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QUALITY EVALUATION OF WHEAT-PUMPKIN-GOLDEN FLAXSEED COMPOSITE BREAD

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Abstract: *The purpose of this study was to optimize the level of wheat, pumpkin seed (PSF) and golden flaxseed flour (GFs) that can be used in order to obtain high quality bread. The independent variables levels used were between 90 and 95 % for wheat flour and between 2.5% and 7.5% for pumpkin seed and golden flaxseed flour. The quality parameters analyzed were the following: loaf volume, porosity, elasticity and bread crumb structure. The mixture experiment design was used for optimization. Special quadratic mixture models were obtained for all the dependent variables. The optimum mixture levels were of 92.43% for wheat flour, 5.06% for pumkin seed flour and 2.51% for golden seed flour. The values of these flours in terms of loaf volume of bread, porosity and elasticity were of 422 cm^3/100g, 76.15%, and 92.82%, respectively. The textural properties (hardness, cohesiveness, adhesiveness, viscosity, elasticity, gumminess, chewiness) were analyzed for the control sample and the optimum bread sample obtained with PSF and GFs addition. For the last one mentioned hardness, elasticity, gumminess and chewiness increase with 25.03%, 7.31%, 23.41%, 25.77% while the cohesiveness value decreases with 1.47%.*

Keywords: *loaf volume, porosity, elasticity, crumb structure, textural properties.*

1. Introduction

Bread is a well known and widely used food all around the world. Wheat is the most common grain used to obtain bread, but it can also be obtained from rye, oats, corn and other grain varieties [1]. The bread making performance obtained from wheat flour is related to its protein quantity and quality. Wheat is the only cereal capable of forming gluten, a viscoelastic mass which stands out from all other commercially available vegetable proteins. In most baking formulation, wheat flour is the predominant ingredient. Other ingredients are used especially in order to improve the quality of the finished bakery product [2, 3].

Apart from gluten, wheat flour also contains many other components such as: non-starch polysaccharides, lipids, e.g. which are important in terms of the quality of the finished bakery products [4]. Bread making producers are trying to improve the nutritional quality of bread by using various additions in order to satisfy the consumers' demand. Also different bakery products are made especially for people suffering from different diseases such as celiac disease, obesity, diabetes, e.g.

Different oilseeds may be used in the bakery products due to their high content in essential amino acids, especially lysine which will improve the nitrogen balance of bread and therefore will increase the coefficient of amino acids assimilation. These seeds can be excellent sources of calcium, iron and also good sources of vitamins from the B complex [5]. From a chemical point of view, oilseeds are characterized by a high level of fat (>20%) which can have beneficial effects in bread making [6].

In this research, the aim was to investigate and scientifically explain the mechanism by which the use of two oilseeds flours namely pumpkin seed and golden flaxseed added in wheat flour may affect the baking quality results.

Pumpkin and flaxseed flour are healthy ingredients used in bakery products nowadays in order to provide them with different minerals and vitamins. Thus, flaxseeds present a high mineral content of P, Mg, K, Na, Fe, Cu, Mn and Zn [7]. Flaxseeds are a rich source of mammalian lignanan α-linolenic acid (ALA) and it has been shown that it is protective in the early promotion stage of carcinogenesis [8]. The antioxidant activities of flaxseed lignin secoisolariciresinol diglycoside (SDG) and its mammalian lignan metabolites, enterodiol (ED) and enterolactone (EL) were evaluated in both lipid and aqueous in vitro model systems [9]. Due to the flaxseed functional components, it presents health benefits in the case of cardiovascular disease, atherosclerosis and neurological disorders [10].

Pumpkin seeds have special properties due to their high content in proteins 37.80–45.40%, oil 25.20–37.00%, dietary fibers 16.84-24.02%, minerals 4.59% and B vitamins [11].

Due to it high content in these elements they are being regarded valuable for the food industry [12]. Therefore pumpkin seeds are valued from a nutritional standpoint, in part at least, for its high protein content and the useful amount of the essential fatty acid, linoleic acid which it provides [13].

