Effect of whey powder and carboxymethyl cellulose (CMC) on the rheological characteristics of dough bread by using response surface methodology

Meshkani, Seyed Mohammad
Dept of Food Science & Technology
Islamic Azad University
Sabzevar, Iran
s.m.meshkani@gmail.com

Pourfallah, Zahra
Dept of Food Science & Technology
Islamic Azad University
Sabzevar, Iran
zahrapourfallah@yahoo.com

Abstract:
Improvement of bread produced of wheat flour has been considered by researchers in all countries. In recent years, lots of research were increase shelf life and enriched bread. Aim of this study, the effect of whey powder and carboxymethyl cellulose (CMC) in wheat flour dough with extraction rate of 85% in the range of 0.2 to 0.6 and 0.1 to 0.5 percent, were respectively. Results showed by increasing the percentage of whey powder and CMC significant amount of dough rheological factors (strength and elasticity) that was found to increase significantly. Also obtained dough had has good smell. Optimization of flour formulation result was showed that for 0.54% of whey powder and 0.5% of CMC, water absorption 53.12%, dough strength 2.73 minutes and farinograph quality number(FQN) 25.69 and dough elasticity by Kieffer probe 23.22 mm.

Keyword:
dough elasticity, carboxymethyl cellulose(CMC), farinograph, wheat flour, whey powder.

I. Introduction

Wheat is a unique cereal having gluten protein which gives viscoelastic properties to the dough for bread making. The other major constituents of wheat grain are starch and fibre. The protein, fat, carbohydrate and ash content of wheat flour was 11.8, 1.5, 72.4 and 1.5 % respectively [1]. Any production of cereal based baked product passes through dough formulation. dough is a viscoelastic material having complex rheological properties which involves many mechanical steps such as kneading, rolling, laminating and forming etc [2].

Farinograph is the most widely used to understand rheological behavior during dough mixing [3]. Farinograph is a recording dough mixer that measures torque needed for mixing dough at a constant speed and temperature. the resistance offered is integrated with time and traced on Farinogram that it is used to evaluate various rheological parameters such as dough development time, dough stability, mixing tolerance index and farinograph quality number(FQN) [4].

Rheological tests have been successfully applied to doughs as indicators of the gluten and starch polymers molecular structure [5]. Viscoelastic properties of wheat flour dough play a significant role in the handling properties of dough during processing and in the quality attributes of finished baked goods [6]. Most of the studies on doughs have been carried out on the relationships between mixing, ingredients and rheology performance in order to evaluate the rheological changes that occur in the gluten viscoelastic network during mixing and their impact on product quality [5].

The present study was to examination of whey powder and CMC on raw flour. The aim of this study was to evaluate the optimal amount of each material used to improve the conditions of raw flour. Therefore from Design Expert 6.0.2 software was used to optimize the formulation of flour as face centered in response surface methodology.

II. Materials and Methods

A. Materials

Commercial wheat flour with 85% extraction grade without improvement (Acee Ard, Mashhad, Iran), Whey powder (Parvar Powder, Mashhad, Iran) and CMC (Merck ، Darmstadt ،Germany).

B. Farinograph test

The mixing properties of the doughs from different formulation of flour blends were examined with the Brabender farinograph (Brabender, Duisburg, Germany) according to Sabanis et al, 2006. Water absorption is indicated as the amount of water needed to develop a standard dough of 500 farinograph units (FU) at the peak of the curve. The maximum consistency was defined as the consistency (in FU) measured at the development time and in the middle of the curve bend width. The dough development time was defined as the time to the point of the curve immediately before the first sign of decrease in consistency, while the dough stability was defined as the decrease of the curve during the first 2min after dough development time. The degree of softening is defined as the difference (in FU) between the line of the consistency and the medium line of the torque curve 12min after development time. This provides information about the dough's stability. Finally, the point of the curve in which the curve has decreased by 30 FU after the maximum (based on middle line of the diagram) is characterised as farinograph quality number (FQN). which is a measure for the quality of the flour [7].

