A liquid improver for Flat bread:
Interrelationship between texture, dough rheology and image features

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***Abstract*—The effect of liquid improver components on texture of Barbari flat bread was examined. Glycerol, sodium stearoyl-2-lactylate (SSL) and enzyme active soy flour (ESF) were evaluated as improver constituents. Texture characteristics were further correlated with dough rheology, quality, image features and shelf life of bread. Statistical analysis suggests that more than 50% of whole structural variance existing between bread samples could be interpreted by texture parameters. The optimum improver combination was found to be 1.27% of glycerol, 0.41% of SSL and 1.59% of ESF when desirable function method was applied.**

Keywords-component; Image analysis, Barbari bread, Liquid Improver.

I. Introduction

Flat breads are the main dietary staple in many Middle Eastern and North African countries. In today's demanding world, the use of bread improvers has become an indispensable part of enhancing the quality of bakery products. Bread improvers are technically sophisticated blends of functional ingredients, which if formulated correctly, will enhance the development of dough structure, facilitate trouble-free production and provide the desired result of consistent products having optimal quality at the lowest possible cost [1]. There are several disadvantages related to the use and handling of solid bread improver compositions. Handling problems occur in medium and large size industrial bakeries. These bakeries would like to employ automatic dosing systems for ingredients such as bread improving compositions and yeast. However, solid bread improver compositions are difficult to be pumped and dosed automatically in comparison with the liquid types. Furthermore, such solid compositions make cleaning of the bread making machinery harder in comparison with the liquid improvers [2].

Among the functional food additives, polyols have been increasingly used to improve the quality and shelf life of bread. Gliemmo, Campos and Gerschenson [3] showed that using polyols can depress the water activity and improve texture and mouthfeel. Glycerol (Gly) as a polyol has been used successfully to extend the shelf life of meal ready to eat bread used by the military [4], Barbari bread fortified with soy flour [5], as well as flour tortillas [6]. Emulsifiers, a subset of surfactants, have been widely used by the baking industry. The function of surfactants, as crumb softening agents, is closely related to their interaction or complex formation with starch, particularly the linear amylose fraction, to retard bread staling. Emulsifiers may also slow the rate of bread firming by forming a complex with the amylopectin fraction within the starch granule [7]. Sodium stearoyl-2-lactylate (SSL) is one of the most efficient surfactants in breadmaking. The improvement in bread quality and rheological characteristics of dough with SSL was reported by several researchers [8-10]. Soybean-derived products such as enzyme active soy flour (ESF) are among the ingredients often considered as suitable supplements in food products, such as bread, because of their known health-promoting activity [11] and staling-reducing effect [12]. A literature survey indicated that no work has been carried out on the effect of a liquid bread improver containing emulsifier, polyol, enzyme active soy flour and water on the quality, shelf life and sensory characteristics of bread. Thus, it is expected that an improver containing all of these ingredients will be more effective. Also, up to now, in most of the bread staling studies, bread features were fitted to the Avrami equation and to the best of our knowledge, there is no any published work that models these characteristics to other mathematical models. Thus, the present study was designed: (a) to examine the effects of Gly, SSL and ESF on Barbari flat bread texture during storage when used alone as well as in combination at different levels; (b) to determine the optimum formulations for Barbari flat bread improver; (c) to check the validity of response surface methodology (RSM) to analyze the additive, synergistic and/or antagonistic effects of improver components on the quality, shelf life, image and sensory properties; and (d) to obtain their relation with dough rheology, quality and image parameters as a way to propose simple procedures to quantify texture that could have an effect on bread shelf life.

II. Materials and Methods

A. Materials

Commercial *Triticum aestivum* wheat flour (locally named Setareh) was procured from the AceeArd Co., Khorasan, Iran. Dried active yeast was obtained from Fariman Co., Khorasan, Iran. Glycerol (Gly) was purchased from J.T. Baker Chemical Company (Phillipsburg, NJ, USA). Sodium stearoyl-2-lactylate (SSL) was provided by Vista Tejarat Company (Tehran, Iran). Enzyme active soy flour (ESF) was obtained from Toos Soya Co., Khorasan, Iran.

