good, 2 bad and worst 1. Each assessment was in triplicate.

Analysis of variance (ANOVA) was used to establish significant differences among treatment. Duncan's multiple range tests was used to separate the means where significant differences existed (SPSS, 2007).

RESULTS AND DISCUSSION

Proximate composition of the unsprouted and sprouted soybean flours

The proximate composition of the unsprouted and sprouted soybean flours are detailed in Table 2. Significant difference exists in moisture, crude protein, crude fibre, crude fat, ash, carbohydrate and vitamin C content between the unsprouted and sprouted soybean flours. The moisture content of the unsprouted and sprouted soybean flour was 46.0 and 67.0 g kg^{-1}, respectively. Their moisture contents were within the range of that reported by Ihekoronye and Ngoddy (1985) for safe storage of soybean flour.

There was a significant reduction in protein content (35.3 g kg^{-1}) of the sprouted soybean flour when compared to the unsprouted flour (38.2 g kg^{-1}). This trend is in agreement with that reported by Hsu et al. (1980). Sprouting significantly increased the vitamin C content of soybean flour from 2.0 to 3.25 mg kg^{-1}. This is in agreement with the report of Hsu et al. (1980) that the

Table 2. Proximate composition of unsprouted and sprouted soybean flours.[1]

	Proximate constituent (g kg^{-1})						
Flour	**Moisture**	**Crude protein**	**Crude fibre**	**Fat**	**Ash**	**Carbohydrate**	**Vitamin C (mg kg^1)**
Unsprouted	46.0^a	381.7^a	123.8^a	174.2^a	56.3^a	246.5^a	2.00^a
Sprouted	67.0^b	353.2^b	176.0^b	152.7^b	34.5^b	188.1^b	3.25^b

[1]Any two means in a column followed by different letters differ significantly ($p \leq 0.05$).


IYK DBE GFT EMM

Plate I. Bread produced with 1% yeast and varying proportions of sprouted soybean flour (5, 10 and 15%). IYK = 1% (control); DBE = 1% yeast + 5% sprouted soybean flour; GFT = 1% yeast + 10% sprouted soybean flour; EMM = 1% yeast + 15% sprouted soybean flour.

ascorbic acid content of three legumes (peas, lentils and faba beans) increased markedly during germination. Kordylas (1990) also reported that there is a significant increase in all the vitamins (including vitamin C), some of which increased by as much as 3 - 4 times their level in the unsprouted seed. It is thought that sprouted soybean flour will be an effective bread improver because of the increased vitamin C content. The significant increase in the fibre content of the sprouted flour is an added advantage to its benefit in bread baking. Uwaegbute et al. (2000) reported similar increase in crude fibre.

The carbohydrate content of the sprouted soybean flour (18.8 g kg^{-1}) was significantly lower than that of the unsprouted soybean flour (24.65 g kg^{-1}). The values are within the range reported by Okaka et al., (2000). The lower value carbohydrate content of the sprouted soybean flour is because the germination process involves the use of stored starch (Kordylas, 1990).

Quality characteristics of the wheat-sprouted soybean loaves

Plates I to III show the bread samples produced with SSF and the controls without sprouted soybean flour. All flour blends produced typical dome shaped loaves. Significant differences exist among the bread samples in loaf weight (g), loaf volume (cm^3), specific loaf volume (cm^3/g) and apparent yield stress (kN/m^2) (Table 3).

Plate I shows the external and internal structure of the loaves with 1% yeast and varying proportions of sprouted soybean flour (5, 10 and 15%). The loaves DBE, GFT and EMM with weights of 231.1 ± 0.5, 232.7 ± 1.6, and 234.6 ± 0.9 g, respectively, were significantly ($p < 0.05$) greater than the control (IYK) with a weight of 227.2 ± 1.6 g. The addition of 5 - 15% sprouted soybean increased the loaf weights. The loaves did not differ significantly ($p > 0.05$) in loaf volume from each other. However, they were significantly higher in loaf volume than the control (IYK). The loaves with SSF were significantly ($p < 0.05$) higher in SLV than the control (IYK). The AYS (kN/m^2) of the loaves increased with increase in SSF. The high AYS indicates increased resistance to penetration of the cone. This suggests a firmer, spongier or honey comb texture of the crumbs as opposed to a gummy texture of the control. The loaf with 15% SSF (EMM) with AYS 89.4 kN/m^2 was spongier than the control (IYK) with apparent yield stress of 71.7kN/m^2.