The four dominant fatty acids are palmitic, stearic, oleic and linoleic acids, these ones making up almost 98% of the total amount of fatty acids in pumpkin seeds [14]. To our knowledge, there has not been published any work on the optimum pumpkin and golden flaxseed addition that may be used in wheat flour in order to obtain high quality bread by using the mixture experiment design. The aim of this study was to evaluate the bread physical characteristics (loaf volume, porosity, elasticity) of bread samples baked with different mixtures made from wheat flour, pumpkin seed flour and golden flaxseed flour. Both the pumpkin seed and golden flaxseed flour contain a high level of fats, proteins and minerals. However, pumpkin seed presents a higher content in protein than flaxseed which presents a lower amount of fats than pumpkin seed. Both types of flours present a high lysine content which exist in a lower amount in wheat flour suggesting its ability to be incorporated in bakery products, especially bread. Regarding its fiber content, in flaxseeds it is significantly higher than in pumpkin seeds and therefore, sustainable to be incorporated in white wheat flour which contains a low amount of fibers due to its high extraction rate [15], [16].

2. Materials and methods

Materials

A commercial wheat flour of 650 type (harvest of 2015) was used as a base for wheat-pumpkin-golden flaxseed flour mixtures. Wheat flour was analyzed according to the international or Romanian standard methods: gluten deformation index, moisture content, wet gluten content, ash content and falling number index (SR 90:2007, ICC methods 110/1, 106/2, 104/2 and 107/1 respectively).

Golden flaxseed and pumpkin seed grains were ground in a domestic blender and the flour obtained was analyzed in terms of its chemical characteristics moisture, protein, ash according to international methods (ICC methods 110/1, 105/2, 104/2) and oil content (SR EN ISO 659-2009) as well.

Baking process and bread analysis

The bread recipe reported to the 100 g wheat-pumpkin-golden flaxseed composite flour mass consisted of dried yeast (3%), sodium chloride (1.5%), pumpkin seed flour (2.5-7.5%), golden flaxseed flour (2.5-7.5%) and water (56.3%) according to wheat flour hydration capacity. We chose this level for golden and pumpkin seed flour addition based on our previous studies [15], [16], the best quality bread being obtained up to a level of 10% pumpkin seed and golden flaxseed flour addition in wheat flour. The dough was kneaded for 15 minutes, rested for 5 minutes, and then dough pieces were modeled and proofed at 30^{o}C for 60 min and 85% RH and baked for 30 min in an electrical bakery convection oven with steam production, ventilation and humidification (Caboto PF8004D, Italy). After the bread samples were cooled (approximativaly 1 h after baking) they were evaluated in terms of loaf volume, porosity, elasticity according to the SR-Romanian Standard Method 91: 2007 and crumb structure using the Motic SMZ–140 stereo microscope with the 20x objective to a resolution of 2048 x 1536 pixels. For the optimum bread sample obtained the textural properties (hardness, cohesiveness, adhesiveness, viscosity, elasticity, gumminess, chewiness) using an electronic texture analyzer Mark-10-ESM301 were determined. The crumb structure and the textural properties of the bread samples were prepared and processed according to [17], [18].