B. Chemical and physical analysis of flours

Moisture (44–15.02), ash (08–07), fat (30–10), wet gluten (38–11) and falling number (56–81) were determined according to official standard methods [13]. Flour's protein was tested using a Kjeltec auto protein tester (model 1030, Tecator Co., Hoeganaes, Sweden). Three replications were taken for each characteristic.

C. Box-Behnken Design

Table 1 shows the generated Box-Behnken design of three factors (liquid improver components) and three levels using the software Design Expert Version 6.0.10 (Stat-Ease Corporation, Minneapolis, MN, USA). The design consists of 15 sets of test conditions where three levels were attributed to each factor at high, central, and low levels, with additional three replicated center points. Maximum and minimum ingredient levels were chosen by carrying out preliminary screening tests and according to the literature reports and economic aspects.

D. Preparation of liquid improvers

Liquid improvers were prepared using glycerol, sodium stearoyl-2-lactylate, enzyme active soy flour and water in the ratio of 1:1:1:4 and according to Table 1. Results of preliminary trials indicated this ratio yield proper viscosity of improver for handling and functional properties of bread. First, dispersions were made, and then the dispersions, under continuous agitation, were heated to 50°C. improvers were prepared by cooling at 4°C.

E. Rheological properties of dough

The effect of the different combinations (15 treatments) of improver ingredients on dough rheology was examined with the Farinograph (Brabender, Duisburg, Germany), Extensograph (Brabender, Duisburg, Germany) and Amylograph (Brabender, Duisburg, Germany) following official standard methods [13].

F. Bread making and evaluation

The bread formula used for this kind of bread consisted of flour (100 parts); compressed yeast (2 parts); salt (2 parts); sugar (1 part); vegetable oil (1 part); water (based on water absorption at 500 BU). Liquid improvers were mixed in the mixer (Electronic Stand Mixer, Hügel, Neuss, Germany) for 10±1 min at 100 rpm with other ingredients of bread formula.

TABLE I. VARIABLES AND LEVELS USED IN BOX-BEHNKEN DESIGN FOR LIQUID IMPROVER PRODUCTION.

Independent variable	Symbol	Addition levels (g/100 g flour basis)		
		-1	*0*	*+1*
glycerol.	Gly	0	2	4
sodium stearoyl-2-lactylate	SSl	0	0.25	0.5
enzyme active soy flour	ESF	0	1	2

Batch size for each treatment was 2 kg. A baking technique, similar in principle to that of commercial procedure, was used for baking experimental loaves (15 × 25 × 2.5 cm) having almost equal volumes. The ingredients were mixed to optimum dough development. The dough samples were fermented in sealed containers at 30±5 ºC and 75–85% relative humidity for 60±5 min, and then divided into 200±1 g pieces and rounded by hand. The pieces were allowed to proof for 10±1 min in a sealed container placed in the proofing cabinet of oven (Minicombo rotor oven, Zucchelli, Trevenzuolo, Italy). The proofed dough pieces were passed through two pairs of sheeting rolls (gap of 2 mm). The oval-shaped dough pieces were then punched with a special hand puncher, which inserted rectangular (1 × 2 mm) holes into the sheeted dough. The dough pieces were then baked in a laboratory air impingement oven for 13±1 min at 260±5 °C to obtain the proper thickness and acceptable color and texture. After cooling, bread samples were packed in polyethylene bags, stored at room temperature and evaluated.

Quality analysis of fresh bread samples was carried out by measuring moisture content and specific volume of the central slice (rapeseed displacement). Moisture content was determined according to AACC standard method 44–15.02 [13]. To determine specific volume, slices of 10 × 10 mm were cut from the center of the bread samples using a metal template [5].

