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Improving the Quality of Bread Made from Corn and Wheat Flour Acceptable by Congolese Consumers

Mikolo Bertin[1, *], Tsoumou Kedar[1], Elenga Michel[2]

[1]Laboratory for the Valorization of Agrorisources, National Polytechnic High School, Brazzaville, Republic of Congo
[2]Human Nutrition and Food Laboratory, Faculty of Sciences and Techniques, Marien University NGOUABI, Brazzaville, Congo

Email address:

mikolobertin@yahoo.fr (Mikolo Bertin), kedartsoumou@gmail.com (Tsoumou Kedar), elengamichel@yahoo.fr (Elenga Michel)
[*]Corresponding author

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Abstract: The study aims to improve the quality of bread made from corn and wheat flours acceptable to Congolese consumers. Wheat is the most consumed food at breakfast, but it is not within the reach of all budgets. To address this shortage, several alternatives exist to replace wheat flour with other cereals or starches. A bread formulation composed of wheat and corn flours acceptable to Congolese consumers was explored. The study involved three experiments to optimize the sensory characteristics of bread made from wheat and corn flours. The first experiment focused on improving the sensory quality of bread made from a mixture of malted and unmalted corn flours. The experiment involved a two-component simplex centroid mixture design, with unmalted corn flour (A) and malted corn flour (B) mixed for a total of 18 g. The second experiment examined the effects of salt and sugar mixture on the quality of corn and wheat flour bread. The third experiment evaluated the effects of humidity and baking time on the color, smell, and taste of bread. The bread samples were made according to a formulation resulting from previous optimization experiments, with the same proportions of ingredients. The bread preparation process involved weighing and mixing the ingredients, kneading manually for a specific time. The optimization resulted in a flour mixture of 11% malted corn and 48% wheat with other ingredients. The sensory evaluation of this bread gave an average score of 7 on a 1 to 9 scale, confirming the predictions of the optimization. The physicochemical characterization gave the following values: 22.76% water content, 10.18% protein, 3% ash, 1.43% lipids and 0.01 to 0.04% calcium, magnesium, iron, and phosphorus.

Keywords: Bread, Maize, Mixture, Optimization, Acceptability

1. Introduction

Cereals are the basis of the world diet. Among them are mainly corn and wheat widely consumed in the form of flour [1]. Bread is the main wheat flour product consumed worldwide [2].

The wheat consumed in developing countries is mainly imported and is increasingly expensive. In fact, wheat production faces numerous constraints [3]. The current Russian-Ukrainian crisis, for example, hampering Ukrainian and Russian wheat exports, threatens global food security, particularly in African countries [4, 5].

There are alternatives to substitute wheat flour with flours from other cereals in an attempt to reduce wheat imports and the cost of bread [6, 7]. To this end, corn flour is one of the most incorporated flours in wheat bread. Sometimes this flour is produced from malted corn. Previous work has shown that sprouting cereals and legumes improves the quality of their products [8–13].

In the Republic of Congo, particularly, the main cereal produced is corn. However, this cereal is mainly consumed only fresh or in the form of porridge. The rest of the production is transformed into animal feed or a traditional liquor called Bouganda.

Research on improving the quality of bread continues through testing the formulation of ingredients and the optimization of bread-making and baking processes [14]. However, the supplementation of wheat flour with other flours influences the quality characteristics of traditional bread; which can have both positive and negative effects on the quality of new products [15, 16].

In view of the foregoing, the objective of this study is to improve the quality attributes of the bread by producing it from wheat and corn flours.

2. Materials and Methods

2.1. Materials

The wheat and white corn flours as well as all the other ingredients (Saris white sugar, Saf Instant yeast, Baleine salt and Evita margarine] came from the stocks of traders of the Total market in Brazzaville.

2.2. Methods

Three experiments were carried out during which six factors were tested at the rate of two factors per experiment. Their objective was to verify whether these factors and/or their interactions exerted significant effects on three sensory characteristics of bread made from wheat and corn flour, then to optimize the response if necessary.

2.2.1. Experiment 1: Optimization of Bread Quality with Malted and Non-Malted Corn Flour Mixture

This experiment consisted in improving the sensory quality of bread made from flour composed of 80 g of wheat flour and 18 g of a mixture of malted and unmalted corn flours. The mixture design consisted in varying the proportions of the two corn flours in the 18 g of corn flour fraction. For this purpose, a two-component centered mixture design: unmalted corn flour (A) plus malted corn flour (B) was designed for a mixture total of 18 g. This gave the experimental matrix shown in Table 1.

Table 1. *Experimental matrix of the corn flour mixture design.*

Essay	Unmalted corn flour (A)	Unmalted corn flour (B)	Total (g)
1	4.5	13.5	18
2	13.5	4.5	18
3	9.0	9.0	18
4	0.0	18.0	18
5	18.0	0.0	18

At each test, the 18 g of corn flour mixture was mixed with 80 g of wheat flour plus the rest of the ingredients kept in constant amounts as shown in the table 2. The experiment was carried out in two replicates.

Table 2. *Basic formulation of bread samples.*

Ingredients	Quantities (g)	%
Mixture of malted and unmalted corn flour	18.00	10.98
Wheat flour	80.00	48.78
Water	58.00	35.37
Fat	3.00	1.83
Salt	1.50	0.91
Yeast	1.50	0.91
Sugar	2	1.22
TOTAL	164.00	100

2.2.2. Experiment 2: Study of Salt and Sugar Mixture Effects on the Quality of Corn and Wheat Flour Bread

This experiment was carried out by a centered mixture design, with 2 components A and B, augmented with the points on the axes; A being salt and B sugar, the two components having lower levels of 0 and upper levels of 6 g (Table 3).