Design of the experiment

In order to obtain an optimum bread quality from the technological point of view the mixture experiment design with the statistical State-Ease Design Expert 10.0.0 software package (trial version) was used. This statistical software from Stat-Ease Inc. is currently used to perform the design of experiments (DOE). It is very used for comparative tests, optimization, mixture designs, and combined designs, e.g. It provides matrices of many factors on which statistical significance are established with the analysis of variance (ANOVA). ANOVA is very useful because it determines the impact of the independent variables on the dependent ones in a regression analysis. It allows us to identify the factors which have contributed to the data set's variability from a statistical point of view. The option Mixture-Optimal was used from the State-Ease Design Expert software program menu. The experimental plan that was used for this study was Mixture Design, v. Simplex Lattice. The method is very effective having in view that the effects of several factors can be studied simultaneously. This allows us to optimize the bread recipe relying on statistical design of experiments depending on the technological characteristics analyzed. This method allowed us to determine the optimum combinations of the three different types of flour used (wheat flour, golden flaxseed and pumpkin seed) in order to obtain bread with the best physical characteristics [19]. For this purpose, we introduced the limit restriction of each component in the Mixture Design for each three types of flour used. The lower and upper quantity set up was the 2.5% and 7.5 % respectively for golden flaxseed flour and pumpkin seed flour reported to the 100 g wheat-pumpkin-golden flaxseed composite flour.

The combinations of the three types of flours (X_1, X_2, X_3) were evaluated by changing their levels (proportions) simultaneously and maintaining the total level (proportions) constant ($X_1 + X_2 + X_3 = 1$). We analyzed 9 different combinations of the mix flours and a control sample made only from wheat flour.

The experimental design used in terms of pseudo components and real levels is shown in Table 1.

Table 1.
Experimental design for ternary mixture of wheat flour, golden flaxseed flour and pumpkin flour in pseudo components and in real levels

Formulation	Component proportion in the composite flour					
	Pseudo components			Real levels (%)		
	Wheat flour	Pumpkin seed flour	Golden flaxseed flour	Wheat flour	Pumpkin seed flour	Golden flaxseed flour
M	1.000	0.000	0.000	0.950	0.025	0.025
P1	0.000	0.500	0.500	0.900	0.050	0.050
P2	0.000	0.000	1.000	0.900	0.025	0.075
P3	0.165	0.667	0.167	0.908	0.058	0.033
P4	0.667	0.167	0.167	0.933	0.033	0.033
P5	0.500	0.500	0.000	0.925	0.050	0.025
P6	0.000	1.000	0.000	0.900	0.075	0.025
P7	0.167	0.167	0.667	0.908	0.033	0.058
P8	0.333	0.333	0.333	0.917	0.042	0.042
P9	0.500	0.500	0.500	0.925	0.025	0.050

This study contained 3 factors (independent variables) and 3 responses (dependent variables). Characteristics such as: loaf volume, porosity and elasticity were selected as the response variables. The response is a function of component proportions. Thus, for the characteristics analyzed, the appropriate model obtained was a special quadratic mixture model in the form of equation (1) which may be converted in the equation (2) [20]:

$$f(x) = \sum_{i} \beta_i x_i \sum_{i \prec j} \beta_{ij} x_i x_j \qquad (1)$$

By using the identity $\sum x_i = 1$ model (1) can be converted to a canonical homogeneous quadratic model as follows:

$$f(x) = \sum_{i} \beta_{ii} x_i^2 \sum_{i \prec j} \beta_{ij} x_i x_j \qquad (2)$$

In the simple mixture experiment, the response (in our case loaf volume, porosity, elasticity) depends on the relative proportions of the components (the proportion/level for the three independent variables used in this study: X_1 - wheat flour, X_2- pumpkin seed flour flour and X_3- golden flaxseed flour). The amounts of components, measured in weights (grams) add up to a common total [21]. The β_1, β_2, β_3 are the linear terms of the model and the β_{12}, β_{13}, β_{23} are the interaction terms of the variables $X_1$and X_2, $X_1$and X_3, and X_1, X_2 and X_3.

3. Results and discussion

Physico-chemical characteristics for wheat, pumpkin seed and golden flaxseed flours are shown in table 2. According to the data shown for wheat flour it is of a very good quality for bread making but with a low alpha-amylase activity due to its high falling number value [2].

