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ORIGINAL RESEARCH PAPER

APPLICATION OF RESPONSE SURFACE METHODOLOGY TO OPTIMIZE SOME FERMENTATION AND FORMULATION CONDITIONS OF WHEAT DOUGH FORTIFIED WITH MALT CULMS FLOUR

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The effect of four different parameters namely the malt culms flour addition, the salt percentage, the fermentation period and temperature on two quality indicators of bread dough: deformation and total titratable acidity was analyzed and interpreted by response surface methodology. The optimization of the imposed experimental conditions led to a quality dough characterized by 23.86 % deformation and 2.64 mL NaOH 0.1 N total titratable acidity. These values were obtained using wheat flour with addition of 7.4 % malt culms flour and salt in a quantity of 2.25 % compared to the total amount of flour. The dough was subjected to fermentation for 43 minutes at a temperature of 36 °C. The bread obtained after baking presented similar organoleptic characteristics to those registered for the white bread its increased nutrient intake recommending its consumption for an equilibrated diet.

Keywords: dough deformation, fermentation, malt culms flour, Response Surface Regression, total titratable acidity

Introduction

The term *dietary fibre* was used for the first time in 1953 by Eben Hipsley in order to describe those compounds that are part of the plant cell walls and include celluloses, hemicelluloses and lignin, which are known as non-digestible by the human body (Hipsley, 1953). Various other definitions based on physical and chemical characteristics (Arrigoni *et al.*, 1984; Kaczmarczyk *et al.*, 2012) but also on their physiological effects (McCleary, 2007) were developed until now. From

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2009, at the suggestion of Nutrition and Dietary Fibre Committee, Codex Alimentarius Commission defined dietary fibres as polymeric carbohydrates (with more than ten monomer units) that cannot be hydrolyzed by endogenous enzymes existing in human small intestine. Codex Commission stipulates that these polymers can be procured directly from foods in which they can be naturally found or indirectly from natural sources by physical, enzymatic and chemical methods (Wenzel de Menezes *et al.*, 2011).

Dietary fibre consumption has many beneficial effects on human body. Along to their indisputable influence on digestion process, they have been associated with reduced risk of gut (Makki *et al.*, 2018), type 2 diabetes (Davison and Temple, 2018; Ewers *et al.*, 2019), cardiovascular diseases (Dieter and Tuttle, 2017; McRae, 2017), ovaries cancer (Xu *et al.*, 2018), breast cancer (Rohan *et al.*, 1992), colon cancer (Chen and Vietta, 2018; Kaczmarczyk *et al*., 2012) etc. Dietary fibre are abundant in fruits (López-Vargas *et al*., 2013; Martínez *et al.*, 2012; Pastell *et al*., 2019; Shanmugam *et al*., 2017), vegetables (O'Shea *et al.*, 2012), cereals (Hollmann *et al*., 2013; Benitez *et al*., 2018; Dhang and Vasanthan, 2019) and in their by-products. One of these by-products is represented by malt culms, which result from malting process and are characterized by a high nutritive value conferred by the rich content of vitamins, hordein, candicine, betaine, purinic bases, nucleotide and allantoine (Banu *et al.*, 2000).

Dietary fibres intake in human nutrition can be increased by incorporating them in foods such as vegetal cheese (Artiga-Artigas *et al.*, 2017; Montesinos-Herrero *et al*., 2006; Noronha *et al.*, 2007), fruit fillings (Cropotova, 2015) cakes or bread (Jeddou *et al*., 2017; Segundo *et al*., 2017; Simion *et al.*, 2015; Vasantha Rupasinghe *et al.*, 2008). In this last particular case, the fermentation involved in dough preparation has the highest influence on product quality. The yeast leads to alcoholic fermentation with carbon dioxide release, which is responsible of dough loosening. Lactic acid bacteria growth takes place insuring the optimum *p*H for yeast development (Ktenioudaki *et al.*, 2009; Soleimani Pour-Damanab *et al*., 2011). The enzymatic reactions conduct to fermentable sugars and aminoacids useful to yeast and bacteria, while the chemical reactions lead among others to the formation of flavour substances, to gluten complex partial degradation, to changes in dough physical properties, to dough mechanical deformation by carbon dioxide bubles obtained by fermentation and to acidity modifications (Jayaram *et al*., 2013).

