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Innovation in Pinsa Romana Production: a Response Surface Methodology Approach

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Pinsa romana (PR) is a typical elongated pizza, produced with the addition of small amount of soy and rice flours to refined soft wheat flour, which guarantee the crust crunchiness and the crumb softness. The current PR recipe asks high water content (75-80 % on flour weight) and long leavening (24 - 72 hours). Therefore, the choice of a correct flour mixture is crucial to obtain a high quality product. This paper aims at using a Response Surface Methodology approach to develop an innovative *pinsa romana*, optimising the proportion between different flours (semi-whole grain soft wheat, whole grain einkorn, rice, soy) and considering multiple characteristics (multi-responses). To do this, four rheological characteristics of the dough (water absorption WA, development time DT, dough stability DS, degree of softening SO) were obtained using a Brabender farinograph. Regression models were considered for WA and DT; the models showed a good adequacy, with elevated coefficient of determination (0.81 and 0.84, respectively) and low absolute average deviation (0.64 and 0.45, respectively). The optimized blend, obtained from the regression models and optimization procedure, contained 84.25 % of semi-whole grain soft wheat flour, 5% of soy flour, 2.75% of rice flour, and 8% of whole grain einkorn flour.

1. Introduction

Pizza is one of the most consumed food products in the world due to the convenience, the variety, the sensory characteristics and the low price. It is the emblem of Italian cuisine worldwide. In Italy, different types of pizza are produced which differ in ingredients, recipes and production technologies. The most famous is the Neapolitan pizza, which received the recognition of an "intangible cultural heritage" by UNESCO in 2017 (Francesca et al., 2019). In recent years, Italian and international consumers have rediscovered a type of pizza, called *pinsa romana* (PR), with a typically elongated shape and produced with ingredients slightly different from traditional pizza. The name pinsa, in fact, derives from the Latin verb “*pinsere*” (to stretch). The current recipe of pinsa involves the use of a mixture of refined soft wheat, rice and soy flours, which guarantee crust crunchiness and crumb softness, and oil, yeast (sourdough or brewer's yeast), salt and high water content (75-80 % on flour weight). Moreover, PR production asks a long leavening (24 - 72 hours). To do this, it is essential to use a high quality wheat flour and a suitable blend of the three flours to ensure a strong gluten network, maximum hydration and carbon dioxide holding capacity. At the same time, from the bakers’ perspective, consistent and standardized baking performance at production line level has to be guaranteed. Therefore, it is necessary to optimize the performance of the blends, identifying the quality and quantity of the flours in order to satisfy bakers’ requests. Optimization in food processes is currently carried out by advanced multivariate statistical methods. Among these, Response Surface Methodology (RSM) is widely used in simultaneously testing several independent process parameters and their interactive effects (Bas et al., 2007) outdoing the traditional, expensive, less efficient and time-consuming one-variable-at-a-time approach.
The present study deals with modelling and optimizing of a composite flour for the production of an innovative *pinsa romana* made using a composite flour of semi-wholemeal soft wheat, whole grain einkorn, rice, and soy.

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To do this, we examined the influence and combined effects of einkorn, rice and soy flours on wheat dough rheological performance using farinograph tests. The developed PR will be able to satisfy the demand from consumers and the processing industry for products based on whole grains, considered healthier than those made using refined flours, as a human diet rich in whole grains reduces a series of health risks (Willet, 2019).

2. Methodology

2.1 Materials

Commercial organic semi-whole grain soft wheat flour (“1” type according to the Italian flour classification), whole grain einkorn flour, rice flour and soy flour were considered for preparing *pinsa romana* (PR). These flours were provided by Naturally Made of Italy Srls (Rieti, Italy), the private funder of the project NaturallyPinsa. Physico-chemical properties of flours are shown in table 1. Fresh sourdough was supplied by Vaiani Lieviti Srl (Pallerone di Aulla, Italy). Certified Sabina DOP extra virgin olive oil, spring water by Antiche Fonti di Cottorella SPA (Rieti, Italy) and salt (NaCl) were acquired from local markets.

Table 1: Physico-chemical characteristics of flours.