Table 2

The physico-chemical characteristics of wheat, pumpkin seed and golden flaxseed flours

Characteristics	Wheat flour (WF)	Golden flaxseed flour (GFs)	Pumpkin seed flour (PSF)
Moisture (%)	14.5	5.6	5.4
Ash (%)	0.65	3.41	5.48
Protein (%)	12.6	20.85	33.58
Fat (%)	1.5	41.12	29.26
Gluten deformation (mm)	8	-	-
Falling number (s)	380	-	-

The best-fit models for loaf volume, porosity and elasticity were special quadratic mixture ones. Table 3 shows the equations obtained for the response variables with the indication of the significantly regression coefficients expressed in terms of coded values, R^2 and *Adj.-*R^2 obtained by the analysis of variance (ANOVA).

Table 3

Effects of formulation factors, expressed as their corresponding coefficients in the predictive models for bread quality characteristics: loaf volume, porosity, elasticity

Factors[a]	Parameters		
	Loaf volume (cm^3/100g)	Porosity (%)	Elasticity (%)
WF	331.47*	77.94	87.90
PSF	418.47*	74.40	90.90
GFs	304.47*	75.45	82.90
WF x PSF	183.86	0.10	13.59
WF x GFs	-56.14	-20.63*	9.59
PSF x GFs	-231.14	-0.43	11.59
WF^2 *x PSF x GFs*	467.82*	-97.67	-171.53
WF x PSF^2 *x GFs*	-7236.18*	-185.86	-567.53
WF x PSF x GFs^2	6344.82	250.42	332.47
R^2	0.99	0.99	0.97
Adj.-R^2	0.97	0.93	0.74

*p < 0.01.
[a]*WF*, wheat flour (g/100g); PSF, pumpkin seed flour (g/100g); GFs, golden seed flour (g/100g); R^2, *Adj.-*R^2 are measures of fit of the model.

ANOVA results for bread ***loaf volume*** highlight that the *F*-test value of 38.74 is not a significant one. For the loaf volume model all the independent variables used are significant ones ($p < 0.01$). The positive value of the terms from the special quadratic mixture model of wheat flour, pumpkin seed flour, golden flaxseed flour and the interaction between wheat flour and pumpkin seed flour show that the loaf volume values increased due to its addition.

The contour surface of bread loaf volume as a simultaneous function of WF, PSF and GFs dose adition in bread recipe is shown in Fig. 1a, emphasizing that the most positive effect on loaf volume value is provided by wheat flour and pumpkin seed flour addition.

Similar results were obtained by Meral and Dogan (2013) on bread with golden flaxseed flour addition where the loaf volume increases up to 15% GFs addition [18]. Also Ptitchkina *et al.* (1998) concluded that the addition of pumpkin pulp flour up to 10% addition increases the loaf volume of the bread samples [23].

For ***porosity*** the coefficient of determination (R^2) of the model was 0.99, implying that only 1% of the total variation was not explained by the model. The adjusted determination coefficient (Adj R^2) was of 0.93, indicating high significance of the obtained model. Table 2 shows clearly that the cross product coefficients (WF x GFs) were significant, with a *p* value ($p < 0.01$). The other term coefficient for the response variable porosity was non significant ($p > 0.05$). Fig. 1b shows the interaction between wheat flour, pumpkin seed flour and golden flaxseed flour.

For ***elasticity*** the ANOVA results highlight that the quadratic terms of the model were not statistically significant. However, the quadratic mixture model is statistically significant at a determination coefficient of $R^2 = 0.97$ showing that the model could be used to explain more than 95 % of the variability in the response. The positive effect of these independent variables on the response showed that the bread elasticity increases with the increased level of wheat flour, pumpkin seed flour and golden flaxseed flour addition. The contour surface of bread elasticity and contour graphs as simultaneous function of WF, PSF and GFs addition is shown in Fig. 1c.