Table 3. *Experimental matrix of the salt/sugar mixture.*

Essay	Salt (g)	Sugar (g)
1	0	6
2	6	0
3	3	3
4	4.5	1.5
5	1.5	4.5

2.2.3. Experiment 3: Study of the Effects of Humidification and Baking Time on the Bread Quality

(i). Experiment Plan Applied

The effects of humidity and baking time on the color, smell and taste of bread were evaluated by a full factorial design with two factors A (baking time) and B (humidification), of lower levels -1 and superior 1, one of which is quantitative (A) and the other qualitative (B). The resulting four-trial design is shown in Table 4.

Table 4. *Experimental matrix of humidification and baking time.*

Run	Baking time	Humidification
E1	-1 (30mins)	-1 (without)
E2	-1 (30mins)	1 (with)
E3	1 (35mins)	-1 (without)
E4	1 (35mins)	1 (with)

During tests E1 and E2, the loaves were moistened before charging.

(ii). Formulation of Samples

The breads were made according to a formulation resulting from previous optimization experiments. All samples were made with the same proportions of ingredients shown in Table 5.

Table 5. *Bread sample formulation.*

Components	Quantities (g)
Wheat	80
Maize	18.5
Salt	1,212
Sugar	2,786
Yeast	1.5
Water	58
Fat	3

(iii). Bread Preparation Process

The bread samples were made according to the process described below [17]. The ingredients were weighed and mixed according to the designed formulations. The mixtures were kneaded manually for 10 minutes to obtain a dough. The latter underwent the score during which it was left to rest for 1 hour. The resulting ball of dough was divided into small balls which were shaped baguettes. These baguettes were left to stand for 1 hour and then baked at 250°C for 35 minutes. The baguettes of experiment 3 were or were not moistened by atomization and cooked for 30 or 35 min.

2.2.4. Evaluation of Sensory Characteristics of the Bread Samples

The assessors first read and signed a declaration of consent [18]. Then each of the assessors received, in addition to the bread samples, a hedonic test form shown in the figure 1 [19]. Three sensory characteristics of the breads (color, smell and taste) were evaluated by about ten assessors not trained by a hedonic test on a scale of 1 to 9 for the first two experiments and from 1 to 5 for the third experiment. Each assessor received 5 bread samples corresponding to the different formulations.

Hedonic rating test for digestive breads

Assessor____________________ Date____________________

Please enjoy the breads in the following order. Use the water provided to cleanse your palate before tasting each sample:

97878 64600 21734 71402 00358

Indicate how much you like the sample by checking the most appropriate sentence below:

9 - I like it extremely
8 - I really like it
7 - I like moderately
6 - Like slightly
5 - Neither love nor hate
4 - I slightly dislike
3 - I dislike moderately
2 - I don't like it very much
1 - I don't really like it

Settings/Code	97878	64600	21734	71402	00358
Color					
Smell					
Taste					

Comments:

Thank you for your participation.

Figure 1. *Questionnaire for a hedonic rating test.*

2.2.5. Evaluation of Physicochemical Characteristics of the Prototype Bread

(i). Determination of Ash Content

The ash content was obtained by dry ashing of 2 g of sample at 550°C in a muffle furnace overnight [20]. The product was weighed and its percentage calculated with respect to the fresh mass of the sample.

(ii). Determination of Water Content

The water content was determined by dehydration of 5 g of sample at 105° C for 6 h [21]. The mass of evaporated water was calculated by difference between the initial mass and the final mass of the sample. Its percentage was calculated with respect to the initial mass of the sample.

(iii). Determination of Total Lipids

Total lipids were determined by the Soxhlet method [22]. Thus, the hexane extraction of these lipids was carried out from 50 g of sample previously dehydrated in a 125 ml Soxhlet for 16 h. The solvent was evaporated and the product weighed. The percentage of lipids was calculated relative to the fresh mass of the sample.

(iv). Determination of Minerals

Calcium and magnesium were determined by the versenate titration method [23].

Phosphorus was determined by the colorimetric method using molybdate and ascorbic acid [24]. Iron was determined by colorimetry [25].

2.2.6. Data Analysis

The data were analyzed after deleting outliers from the raw data. The effects of the factors of factorial experiments studied were examined by analysis of variance at the 5% significance level and Pareto plots of the effects. The overall regression was considered as statistically significant, when the corresponding tail probability was inferior to the significant level of 5%.

The normal plot of the residuals was used to assesses the normality of the residuals, by plotting the observed ordered residuals on one axis and the expected positions (under normality) of those ordered residuals on the other. The plot should look like a straight line (roughly). Isolated points represented unusual observations, while a curved line indicates that the errors were probably not normally distributed. and tests. The residuals were also plotted versus the fitted values and versus time. The absence of a cyclical structure, indicated that the errors were uncorrelated.

The data were processed using Minitab 17.3.1 software. To process the data in Minitab, we redesigned the experiments that prepared the samples. The only difference was the number of replicates which this time was the product of the number of formulations and the number of assessors. We must point out that the incorrectly completed forms have been discarded.

3. Results

The raw results of the three experiments are mentioned in tables 6-8.

