Improved quality characteristics of Sangak bread by response surface optimisation of farinograph and extensograph traits of doughs formulated with fenugreek gum

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RESEARCH ARTICLE

Abstract

Fenugreek gum (FG) was evaluated as a potential material for the improvement of dough farinographic and extensographic characteristics and quality of an Iranian flat bread 'Sangak' in terms of moisture content (MC), loaf volume, textural, colour, and sensorial attributes. Response surface methodology-central composite rotatable design was used to optimise the effects of FG content and leavening time on the dough water absorption (WA), development time (DDT), stability time (ST), softening degree (SFD), resistance to extension (R_{50}), extensibility (E), and R/E values. The significant second-order polynomial regression equations with high R^2 (>0.888) were successfully fitted for all responses as function of independent variables. However, the quadratic and interaction effects were of independent variables shown to be non-significant on the R/E. The dough formulated with 5.5% w/w FG and leavened for 2.61 h yielded to the maximum WA (63.69%), DDT (2.85 min), ST (6.88 min), and E (284.58 mm) values, minimum SFD trait (46.52 Brabender Units; BU), and optimum R_{50} (289.13 BU) and R/E (1.00) amounts. Experimental data at the optimum conditions were very close to the amounts predicted by the constructed models. The bread baked with optimal dough significantly had higher MC, loaf volume, softness and lightness than the control bread (P<0.05). Sensory evaluation by a consumer panel showed a higher score for overall acceptability to the formulation supplemented with 5.5% FG. The levels of MC and softness for control bread due to the staling process were significantly reduced during 3-day storage.

Keywords: flat bread, fenugreek gum, farinograph and extensograph properties, colour and textural attributes, response surface methodology

1. Introduction

Bread is a staple food in many countries and an important source of nutritional ingredients such as iron and zinc. Flat breads are the oldest and most well-known bread types worldwide, with estimates showing that over 1.8 billion people consume various types of flat breads in regions of Central America, South Europe, South Africa, Scandinavia, the Middle East and part of China P.R. (Ajo, 2013; Chavan and Chavan, 2011). The fresh breads are soft, pliable and elastic, but are staled within a few hours when kept at room temperature. Suitable volume, low density, fresh with attractive aroma, good taste, soft crumb, crispy and brittle crust, clean colour and long shelf life are several critical attributes for high quality of these breads from the consumers' point of view (Al-Dmoor, 2012; Pourfarzad *et al.*, 2012).

Because of improper formulation and lack of gluten of the flat breads, the resulting dough cannot raise enough and, thus, the bread will have a poor volume and texture. In order to obtain a large, open-crumb, good volume flat bread, the cell wall of the dough should be strengthened to retain moisture (Upadhyay *et al.*, 2012). Hydrocolloids are one of the most important components to retard the migration of moisture to the bread surface and also retard the staling process during storage (Sciarini *et al.*, 2012; Upadhyay *et al.*, 2012). Fenugreek gum (FG) is a galactomannan extracted from the seed endosperm of fenugreek herb (*Trigonella foenum-graecum*). Galactomannans are structurally composed of a linear backbone of β-D (1→4) D-mannose units with α-D (1→6) D-galactose units attached as side chains (Youssef *et al.*, 2009). It has a uniform distribution of galactose to mannan backbone in the ratio of 1:1 or 1:2. This highly branched structure of FG may explain the lower viscosity when compared to other galactomannans (such as guar gum and locust bean gum) at the same molecular weight and concentration. However, this gum shows an appropriate viscosity in aqueous solutions and thus can extensively use as thickening, water holding, stabilising, and emulsifying agents in many food products (Gharibzahedi *et al.*, 2012b).

Indrani *et al.* (2010) investigated the effect of replacement of wheat flour with of fenugreek seed powder (FSP) on the dough rheology, microstructure and quality of an Indian bread 'parotta'. They showed that acceptable quality parotta with perceptible fenugreek flavour could be produced with 5% FSP. Roberts *et al.* (2012) also by studying the influence of FG and extrusion modified FG on bread quality observed that an increase in dough farinograph water absorption (WA) compared with the control, but extruding the gum led to an even greater increase in WA as compared with the non-extruded gum. However, to the best our knowledge, no reports were found in the literature attending to this aspect of Sangak bread (Figure 1A and 1B). Thus, the aim of this research was to study the possible impact of FG addition and leavening time (LT) on the dough characteristics and Sangak quality attributes.