G. Sensory evaluation

Sensory analysis was performed by 10 trained panelists. The bread quality was investigated using the Iranian flat bread evaluation method described by Rajabzadeh [14]. The overall quality of bread was evaluated by considering the quality characteristics such as bread shape, crust, upper and beneath surface, cavity and porosity, firmness and softness of texture, chewing ability, taste and aroma.

H. Image analysis

For each bread loaf, three slices were obtained from the cross and longitudinal sections of central region and images were captured using a flatbed HP Scanjet G4010 Photo Scanner (Hewlett-Packard, Palo-Alto, CA, USA) supporting Desk Scan II software (Hewlett Packard, USA). A single 60 mm×60 mm square field of view was evaluated for each image. Brightness was adjusted to150 units and contrast to 170 units. Images were scanned full-scale in 256 grey levels at 150 dots per inch (dpi) each comprising 355 columns by 355 rows of picture elements (pixels)[15]. JPEG image file format were analyzed with ImageJ 1.4g (National Institute of Health, USA).

The CIE L*a*b* (or CIELAB) color model was used for determination of the crumb and crust colour. The three parameters of such model represent the lightness of color (L*) which ranges from 0 to 100 (black to white), its position between red and green (a*, negative values indicate green while positive values indicate red) and its position between yellow and blue (b*, negative values indicate blue and positive values indicate yellow) [16]. Since images were acquired in the RGB color space, space conversion were carried out to obtain CIE L*a*b* model parameters. The average values of L*, a* and b* colors describing the outer crust and inner crumb regions were obtained from all 15 baked samples. The total color difference, ΔE of the bread slices from the reference is:

$$\Delta E = [(L_0 - L)^2 + (a_0 - a)^2 + (b_0 - b)^2]^{\frac{1}{2}}$$

(1)

where $L_o = 100$, $a_o = 0$ and $b_o = 0$ [17].

To evaluate crumb structure, color images were converted to 8-bits 256 gray level images. The thresholding method (conversion to a binary image) of the 256 gray level digital images was used for image segmentation according to Otsu [18]. The selected crumb grain features were the average size, area fraction (cell to total area ratio), solidity (area to convex area) and circularity ($4 \times pi \times area/perimeter^2$) [19-20]. The fractal dimension data were computed using the "Map Fractal Count" plugin of ImageJ software, based on the Minkowski-Bouligand dimension method, also known as box-counting dimension. It systematically lays a series of grids of decreasing box size over the grayscale elevation map and records the number of boxes for each successive grid size, finding the fractal dimension as the slope of the logarithmic regression line for the box numbers and grid sizes [21]. Moreover, cell wall thickness was evaluated using "Euclidian distance map (EDM)" plugin of ImageJ software based on the coupled analysis of binary and skeletonized (linearized) images.

I. Texture analysis

Staling phenomenon and its changes were evaluated by penetration test. A texture analyzer (model QTS 25 kg, CNS Farnell, Hertfordshire, UK) was used to measure the force required for penetration of a round-bottom (2.5 cm diameter × 1.8 cm height) probe at a velocity of 30 mm/min into the bread samples. The probe descended 30 mm (a sufficient distance to pass through the slice of 10 × 10 cm of bread) and the trigger force was set at 0.05 N [5]. The bread samples were evaluated 1 hour, 2, 4, 6 and 8 days after baking for shelf life by monitoring the bread hardness.