Dough fermentation process is affected by the employed ingredients but also by the used time interval and temperature (Bajd and Serša, 2011). These parameters have an impact on the intensity of enzymatic reactions, on microbiological, physical, chemical, biochemical and colloidal processes and on dough properties. Fermentation takes place optimally at temperatures between 28 and 32 °C when the flour employed is of high quality. In this case, enzymatic and fermentative processes are accelerated without degrading dough properties.

The moment when fermentation is finalized can be known by following specific indicators. One of these factors is dough deformation which is due especially to the important amount of gazes formed. Another parameter able to designate the optimal fermentation is the dough total titratable acidity.

In this context and, since to the best of our knowledge, there are no reports on the use of malt culms flour in bread production, our work was aimed to study its influence on dough quality in order to insure an amplified intake of nutrients necessary for yeast development and for obtaining a product with high fibre amount.

To this purpose, an experimental program was established. The effect of four different parameters namely the malt culms flour percentage, the salt percentage, the fermentation temperature and its time extension on two of the most important dough quality (deformation and total titratable acidity) were followed.

The Response Surface Methodology, an assembly of mathematical and statistical techniques (Madi-Azegagh *et al.*, 2018; Popa *et al.*, 2015a; Popa *et al.*, 2015b; Simion *et al.*, 2017), was employed to analyze the obtained experimental data in order to establish mathematical models able to allow the determination of optimal values for the studied parameters. The obtained dough was baked and the porosity, resilience and total titratable acidity of the resulting bread were analyzed.

Materials and methods

Dough ingredients

The wheat white flour, provided by a local producer (Pambac Bacau, Romania) and used for dough preparation, had the following characteristics: moisture content of 14 % (w/w), total titratable acidity of 2.2 mL NaOH 0.1 N, wet gluten content of 26 % (w/w), gluten deformation index of 18 % (w/w) and ash content of 0.48 % (dry basis).

Malt culms flour was obtained by malt culms milling in a Sadkiewicz WZ-2 laboratory scale mill. Chemical composition of the malt culms flour in presented in Table 1, and was established based on AACCI methods (2000) 44-19.01 (water content), 32-45.01 (fibres content), 08.01-01 (ash content), 80-50.01 (sugars content), 32-40.01 (starch content) and ICC standard no. 105/2 (2003) (proteins content).

Table 1. Proximal chemical composition of malt culms flour used in this work

Constituent	*Amount, %*	*Constituent*	*Amount, %*
Water	8.80	Ash	7.20
Proteins	30.80	Sugars	2.90
Fibres	16.33	Starch	26.70

Iodized salt (99% sodium chloride (w/w) and maximum 0.5% moisture content (w/w)) was produced by Comax M&M Romanian company.

Yeast (provided by Rompak – Romania) with 70% moisture had an amount of 55% proteins (reported on dry basis) according to producer data.

Farinograph test

Farinograph test was performed on a Brabender Farinograph®-E (Brabender GmbH & Co. KG, Germany) following the indications of ISO 5530-1 (2013) procedure.

Reagents

Ethanol and sodium hydroxide were purchased from Redox Lab – Bucharest (Romania). Double distilled water used for solutions preparation was procured from Chemical Company Iasi (Romania).

Dough preparation

Dough was prepared based on the experimental program detailed in Table 2 and Table 3. The added water volume was of 45 mL for 100 g of flour. The final blend was kneaded for 10 minutes.

Dough extensograph test

Extensograph test was carried out with a Brabender Extensograph®-E (Brabender GmbH & Co. KG, Germany) in accordance to ISO 5530-2 method (2013).

Dough deformation analysis

Dough deformation analysis was carried out based on the method described by Auerman (1964) and expressed in percentage.

Dough baking

In order to establish the impact of the studied parameters on bread quality 500 g of dough obtained in the optimal experimental conditions and 500 g of dough without malt culms flour addition were divided in 5 portions of 100 g each and baked at 180 ºC for 30 minutes.

Bread analysis

Bread loaves were evaluated 1 h after baking. The specific bulk volume was determined according to AACCI 10-05.01 (2000) standard method. The crumb porosity and resilience were established following the procedures described by Canja *et al.* (2015).

Dough and bread total titratable acidity (TTA) analysis

TTA was determined at the end of the fermentation process and respectively after baking by using AACCI Method 02-31.01 (2000).

Experimental design and statistical analysis

Experimental design, mathematical modeling, and optimization were performed using Design-Expert 7.0 software. A custom central composite design (CCD) was used to determine the effects and interactions of four different parameters (the percentage of added malt culms flour, X_1, salt percentage, X_2, temperature, X_3 and fermentation duration X_4) on the obtained dough quality. Data were analyzed by the response surface regression (RSREG) procedure to fit the following second-order polynomial model (equation 1).