Table 6. *Color, smell and taste scores of breads according to corn flours.*

Run	Unmalted corn	Malted corn	Color	Smell	Taste	Run	Unmalted corn	Malted corn	Color	Smell	Taste
1	0	18	4	8	9	31	9	9	7	5	6
2	0	18	5	4	7	32	9	9	2	3	1
3	0	18	8	6	6	33	9	9	6	5	3
4	0	18	8	7	8	34	9	9	7	7	5
5	0	18	6	6	6	35	9	9	8	7	8
6	0	18	7	2	8	36	9	9	6	6	6
7	0	18	7	5	7	37	13.5	4.5	4	8	8
8	0	18	9	9	9	38	13.5	4.5	5	4	4
9	0	18	8	6	8	39	13.5	4.5	7	7	6
10	0	18	7	8	9	40	13.5	4.5	7	6	6
11	0	18	6	8	9	41	13.5	4.5	7	7	7
12	0	18	8	6	6	42	13.5	4.5	9	2	6
13	4,5	13,5	3	4	7	43	13,5	4,5	6	5	6
14	4,5	13,5	8	9	6	44	13,5	4,5	7	9	8
15	4,5	13,5	7	6	7	45	13,5	4,5	5	3	3
16	4,5	13.5	6	8	6	46	13.5	4.5	7	7	6
17	4.5	13.5	7	6	5	47	13.5	4.5	3	6	3
18	4.5	13.5	8	2	7	48	13.5	4.5	5	5	5
19	4.5	13.5	7	6	7	49	18	0	2	6	8
20	4.5	13.5	8	6	9	50	18	0	7	7	5
21	4.5	13.5	5	6	6	51	18	0	6	6	6
22	4.5	13.5	7	8	7	52	18	0	5	5	6
23	4.5	13.5	5	7	3	53	18	0	7	6	6
24	4.5	13.5	2	5	5	54	18	0	5	2	6
25	9	9	4	7	8	55	18	0	7	5	6
26	9	9	6	3	7	56	18	0	4	2	4
27	9	9	7	6	6	57	18	0	8	6	6
28	9	9	6	6	6	58	18	0	7	7	8
29	9	9	7	4	6	59	18	0	6	7	7
30	9	9	9	3	8	60	18	0	5	5	5

It turns out that certain samples received maximum scores for the characteristics that were evaluated. The breads submitted to the assessors were therefore acceptable. The analyzes of the data obtained led to the results of regression analyses shown in Table 9. It can be seen that there were significant effects of the mixtures tested except for the salt/sugar mixture on the color and the smell, and the factors cooking time and humidification on the color of the bread.

3.1. Influence of Corn Flour on Bread Quality

Table 7. *Color, smell and taste scores of breads according to salt/sugar mixture.*

Run	Salt	Sugar	Taste	Smell	Color	Run	Salt	Sugar	Taste	Smell	Color
1	0	6	4	7	5	24	3	3	4	7	7
2	0	6	4	4	5	25	3	3	7	7	7
3	0	6	9	9	7	26	3	3	4	5	5
4	0	6	5	5	7	27	3	3	5	7	7
5	0	6	2	4	7	28	4.5	1.5	4	4	5
6	0	6	7	5	7	29	4.5	1.5	5	4	5

Run	Salt	Sugar	Taste	Smell	Color	Run	Salt	Sugar	Taste	Smell	Color
7	0	6	4	5	9	30	4.5	1.5	4	7	9
8	0	6	4	7	4	31	4.5	1.5	4	5	5
9	0	6	7	5	7	32	4.5	1.5	2	7	5
10	1.5	4.5	5	7	5	33	4.5	1.5	4	9	5
11	1.5	4.5	7	4	5	34	4.5	1.5	5	7	7
12	1.5	4.5	5	5	7	35	4.5	1.5	5	5	4
13	1.5	4.5	9	9	9	36	4.5	1.5	5	7	7
14	1.5	4.5	9	9	9	37	6	0	4	4	4
15	1.5	4.5	7	5	5	38	6	0	5	5	7
16	1.5	4.5	9	9	7	39	6	0	4	7	7
17	1.5	4.5	5	5	5	40	6	0	5	7	5
18	1.5	4.5	7	7	7	41	6	0	4	5	7
19	3	3	7	9	5	42	6	0	2	5	5
20	3	3	9	5	7	43	6	0	4	5	5
21	3	3	7	9	9	44	6	0	4	5	5
22	3	3	5	5	7	45	6	0	4	7	7

Table 8. *Color, smell and taste scores of breads according to bread humidification and baking duration.*

Run	Duration	Humidification	Smell	Taste	Color	Texture
1	-1	1	5	5	4	5
2	-1	1	4	4	3	3
3	-1	-1	4	5	5	4
4	-1	1	3	4	5	4
5	-1	-1	3	4	3	2
6	-1	-1	3	5	5	5
7	-1	1	3	3	4	3
8	-1	1	4	3	4	3
9	-1	-1	4	5	5	5
10	-1	-1	4	5	4	4
11	-1	1	4	3	5	4
12	-1	-1	3	4	3	1
13	-1	1	3	4	4	3
14	-1	1	5	5	5	4
15	-1	1	4	4	3	2
16	1	1	4	4	5	4
17	1	-1	4	4	4	5
18	1	1	5	5	4	4
19	1	-1	3	4	3	2
20	1	-1	3	4	4	4
21	1	1	4	3	3	3
22	1	-1	3	4	5	4
23	1	-1	4	4	3	2
24	1	1	5	5	4	2
25	1	1	4	3	4	4
26	1	-1	4	3	5	4
27	1	1	5	4	2	1
28	1	-1	4	4	3	4
29	1	1	5	5	4	5
30	1	1	4	4	4	4