C. Dough extensibility test

The test according to Meshkani et al, 2012; used the texture analyzer with kieffer probe (TAXT Plus, Surrey, UK) for dough and gluten extensibility. After resting the dough balls for 10 min in the proofing chamber, 10 g of one dough ball was weighed and rolled into a cylindrical shape, placed into the grooved mold, rested for 10 min at $50^{°c}$ in incubator, and evaluated. Dough extensibility and resistance to extension were determined [8].

D. Statistical analysis

Response surface methodology (RSM) was used to evaluation the effect of independent variables (Whey powder percent, x_1; CMC concentration, x_2) at three variation levels (Table 1) on water absorption(%), stability(min) in Farinograph test and extensibility(mm), toughness(N/mm) in dough extensibility test. A Face Central Composite Design was used to study the response pattern and to determine the optimum combination of variables. The RSM was applied to the experimental data using a commercial statistical package, Design-Expert version 6.0.2 (Stat-Ease, Inc, Minneapolis, USA). The design included 13 experiments and it is adopted by adding 5 central points. The center runs provide a means for estimating the experimental error and a measure of lack-of-fit [9]. The response functions (Y) were water absorption(%), stability(min) in Farinograph test and extensibility(mm), toughness(N/mm) in dough extensibility test. These values were related to the coded variables (x_i, $_i$=1 and 2) by a second-order polynomial using Equation (1):

$$Y=\beta_0+\beta_1x_1+\beta_2x_2+\beta_{11}x^2+\beta_{22}x^2+\beta_{12}x_1x_2 \quad (1)$$

The coefficients of polynomial model were represented by β_0 (constant term), β_1 and β_2 (linear effects), β_{11} and β_{22} (quadratic effects), and β_{12} (interaction effects). Data were modeled by multiple regression analysis adopting manual analysis. The variables significant at $p<0.01$ levels were only selected for the modeling. The significant terms in the model were found by analysis of variance (ANOVA) for each response. The adequacy of model was checked accounting for R^2 and adjusted R^2. Numerical and graphical optimization techniques available on Design-Expert software were used for simultaneous optimization of multiple responses.

Table 1, *Table of independent variable for wheat flour.*

Independent variables	code	Levels		
		-1	0	+1
Whey powder(%)	X_1	0.2	0.4	0.6
CMC(%)	X_2	0.1	0.3	0.5

III. Results and discussion

A. statistical analysis

As described before, the variation of each response variable (Y) was assessed as a function of linear, quadratic and interaction effect of whey powder (x_1) and CMC (x_2). The estimated regression coefficients of the models for the response variables, along with the corresponding coefficients of determination (R^2), adj-R^2 and coefficient of variation (CV) are given in Table 2 a and b. Multiple linear regression analysis of the experimental data produced second-order polynomial equations for water absorption(%), stability(min), extensibility(mm) and toughness(N/mm) as postulated before. The statistical analysis indicated that the proposed model was adequate, showing no significant lack-of-fit ($p>0.01$) with very satisfactory values of R^2 for all responses.

The R^2 values for water absorption(%), stability(min), extensibility(mm) and toughness(N/mm) were 0.995, 0.977, 0.993, 0.973 respectively; indicating that a high percentage of response variations were described by the response surface models.

Adjusted R^2 is a modification of R^2 that adjusts for the number of explanatory terms in a model. Vice versa R^2, the adjusted R^2 increases only if the new term improves the model more than would be expected by chance. Thus, it is recommended using an adj-R^2 to evaluate the model adequacy [10]. In this study, the values of adj-R^2 coefficient were large enough advocating the high significance of the model. The coefficient of variation (CV), which indicates the extent to which the data were dispersed, were found to be 0.097%, 1.75%, 0.057% and 0.76% for water absorption(%), stability(min), extensibility(mm) and toughness(N/mm), respectively (Table 2a and b). From the above, it can be concluded that the selected model adequately displayed the data for all the responses acquired.