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_i^2 + \sum_{i=1}^{k} \sum_{j=1}^{k} \beta_{ij} X_i X_j + e_0 \quad (1)$$

Here, Y is the predicted response of dough deformation (Y_1) and the total titratable acidity (Y_2); X_i and X_j are variables; β_0 is the constant coefficient; and β_i is the coefficient that determines the influence of parameter i in the response (linear term), β_{ij} is the cross-product coefficient and β_{ii} is the quadratic coefficient, which refers to the effects of the interaction among independent variables. The multiple regression analysis can be applied to obtain the coefficient, and the equation can be used to predict the response. The coded values of the parameters can be determined from the following equation:

$$x_i = \frac{X_i - X_o}{\delta X} \quad (2)$$

In equation 2 X_0 is the real value of the independent variable at the center point, X_i is the real value of the independent variable, and δX is the step change values between low (−1) and high (+1) levels (Table 2).

Table 2. Experimental ranges and levels of the independent test variables

Variables	*Symbol*	*Unit*	*Low actual*	*High actual*	*Low coded*	*High coded*
Malt culms flour	A	%	3	9	-1	1
NaCl	B	%	1.50	3.00	-1	1
Fermentation duration	C	min.	35	45	-1	1
Fermentation temperature	D	ºC	33	37	-1	1

In order to check the validity and to avoid generating an optimal point outside the studied range, for each of the four independent variables, two extreme points were entered in the experimental runs, corresponding to the coding variables -2 and 2. The considered values were: 0% and 12% for malt culms flour addition, 0.75% and 3.75% for NaCl amount, 30 min. and 50 min. for fermentation period and 31 ºC and 39 ºC for fermentation temperature.

Results and discussion

The fitting of models

A four-factor three level custom central composite design consisting of 31 experimental runs was adopted to optimize the experimental data, including replications at the center point. Table 3 summarizes the complete design matrix that uses four factors as independent variables and the recorded responses. The empirical second order polynomial equations used to describe the mathematical models are expressed in relations 3 and 4.

$$Y_1 = 21.80 - 0.27A - 0.1B + 1.26C + 2.53D + 0.075AB - 0.021AC - 0.55AD + 0.11BC - 0.10BD - 0.60CD - 0.12A^2 - 0.31B^2 - 0.17C^2 + 0.55D^2 \quad (3)$$

$$Y_2 = 2.36 - 0.084A + 0.088B + 0.23C + 0.19D + 0.011AB - 0.036AC - 0.036AD + 0.36BC + 0.053BD + 0.088CD - 0.014A^2 - 0.07B^2 - 0.02C^2 + 3.777E - 003D^2 \quad (4)$$

where, Y_1 and Y_2 represent the dough deformation and the total titratable acidity, respectively. *A*, *B*, *C* and *D* are the coded values for the four independent variables.

Table 3. Four factors three level custom central composite design (CCD): design matrix, measured and predicted responses

Run	Independent variable (uncoded)				Measured response		Predicted response	
	Malt culms flour, %	*NaCl, %*	*Fermentation period, min.*	*Fermentation temperature, °C*	*Dough* deformation, %	*Titratable* acidity, 0.1 N NaOH mL	*Dough* deformation, %	*Titratable* acidity, 0.1 N NaOH mL
1	3	1.5	35	33	20.80	2.10	20.78	2.14
2	6	1.5	35	33	25.80	2.83	24.96	2.96
3	3	3	35	33	22.30	2.38	21.80	2.36
4	6	3	35	33	16.80	1.89	17.59	1.95
5	3	1.5	45	33	25.80	2.50	25.14	2.61
6	6	1.5	45	33	21.80	2.44	21.80	2.36
7	3	3	45	33	20.60	2.20	21.31	2.30
8	6	3	45	33	20.60	2.00	20.75	1.91
9	3	1.5	35	37	20.50	2.40	20.35	2.26
10	6	1.5	35	37	21.80	2.41	21.80	2.36
11	3	3	35	37	23.30	2.90	23.63	2.74
12	6	3	35	37	21.80	2.60	21.85	2.48
13	3	1.5	45	37	27.90	2.89	29.05	2.75
14	6	1.5	45	37	25.90	3.09	25.80	3.09
15	3	3	45	37	22.00	2.37	21.80	2.36
16	6	3	45	37	20.10	2.10	18.95	2.01
17	0	2.25	40	35	23.70	2.23	23.82	2.31
18	12	2.25	40	35	16.90	1.92	17.05	1.96
19	6	0.75	40	35	26.00	2.70	26.12	2.76
20	6	3.75	40	35	20.90	2.12	21.09	2.16
21	6	2.25	30	35	23.60	2.19	23.41	2.25
22	6	2.25	50	35	16.70	1.90	17.36	1.95
23	6	2.25	40	31	18.90	1.90	18.58	1.83
24	6	2.25	40	39	21.10	2.20	20.97	2.24
25	6	2.25	40	35	21.60	2.33	21.80	2.36
26	6	2.25	40	35	21.00	2.30	21.05	2.36
27	6	2.25	40	35	24.60	2.00	24.04	2.04
28	6	2.25	40	35	16.80	1.92	16.67	1.94
29	6	2.25	40	35	21.50	2.35	21.80	2.36
30	6	2.25	40	35	21.60	2.42	21.80	2.36
31	6	2.25	40	35	24.80	2.10	24.60	2.12

