A case study on the relationships between selected crumb image and dough rheological features of Barbari flat bread as influenced by dough mixing and proofing time

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Abstract— **To survey the relationship between crumb image and some dough rheological features (adhesiveness, cohesiveness, hardness, stickiness, resilience and chewiness) of Barbari bread based on dough proofing time (20-60, min), mixing time in low (2-8, min) and in high speed (2-8, min) a central composite rotatable design was applied. Results revealed that both crumb ΔE and crumb lightness of bread had a noticeable correlation with dough cohesiveness (r= 0.53, r= -0.63) and dough chewiness (r= -0.64, r= 0.50), respectively. Besides, crumb lightness may be presumably considered as an indicator for dough adhesiveness (r= 0.63), stickiness (r= 0.60). Also, crumb ΔE may be likely used for study of dough hardness variation (r= -0.56) and resilience (r= 0.50). Our finding showed that the variation of bread crumb color can be useful for study of some dough rheological behavior.**

Keywords- ***Barbari flat bread; dough mixing; dough proofing; image analysis; dough rheology***

I. INTRODUCTION

Among bakery products, bread quality is important due to its every day consumption. Flat breads are the major form of breads in many Middle Eastern and North African countries. Quality enhancement of bread was subject of some studies, however application of bread baking process variables is an affordable method that may useful to improve the quality of bread in large scale production.

Different studies have been conducted toward the effect of bread making parameters on dough and bread quality but no attempt in survey of relationship between crumb image and rheological dough features of flat bread.

Dough mixing process is a critical stage of bread production which strongly affects baked bread quality. Several changes are occurred during dough mixing: (i) structure changes in the gluten network (glutathione Sulfide bounds (GSH) are decreased and disulfide bounds between gluten and glutathione (PSSG) and glutathione to glutathione (GSSG) are increased) (ii) dough aeration [3,7,10,16]. Dough mixing speed is another effective factor during mixing process. Utilization of greater speed leads to higher gas content, higher bubble stability and higher degree of development [7, 17]. Also in higher dough speed due to more forces incoming to the dough, the gas cell bubbles are fractured, consequently gas cell bubbles' sizes are decreased [9]. It is noteworthy mentioned that the lower size of gas cell bubble is preferred due to sensory perceptions.

During fermentation, CO_2 produced by yeast can form bubbles in mixing stage and cause expand gas cells [6]. The restriction of cell bubbles' expansion is pertained to their stability [11] which was described that coalescence (failure of the membrane of closer gas cells) and disproportionate (mass transport of gas from small to large bubbles) were two instability factors of gas bubbles which resulted in lower quality (porosity of bread crumb) of bread [8].

The aim of this work was survey the relationships between selected crumb image and dough rheological features of Barbari flat bread as influenced by dough mixing and proofing time.

II. MATERIALS

Commercial wheat flour with 105.2 g/kg (w.b.) moisture, 128 g/kg protein, 17.6 g/kg lipid, 8 g/kg ash, and 267 g/kg wet gluten and 407 s falling number was procured from the Acee Ard Co., Mashhad, Khorasan., Iran. Wheat flour, active dry yeast (*S.cerevisiae*) powder (Leaven Razavi Co., Mashhad, Khorasan., Iran), vegetable oil (Narges Co., Shiraz, Fars., Iran) and other ingredients applied in this study wholesale purchased from local market and keeping at low temperature.

III. METHODS

A. Flour analysis

Moisture (moisture of commercial wheat flour), ash, fat and wet gluten were determined according to AACC method (2000) 44-16 A, 08-07, 30-10 and 38-11, respectively. Flour protein was tested according to method of Kjeldahl on a Kjelteca Kjeltec auto protein tester (model 1030, Tecator Co., Sweden). Falling number was determined based on AACC method 56-81(2000).