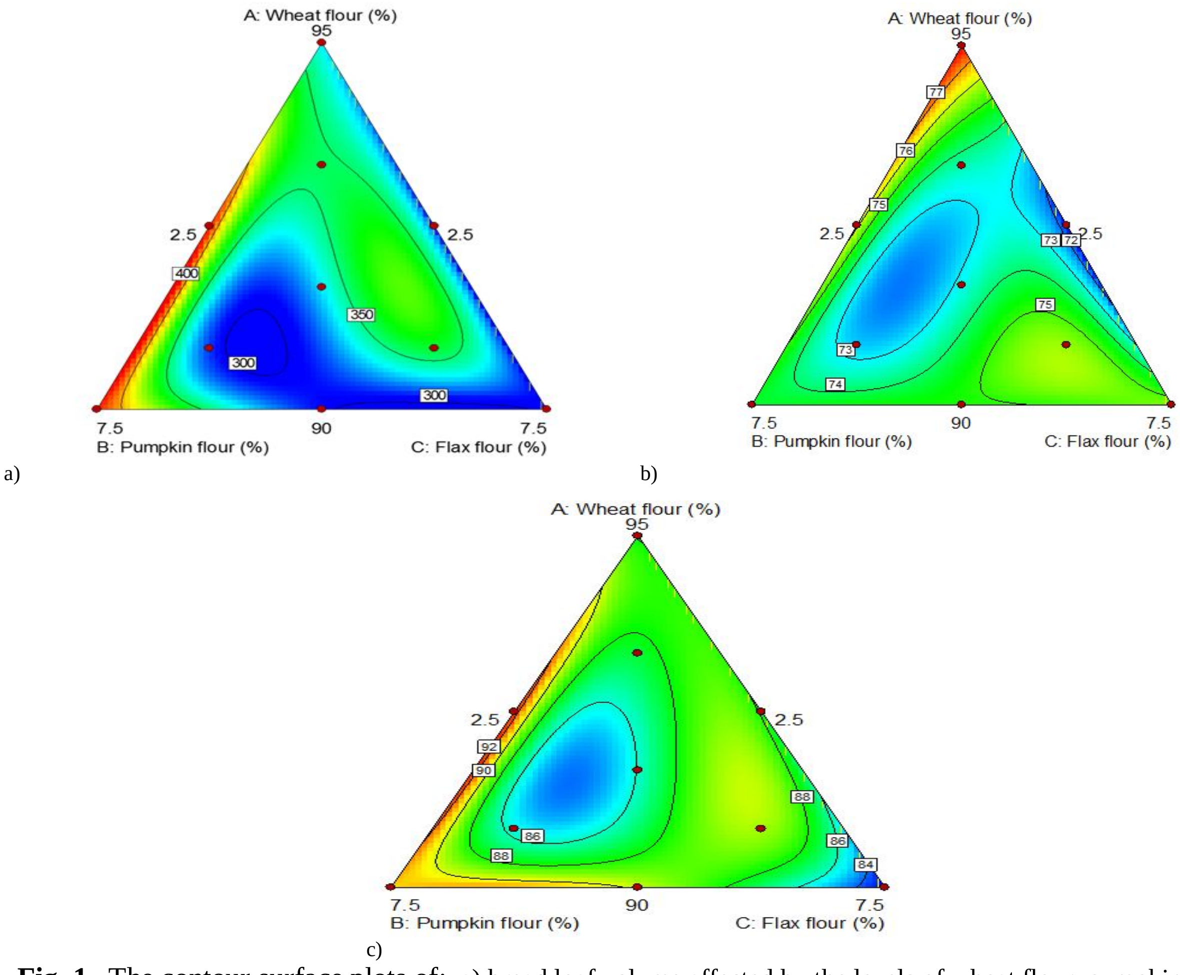

Fig. 1. The contour surface plots of: a) bread loaf volume affected by the levels of wheat flour, pumpkin seed flour and golden flaxseed flour; b) bread porosity affected by the levels of wheat flour, pumkin seed flour and golden flaxseed flour; c). bread elasticity affected by the levels of wheat flour, pumpkin seed flour and golden flaxseed flour.