The quality of the models was statistically evaluated based on the coefficient of determination (R^2) and on the analysis of variance (ANOVA) (Table 4).

Table 4. ANOVA results of the response surface quadratic models for dough deformation and total titratable acidity

Source	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*F-value*	*p-value*
		Y_1, Dough deformation			
Model	242.2010	14	17.3000	41.9644	< 0.0001
Residual	6.5961	16	0.4123	-	-
Lack of Fit	6.1361	10	0.6136	8.0036	0.0096
Pure Error	0.4600	6	0.0767	-	-
Corected Total	248.7970	30	-	-	-
$R_{squared}$ = 0.9735, *Adjusted* $R_{squared}$ = 0.9503, *Predicted* $R_{squared}$ = 0.8512					
		Y_2, Total titratable acidity			
Model	2.9300	14	0.2093	18.0528	< 0.0001
Residual	0.1854	16	0.0116	-	-
Lack of Fit	0.1761	10	0.0176	11.2760	0.0039
Pure Error	0.0093	6	0.0016	-	-
Corected Total	3.1155	30	-	-	-
$R_{squared}$ = 0.9405, *Adjusted* $R_{squared}$ = 0.8884, *Predicted* $R_{squared}$ = 0.3761					

The ANOVA results showed that the models were highly significant. This conclusion is sustained by the fact that the *F*-values (41.9644 and 18.0528 for the two responses) are greater than 0.001. The *p*-values are lower than 0.05. There are only 0.01% of the total variation that could not be explained by the model. The lack of fit (with *F*-values of 8.0036 and 11.276 respectively) reveal no statistical meaning as the *p*-values of each are lower than 0.05 (0.0096 and 0.0039, respectively). The registered values for the correlation coefficient R^2 are 0.9735 for the dough deformation and 0.9405 for the total titratable acidity, and this means that only 1.65% and 5.95% of the total variables for responses were not explained by the model. The adjusted R^2 value also explains the adequacy of the model. Figure 1 shows the measured values versus the predicted responses by the models.

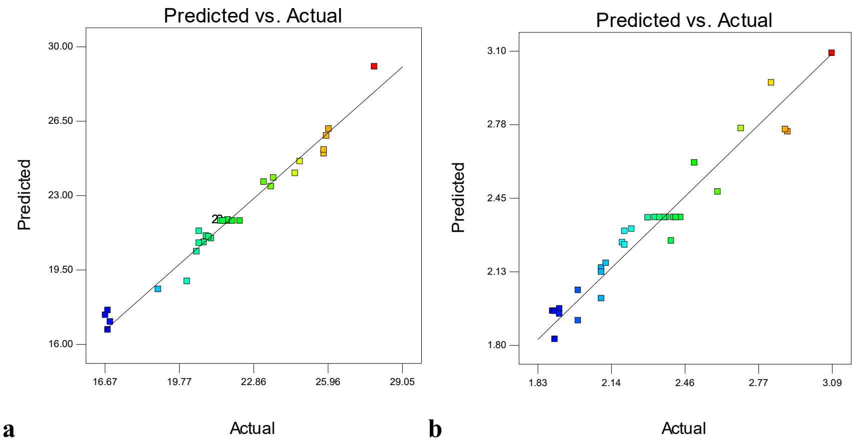
Table 5 shows the ANOVA of the quadratic models coefficients for each response type. Two terms (C and D with $p < 0.0001$) were found to be statistically significant for dough deformation. The interaction terms AD and CD between malt culms flour addition and fermentation temperature respectively fermentation time and fermentation temperature and the quadratic terms B^2 (NaCl percentage) and D^2 were highly significant based on a 95 % confidence level ($p < 0.05$).