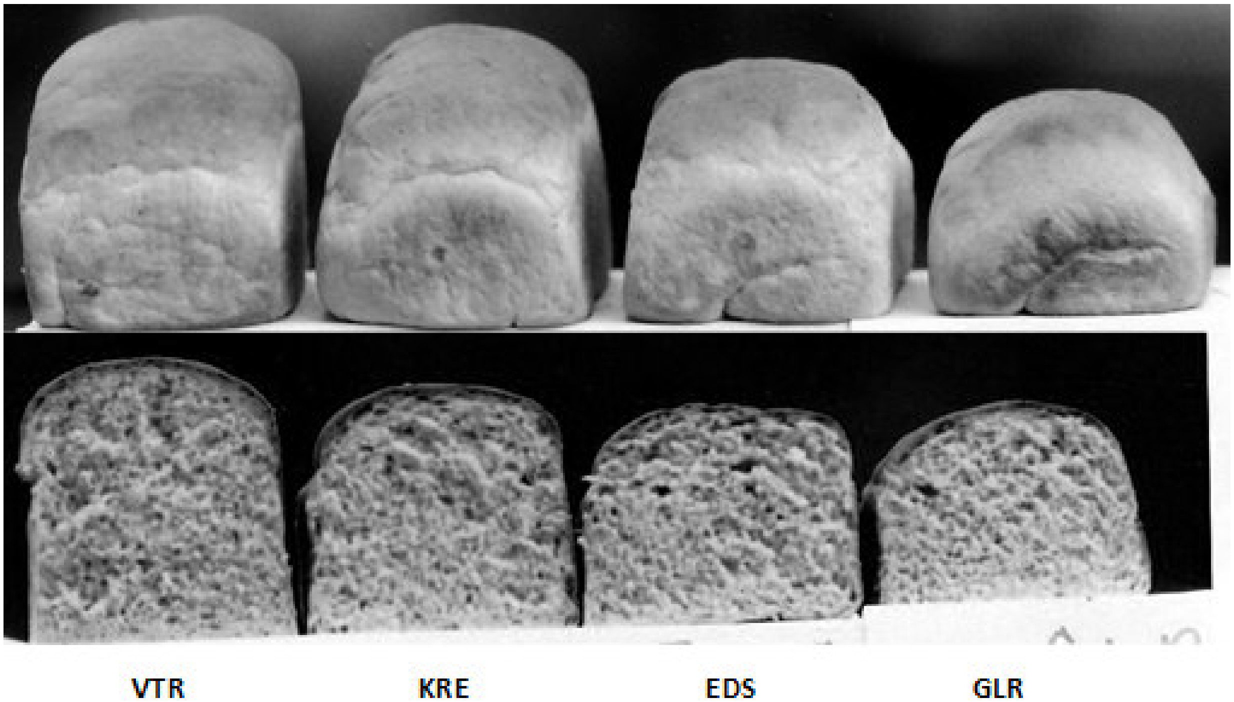

Plate II. Bread produced with 2.5% yeast and varying proportions of sprouted soybean flour (5, 10 and 15%). VTR = 2.5% yeast (control); KRE = 2.5% yeast + 5% sprouted soybean flour; EDS = 2.5% yeast + 10% sprouted soybean flour; GCR = 2.5% yeast + 15% sprouted soybean flour.