2. Materials and methods

Materials

The wheat flour (WF) used in this study for the preparation of bread samples was commercial-type flour (Amin Flour Company, Karaj, Iran) with an extraction degree of 93%, which is specific for Iranian Sangak bread. Physicochemical properties of the wheat flour including moisture

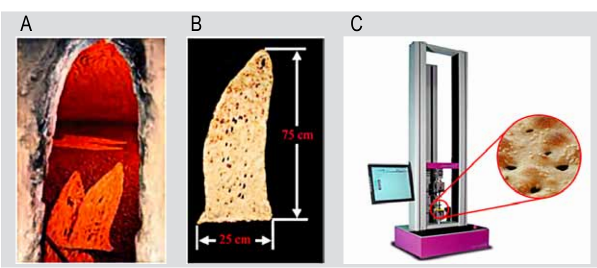

Figure 1. (A) Traditional furnace for making Sangak bread used in the present research. (B) A real Sangak bread produced from the dough formulated with fenugreek gum. (C) A cube-shaped piece of the crumb (3×3×3 mm) separated from the bread centre to evaluate staling using a texture analyser machine.

(12.33±1.61%), ash (1.23±0.02%), wet gluten (20.17±0.48%), crude fibre (0.73±0.18%), fat (1.47±0.14%) and protein (10.81±1.12%) contents, falling (395±12 s) and Zeleny (25.6±0.24 ml) number, and acidity (3.45±0.05 mg KOH/100 g) were determined according to the standard methods of American Association of Cereal Chemists International (AACCI, 2000). FG was provided from Canafen Gum® (Emerald Seed Products, Avonlea, Canada). Salt, sourdough and dried instant yeast were purchased from Sabzdasht Co. (Semnan, Iran), Razavi Yeast Co. (Mashhad, Iran), and Iran Mellas Co. (Mashhad, Iran), respectively.

Dough preparation and baking procedure

Sangak dough was prepared using 100 g WF, FG (1.46-8.54%), 1.5% salt, 15% sourdough along with 0.5% yeast which is called Torsh (sour) and an appropriate amount of distilled water. All the ingredients were mixed thoroughly and the dough was rested at room temperature for the different times (0.59-3.41 h). Baking of the prepared dough samples was carried out at 270±10 °C for about 10±2 min in a traditional furnace using a bed of small sands. The breads were taken out of the furnace with the discretion of the baker according to the typical appearance of regular Sangak breads.

Dough characteristics

Farinographic assay

The addition influence of FG to the flour and LT on the mixing behaviour in terms of dough WA (percentage of water required to yield a dough consistency of 500 Brabender Units; BU), development time (DDT; time to reach maximum consistency, min), stability time (ST; time during which dough consistency is kept at 500 BU, min), and softening degree (SFD; consistency difference between height at peak and that at 5 min later, BU) was evaluated using a farinograph (Brabender GmbH, Duisburg, Germany) with a 300×*g* mixer. The thermostat was maintained at 30 °C and all doughs were mixed in the farinograph bowl to 500 BU.

Extensographic assay

The dough stretching properties especially the dough R_{50} and its extensibility (E) can be measured using an extensograph by determining the force required to stretch the dough with a hook until it breaks. The effects of FG concentration and LT on the resistance to extension (R_{50}, Bu), E (mm), and R/E value in 45 min based on the standard method of AACCI (2000) using an extensograph-E (Brabender GmbH) was studied.

Bread quality characteristics

The critical quality attributes of bread baked at optimal conditions of dough production and the control sample (without FG) were compared.

Moisture content determination

Moisture content (MC) was measured based on the standard AACCI, method 44-15 A (AACCI, 2000).

Loaf volume measurement

The bread volume was measured using the rapeseed displacement method (method 10-05; AACCI, 2000). Data are reported as the mean of measurements from at least three loaves.

Analysis of bread crumb firmness

To evaluate texture changes and staling effects of Sangak bread after baking, cube-shaped pieces of the crumb (3×3×3 mm) were separated from the bread centre and then a penetration test was applied using an Universal Testing Machine (M350-10AT; Testometric, Rochdale, UK) equipped with a 50 kg compression load cell and integrator (Figure 1C). The crumb firmness was determined by means of a stainless steel probe with 3 mm diameter and test velocity was 60 mm/min. Maximum peak force (N) was measured from the penetration curve and expressed as the hardness (Sadeghi *et al.*, 2008).

Determination of colour attributes

The method of Little (1975) was applied to determine the colour attributes of Sangak crust using a Hunter colorimeter (D25 L model; Hunter Associates Laboratory, Reston, VA, USA). About 25 g of the pieces were placed in the sample cup and colour values were recorded as 'L' (0 = black; 100 = white), 'a' (-a = greenness; +a = redness), and 'b' (-b = blueness; +b = yellowness). The total colour difference (ΔE) was calculated using Equation 1:

$$\Delta E = \sqrt{(L^*-L)^2 + (a^*-a)^2 + (b^*-b)^2} \quad (1)$$

where L* (=96.84), a* (=-0.02), and b* (=1.95) are the colour parameter values of the standard and L, a, and b are the colour parameter values of the sample.