J. Statistical analyses

For each of the response variables, multiple linear regression analysis was used and the data were fitted as linear or quadratic models. From this information, the most accurate model was chosen via the sequential F-tests, lack-of-fit tests and other adequacy measures. In this study, predictor variables were permitted to be at any level within the range of the design. All experiments were carried out in triplicate. Quadratic equation for the variable was as follows:

$$Y: \beta_0 + \sum\beta_i X_i + \sum\beta_{ii} X_i X_j + \sum_i \sum_j \beta_{ij} X_i X_j$$

(2)

where Y is the predicted response; β_0 a constant; β_i the linear coefficient; β_{ii} the squared coefficient; and β_{ij} the cross-product coefficient. In addition, Lack of fit, coefficients of determination (R^2), adj-R^2, coefficient of variation (CV) and significant probabilities were calculated to check the model adequacy. The above quadratic equation was used to build surfaces for the variables. The software Design Expert Version 6.0.10 was used to analyze the results. Regression and correlation analyses were conducted using Minitab 15 software (Minitab Inc., State College, PA, USA).

K. Optimization and verification procedures

Besides explaining the behavior of variables by the contour curves, the models fitted in this study could also be utilized for optimization purposes using the desirability function. Optimization was based on generation of the best results for rheology, quality, shelf life, sensory and image properties of Iranian Barbari flat bread. The calculation of the optimal levels of ingredients to be used was performed using a multiple response method called desirability. This optimization method incorporates desires and priorities for each of the variables.

The rheology, quality, shelf life over seven days, sensory and image properties of Barbari bread were determined after improver production under optimal formulation. In order to determine the validity of the model, the experimental and predicted values were compared by paired t-test using Minitab 15 software.

Ease of Use

III. Results and Discussion

A. Chemical and rheological characteristics of flour samples

The characteristics of the flour used in this study are in the range of typical values of medium strong flour, suitable for Iranian Barbari flat bread. The flour had 10.52 ± 0.36% moisture, 10.8 ± 0.24% protein, 1.76 ± 0.5% fat, 0.79 ± 0.006% ash, 26.7 ± 0.55% wet gluten, 82 ± 1.5% extraction rate and falling number of 407 ± 3s.

B. Interrelationship between rheological characteristics of dough and texture characteristics of bread

Correlation coefficients between various rheological characteristics of dough and texture characteristics of breads are given in Table 2. It is evident from the data that most of the rheological characteristics of dough have significantly affected the texture characteristics of bread. The texture features of the breads were influenced by various rheological parameters. However, among rheological characteristics,

TABLE II. CORRELATION COEFFICIENTS BETWEEN VALUES OF RHEOLOGICAL CHARACTERISTICS OF DOUGH AND TEXTURE OF BARBARI BREAD.

Parameter	Water Absorption	Arrival Time	Dough Development Time	Stability	Mixing Tolerance Index	Degree of Softening	Resistance to extension	Extensibility	R/E	Gelatination Temperature
H_0		-0.657**	-0.611*	-0.537*		0.615*	-0.532*			
H_2				-0.668**	0.636*	0.746**	-0.654**			
H_4				-0.56*	0.53*	0.679**	-0.56*			
H_6				-0.749**	0.652**	0.662**	-0.838***		-0.583*	
H_8				-0.808***	0.818***	0.765**				
H_{0-2}										
H_{0-4}								-0.579*		
H_{0-6}							-0.686**			
H_{0-8}				-0.613*	0.659**					

not shown correlation: no significant effect at level <0.05; * $p<0.05$; ** $p<0.01$; *** $p<0.001$; H_t is the bread hardness at t time; H_{0-t} is the bread hardness difference between first day and t time.

stability and degree of softening had the greatest significant coefficients of correlation with texture features. Resistance to extension as an extensographic parameter was found to be negatively correlated to hardness between the first and the 6th days of storage. On the other hand, it was observed that among the texture characteristics, hardness at the first and the 6th days have shown the greatest significant correlations with rheological parameters of dough. No significant correlation was found between water absorption, gelatinization temperature and any of the texture properties. The correlation between bread texture and dough rheology has been reported by many researchers [22-23].