The normal plot of residuals in Figure 2 shows that the plotted points are roughly aligned along a straight line, so the residuals are normal or at least approximately normal. The plot of residuals versus the fitted values shows that the residuals have about the same amount of variation at all levels of the fitted value, that is, it appears that the residuals are homoscedastic with respect to the fitted values. The figure also shows no general tendency for the residuals to swing above and below e = 0, so there is no evidence of lack of linear fit. The plot of residuals versus run order shows that the residuals are random and uniformly distributed about e = 0, so the residuals appear to be homoscedastic with respect to time. There are no patterns that allow a residual to be predicted from those that precede it, so the errors appear to be independent. All of the assumptions required to validate the use of regression for this problem appear to be satisfied.

Analysis of the bread sample color data yield coefficients of determination R squared = 27.81%, R squared (Pred) = 20.32% and R squared (adj) = 26.13% and values of p = 0.000 < 0.05 for linear regression. This leads to say that the main effects of the malted corn flour and non-malted corn flour variables have significant effects on the color score. The interaction between the two flours are not significant.

This leads to the following regression equation:

$$\hat{Y} = 0.33878X_1 + 0.413387X_2,$$

where Y represents the estimate of the color score, X_1 and X_2 the respective proportions of unmalted corn and malted corn flours. The optimization whose objective is to maximize the color score gives the results shown in Figure 3. It can be seen that the maximum value of $\hat{y}$= 7.4 is obtained at the upper level (18 g) of malted corn flour and lower level (at 0 g) unmalted corn flour. Unmalted corn gives bread color less enjoyed by assessors.