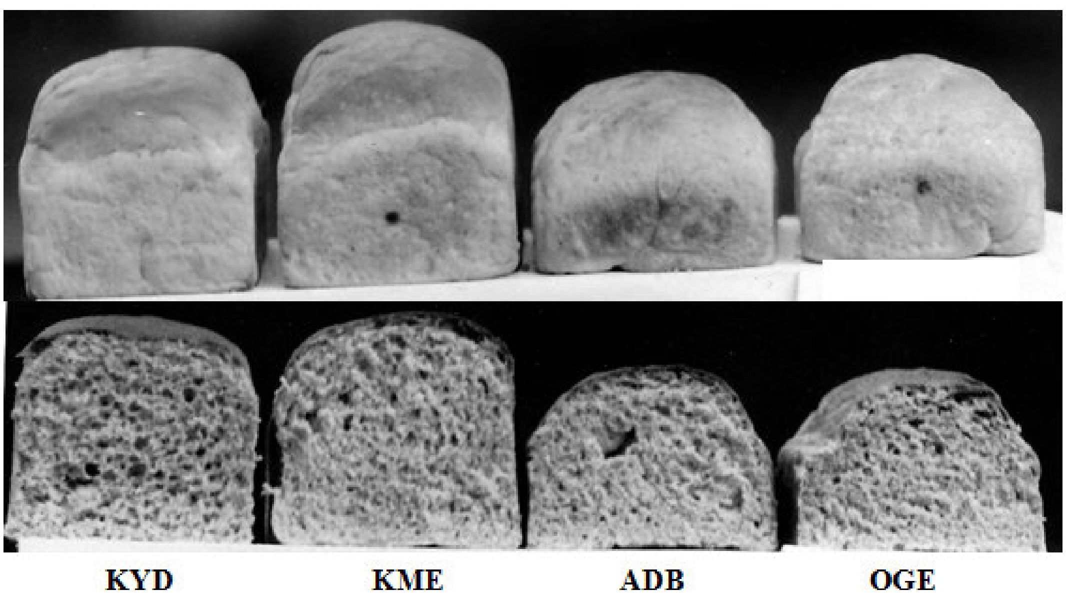

Plate III. Bread produced with 4% yeast and varying proportions of sprouted soybean flour (5, 10 and 15%). KYD = 4% yeast (control); KME = 4% yeast + 5% sprouted soybean flour; ADB = 4% yeast + 10% sprouted soybean flour; OGE = 4% yeast + 15% sprouted soybean flour.

Plate II shows the external and internal structure of the loaves with 2.5% yeast and varying proportions of SSF (5, 10 and 15%). The loaves KRE, EDS and GLR with loaf weights of 225 ± 0.5, 228.7 ± 0.8 and 233.4 ± 0.7 g, respectively were significantly ($p < 0.05$) higher in loaf weight than the control VTR with loaf weight of 223.4 ± 3.0 g. The incorporation of 5, 10 and 15% SSF resulted in significant increase in loaf volume for KRE (906.7 ± 28.9

Table 3. Loaf weight, volume, specific loaf volume and apparent yield stress of the wheat-sprouted soybean loaves[a, b].

Sample code[c]	Independent variable[a]		Response variable[b]			
	Yeast (X_1)	Sprouted soybean flour (X_2)	Loaf weight (g)	Loaf volume (cm^3)	Specific loaf volume (Y_1) (cm^3/g)	Apparent yield stress (Y_2) (kN/m^2)
DBE	-1	-1	231.1 ± 0.5[a]	800.0[a]	3.46 ± 0.01[a]	56.0 ± 4.0[a]
KRE	0	-1	225.0 ± 0.5[b]	906.7 ± 28.9[b]	4.03 ± 0.12[b]	76.6 ± 0.6[b]
KME	1	-1	227.7 ± 2.0[c]	900.0 ± 17.3[b]	3.95 ± 0.04[b]	45.8 ± 0.9[c]
GFT	-1	0	232.7 ± 1.6[d]	810.0 ± 85.4[a]	3.48 ± 0.36[a]	66.3 ± 2.6[d]
EDS	0	0	228.7 ± 0.8[a]	866.7 ± 40.4[a]	3.79 ± 0.17[b]	144.7 ± 26.1[e]
ADB	1	0	225.5 ± 1.3[e]	573.3 ± 46.2[c]	2.54 ± 0.19[c]	46.1 ± 5.1[b]
EMM	-1	1	234.6 ± 0.9[d]	800.0a	3.41 ± 0.01[d]	89.4 ± 5.3[b]
GLR	0	1	233.4 ± 0.7[d]	800.0a	3.43 ± 0.01[d]	69.4 ± 6.5[d]
OGE	1	1	226.4 ± 0.4[f]	700.0[d]	3.09 ± 0.01[e]	57.8 ± 6.9[e]
IYK			227.2 ± 1.6[f]	750.0 ± 86.6[e]	3.30 ± 0.36[d]	71.7 ± 5.2[b]
VTR			223.4 ± 3.0[g]	933.3 ± 57.7[b]	4.03 ± 0.06[b]	121.4 ± 17.1[f]
KYD			228.7 ± 0.9[a]	860.0 ± 52.0[a]	3.76 ± 0.23[b]	35.6 ± 3.2[g]