Sensory evaluation

Sensory evaluations of Sangak breads during the storage were conducted by 30 panellists, consisting of staff and students of the Department of Food Science & Technology of Islamic Azad University using a 1 to 9 hedonic rating scale for the texture, taste, crust and crumb colour, odour and overall acceptability, where 9 means extreme satisfaction and 1 extreme dissatisfaction.

Experimental design and statistical analysis

Fourteen treatments in terms of a response surface methodology-central composite rotatable design (RSM-CCRD; Table 1) were conducted to study the effects of two parameters of FG content (1.46-8.54% w/w, X_1), and LT (0.59-3.41 h, X_2) on the dough WA (Y_1), DDT (Y_2), ST (Y_3), SFD (Y_4), R_{50} (Y_5), E (Y_6) and R/E (Y_7). The Design Expert (Trial version 7.1.3, Stat-Ease Inc., Minneapolis, MN, USA) was applied for regression and graphical analyses of the obtained data. The generalised regression second-order polynomial model proposed for predicting the response variables is given as:

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

The coefficients of the polynomial were represented by b_0 (constant term), b_1 and b_2 (linear effects), b_{11} and b_{22} (quadratic effects), and b_{12} (interaction effects). The suitability of the fit of the polynomial equations was tested by the coefficient of determination (R^2), adjusted-R^2, predicted-R^2 (R^2-pred), coefficient of variation (CV) and adequate precision (AP) as previously explained by the literature (Gharibzahedi *et al.*, 2013a). Finally, additional confirmation experiments were carried out to verify the accuracy of statistical experimental design. Determination of significant statistical difference between experimental and predicted values for the different responses of farinographic and extensographic was performed using SPSS 13 software (SPSS Inc., Chicago, IL, USA). The means of quality attributes values for breads produced with two optimum and control formulations were also compared using the student's t-test at a significant level of $P<0.05$.

3. Results and discussion

Model fitting

Multiple linear regression analysis of the experimental data yielded quadratic models for predicting the independent variables as postulated at the beginning of the research. The results of analysis of variance (ANOVA) indicate that the contribution of the quadratic models was very significant ($P<0.0001$; Table 2). However, a linear model was adequately fitted for evaluating the R/E. Since the models have shown lack of fit to be insignificant the responses surfaces (Table 2) were sufficiently explained by the regression equations (Gharibzahedi *et al.*, 2013b). As revealed in Table 2, the significant response surface models with high R^2 and R^2_{adj}, R^2-pred values varied from 0.888-0.995, 0.867-0.991, and 0.810-0.924, respectively. These values showed a good agreement between the experimental and the predicted values and indicated that the models were very reliable

Table 1. The response surface methodology-central composite rotatable design matrix and experimental data obtained for the response variables.[1]

	FG content	LT	Farinographic characteristics				Extensographic characteristics		
Run	(X_1, % w/w)	(X_2, h)	WA (Y_1, %)	DDT (Y_2, min)	ST (Y_3, h)	SFD (Y_4, BU)	R_{50} (Y_5, BU)	E (Y_6, mm)	R/E (Y_7)
1	2.5	1	56.59±0.26	2.0±0.2	6.6±0.2	56±3	261±11	235±7	1.11±0.12
2	7.5	1	60.54±0.15	2.6±0.0	6.9±0.0	51±1	275±2	279±3	0.98±0.03
3	2.5	3	60.42±1.12	2.2±0.1	6.8±0.1	53±1	262±6	253±1	1.03±0.51
4	7.5	3	62.48±0.95	2.6±0.2	7.0±0.0	42±1	308±13	342±5	0.90±0.06
5	5.0	2	63.79±0.14	2.8±0.3	6.9±0.1	49±0	279±5	270±2	1.03±0.18
6	5.0	2	62.85±0.35	2.8±0.4	6.8±0.0	50±2	283±1	260±9	1.08±0.28
7	5.0	2	64.06±0.29	2.8±0.1	6.8±0.1	47±1	285±6	261±2	1.09±0.04
8	1.46	2	56.26±0.48	1.8±0.0	6.6±0.0	56±0	242±1	215±2	1.12±0.11
9	8.54	2	58.64±0.06	2.5±0.0	7.2±0.3	44±0	295±5	312±11	0.94±0.12
10	5.0	0.59	57.13±0.01	2.6±0.1	6.6±0.2	57±1	272±3	257±5	1.05±0.19
11	5.0	3.41	63.79±0.09	2.7±0.2	6.8±0.4	47±4	292±5	295±0	1.00±0.25
12	5.0	2	62.10±1.16	2.8±0.1	6.8±0.0	49±0	280±3	265±2	1.05±0.20
13	5.0	2	62.42±0.28	2.9±0.0	6.8±0.1	48±1	274±1	265±5	1.03±0.13
14	5.0	2	61.51±0.74	2.9±0.2	6.9±0.2	51±3	277±8	263±1	1.05±0.24

[1] BU = Brabender units; DDT = development time; E = extensibility; FG = Fenugreek gum; LT = leavening time; R_{50} = resistance to extension; SFD = softening degree; ST = stability; WA = water absorption.