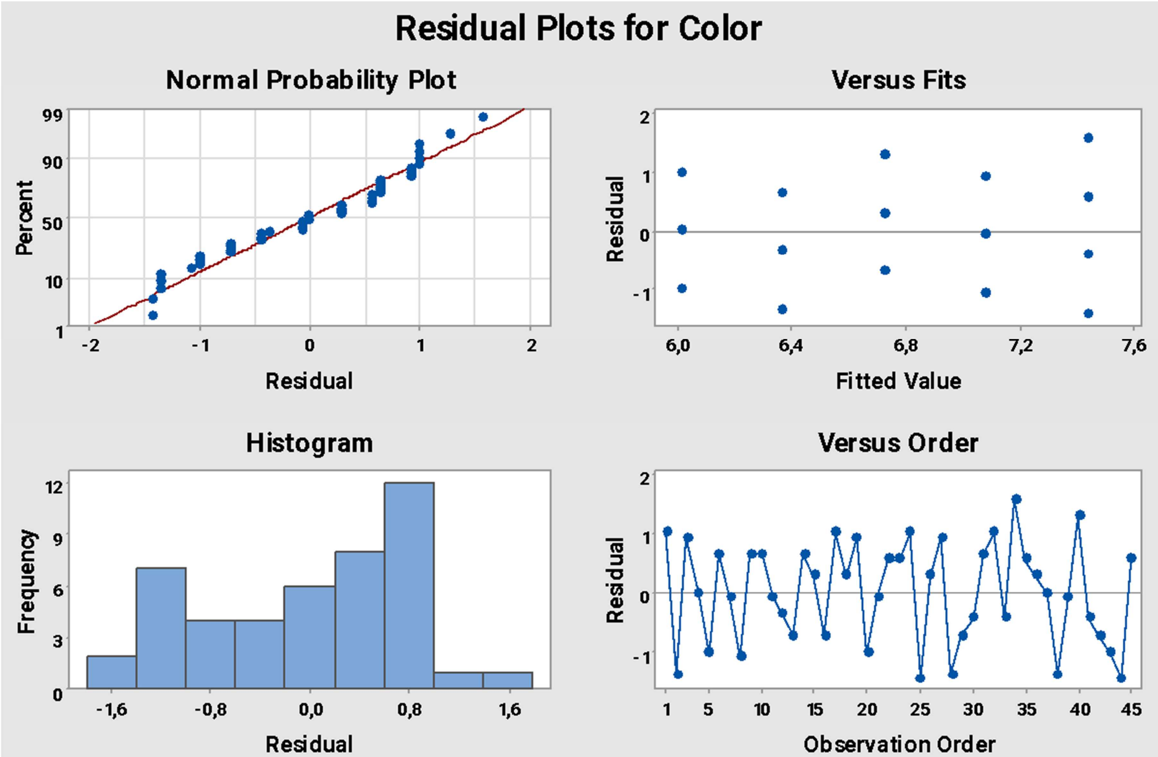

Figure 2. *Residuals plot for color with corn flour.*

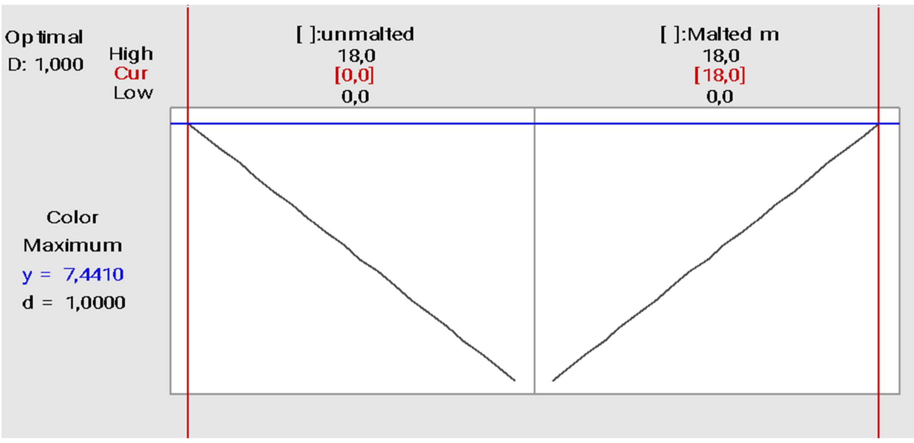

Figure 3. *Color optimization plot with corn flour.*

Regression analysis of smell against malted and unmalted corn flour mixtures yields low values of coefficients of determination R sq = 14.44%, % R sq (pred) = 4.82% R square (adjust) = 10.94%. However, the p-value for the quadratic regression is 0.023 < 5% significance level. This indicates that the two components and their interactions influence the bread smell score. The residual and optimization plots are shown in figures 4 and 5 respectively. The plots of the residuals show that the points fall around Henry's straight line and show no particular trend depending on the fitted values and the order of the observations. In addition, the p-value of the Anderson-Darling test is equal to 0.262; confirming the normality of the residual values. So; the quadratic regression model is accepted and its estimated equation given as follows:

$$\hat{Y} = 0.337448X_1 + 0.386337X_2 - 0.0126800X_1X_2.$$

The optimization result plot in figure 5 shows a maximum score of 6.95 expected for smell with only 18 g of malted corn.