The numerical optimization technique of the statistical State-Ease Design Expert 10.0.0 software package (trial version) was used for simultaneous optimization of the multiple responses analyzed: loaf volume, porosity and elasticity. For each factor and response, the desired goals were chosen namely for the response variables the maximum goal was used. The overlay plot (Fig. 2) shows the interactive effect of the independent variables (wheat flour, pumpkin seed flour, golden flaxseed flour) on loaf volume, porosity and elasticity values of breads. The mixture experiment design suggested the ***optimal solution*** for the composition of bread ingredients with maximum desirability (*D* = 0.983) for 92.43% wheat flour, 5.06% pumpkin seed flour and 2.5% golden seed flour. Due to the fact that D value is closed to 1, it means that our solution is a good one to predict the best bread quality for the independent variables chosen. The flour levels in terms of loaf volume of bread, porosity and elasticity were predicted to be 422 cm^3/100g, 76.15%, and 92.82%, respectively.

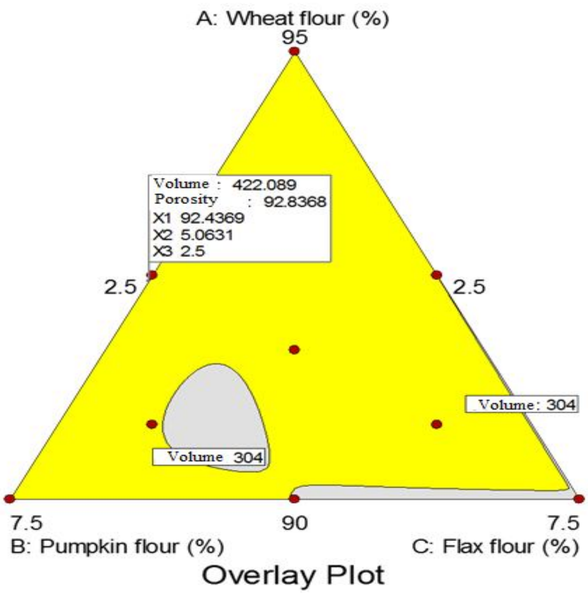

Fig. 2. The over plot of the mixture experiment design used for bread quality evaluation

Fig. 3 shows the ***bread crumb structure*** for the samples obtained with different combinations of mix flours as indicated in the Table 1. As we can see, together with the increase level of PSF and GFs addition, more and larger cells can be noticed maybe due to the decrease of the gluten content, a low content not being capable of retaining the gases formed during fermentation.

The ***textural characteristics*** of bread samples (the control sample and the optimum sample suggested by Mixture experiment design) are shown in Table 4. It can be noticed that for the optimum sample hardness, elasticity, gumminess and chewiness increased whereas the cohesiveness value decreased. These results are in agreement with those obtained by Conforti and Davis (2006) who found that by flaxseed addition the hardness value increases [20].

Fig. 3. Crumb structure of bread samples with wheat flour, golden flaxseed flour, pumpkin seed flour at various levels (M-P9) according to the Table 1

Table 4

Textural parameters of bread samples

Textural parameters	Control sample	Optimum sample
Hardness (N)	16.22 ± 0.22	20.28± 0.20
Cohesiveness	0.69 ± 0.11	0.68± 0.09
Elasticity	0.82 ± 0.15	0.88± 0.11
Gumminess (N)	11.19 ± 0.17	13.81± 0.14
Chewiness (N)	9.62 ± 0.09	12.1± 0.10

4. Conclusions

The mixture experiment design was successfully applied to optimize the quality of breads obtained from different mixtures of wheat-pumpkin-golden flaxseed flours. With the increase level of PSF and GFs the bread quality characteristics are improved namely loaf volume, porosity and elasticity. The optimal solution for the independent variables was obtained at a high desirability (D = 0.983) indicating the adequacy of the method used. The optimum values obtained for the WF, PSF and GFs levels were 92.43%, 5.06% and 2.5% for which the bread loaf volume, porosity and elasticity were of 422 cm^3/100g, 76.15%, and 92.82%.

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