[a]Mean ± standard deviation of triplicate determination. Coded levels of yeast (-1, 0, 1) correspond to 1, 2.5 and 4% respectively; that of unsprouted soybean flour correspond to 5, 10 and 15% respectively.
[b]Any two means in a column followed by different letters differ significantly ($p \leq 0.05$).
[c]Sample DBE = 1 % yeast + 5 % sprouted soybean flour; KRE = 2.5 % yeast and 5 % sprouted soybean flour; KME = 4 % yeast + 5 % sprouted soybean flour; GFT = 1 % yeast + 10 % sprouted soybean flour; EDS = 2.5 % yeast and 10 % sprouted soybean flour; ADB = 4 % yeast + 10 % sprouted soybean flour; EMM = 1 % yeast and 15 sprouted soybean flour; GLR = 2.5 % yeast and 15 % sprouted soybean flour; OGE = 4 % yeast + 15 % sprouted soybean flour.

ml/g), EDS (866.7 ± 40.4 ml/g) and GLR (800 ml/g). The loaves did not differ significantly from the control in SLV. However, loaf with 15% SSF significantly decreased the SLV when compared with the control. The loaf with 10% SSF (EDS) had significantly higher AYS (144.7 ± 26.1 kN/m^2) than the control VTR (121.4 ± 17.1 kN/m^2). Consequently, the addition of 10% SSF with 2.5% yeast produced a firmer, spongy and elastic loaf.

Plate III shows the external and internal structure of the loaves with 4 % yeast (KYD) and varying proportions of SSF (KME, ADB, OGE) respectively containing 5, 10 and 15% SSF. The loaves differed significantly ($p < 0.05$) from each other in loaf weight (Table 3). Loaf KME (4% yeast, 5% SSF) was significantly higher in loaf volume than the control. There was no significant difference in SLV between the loaves produced with 4% yeast and 5% SSF (KME) and the control (KYD). Increase in SSF significantly decreased the SLV. The loaf with 10% SSF was significantly firmer, spongier and more elastic than the control.

The incorporation of SSF into wheat bread resulted in increased loaf volume and a firmer, spongy and more elastic loaf. However, increasing the sprouted soybean flour beyond 10% adversely affected these qualities.

Sensory characteristics of the wheat-sprouted soybean loaves

The mean sensory characteristics of the wheat-sprouted soybean loaves are detailed in Table 4. The panelists could not detect any significant different in all the sensory attributes between the loaves baked with 1 or 2.5% yeast with varying quantities of the SSF and their respective controls. However, the loaf with 5% SSF was higher in overall acceptability than the control.

Significant differences ($p < 0.05$) existed between the loaves baked with 4% yeast with varying quantities of SSF and the control in taste and general acceptability. The loaf with 5% sprouted soybean was significantly rated better in taste and general acceptability than the control.

Proximate composition of the overall acceptable bread

The proximate composition of the loaves merging best in their groups, KRE (2.5% yeast + 5% sprouted soybean flour) and KME (4% yeast + 5% sprouted soybean flour) compared to their respective controls VTR (2.5% yeast) and KYD (4% yeast) are detailed in Table 5. Significant differences exist ($p < 0.05$) in the proximate composition between the wheat-sprouted loaves and their respective controls. The addition of the 5% sprouted soybean resulted in a significant increase in protein, fibre and ash content of the bread. Similar effect was reported for acha bread (Jideani et al., 2008). Dhingra and Jood (2001) reported that breads made from blends containing dehulled soy flour (full fat and defatted) showed a decrease

Table 5. Proximate composition of the best loaves and their controls.