	Wheat	Einkorn	Rice	Soy
Moisture (%)	14.1	10.7	12.6	6.8
Protein (g/100 g)	15.1	14.1	7.8	39.4
Ash (g/100 g)	0.74	2.12	0.60	5.09
W (10^{-4} J)	284			
P	76			
L	104			
P/L	0.73			
WA (%)	58.2			
DS (min)	12.2			
DT (min)	9.5			
SO (FU)	43			

2.2 Proximate Composition

Moisture, proteins, lipids and ashes were determined by the ICC standard methods 110/1, 105/2, 136, 104/1, respectively (ICC, 2003). Protein content was estimated using the conversion factor 5.70 for wheat and einkorn flours, 5.71 for soy flour and 5.95 for rice flour.

2.3 Design of Experiments

The experiments were established based on a Box–Behnken design (BBD) with three independent factors (rice content, soy content, and einkorn content), which could greatly affect physical performance of dough for PR. Soft wheat flour was not considered as the fourth factor in BBD, as it is complementary to einkorn, soy and rice flours. In fact, 100% flour was divided between soft wheat flour, einkorn flour, soy flour and rice flour. By varying the percentages of einkorn, soy and rice flours, the percentage of soft wheat flour will vary accordingly. BBD considers a specific subset of the factorial combinations from the 3^k factorial design. The design included 15 runs; each run was replicated three times. Each factor was coded at three levels, -1, 0, +1. Rice and soy contents ranged between 2 % and 5 % on total weight flour; einkorn content between 2 % and 8 % on total flour weight (Table 2). We established the levels of the three factors according the values usually considered for the PR production.

The predicted response was obtained using a second-order polynomial equation, as follows:

$$Y_i = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_{ii}^2 + \sum_{ij,i<j} \beta_{ij} X_i X_j + e_i \tag{1}$$

where Y = water absorption (WA), or dough stability (DS), or dough development time (DT), or degree of softening (SO); X_1 = rice content (%); X_2 = soy content (%); X_3 = einkorn content (%); β_0 = intercept; β_i, β_{ii}, β_{ij} = linear, quadratic and interactive coefficients, respectively; e_i = error term.

2.4 Statistical analysis

The experimental design, data analysis and optimization procedure were created using Statistica statistical package software (Stat Soft Inc., Tulsa, USA).

The statistical significance of the main effects, the interactions and the quadratic terms, regression coefficients and model fitting were found by analysis of variance (ANOVA). Model adequacy was checked by coefficient of determination R^2, adjusted coefficient of determination R_{adj}^2, and Absolute Average Deviation (AAD) (Bas et al., 2007). In order to obtain a better accuracy, R^2 and R_{adj}^2 must be close to 1.0 and the AAD between the predicted and experimental data has to be small as possible (Bas et al., 2007). 3D graphs were outlined to understand the relationships between the response and experimental levels of each factor.

Table 2: Box–Behnken design with coded and uncoded parameters of rice content (X_1), soy content (X_2) and einkorn content (X_3) on flour weight, and experimental and predicted response values of farinograph parameters (water absorption WA, and development time DT).

	Coded factors			Uncoded factors			WA (%)		DT (min)	
Run	X_1	X_2	X_3	X_1 (%)	X_2 (%)	X_3 (%)	Exp	Pred	Exp	Pred
15	0	0	0	3.5	3.5	5	62.5	62.5	12.4	12.4
11	0	-1	1	3.5	2	8	61.6	63.2	12.3	12.3
10	0	1	-1	3.5	5	2	61.8	60.2	12.3	12.3
1	-1	-1	0	2	2	5	61.4	61.5	14.1	14.3
2	1	-1	0	5	2	5	61.2	60.4	13.8	13.3
9	0	-1	-1	3.5	2	2	62.0	61.0	13.0	13.3
7	-1	0	1	2	3.5	8	62.0	60.3	13.5	13.3
5	-1	0	-1	2	3.5	2	56.9	57.8	14.2	13.7
12	0	1	1	3.5	5	8	56.9	57.9	13.6	13.3
8	1	0	1	5	3.5	8	57.2	56.3	12.4	12.9
6	1	0	-1	5	3.5	2	57.2	58.9	12.1	12.3
4	1	1	0	5	5	5	57.1	57.0	13.6	13.4
14	0	0	0	3.5	3.5	5	62.5	62.5	12.4	12.4
3	-1	1	0	2	5	5	57.9	58.7	13.7	14.2
13	0	0	0	3.5	3.5	5	62.5	62.5	12.4	12.4