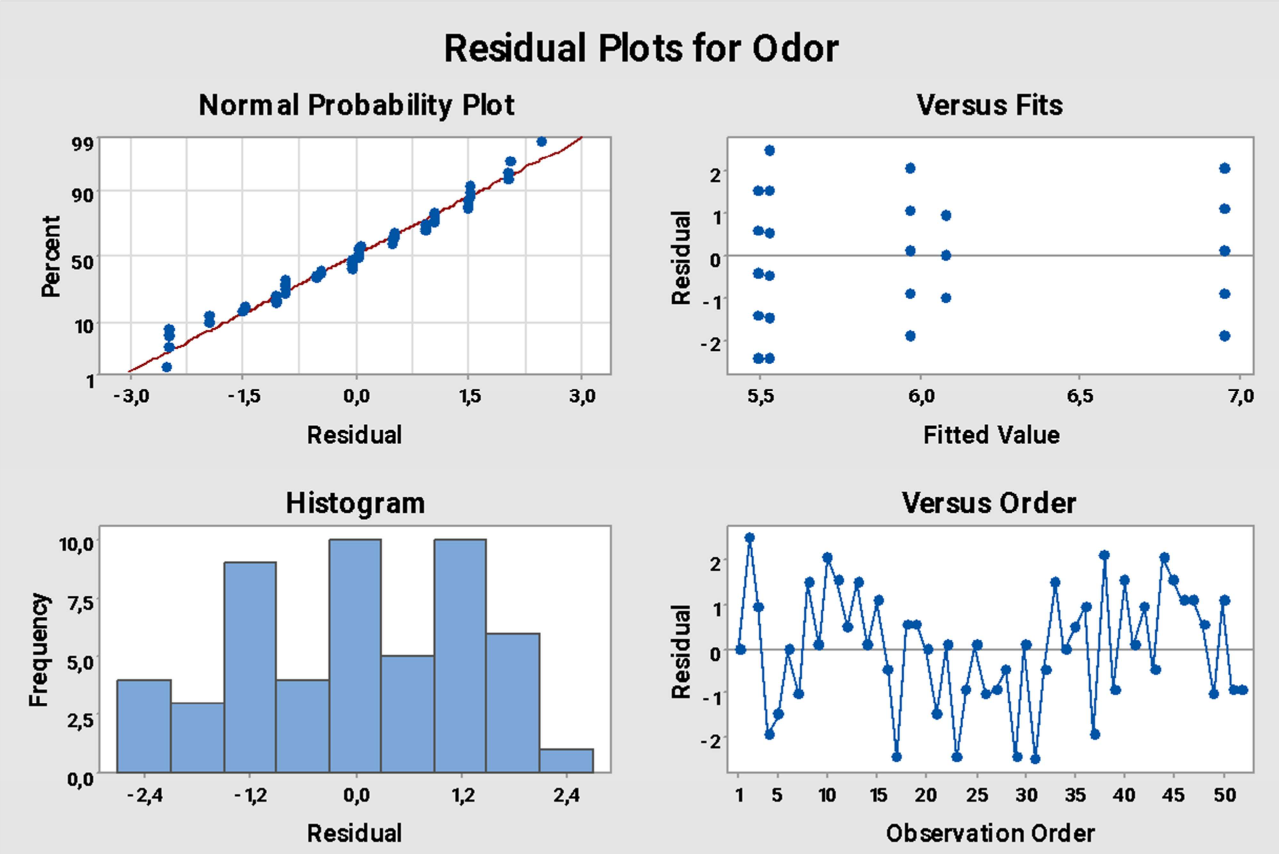

Figure 4. *Residual plot for smell with corn flour.*

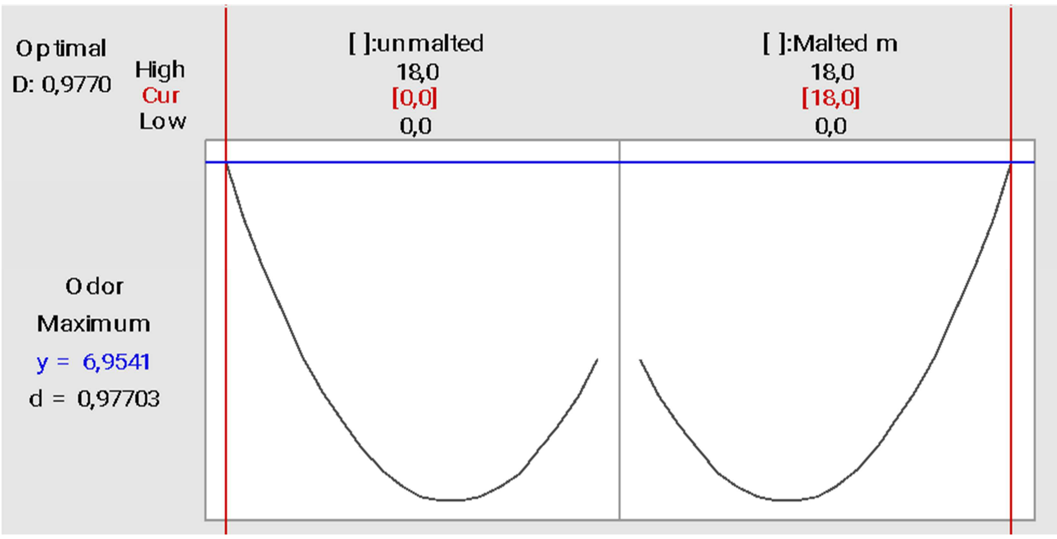

Figure 5. *Smell optimization plot for corn flour mixture.*

The results of the regression analysis for taste are similar to those of color and smell. The coefficients of determination are also low: R squared = 16.90% R squared (pred) = 9.90% R squared (adjust) = 15.27%. The interaction between the two flours is not significant, and the p-values is 0.002 < 0.05 for the linear regression. The residual values follow a normal distribution (AD = 0.714; p = 0.059 > 0.05) and the fitted values does not show any particular trend indicating the absence of dependence between the variables (Figure 6). This results in the following regression equation:

$$\hat{Y} = 0.327285X_1 + 0.406327X_2.$$

The results of optimization show that the score of 7 is predictable if the corn flour fraction consists of only 18 g unmalted corn flour (Figure 7).