An intense effect on dough deformation is determined by the time and fermentation temperature. The amount of malt culms flour plays an important role only in combination with the other two parameters.

Also, from Table 5 one can note that only two terms, C and D, with $p < 0.0001$ and four terms A, B, CD, B^2 with $p < 0.05$ are relevant for dough acidity.

The sum of squares (SS) for each model component was used to calculate the percentage contributions (PC) of individual terms. For dough stability, the fermentation time (D) showed the highest level of significance with a contribution of 68.57 % as compared to other components. Dough acidity showed the highest level of significance on the fermentation temperature (C) with a contribution of 42.75 %.

The malt culms flour addition (A) has more influence on dough stability and affects less its acidity with a contribution of 0.60 % and respectively 4.57 %.



a **b**

Figure 1. Plots of the actual and predicted values for dough deformation (%) (a) and the total titratable acidity (0.1 N NaOH mL) (b)

Figures 2 and 3 show the influence of single factors while maintaining constant all the others at coded values 0. Dough stability was almost unchanged with the variation of NaCl amount. On the other hand, temperature and fermentation time had a negative effect. The malt culms flour addition decreased the dough stability in combination with the fermentation temperature and NaCl percentage augmentation but in report with fermentation time rise an increase of stability could be observed.

In the case of dough acidity, the augmentation of malt culms flour amount added determined a moderate decrease of acidity the only observed synergic effect being in the rise of acidity, when NaCl amount is increased.

In the studied conditions dough deformation ranged between 16.7 % and 27.9%, and its TTA between 1.9 and 3.09 mL of 0.1M NaOH. The realized experiments have shown that these parameters presented optimum values (23.86 % deformation, 2.64 mL NaOH 0.1M) when using an addition of 7.4 % of malt culms flour. At the same time, it was noticed that the excess dietary fiber inserted in the dough with malt culms flour implied an increase of salt percentage (2.55 % reported on the total amount of flour). The salt improved the dough quality since this became more elastic and no longer flattened during leavening as happened when the percentage of salt introduced was smaller.

Table 5. ANOVA results for the coefficient of quadratic model for dough deformation (%) and dough acidity (0.1 N NaOH mL)

***Y_1*, Dough deformation**

Standard deviation	***Mean***	***Coefficient of variance, %***	***Predicted residual error sum of square***	***Adequate precision***
0.64	21.85	2.94	37.03	27.720

Factor	***Coefficient***	***95% Confidence interval***		***Standard error***	***F-value***	***p-value***	***Sum of squares***	***Percentage contribution (%)***
		Low	***High***					
Intercept	21.79617	21.29	22.30	0.24	-	-	-	-
A	-0.26585	-0.65	0.12	0.18	2.18	0.1590	0.90	0.60
B	-0.1	-0.44	0.24	0.16	0.39	0.5421	0.16	0.11
C	1.2625	0.92	1.60	0.16	61.86	< 0.0001	25.50	17.14
D	2.525	2.18	2.87	0.16	247.44	< 0.0001	102.01	68.57
AB	0.075	-0.51	0.66	0.28	0.07	0.7908	0.03	0.02
AC	-0.2125	-0.80	0.38	0.28	0.58	0.4558	0.24	0.16
AD	-0.55	-1.14	0.04	0.28	3.91	0.0654	1.61	1.08
BC	0.1125	-0.23	0.45	0.16	0.49	0.4935	0.20	0.14
BD	-0.1	-0.44	0.24	0.16	0.39	0.5421	0.16	0.11
CD	-0.6	-0.94	-0.26	0.16	13.97	0.0018	5.76	3.87
A^2	-0.12008	-0.38	0.14	0.12	0.97	0.3403	0.40	0.27
B^2	-0.31093	-0.57	-0.05	0.12	6.42	0.0221	2.65	1.78
C^2	-0.17343	-0.43	0.09	0.12	2.00	0.1768	0.82	0.55
D^2	0.551571	0.29	0.81	0.12	20.19	0.0004	8.33	5.60

***Y_2*, Dough acidity**

Standard deviation	***Mean***	***Coefficient of variance, %***	***Predicted residual error sum of square***	***Adequate precision***
0.11	2.31	4.66	1.94	16.884