C. *Interrelationship between shelf life, quality characteristics and image features of bread*

Some of the quality and image characteristics of breads were found to be significantly correlated to shelf life (Table 3). ΔE as an important image parameter, was found to had good correlations with hardness during storage. Breads having a higher ΔE resulted in longer shelf life. It is evident from the data that among quality characteristics of bread, overall quality score was the only parameter that significantly correlated with hardness at the 8th day. Many researchers [24-25] reported significant correlations between structural characteristics, sensory scores and mechanical characteristics of bakery products. For example, Kamman [26] stated that the physical and visual texture of bread crumb are interrelated quality factors that should be considered as a single entity. It was also speculated that crumb physical texture is largely determined by the character of the grain, e.g. cell wall thickness, cell size and uniformity.

D. *Interrelationship between texture features of bread*

The interrelationships of texture characteristics are summarized in Table 4. The data revealed positive correlation between hardness of bread at the first day and during storage. Hardness difference during storage showed positive significant correlation with hardness of each day. The correlation between textural parameters in cakes and white breads has been reported by many researchers [27-28].

E. *Optimization of improver components and Verification of results*

Multiple response optimizations were performed to measure the optimum levels of independent variables to achieve the desired response goals. Specific volume and sensory aspects were desired maximal whereas hardness as an indicator of shelf life was specified as minimum desirable. It is well known that the moisture content of bread crumb is a major contributor to the perception of product freshness and that, within limits, the higher the moisture content, the fresher the bread will be perceived by the consumer. Thus, moisture content was specified as maximum level desirable. Other parameters were fixed to intermediate level.

TABLE III. CORRELATION COEFFICIENTS BETWEEN VALUES OF QUALITY, IMAGE AND TEXTURE OF BARBARI BREAD.

Parameter	Overall Quality Score	Moisture Content	Specific Volume	ΔE	Average Size	Fractal Dimension	Area Fraction	Cell Wall Thickness	Circularity	Solidity
H_0					-0.746**		-0.573*			
H_2				-0.775**	-0.713**					
H_4				-0.732**	-0.579*					
H_6				-0.857***	-0.658**					
H_8	-0.623*			-0.544*	-0.541*					
H_{0-2}				-0.661**						
H_{0-4}										
H_{0-6}										
H_{0-8}	-0.605*			-0.874***						0.519*

not shown correlation: no significant effect at level <0.05; * $p<0.05$; ** $p<0.01$; *** $p<0.001$; H_t is the bread hardness at t time; H_{0-t} is the bread hardness difference between first day and t time.

TABLE IV. CORRELATION COEFFICIENTS BETWEEN TEXTURE CHARACTERISTICS OF BARBARI BREAD.

Parameter	H_0	H_2	H_4	H_6	H_8	H_{0-2}	H_{0-4}	H_{0-6}	H_{0-8}
H_2	0.704**								
H_4	0.56*	0.924***							
H_6	0.571*	0.81***	0.731**						
H_8		0.601*		0.599*					
H_{0-2}			0.571*						
H_{0-4}	0.603*					0.701**			
H_{0-6}		0.656**	0.654**	0.861***		0.686**			
H_{0-8}					0.851***				

not shown correlation: no significant effect at level <0.05; * p<0.05; ** p<0.01; *** p<0.001; H_t is the bread hardness at t time; H_{0-t} is the bread hardness difference between first day and t time.

The final result for this optimization suggested that a mixture containing 1.27% of Gly, 0.41% of SSL and 1.59% of ESF in liquid improver formulation could be a good mixture of these three improver compounds in order to achieve the best quality, shelf life, sensory and image properties of Barbari bread. This new mixture was submitted to the same experimental procedures applied as those from the beginning of this study (data not shown). There was no significant difference between the estimated and observed values (P< 0.05), suggesting a good fit between the models to the experimental data.

IV. CONCLUSIONS

Texture analysis was a useful tool to evaluate Barbari flat bread staling, detecting differences among the different kinds and levels of liquid improver components analyzed. The Box-Behnken design was an efficient statistical tool to model the influence of additives on bread quality, shelf life, sensory and image properties of Barbari bread. These results also suggested that by modifying the proportion of these additives, a large range of variations may be obtained.

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