Table 2a, *Table of ANOVA for the experimental variables as a linear, quadratic and interaction terms of each response variable and corresponding coefficients for the predictive models and optimized model.*

Source	DF	Water absorption(%)			Stability (min)		
		Coefficient	Sum of Squares	p-Value	Coefficient	Sum of Squares	p-Value
Model	5	52.25	3.64	<0.0001	2.32	0.5	<0.0001
Linear							
b_1	1	0.25	0.37	<0.0001	0.13	0.11	<0.0001
b_2	1	0.73	3.23	<0.0001	0.25	0.37	<0.0001
Quadratic							
b_{11}	1	-0.081	0.018	0.0320	-0.01	2.96×10^{-4}	0.6856 ns
b_{22}	1	-0.031	2.66×10^{-3}	0.3406 ns	0.04	4.34×10^{-3}	0.1496 ns
Interaction							
b_{12}	1	0.05	0.01	0.0879 ns	0.05	0.01	0.0438 ns
Residual	7		0.018			0.012	
Lack-of-fit	3		5.82×10^{-3}	0.6250 ns		3.61×10^{-3}	0.6475 ns
Pure error	4		0.012			8×10^{-3}	
Total	12		3.66			0.51	
R^2		0.9951			0.9971		
Adj-R^2		0.9917			0.9608		
CV		0.097			1.75		
Optimized model		$Y=50.41+2.5X_1+3.63X_2$			$Y=1.87+0.5X_1+0.16X_2$		

Table 2b, Table of ANOVA for the experimental variables as a linear, quadratic and interaction terms of each response variable and corresponding coefficients for the predictive models and optimized model.

Source	DF	Extensibility(mm)			Toughness (N/mm)		
		Coefficient	Sum of Squares	p-Value	Coefficient	Sum of Squares	p-Value
Model	5	22.99	0.16	<0.0001	2.07	0.13	<0.0001
Linear							
b_1	1	0.043	0.011	<0.0001	-1.77	0.02	0.0004
b_2	1	0.15	0.14	<0.0001	0.45	0.11	<0.0001
Quadratic							
b_{11}	1	0.03	2.5×10^{-3}	0.0067	1.10	8.1×10^{-4}	0.2535 ns
b_{22}	1	0.039	4.2×10^{-3}	0.0017	0.11	1.4×10^{-4}	0.6223 ns
Interaction							
b_{12}	1	-0.017	1.23×10^{-3}	0.0321 ns	-0.43	1.2×10^{-3}	0.1687 ns
Residual	7		1.21×10^{-3}			3.6×10^{-3}	
Lack-of-fit	3		1.17×10^{-3}	0.0019		3.1×10^{-3}	0.0481
Pure error	4		3.88×10^{-5}			6×10^{-4}	
Total	12		0.16			0.14	
R^2		0.9927			0.9732		
Adj-R^2		0.9875			0.9541		
CV		0.057			0.76		
Optimized model		$Y=22.83-0.25X_1+0.36X_2+0.75X_1^2+0.98X_2^2$			$Y=2.82-0.18X_1+0.39X_2$		

B. Farinograph test

According to Tables 2a, the models had significant for farinograph resistance test and water absorption, the linear effect was obtained on whey powder and CMC (P<0.01). Factors contributing to reasonable fit model, results of the modeling and optimization of wheat flour formulation were showed in Table 2a. In this study used of very weak wheat flour on rheological quality. The aim of used pure materials was to improvement. According to observed in the field farinograph resistance in Figure 1a, with the increasing percentage of whey powder 0.2 to 0.6%, the dough resistance was increased that probably, due to disulfide bonds strengthening and improved were complex between starch and gluten. Also according to Figure 1b, with increase in the percentage of improvements, water absorption was increased. In the diverse studies conducted by the other researchers, were observed that the using of milk products, such as whey powder, increased the water absorption. Collar et al, 2001; by the effect of CMC and HPMC on wheat dough and bread, with existence these compounds in the dough water absorption was increased [11]. In the other studies on wheat flour improved with CMC and HPMC by Tavakolipour and Kalbasi-Ashtari, 2006; on two variety of wheat (Sardari and Sorkhe) in Iran, with increased were observed on three parameters, dough development time, dough stability and water absorption for example [12]. Also Schirali et al, 1996; Kadharmestan et al, 1998; showed which with whey powder increasing, water absorption and bread volume had increased [13,14].