(Gharibzahedi *et al.*, 2012a). The low variation coefficient values (CV=0.95-3.11%) indicates the experiments' high precision and reliability. AP measures the signal-to-noise ratio. A ratio greater than four is desirable (Ghasemlou *et al.*, 2012). These values for the proposed models were between 10.89 and 46.28. All these statistical parameters show the reliability of the constructed models.

Farinograph parameters

Table 2 shows that WA, DDT and ST of Sangak dough were significantly affected by the linear and quadratic of all the independent variables. The SFD was also significantly associated with the linear and quadratic effects of all independent variables, except the quadratic effect of FG content that was no significant (Table 2). The results revealed that the interaction effect of FG content and LT only significantly influenced the DDT and SFD (P<0.05) (Table 2; Figure 2). As shown in Table 2, the quadratic effect of FG content had the most significant (P<0.05) effect on the changes of dough WA and DDT values. This fact shows that use of FG in the formulation of bakery products can help to control WA and, consequently, improve dough rheology and shelf life. The increase of dough WA and DDT by increasing FG content can be due to the hydroxyl groups in the hydrocolloid structure and chain conformation which allows more water interaction through hydrogen bonding (Collar *et al.*, 1999). The similar results were reported by Guarda *et al.* (2004) and Naji *et al.* (2012) in relation to more WA and DDT by adding hydrocolloids to the dough formulation. The dough's high WA and DDT at long LT can be probably attributed to the increase of intermolecular interactions or spectral overlap between water and starch (Indrani *et al.*, 2010). An increase in amounts of two independent variables also led to an increase in ST value, and a decrease in SFD level (Figure 2). The ST value is an indication of flour strength, with higher values suggesting stronger dough. Thus, the hydrogen bonds can be considerably increased at high FG amounts and form a strong complex in the dough structure (Gharibzahedi *et al.*, 2012b). Moreover, it seems that a more association between the amylose and the galactomannan components of the FG at higher LT has happened (Alloncle and Doublier, 1991). Sharma and Chauhan (2000) also reported that when debittered fenugreek flour (FF) was supplemented from 1.5 to 9% level of substitution, the dough ST values due to the slow hydration characteristics of FF increased beyond a 4-5% level. The individual optimisation procedure exhibited that wheat dough containing 7.35% w/w FG with a LT of 2.4 h was predicted to provide the least SFD and the highest WA, DDT and ST.

Extensograph parameters

Generally, a combination of the characteristics of good resistance and suitable extensibility show desirable dough. The extensograph equipment determines dough extensibility for its R_{50} (Rosell *et al.*, 2001). The results

Table 2. ANOVA and regression coefficients of the second-order polynomial model for the response variables obtained from the farinographic and extensographic assays.[1]

Source (farinographic)	DF	WA (Y_1, %)			DDT (Y_2, min)			ST (Y_3, time)			SFD (Y_4, BU)		
		Coefficient	Sum of squares	*P*-value[2]	Coefficient	Sum of squares	*P*-value	Coefficient	Sum of squares	*P*-value	Coefficient	Sum of squares	*P*-value
Model	5	62.79	87.28	0.0001	2.83	1.49	<0.0001	6.83	0.31	0.0012	49.00	244.81	<0.0001
Linear													
β_1	1	1.17	10.99	0.0032	0.25	0.49	<0.0001	0.17	0.23	0.0001	-4.12	135.88	<0.0001
β_2	1	1.90	28.84	0.0002	0.043	0.015	0.0074	0.073	0.042	0.0151	-3.27	85.43	0.0001
Quadratic													
β_{11}	1	-2.41	42.75	<0.0001	-0.35	0.93	<0.0001	0.04	0.012	0.012	-	1.04	ns
β_{22}	1	-0.90	6.00	0.0142	-0.10	0.08	<0.0001	-0.06	0.027	0.027	1.38	13.96	0.0169
Interaction													
β_{12}	1	-	-0.47	ns	-0.05	0.01	0.0176	-	0.0025	ns	-1.50	9.00	0.0408
Residual	7		3.99			0.007			0.029			10.05	
Lack-of-fit	3		2.76	0.1595^{ns}		0.0008	0.9336^{ns}		0.016	0.2540^{ns}		0.72	0.9546^{ns}
Pure error	4		1.23			0.006			0.013			9.33	
Total	13		96.90			1.51			0.34			256.0	
R^2		0.956			0.995			0.915			0.960		
Adj-R^2		0.925			0.991			0.854			0.932		
CV (%)		1.24			1.26			0.95			2.40		
Adequate precision		14.49			46.28			12.95			17.80		