2.5 Optimized conditions

A desirability-based method for yielding compromise solutions with desired response's properties (Derringer et al., 1980) was used to assess optimal variable settings of each factor. The overall desirability (D) is defined as the geometric mean of the individual desirability of each response. It ranges between 0 and 1, where 0 is completely undesirable and 1 is most favorable response. The optimal combinations of factors will be those that maximize the overall desirability. Once the optimal combinations of factors had been determined for each of the farinograph parameters, the final choice of values to create the most favorable blend was made by analyzing the significance of the regression coefficients of the obtained mathematical models. The significance of the regression coefficients and their signs for each of the factors in the farinographic parameters models will be identified. Once optimized the rice, soy and einkorn contents to obtain the best performance of the dough, new rheological tests were carried out.

2.6 Rheological Tests

Chopin Alveograph was used to determine dough strength (W), dough tenacity (P), dough extensibility (L), and configuration ratio (P/L) of flours (Method 54-30 A) (AACC, 2003). Water absorption (WA) at 14 % moisture content and 24 °C, dough stability (DS), development time (DT), and degree of softening (SO) were obtained with a Brabender farinograph, according to Standard Method No. 54-21 (AACC, 2003).

2.7 *Pinsa* making procedure

Pinsa dough was formed using optimized values for rice, soy and einkorn contents. Taking into account the quantities of ingredients suggested for the PR preparation recipe, 1000 g of flour (soft wheat, einkorn, soy and rice), 770 mL water (77 % on flour weight) at a temperature of 3 °C; 50 g of fresh sourdough (5 % on flour weight), 20 g of salt (2 % on flour weight), and 15 g of extra virgin olive oil (1.5 % on flour weight) were mixed for about 20 minutes in a planetary machine, following six steps: 1) mixing the flour and yeast for one minute at low speed; 2) adding 655 mL of water (equal to 85 % of the water content) and mixing for 2 minutes at low speed; 3) mixing for 2 minutes at high speed; 4) adding salt and mixing for 2 minutes at high speed; 5) adding extra virgin olive oil and mixing for 2 minutes at high speed; 6) gradual addition of 15 % remaining water and mixing at high speed until complete absorption and formation of a resistant gluten network. After mixing, dough was placed into graduated containers, and moved to a proofing cabinet at 24 °C for 24 hours.

Then, the dough was divided into parts to form dough balls, each weighing 200 g, as commonly made for pinsa. The balls were allowed to rise for 2 hours at 30 °C in a proofing cabinet, up to double their initial volume. The balls were then spread out to form a rectangular of about 30 cm lenght, 20 cm width and 0.5 cm thickness, and baked for 1.5 min at 330 °C min and other 4 min at 300 °C in an electric pizza oven, to develop the bubbles typical of *pinsa romana*.

3. Results and discussions

3.1 Box–Behnken design and analysis of the models

In this study, a three-factor three-level Box–Behnken design was employed to realize an optimal blend of flours, considering percentages of soft wheat, einkorn, rice and soy flours on flour weight. The experimental design matrix and the responses based on experimental fifteen runs are shown in table 2. The predicted values are also reported in the same table. Four parameters from farinograms were considered to assess baking qualities and performance of blend doughs.

To ensure PR dough with 75-80% hydration, farinograph water absorption (WA) must be as high as possible. The WA mean values showed a good absorption being distributed between 56.9 % and 62.5 %. The development time (DT) is time taken for the dough to reach maximum resistance to mixing from the start of mixing. Stronger flours with higher protein content have a longer development time than weaker flours with equivalent particle size distribution. The development time mean values ranged between 12.1 min and 14.2 min, showing a high gluten strength. The dough stability (DS) is a measurement of how well a flour resists overmixing. High values of this factor guarantee that the flour can withstand long leavening and prolonged mechanical stress. Since the PR is a product prepared with a slow proving process (between 24 and 48 hours) and whose dough is mixed in 20-30 minutes, stability can be a key factor in the choice of a flour. The dough stability mean values varied from 15.1 min to 18.9 min. At last, degree of softening (SO) is defined as the difference in height between the centre of the graph at maximum resistance to mixing and the centre of the graph at a point 12 minutes later. It indicates how fast the gluten structure breaks down after reaching its full development. High WA coupled with low SO indicates good quality flour, whereas high WA combined with high SO denotes poor quality flour. SO mean values ranged between 9 FU and 20 FU.