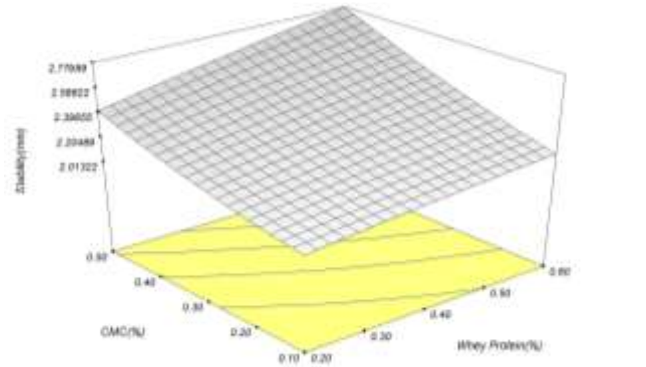

Fig 1a, *Response surface for the effect of Whey powder and CMC on Stability (min).*

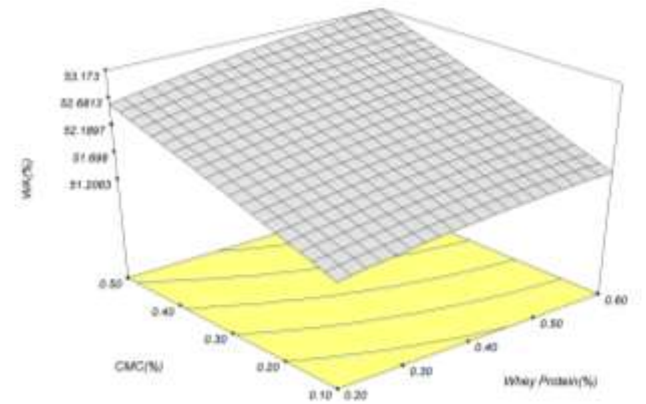

Fig 1b, *Response surface for the effect of Whey powder and CMC on Water Absorption (%).*

C. Dough extensibility test

In this method, were used of texture analyzer and kieffer probe for dough extensibility test. According to Table 2b, the linear and quadratic effects were significant in dough toughness test (P<0.01). Also the results of modeling and formula optimization of flour testing in Table 2b, were observed. According to Figure 2a and b, were showed with increasing percentage of improvements, toughness and tensile had increased significantly (P<0.01). Due to the effect of whey powder and CMC on dough network, so the materials were effective on disulfide bonds. In the other studies, Sudha et al, 2007; observed when the rice bran powder increased 10 to 40 percent in bread formulation, so water absorption and dough development time had increased, but stability and extensibility had decrease [15].

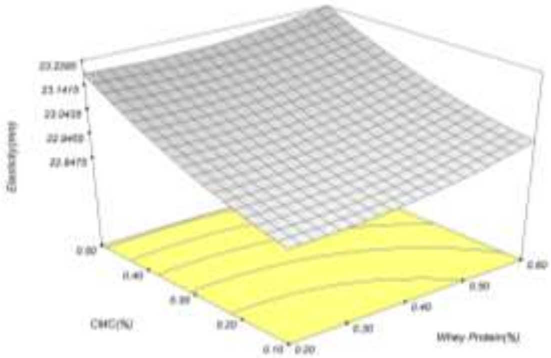

Fig 2a, *Response surface for the effect of Whey powder and CMC on Elasticity (mm).*

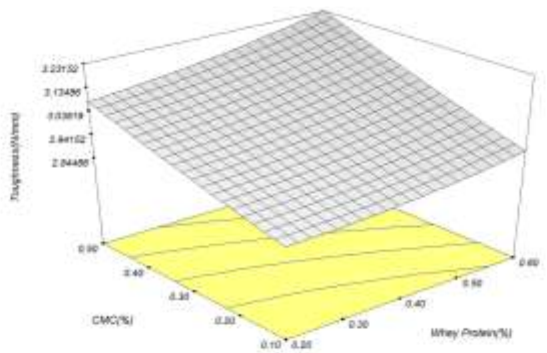

Fig 2b, *Response surface for the effect of Whey powder and CMC on Toughness (N/mm)*

D. Optimization of wheat flour formulation

Results of optimization for wheat flour formulation whey powder and CMC contain, by Design-Expert 6.0.2 software were calculated. According to Table 3, for having optimum rheological characteristics for wheat flour with desirability to 0.944, whey powder 0.54% and CMC 0.50% were calculated.