Source (extensographic)	DF	R_{50} (Y_5, BU)			E (Y_6, mm)			R/E (Y_7)		
		Coefficient	Sum of squares	*P*-value	Coefficient	Sum of squares	*P*-value	Coefficient	Sum of squares	*P*-value
Model	5	279.67	3249.01	<0.0001	264.0	12038.3	<0.0001	1.03	0.04	0.0004
Linear										
β_1	1	16.87	2276.5	<0.0001	33.77	9124.5	<0.0001	-0.064	0.033	0.0002
β_2	1	7.79	484.9	0.0004	15.96	2037.4	0.0002	-0.029	0.0066	0.0293
Quadratic										
β_{11}	1	-5.27	205.1	0.0042	-	27.72	ns	-	-	-
β_{22}	1	-	16.1	ns	6.94	355.4	0.0219	-	-	-
Interaction										
β_{12}	1	8.00	256.0	0.0024	11.25	506.2	0.01	-	-	-
Residual	7		82.99			288.8			0.010	
Lack-of-fit	3		46.33	0.3066^{ns}		225.5	0.0833^{ns}		0.0079	0.2225^{ns}
Pure error	4		36.67			63.3			0.0023	
Total	13		3363.5			12404.9			0.050	
R^2		0.975			0.976			0.888		
Adj-R^2		0.957			0.959			0.867		
CV (%)		1.24			2.39			3.11		
Adequate precision		27.21			26.07			10.89		

[1] BU = Brabender units; DDT = development time; DF = degrees of freedom; E = extensibility; R_{50} = resistance to extension; SFD = softening degree; ST = stability; WA = water absorption.

ns = not significant (*P*>0.05).

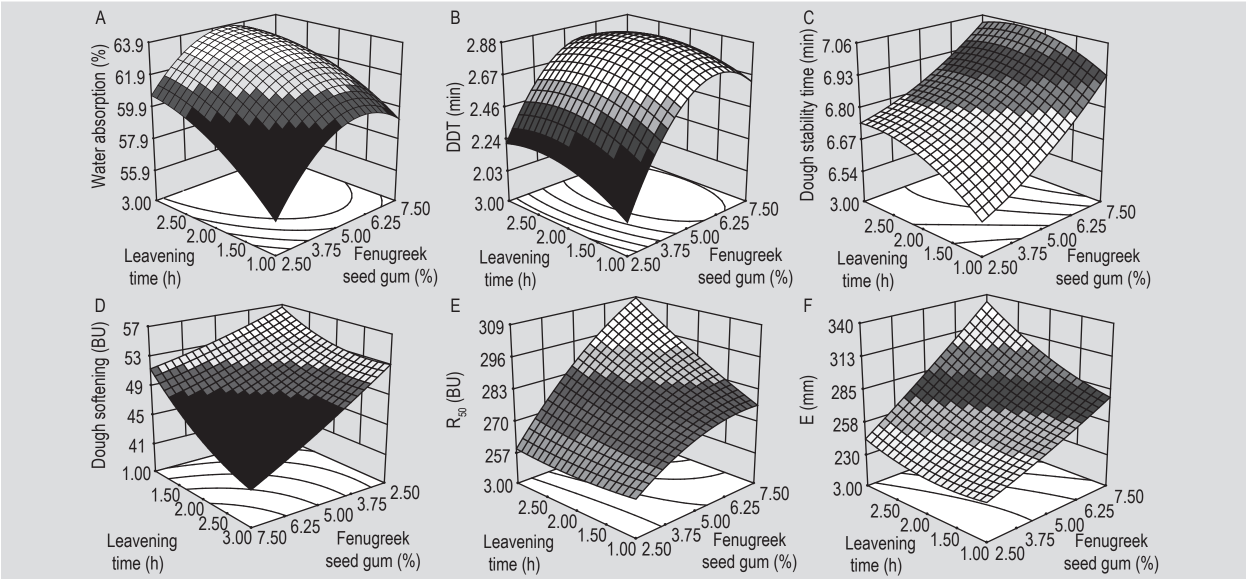

Figure 2. Response surface plots showing the interaction effects on the dough (A) water absorption, (B) development time (DDT), (C) stability time, (D) softening degree, (E) resistance to extension (R_{50}) and (F) extensibility (E).