Factor	***Coefficient***	***Low***	***High***	***Standard error***	***F-value***	***p-value***	***Sum of squares***	***Percentage contribution (%)***
Intercept	2.364426	2.28	2.45	0.04	-	-	-	-
A	-0.08404	-0.15	-0.02	0.03	7.76	0.0132	0.09	4.57
B	0.088125	0.03	0.15	0.03	10.72	0.0048	0.12	6.31
C	0.229375	0.17	0.29	0.03	72.61	< 0.0001	0.84	42.75
D	0.186875	0.13	0.24	0.03	48.20	< 0.0001	0.56	28.38
AB	0.010625	-0.09	0.11	0.05	0.05	0.8226	0.00	0.03
AC	-0.03563	-0.13	0.06	0.05	0.58	0.4559	0.01	0.34
AD	-0.03563	-0.13	0.06	0.05	0.58	0.4559	0.01	0.34
BC	0.035625	-0.02	0.09	0.03	1.75	0.2043	0.02	1.03
BD	0.053125	0.00	0.11	0.03	3.90	0.0660	0.05	2.29
CD	0.088125	0.03	0.15	0.03	10.72	0.0048	0.12	6.31
A^2	-0.01385	-0.06	0.03	0.02	0.46	0.5088	0.01	0.27
B^2	-0.06997	-0.11	-0.03	0.02	11.56	0.0037	0.13	6.80
C^2	-0.01997	-0.06	0.02	0.02	0.94	0.3463	0.01	0.55
D^2	0.003777	-0.04	0.05	0.02	0.03	0.8567	0.00	0.02

The optimal fermentation period was of 43 minutes. The process has led to the best results when the temperature used was set at 36 °C. In this case, the production of carbon dioxide by the yeast was favored fact that conducted to a better dough expansion. However, at higher temperatures, the expansion process diminished due to the combined effect of dough weakening and of carbon dioxide solubility reduction.