B. Determination of dough mechanical properties

of Dough Mechanical Properties

Dough mechanical properties were evaluated using a QTS texture analyzer (CNS Farnell, Hertfordshire, UK[1]. For dough texture analysis, a two –stage method of TPA test was carried out with probe diameter of 5 centimeters and a load cell of 5 kg. A 30g piece of dough was placed under the probe. The velocity of probe was 1 mm/s, the time recovery between two stages was 75 second and penetration was 60%. Main attributes of texture without adhesiveness were evaluated. For this purpose, a plastic cover was placed on the dough so that negative peak resulting from dough sticking to probe was deleted. Obtained graph from dough TPA test gives us some parameters which are effective on studying dough properties (Fig 1). These parameters were as follows; cohesiveness, A2/A1; hardness, H1; adhesiveness, A3; Chewiness, H1× (A2/A1) × (L2/L1); resilience, (Area cycle1- Hardness 1work done)/ (Hardness1 work done).

C. Determination of Dough Adhesiveness

Dough adhesiveness measurement is the same as mechanical properties and was separately evaluated without placing plastic cover on the top of dough (Armero and Collar, 1997) [1].

D. Determination of dough stickiness

Dough stickiness was assessed by the method of Armero and Collar (1997) [1]. Based on compression test (with a probe with 25 mm diameter and load cell using force 25kg), 25 g dough was placed in a special cup, after closing lid of cup, some of dough came out from pore of cup surface (because of imposing force on the dough). In the time of contacting probe to the dough, height of external dough from cup surface must be 5 mm. Characteristics of this test are as follows: the velocity of probe 10 mm/s; penetration 60%, trigger value 5g and target value 100g.

E. Bread making procedure

The bread investigated in this study was Barbari, which is one of the most consumed flat breads in Iran. This Bread was produced using a standard method described by Pourfarzad etal.(2011) [14].

F. Image acquisition and analysis

For bread image analysis, first of all, slices of 30×30 mm were cut from the center of the bread samples using a metal template [5, 13]. Slice images were captured using a flatbed HP Scanjet G4010 Photo Scanner (Hewlett-Packard, Palo-Alto, CA, USA) and saved in JPEG format. Scanning was assessed by Desk Scan II software (Hewlett Packard, USA) with resolution of 180 dots per inch (dpi). Afterward, by using Image J software 1.40g (National Institute of Health, USA) square of 500×500 pixel was selected from the center of the bread samples and future analysis was performed in this area. RGB color space was converted in L*a*b space (CIELAB) and CIELAB color model was applied for crust and crumb color analysis. Based on Mohd Jusoh *et al.*, (2009) method, the total colour difference of the bread slices was determined as the following:

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

Where ΔE is the total colour difference, $L_0=100$, $a_0=0$ and $b_0=0$ [12].

In crumb analysis, captured color images were converted into 8-bit grayscale with 256 grey levels. Thresholding process was performed based on Otsu (1979) method to divide images in two regions of holes and bolds which the hole regions relate to cells and bolds regions link to cell walls (supplementary Fig 1). In this study several parameters namely lightness of crumb, cell count (number of gas cells), mean cell area or cell size (mm2), porosity (cell/total area; or void fraction) were extracted from scanned images.

G. Experimental design and statistical analysis

In current study, the central composite rotatable design was applied Final proofing time, mixing time in low speed and mixing time in high speed were as a independent variables included at three levels 20, 40 and 60; 2.05, 5.05 and 8.05; and 2.05, 5.05, and 8.05 min, respectively (Table 1). The Response surface methodology was applied to analysis the experimental data with backward multiple regression method using Design Expert software Version 6.0.2 (Stat-Ease Inc, Minneapolis, MN, Minnesota). Results were reported as regression quadratic models as a function of dependent and independent variables and pertained coefficients. All responses (features) were considered as dependent variables and process variables were as independent variables. Represent models are in second-order polynomial which is fitting all data as a function of the independent variables as the following:

$$Yi = \beta_0 + \sum \beta_i X_i + \sum \beta_{ii} X_i^2 + \sum \beta_{ij} X_i X_j$$

Where, Y is the predicted response; β0 is the intercept; β_i, β_{ii} and β_{ij} are regression coefficients for Xi, Xii and X_{ij} as linear, quadratic and interaction terms of independent variables, respectively. Results were reported as the average of three replicates (three individual batches).

TABLE I. EXPERIMENTAL AMPLITUDE ACCORDING TO ROTATABLE CENTRAL COMPOSITE DESIGN (CCRD).