presented in Table 2 and Figure 2 showed that the linear effects of FG content and LT also significantly influenced all the extensograph factors (P<0.0001, P<0.001, P<0.05). The quadratic effects of FG content and LT, respectively, had a significant effect on the R and E values. The mutual interaction of FG concentration with LT was also significant (P≤0.01) on these values (Table 2). Based on the sum of squares, the linear effect of FG content had the largest effect on extensograph parameters (Table 2). The simultaneous increase of R_{50} and E amounts shows an enhancement in elasticity and viscosity levels. Brennan *et al.* (2006) and Roberts *et al.* (2012) previously revealed that the G' (storage or elastic modulus), and G" (loss or viscous modulus) of wheat doughs could be increased by partial substitution with galactomannans of commercial purified fenugreek samples. The strengthening effect on gluten by FG can be because of the strong interactions between gluten and hydrocolloid networks resulting in physical entanglements (Metwal *et al.*, 2011). Brennan *et al.* (1996) by studying microstructure of guar galactomannan-wheat bread found that higher numbers of the galactomannans present in guar flour by increasing time of dough leavening become dispersed and intimately mixed with the starch granules and protein matrix. Thus, an increase in hydration rate and dough gluten development can lead to the suitable extensibility of dough. The results suggested that Sangak dough containing 4.16% w/w FG leavened for 3 h would result in the best values of extensograph parameters.

Optimal conditions and verification of the of models

The optimal values of the selected variables were obtained by solving the regression equations according to the RSM-CCRD analysis using Design-Expert software. The best farinographic (maximum WA (63.69%), DDT (2.85 min) and ST (6.88 min), and minimum SFD (46.52 BU)) and extensographic (maximum E (284.58 mm), and optimum R_{50} (289.13 BU) and R/E (1.00)) characteristics can be achieved for the dough formulated with 5.50% w/w FG and leavened for 2.61 h. In order to verify the models prediction, doughs were produced by repeating four additional experiments under the optimum conditions. The results showed that the corresponding experimental values for dough WA, DDT, ST, SFD, R_{50}, E and R/E at the optimum production conditions were 64.23±0.25%, 2.92±0.03 min, 6.76±0.91 min, 44.41±0.51 BU, 290.0±0.0 BU, 285.0±0.05 mm and 1,010.09, respectively. No significant difference (P>0.05) was found between the experimental and predicted value, which indicates the high accuracy of the constructed models. Thus, the quality attributes of breads baked from doughs produced at control and optimal conditions were compared to evaluate the optimisation effect of farinographic and extesographic traits of Sangak dough.

Moisture content and loaf volume

Figure 3A depicts that the breads baked with optimal dough had higher MC than control breads. FG as a hydrophilic emulsifier can interact to a greater degree with polar water molecules and hold moisture, thus increasing the MC of dough and bread (Pourfarzad *et al.*, 2012; Sharma and Chauhan, 2000). Loaf volume is an important quality factor which highly dependent on the quantity and quality of the gluten in the flour, baking conditions and the increase in gas volume during processing (Hayman *et al.*, 1998). The results showed that Sangak produced from dough formulated with FG (5.50% w/w) had a higher loaf volume than the control sample (Figure 3B). This fact can be