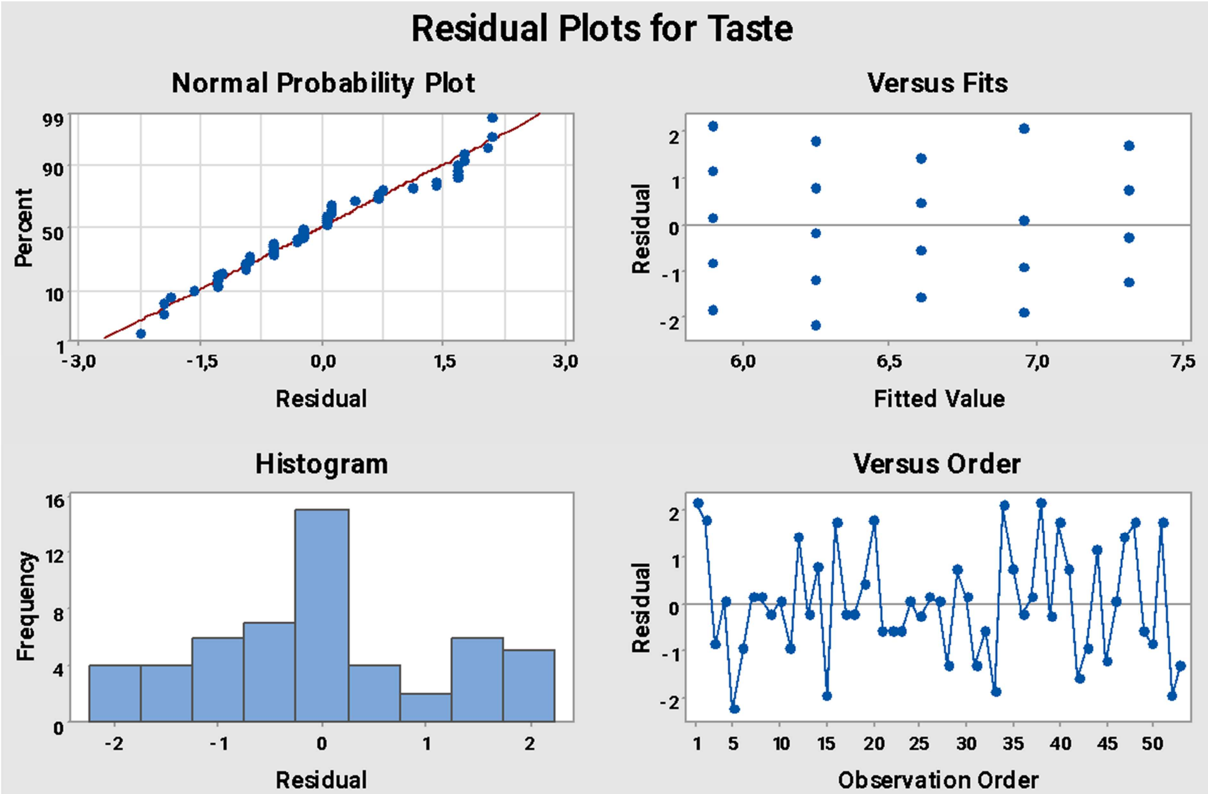

Figure 6. *Residual plots for taste with corn flour.*

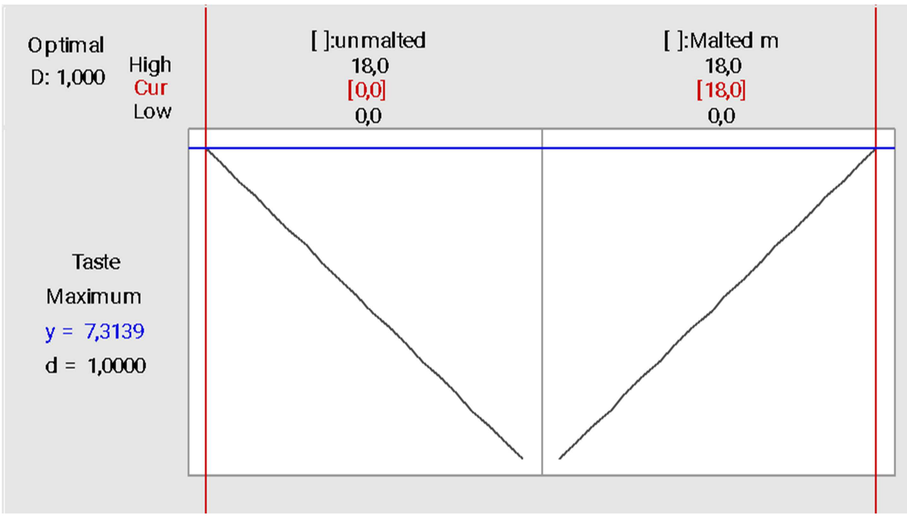

Figure 7. *Taste and smell optimization plot for corn flour.*

3.2. Effects of Salt and Sugar Mixture on the Bread Quality

The results of the regression analysis of the data shown in table 9 give a p-value = 0.04 (quadratic regression) for taste, p = 0,248 for the smell and p = 0.150 for color. It can be seen that the regression was significant only for the taste characteristic the p value of which was lower than that of the significance threshold of 0.05, contrary to what was observed for the color and smell characteristics. The results of the regression analysis of the taste score according to the proportions of salt and sugar give a value of $p = 0.004 < 0.05$ for the interaction between the two components; which led us to retain the quadratic regression model.

The values of the coefficients of determination R squared = 33.19% R squared (pred) = 22.52% R squared (adj) = 29.76%, although low, are not negligible for the results of a sensory evaluation. The plots of the residuals are shown in Figure 8. The individual values follow a straight line and are then normally distributed (AD = 0.725; $p = 0.054 > 0.05$); confirming the regression assumptions. We also note that there are no particular trends in the residual values as a function of the adjusted values or of the observations. It is concluded that the salt and sugar variables are independent. This results in the following regression the equation:

$$\hat{Y} = 0.571837X_1 + 0.907591X_2 + 0.195673X_1X_2;$$

where $\hat{Y}$= the adjusted taste score, X_1 and X_2 the respective proportions of salt and sugar.

Table 9. *Regression parameters.*

Experiment	Components	Characteristic	R-Sq (%)	R-Sq(pred) (%)	R-Sq(adj) (%)	Regression	P Value
	Unmalted corn flour	Color	27.81	20.32	26.13	Linear	0.000
1		Smell	14.44	4.82	10.94	Quadratic	0.023
	Malted corn four	Taste	16.90	9.90	15.27	Linear	0.000
	Salt	Color	6.22	0.00	3.82	Linear and quadratic	>0.05
2		Smell	6.43	0.00	1.97	Linear and quadratic	>0.05
	Sugar	Taste	33.19	22.52	29.76	quadratic	0.04
	Duration	Color	2.28	0.00	0.00	Linear and quadratic	>0.05
3		Smell	27.64	22.28	11.17	Linear	0,013
	Humidification	Taste	18.68	9.29	0.00	Quadratic	0,047

Taste optimization gives the result shown in the figure 9 and predicts a maximum taste score of 6.3433 with a mixture of 2.1212 g of salt and 3.8788 g of sugar.