Table 3, *Optimization of wheat flour formulation with whey powder and CMC.*

Whey powder (%)	CMC (%)	Water absorption (%)	Stability (min)	Toughness (N/mm)	Extensibility (mm)	Desirability
0.54	0.50	53.12	2.73	3.2	23.22	0.944

IV. Conclusions

The results showed that whey powder and CMC were useful tool for optimizing the formulation of wheat flour and achieving desirable response variables. Second-order polynomial models were demonstrated to be appropriate for predicting the water absorption, stability, extensibility and toughness of then rheological wheat flour. It was also found that both the whey and CMC greatly influenced the quality attributes of wheat dough. The contribution of CMC, however, seemed to be more prominent than that of whey powder.

V. References

[1] M. Ahmed, M. Burhan Uddin, A. Sorifa, and E. Jong-Bang. Effect of processing treatments on quality of cereal based soybean fortified instant weaning food. Pak. J. Nutr. 2008. 7: 493-496.

[2] B. L. Launay and C. Michon. Rheology of wheat flour doughs: Measurment in encyclopedia of agricultural, food and biological engineering, Heldman, D. R.(ed). Taylor nad Francis, New York, UK. 2006.

[3] Y. Pomeranz and C. E. Meloan. Rheology. food analysis theory and practice. 3rd Edn. Chapman and Hall, Inc., New York. 1994. pp: 449-483.

[4] A. Kaur, R. Bala, B. Singh and J. Rehal. Effect of replacement of sodium chloride with mineral salts on rheological characteristics of wheat flour. American Journal of Food Technology. 2011. 6(8): 674-684.

[5] B. J. Dobraszczyk and M. P. Morgenstern. Rheology and the breadmaking process. Journal of Cereal Science. 2003. 38(3), 229–245.

[6] A, Angioloni and M. Dalla Rosa. Effects of cysteine and mixing conditions on white/whole dough rheological properties. Journal of Food Engineering. 2007. 80:18–23.

[7] D. Sabanis, E. Makri and G. Doxastakis. Effect of durum flour enrichment with chickpea flour on the characteristics of dough and lasagna. J Sci Food Agric. 2006. 86:1938–1944.

[8] S. M. Meshkani, Z. Pourfallah, M. Mohammadi and M. Nahardani. Effect of ascorbic acid and DATEM on bread dough rheological properties by using response surface methodology. The Second of National Seminar on Food Security. Azad Islamic University of Savadkooh. 2012. 2726.

[9] D. C. Montgomery. Design and analysis of experiments. New York: Wiley. 2001. 5th ed. pp. 455e492.

[10] A. Koocheki, R. Kadkhodaee. Effect of Alyssum homolocarpum seed gum, Tween 80 and NaCl on droplets characteristics, flow properties and physical stability of ultrasonically prepared corn oil-in-water emulsions. Food Hydrocolloids. 2010. p:1- 9.

[11] C. Collar, J. C. Martinez and C. M. Rosell. Lipid binding of fresh and stored formulated wheat breads. Relationship with dough and bread technological performance. Food Sci. Technol. Int. 2001. 7, 501-510.

[12] H. Tavakolipour and A. Kalbasi-Ashtari. Influence of gums on dough properties and flat bread quality of two Persian wheat varieties. Bread Quality. 2006. 1-14.

[13] A. Schirali, L. Piazza, O. Brenna and E. Vittadini. Structure and properties of bread dough and crumb. Journal of Thermal Analysis. 1996. 47, 1339-1360.

[14] C. Kadharmestan, B. Byung-Kee and Z. Czuchajowska. Whey protein concentrate treated with heat or high hydrostatic pressure in wheat based products. Cereal Chemistry. 1998. 75, 762-766.

[15] M. L. Sudha, R. Vetrimani, K. Leelavathi. Influence of fibre from diferent cerealson the rheological characteristics of wheatflour dough and on biscuit quality, FoodChemistry, Volume 100. 2007. 4, 1365-1370.