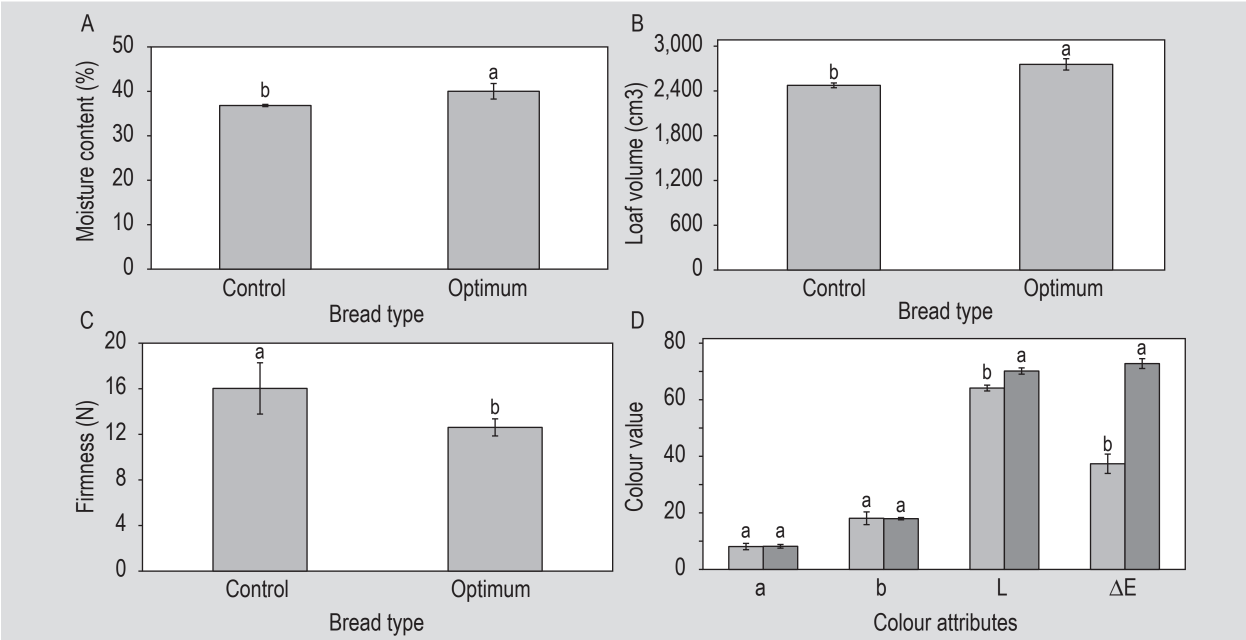

Figure 3. (A) Moisture content, (B) loaf volume, (C) firmness and (D) Hunter lab colour values, L (0 = black; 100 = white), a (-a = greenness; +a = redness), b (-b = blueness; +b = yellowness), and ΔE (total colour difference) of the different breads produced in this investigation. Columns (dark grey = optimal formulation, and light grey = control formulation) marked by the same letter are not statistically different at *P*<0.05.

attributed to a combination of parameters such as the gluten dilution with FG substitution for WF, the gluten network disruption and the water binding by FG addition resulting in less water available for gluten network formation. This may be attributed to the fact that FG is effective in gluten development and water retention capacity of dough and create a uniform starch-gluten matrix. This matrix in turn inhibits the gases in the dough to escape while baking (Collar *et al.*, 1999). In contrast, Roberts *et al.* (2012) reported that the loaf volume was significantly reduced by addition of FG to dough. This discrepancy can be because of high levels of the used hydrocolloid. At higher levels of FG there may be a breakdown of the starch-gluten matrix due to an excess amount of water which fails in retaining the gases from the dough.

Texture/firmness of bread crumb

Figure 3C illustrates that the firmness values of breads containing 5.5% FG were significantly lower than the control ($P<0.05$). Staling process is very complex which cannot be elucidated by a single effect and involves reorganisation of polymers within the amorphous region and amylopectin retrogradation (Rojas *et al.*, 2001). The effects of hydrocolloids addition on starch structure and properties are a result of two opposite phenomena: (1) an increase in rigidity as a result of decrease in the swelling of starch granules and reduced amylose leaching from the granules; and (2) a weakening effect on the starch structure due to the inhibition of the amylose chain associates, although the weight of each effect will be dependent on the specific hydrocolloids (Guarda *et al.*, 2004). However, it seems that FG has a weakening effect on the starch structure, leading to better water distribution and maintenance and also a decrease in the crumb firmness. Similar results were previously reported by Kohajdová and Karovičová (2009).

Colour attributes

Figure 3D shows that a significant increase in L-value (lightness) of bread crumb containing FG in comparison to the control sample was observed. However, there were no differences in a- and b-values between the breads developed with and without FG (Figure 3D). Thus, the ΔE amount for the breads containing fenugreek hydrocolloid was higher than the control sample because of more L-value and a- and b-values of almost the same level. The lightening influence of FG can be due to the effect of this hydrocolloid to increase WA and dilution of interactive materials which highly decreased Maillard browning and caramelisation reactions (Mezaize *et al.*, 2009). These results were in agreement with those of Lazaridou *et al.* (2007) for gluten-free breads containing xanthan gum.

Sensory evaluation

The sensory evaluation of the fresh bread was performed by untrained panellists using a hedonic scale of nine points for texture, taste, crust and crumb colour, odour and overall acceptability. The results revealed that all the traits particularly overall acceptability were improved with incorporation of FG in Sangak dough except for taste (Figure 4).

Stored bread quality

Changes of MC and firmness of the crumb during storage time are the most important factors affecting quality of produced Sangak breads. As considered in Figure 5, the MC and firmness values for the crumb of both control and FG-formulated samples by increasing the storage were decreased. However, a lower reduction was found for Sangak breads prepared with doughs containing FG (Figure 5). Rosell *et al.* (2001) showed an increase of water activity as well of moisture retention due to the higher water holding capacity of the hydrocolloids. This fact reveals that FG presence in the dough structure can highly prevent the staling process during 3 day storage.