Sample code[2]	Proximate constituent ($g\ kg^{-1}$)[1]					
	Moisture	**Crude protein**	**Crude fibre**	**Ash**	**Fat**	**Carbohydrate**
2.5 % yeast						
VTR (Control)	129.4[a]	81.2[a]	15.7[a]	10.3[a]	13.4[b]	740[a]
KRE	127.8[a]	84.2[a]	26.6[b]	18.4[b]	14.2[b]	739[a]
4% Yeast						
KYD (Control)	134.3[a]	110.2[a]	17.9[a]	11.2[a]	14.0[a]	712[a]
KME	130.5[b]	112.2[b]	18.9[b]	14.1[b]	21.1[b]	703[b]

[1]Any two means in a column followed by different superscript differ significantly ($p \leq 0.05$).
[2]VTR = 2.5% yeast (control); KRE = 2.5% yeast + 5% sprouted soybean flour; KYD = 4% yeast (control); KME = 4% yeast + 5% sprouted soybean flour.

Table 6. Optimum levels of yeast and sprouted soybean flour for specific loaf volume and yield stress of the loaves.

Dependable variable	Yeast (%)	Sprouted soybean flour (%)	Predicted value	Nature of stationary point
Specific loaf volume (cm^3/g)	2.2	11.8	3.6	Saddle
Apparent yield stress (kN/m^2)	2.4	10.6	120.0	Maximum

in total and insoluble dietary fibre whereas increase was found in soluble dietary fibre contents. Insoluble fibres are mainly present in hulls and soluble fibres are in cotyledons. Undehulled SSF was used in this study thus the increased fibre and the lower carbohydrate content of the loaves with 5% sprouted soybean may provide the consumers with the benefit of insoluble and soluble fibres. It has also been reported that soluble fibre is associated with cholesterol-lowering and improved diabetic control whereas insoluble fibre is associated with enhanced bowel functions (Dhingra and Jood, 2001).

Adequacy of the second-order polynomial model

Table 3 shows the 3^2 factorial design arrangement and responses of SLV and AYS of the bread samples. The response variables (SLV and AYS) were modeled with quadratic polynomial and tested for adequacy and fitness by analysis of variance. The F-ratio for lack of fit in each case was less than the F-distribution with 12 numerator and 9 denominator degree of freedom (DF) with R^2 (0.86) (Table not shown). Hence the second-order model was judged to be adequate at 0.05%. Since the fitted second-order model provides a good fit, it was used to search for optimum levels of yeast and sprouted soybean flour.

Optimum conditions for wheat-sprouted soybean bread

Using the determined regression coefficients of the second-order polynomial model, the predicted models for SLV $(\hat{Y}_1)$ and AYS $(\hat{Y}_2)$ were respectively:

$$\hat{Y}_1 = 0.1968 - 0.2781X_1 - 0.5537X_2 - 0.9342X_1^2 + 0.6391X_2^2 - 0.4445X_1X_2 \quad (3)$$

$$\hat{Y}_2 = 1.4187 - 0.1841X_1 + 0.2205X_2 - 1.0947X_1^2 - 1.0333X_2^2 - 0.1853X_1X_2 \quad (4)$$

The negative coefficients for X_1 and X_2 in equation 3 indicate that linear effect of yeast and SSF decreased the SLV. Increasing yeast decreased the SLV more than the effect of the SSF. Positive coefficients of X_2 (equation 4) indicates that the SSF resulted to increase in AYS of the bread i.e. a firmer and more spongy bread. The effect of yeast (X_1) was a decrease in AYS giving softer and gummier loaves.

Since the fitted second-order model provided a good fit, it was used to search for optimum levels of yeast and SSF. The optimum levels and their corresponding predicted values are shown in Table 6. The optimal level of yeast and SSF in each case was located near the centre of the experimental design. The optimum levels yeast (2.15%) and SSF (11.76%) for SLV and yeast (2.36%) and SSF (10.58%) for AYS, were all located within the range of experimental values of the independent variables, hence the fitted response equation was adequate for depicting responses near the stationary point.