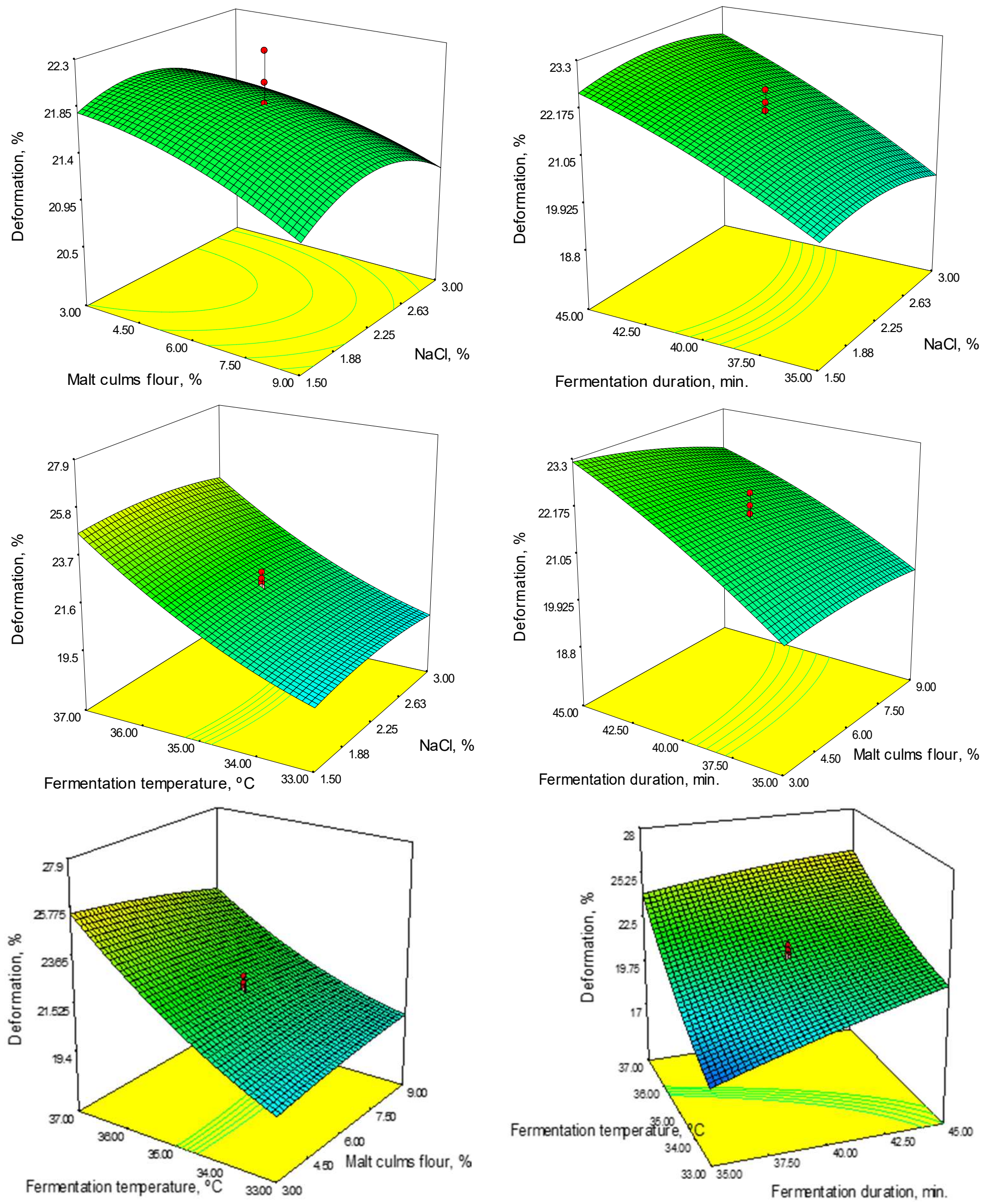


Figure 2. Response surfaces generated when studying the influence of malt culms flour addition, NaCl percentage, fermentation duration and fermentation temperature on dough deformation