4. Conclusions

The present study was conducted to optimise the dough farinographic and extensographic parameters of Iranian flat bread 'Sangak' as a function of FG concentration and LT. Also, the MC, loaf volume and colour, textural and sensory attributes of bread prepared from the optimal dough were compared with the bread without FG. Results showed that there is a very good agreement between the predicted results by CCRD and the measured ones obtained experimentally, indicating the high accuracy of the RSM. The prepared dough with 5.50% w/w FG and leavened for 2.61 h had the best WA, DDT, ST, R_{50}, E and R/E characteristics. The bread developed with this formulation in comparison to the control sample also had a higher MC, loaf volume, lightness, and a lower firmness and Hunter colour a and b values. This bread also had a higher overall acceptability score than the control bread. Evaluation of water activity and firmness value during 3-day storage showed that the Sangak breads containing FG had more ability to retard staling process.

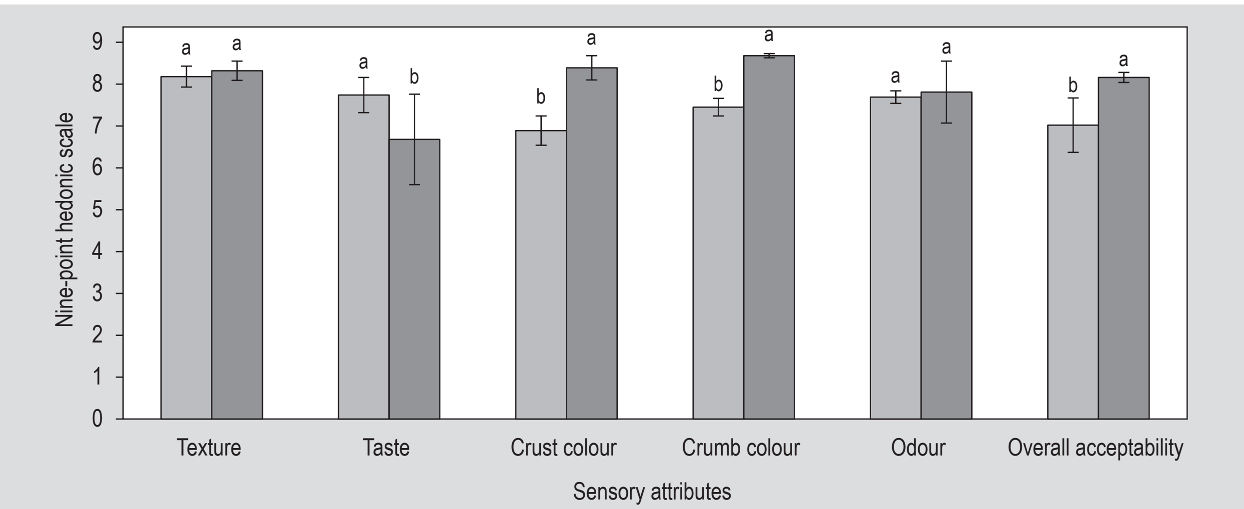

Figure 4. Evaluation of sensory attributes of the breads produced under control (light grey columns) and optimal (dark grey columns) conditions. Traits with the same letter are not significantly different (*P*<0.05).

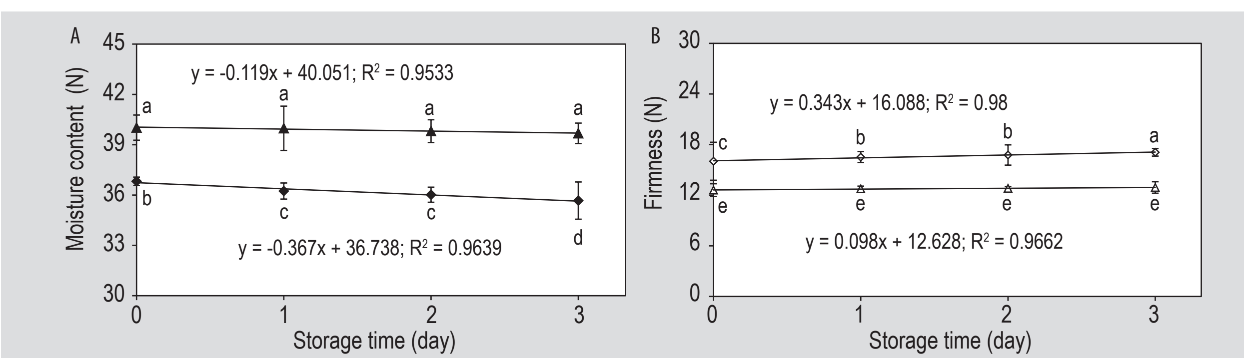

Figure 5. (A) Moisture content and (B) firmness of the breads produced under control (diamonds) and optimal (triangles) conditions during 3-day storage. Symbols marked by the same letter are not statistically different at *P*<0.05.

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