Canonical analysis on the predicted variables

Canonical analysis was performed to examine the overall

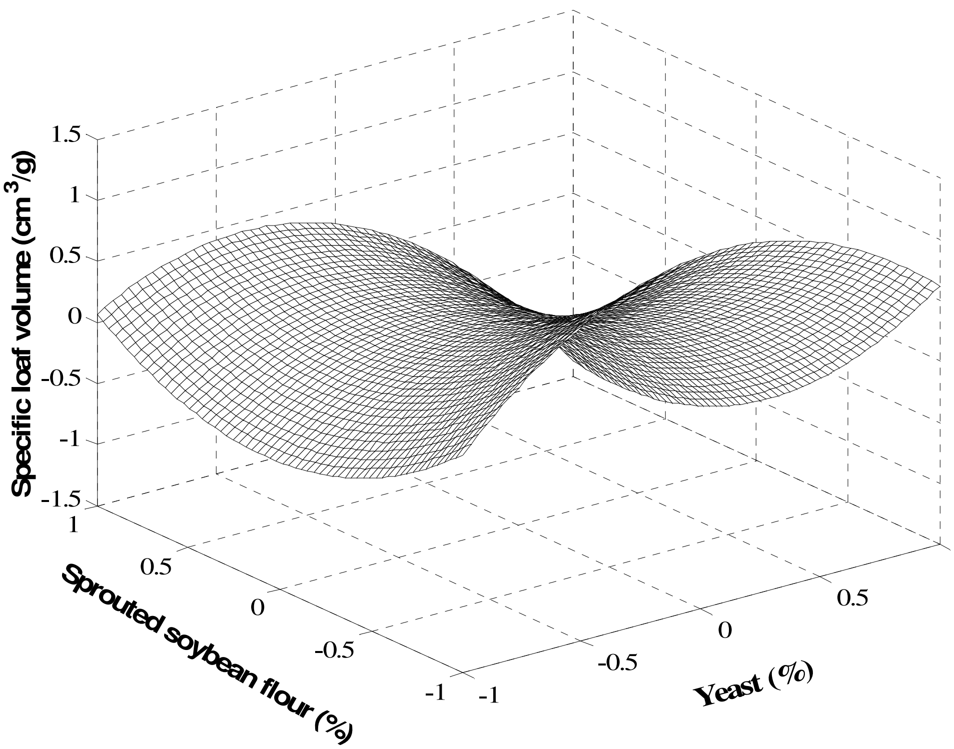

Figure 1. Response surface for the effects of sprouted soybean flour and yeast on specific loaf volume of wheat-sprouted soybean bread. Levels of yeast (-1, 0, 1) is equivalent to 1, 2.5 and 4%, respectively; levels of sprouted soybean flour (-1, 0, 1) is equivalent to 5, 10 and 15%, respectively. Y-axis is standardized scores ($z = \frac{x - \bar{x}}{s}$ where x = specific loaf volume; $\bar{x}$ = mean of specific loaf volume (3.47 cm^3/g) and s = standard deviation (0.456 cm^3/g).

shape of the responses and to characterize the nature of the stationary points (Wanasundara and Shahidi, 1996). The fitted response model in the canonical form for SLV and AYS were respectively:

$$SLV = 0.2851 - 0.9650V_1^2 + 0.0670V_2^2 \quad (5)$$

$$AYS = 1.5291 - 1.1617V_1^2 - 0.9663V_2^2 \quad (6)$$

where V_1 and V_2 are the axes of X_1 and X_2 considering the stationary point as origin for the new coordinate system. The coefficients of V_1 and V_2 are the eigen values of the symmetric matrix containing the estimate quadratic terms for X_1 and X_2 respectively as the main diagonal elements (Cornell, 1992). The large value of V_2 for SLV (equation 5) is indicative of rapid changes in the responses along the X_2 (SSF) axis (Gacula and Singh, 1984). This implies that the SSF results in significant improvement in loaf volume. The yeast exerted a slower change on AYS than the SSF.

The eigen values obtained for SLV were of opposite signs, thus indicating that the response surface was saddle shaped (Figure 1) where a maximum or minimum of the response variable is found at various combinations of the independent variables. Additional experiments may need to be designed for optimum responses. The eigen values obtained for AYS were negative indicating that the response surface (Figure 2) has a maximum response value for AYS 120 kN/m^2, corresponding to the optimal levels of yeast (2.4%) and SSF (10.6%).