In dependent Factor levels	In dependent Factor		
	Final proofing time (FPT)(min) (x_1)	Mixing time in low speed (MTLS) (min)(x_2)	Mixing time in high speed (MTLS) (min)(x_3)
augmented form (-1.682)	6.36	0.00	0.00
factorial point(-1)	20	2.05	2.05
central point (0)	40	5.05	5.05
factorial point(1)	60	8.05	8.05
augmented form (1.682)	73.64	10.095	10.095

IV. RESULT AND DISCUSSION

The summarized linear correlation coefficient between dough rheological and bread image features were tabulated in Table 2.

TABLE II. COEFFICIENT OF LINEAR CORRELATION BETWEEN CRUMB IMAGE AND RHEOLOGICAL DOUGH FEATURES OF BREAD.

Variables	ΔE Crumb	Lightness of crumb	Cell count	Mean cell area	Porosity
Dough adhesiveness	-0.155	**0.630**	0.297	-0.194	0.407
Dough cohesiveness	**0.536**	**-0.637**	-0.501	0.111	-0.675
Dough hardness	**-0.562**	0.156	0.100	-0.303	0.036
Dough stickiness	-0.107	**0.603**	0.182	-0.426	0.259
Dough resilience	**0.507**	-0.289	-0.291	-0.133	-0.407
Dough chewiness	**-0.649**	**0.501**	**0.661**	**-0.637**	**0.602**

The several attractive correlations were observed such as the positive correlation between crumb ΔE with dough cohesiveness (r= 0.53) and resilience (r= 0.50), respectively and negative correlation with dough hardness (r= -0.56) and chewiness (r= -0.64) with specific volume. So, it may be likely found that crumb ΔE as a factor for showing dough chewiness, resilience, hardness and cohesiveness variation. Crumb lightness were relatively correlated well with dough adhesiveness (r=0.63), cohesiveness (r= -0.63), stickiness (r= 0.60) and chewiness (r= 0.50). As for table 2, cell count as well as porosity had a negative correlation with dough cohesiveness (r= -0.50, r=-0.67) while their coefficient of correlation with dough chewiness (r=0.63, r=0.60) were positive, respectively. Besides, the negative correlation (r= -0.63) of mean cell area with dough chewiness and above founding approve that the cell size in the crumb is effective factor in texture and color of dough and bread. Burhans and Clapp (1942) indicated that increasing large number of small cells lead to augments whiteness of bread crumb [4]. The power of the reflected light was related to the cellular structure of the bread crumb which the finer and coarser crumb structure reflect more and less light, respectively [15]. Besides, Baker and Mize (1941) found that optimally mixed dough led to formation of a crumb with higher brightness [2].

V. CONCLUSION

Our results indicated that crumb image features especially crumb color is useful factor for survey of rheological dough features in bread making variables studies. Cell size was the main factor in some crumb bread and rheological dough features. From correlation result, both crust lightness and crumb ΔE may be likely considered as a proper factor for prediction of dough cohesiveness and chewiness, and also dough hardness, resilience and stickiness can be likely predicted with crumb ΔE and crust lightness, respectively.

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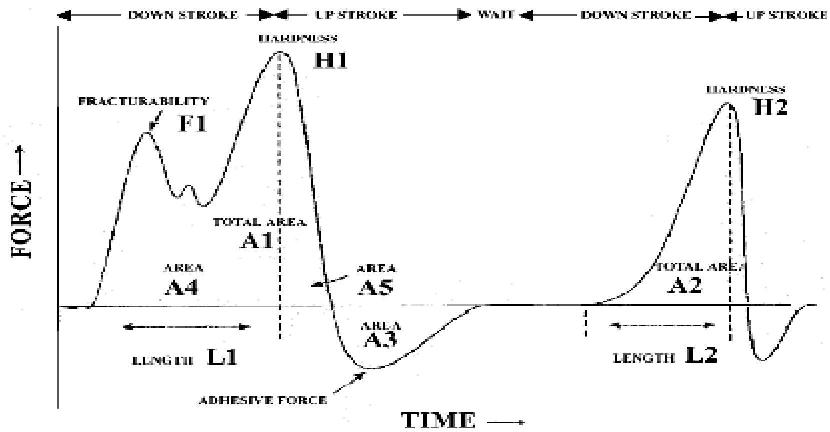

Figure 1. TPA graph for analysis of dough mechanical features.