3.2 Model fitting and analysis of response surface

Based on the experimental design given in table 2, regression analysis was applied and second-order polynomial models were developed. The mathematical relationship among the independent variables and the responses were obtained as follows:

$$WA = 36.597 + 9.514\,X_1 - 1.189\,X_1^2 + 1.764\,X_2 - 0.189\,X_2^2 + 3.525\,X_3 - 0.167\,X_3^2 - 0.067\,X_1X_2 - 0.283\,X_1X_3 - 0.250\,X_2X_3 \quad (2)$$

$$DT = 23.733 - 3.222\,X_1 + 0.367\,X_1^2 - 2.422\,X_2 + 0.256\,X_2^2 - 0.381\,X_3 - 0.019X_3^2 + 0.022\,X_1X_2 + 0.056\,X_1X_3 + 0.111\,X_2X_3 \quad (3)$$

where: X_1, X_2, and X_3 are the coded variables for rice content, soy content, and einkorn content, respectively. Only the models for WA and DT were considered, as those for SO and DT showed a low adequacy (R^2=0.50).

The predicted values were close to measured values (table 2). In fact, experimental WA values ranged from 56.9 to 62.5, whereas the predicted values from 56.3 to 63.2. Experimental and predicted DT values were distributed between 12.1 and 14.2 and between 12.3 and 14.3, respectively.

Analysis of variance (ANOVA) was performed to assess adequacy and fitness of the developed models (table 3). All the models were found highly significant (p<0.0001). The coefficient of determination R^2 ranged from 0.81 for WA to 0.84 for DT; the adjusted coefficient of determination R_{adj}^2 between 0.79 for WA and 0.81 for DT; the absolute average deviation ADD from 0.45 for DT to 0.64 for WA (table 3). These three metrics indicated that the model equations were adequate to describe the experimental data. ANOVA was also applied to assess the significance of each terms in the two models (table 3). A positive or negative regression coefficient indicates a synergistic or antagonist effect, respectively. Linear and quadratic terms of rice content and linear term of einkorn content were significant for WA. The development time resulted influenced by the rice and soy contents.

The significance analysis of the factors and their interactions has provided useful indications on the behavior of the various ingredients within the different composite flours considered in this study. The balancing of the quantities of the four ingredients (soft wheat, soy, rice and einkorn) to obtain the optimal blend for the preparation of the *pinsa romana* must be a compromise between the responses of the individual farinograph parameters. The effects on the overall response desirability of different combinations of levels of each pair of independent variables are evaluated using 3D-response surface plots (Figure 1-2). These plots are useful for obtaining the optimal values for each parameter and assessing the effect of interactions between parameters.

Table 3: ANOVA for the second-order polynomial equation for the developed models, and significance of regression models (significant values are in bold).

	WA		DT	
	Sum of Square	p-value	Sum of Square	p-value
X_1	3.7813	**0.0375**	1.6200	**0.0260**
X_1^2	26.4208	**0.0347**	2.5131	**0.0202**
X_2	19.5313	0.6246	0.0020	0.9435
X_2^2	0.6669	0.6668	1.2208	**0.0487**
X_3	8.3077	**0.0498**	0.0050	0.8948
X_3^2	0.0050	0.1676	0.1131	0.5365
X_1X_2	0.0900	0.8732	0.0100	0.8514
X_1X_3	6.5025	0.2129	0.2500	0.3693
X_2X_3	5.0625	0.2635	1.0000	0.1056
Residual	15.9625		1.2850	
Total SS	83.6373		7.9373	
Significance of model		<0.0001		<0.0001
R^2	0.81		0.84	
R_{adj}^2	0.79		0.81	
ADD	0.64		0.45	

Figure 1 showed the effect of the independent variables on water absorption. The surface plots indicated that the higher the einkorn content and the lower the rice content in the blend, the higher the WA. The development time was strongly influenced by soy and rice contents (figure 2): as the einkorn and soy contents increased, and the rice content decreased, the development time increased.