Conclusion

The incorporation of sprouted soybean flour into wheat bread resulted in increased loaf volume and a firmer, spongy and more elastic loaf. However, increasing the sprouted soybean flour beyond 10% adversely affected these qualities. The loaf with 5% SSF + 4% yeast was significantly rated better in taste and general acceptability than the control. The increased fibre and the lower carbohydrate content of bread with 4 and 5 % SSF is of benefit since it will aid in the digestion of the bread in the colon and reduce constipation often associated with white

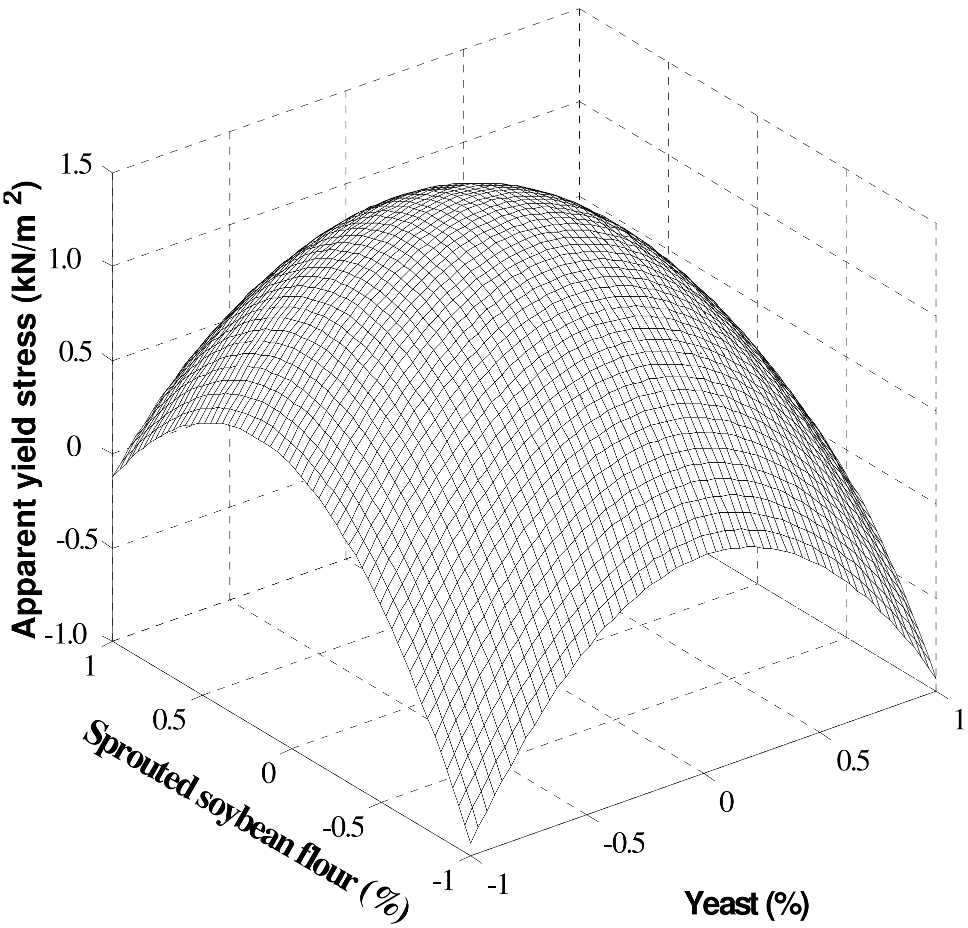

Figure 2. Response surface for the effects of sprouted soybean flour and yeast on apparent yield stress of wheat-sprouted soybean bread. Levels of yeast (-1, 0, 1) is equivalent to 1, 2.5 and 4%, respectively; levels of sprouted soybean flour (-1, 0, 1) is equivalent to 5, 10 and 15%, respectively. Y-axis is standardized scores ($z = \frac{x - \bar{x}}{s}$ where x = apparent yield stress; $\bar{x}$ = mean of apparent yield stress (75.78 kN/m^2) and s = standard deviation (28.92 kN/m^2).

wheat bread. Sprouted soybean flour resulted to increase in AYS of the bread i.e. firmer and spongier bread. The effect of yeast was a decrease in yield stress giving softer and gummier loaves. The response surface for specific loaf volume was saddle shaped. Additional experiments may need to be designed for optimum responses. The response surface for apparent yield stress (firmness) had a maximum.

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