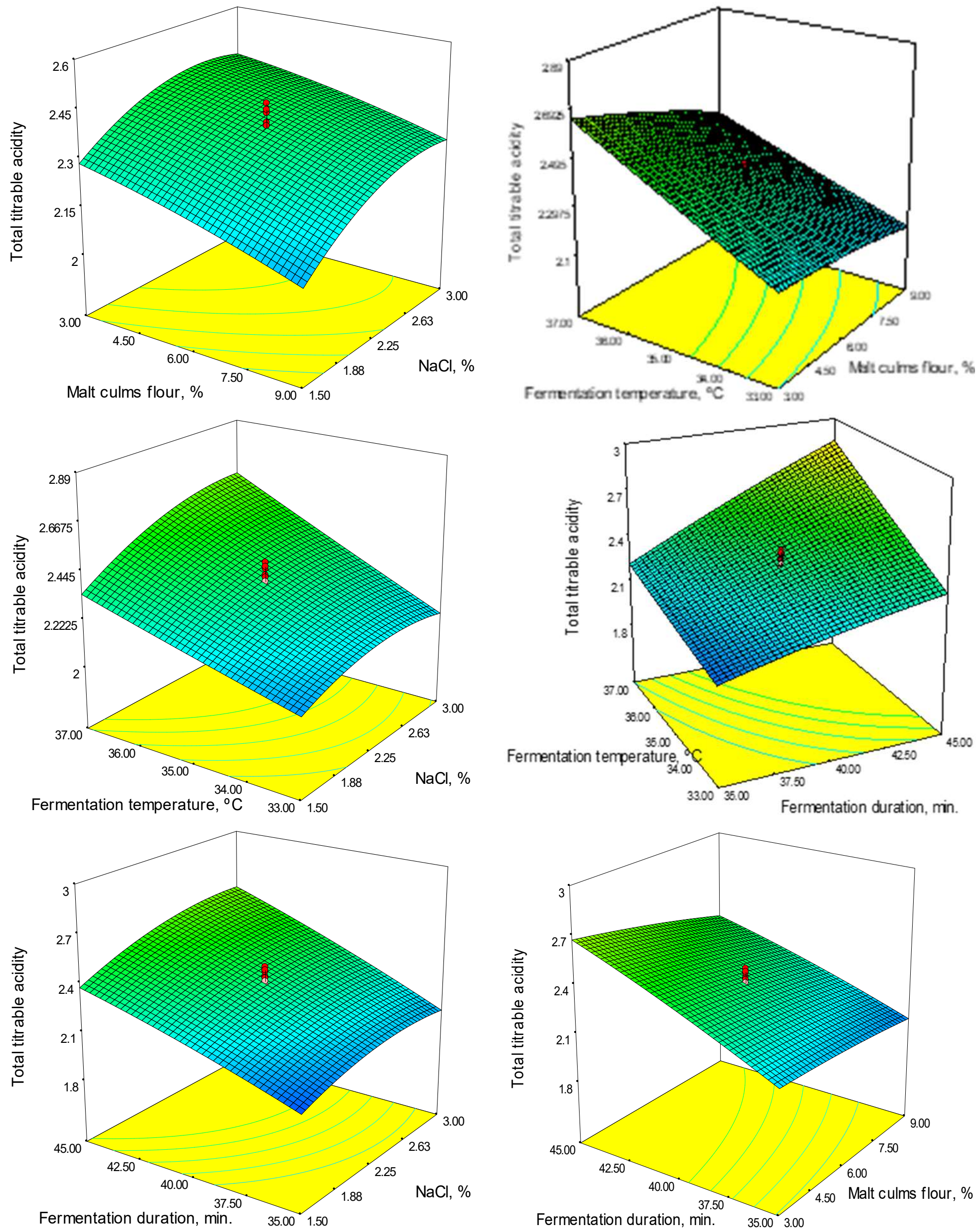


Figure 3. Response surfaces generated when studying the influence of malt culms flour addition, NaCl percentage, fermentation duration and fermentation temperature on dough acidity

Optimal conditions testing

The farinograph test of the flour mix with 7.4 % of malt culms flour revealed the following results: 14.3 % flour moisture, 58.1 % water absorption (WA) at 502

Brabender unit (BU), 58.2 % WA corrected to 500 BU, 58.7 % WA corrected to 14 % moisture, 2.7 min. dough development, 11.4 min. stability time, 23 BU softening degree (SD) at 10 min., 37 BU SD at 12 min. and 125 Farinograph® quality number (FQN).

The validation of the obtained mathematical models was verified by performing 10 replicates on the optimum determined conditions. According to the statistical analysis, dough deformation was of 23.86 ± 0.5 %, while its TTA ranged between 2.35 and 2.7 mL NaOH. The differences observed between the experimental results and those raised from the application of mathematical equations were statistically insignificant.

The extensograph test registered at 30/60/90 minutes showed at 56.0 % WA and 2.5 % sodium chloride: 113/113/117 cm^2 energy, 366/502/521 BU resistance to extension, 159/134/138 mm extensibility, 519/655/668 BU maximum resistance to extension.

In order to establish the influence of the studied parameters on bread quality 10 loaves obtained after baking were submitted to a sensorial analysis. The volume, porosity, resilience and TTA for each bread samples were also recorded. The organoleptic aspects revealed no cracks on bread crust and a uniform color. Shell color was golden yellow with a slightly darker shade for bread with malt culms flour addition. The core was well grown, with fine pores, uniform, elastic, un-sticky. The aroma was pleasant without foreign smell. The taste was pleasant and slightly salty.

Substitution of a part of wheat flour with malt culms flour leaded to a reduction in loaf volume, which ranged between 340 g/cm^3 and 355 g/cm^3 for simple bread and between 298 g/cm^3 and 320 g/cm^3 for that with fiber addition. The porosity in this case was slightly lower (68 ± 0.8 % for fiber-enriched bread compared with 75 ± 1.1 % for that obtained only from white flour). The same observation applies to core resilience. A value of 71 ± 1.5 % was obtained for the white bread while for the bread with malt culms flour addition the resilience reached only 67 ± 1.3 %. For this bread a slight increase of crumb TTA was noted (2.64 mL NaOH 0.1 N) compared to that registered for the white bread (2.4 mL NaOH 0.1 N).

There are no reports on the use of malt culms flour in bread production. However, when other substitutes such as apricot kernel flour (Dhen *et al.*, 2018), fermented chickpea flour (Shrivastava and Chakraborty, 2018), banana peels flour (Al-Sahlany and Al-Musafer, 2018) or chia flour (Coelho *et al.*, 2015) were employed to partially replace the wheat flour in dough formulation, researches showed similar results for its rheological properties. The mentioned studies reveal also that the end products were enriched in various nutrients including protein, fibers or fat and the bread final has acceptable or even ameliorated physical characteristics.

Conclusions

The study was aimed firstly at determining the effect of four different parameters (malt culms flour addition, used salt percentage, fermentation temperature and fermentation duration) against two of the most important characteristics of dough: deformation and total titratable acidity. The RSM leaded to the optimum values of these parameters (7.4% culm malt flour, 2.25% salt, 43 minutes of fermentation at 36°C) and conducted to mathematical models capable to accurately describe the monitored response functions.

The realised experiments revealed also that the bread enriched in dietary fiber from malt culms flour presented similar characteristics to those of the white bread. The lower values recorded of the studied physicochemical characteristics obtained in the first case are counterbalanced by the possibility of incorporating larger amounts of fiber into the human diet.

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