3.3 Optimization

The main objective of this work was to determine the optimum values of the investigated variables (rice, soy and einkorn contents) for the preparation of *pinsa romana*. The predicted optimal values for the independent variables were: X_1=3.5%, X_2=2% and X_3=8% for WA, and X_1=2%, X_2=5% and X_3=8% for DT. These optimal values deriving from each model showed apparently discordant values for X_1 and X_2. However, in order to decide the quantities of the ingredients, it was necessary to simultaneously consider the optimal values, the significance of the regression coefficients in table 3, and the desirability function for each parameter. Furthermore, the characteristics of a good composite flour for PR preparation (i.e., high absorption capacity; ability to withstand long mixing; high quality of the flour) have been taken into account. Therefore, considering all these aspects, the optimal values of the ingredients for the composite flour were: rice content = 2.75 %; soy content = 5 %; einkorn content = 8 %. Under these optimized values the observed values were found as 61.3 %, 11.1 min, 18.5 min, 31 FU, respectively.

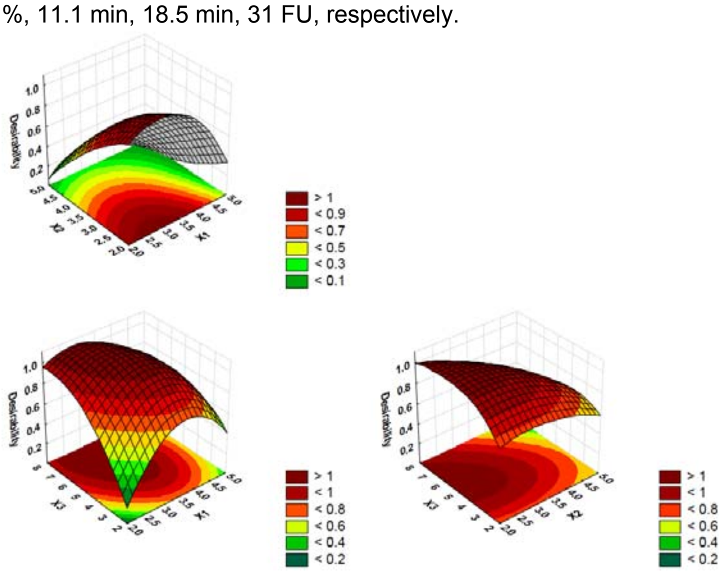

Figure 1: Response surface and contour plots of water absorption (WA) as a function of X_1 = rice content; X_2 = soy content; X_3 =einkorn content.

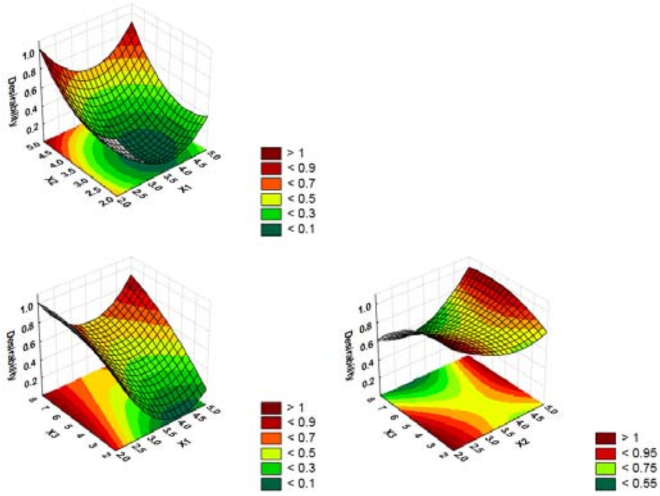

Figure 2: Response surface and contour plots of development time (DT) as a function of X_1 = rice content; X_2 = soy content; X_3 =einkorn content.

The optimized composite flour was employed to prepare *pinsa romana*. A portion is shown in figure 3. The pinsa crust appeared thin and crunchy. The crumb was soft and highly porous.

Figure 3: Pinsa romana prepared with the optimized composite flour.

4. Conclusions

The results of the present study pointed out the advantages of the application of Response Surface Methodology in the optimization of different composite flours for the production of *pinsa romana*. Compared to conventional methods, different factors and their interactions were analyzed simultaneously. Understanding soy-rice-einkorn-wheat protein interactions and the dough physical modification during mixing should give an insight into possible ways of minimizing the dough weakening effect of einkorn, soy and rice flours in wheat doughs. Moreover, this study highlighted the positive effect of soy flour and whole grain flours on water absorption and a good machinability if rice flour remain at low levels. In conclusion, our results offer a potential lead for further improving the technological properties of soy–rice–einkorn–wheat composite flours. At the same time, the RSM methodology can be successfully applied in the determination of flour mixtures, as well as other ingredients.

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