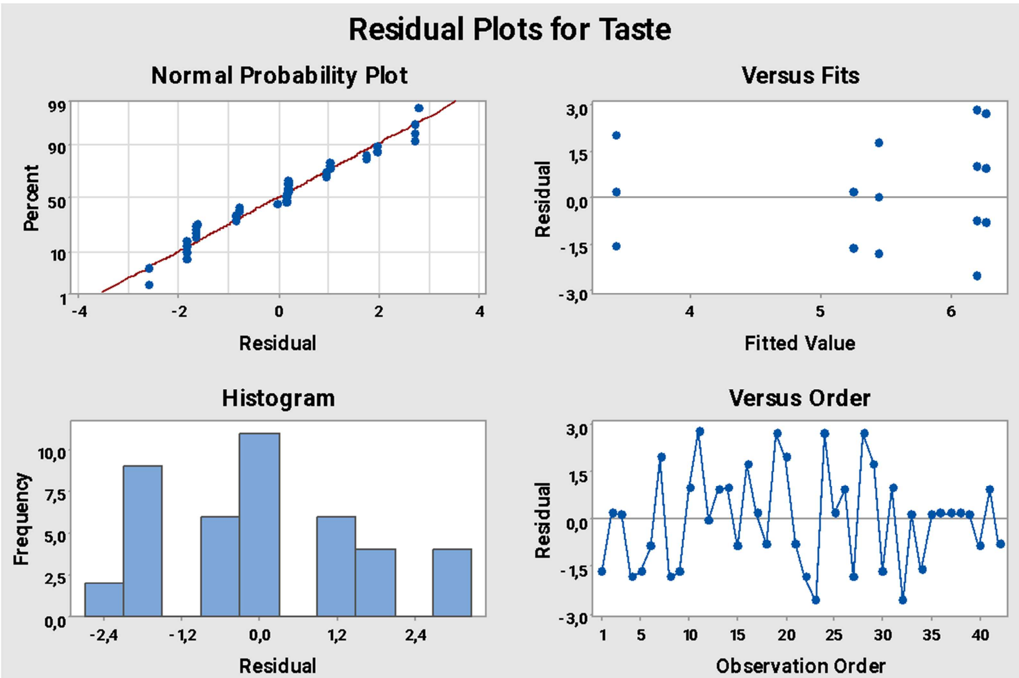

Figure 8. *Residual plots for taste with salt and sugar mixture.*

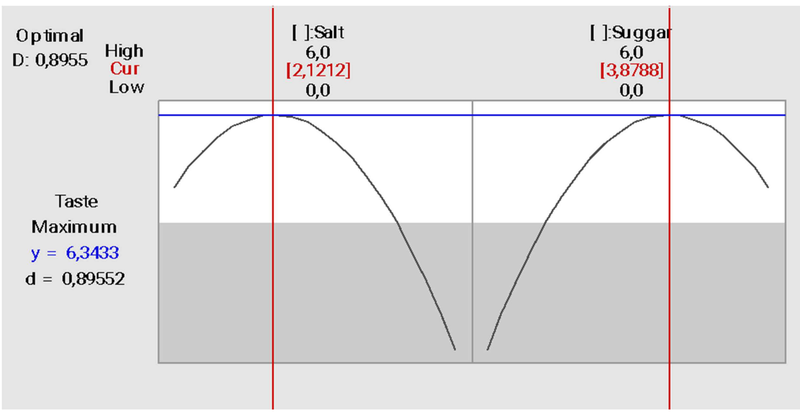

Figure 9. *Taste optimization plot with salt and sugar mixture.*

3.3. Influence of Baking Duration and Humidification Factors on Bread Quality

The data of the taste, smell and color scores of the bread samples according to the baking time (A) and humidification (B) factors are shown in table 10. The results of their analysis in figures 10-13 shows that the B factor and the AB interaction had significant effects on the smell and taste characteristics respectively. There is no significant effect of these factors or their interaction on the color. The residual plots presented in Figures 11 and 13 show that the points are arranged around a straight line; the data follow a normal distribution; what allows us to use the least square methods for regression estimations.

Table 10. *Process parameters.*

Process variables	Levels
Humidifying	1 (with)
Baking time (min)	1 (35 mins)
Temperature	250°C

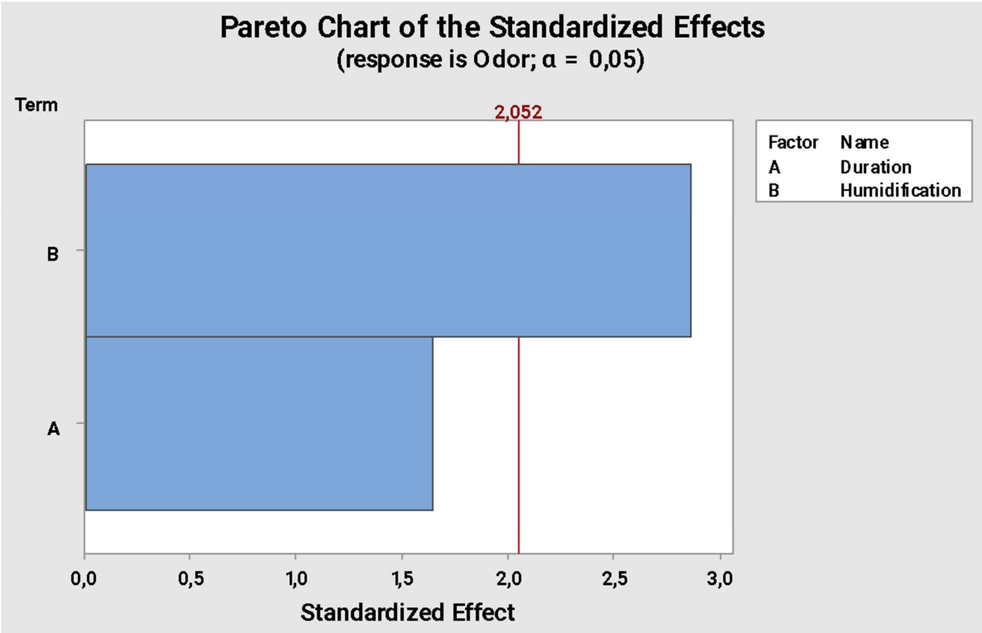

Figure 10. *Pareto chart of standardized effects (response is smell).*

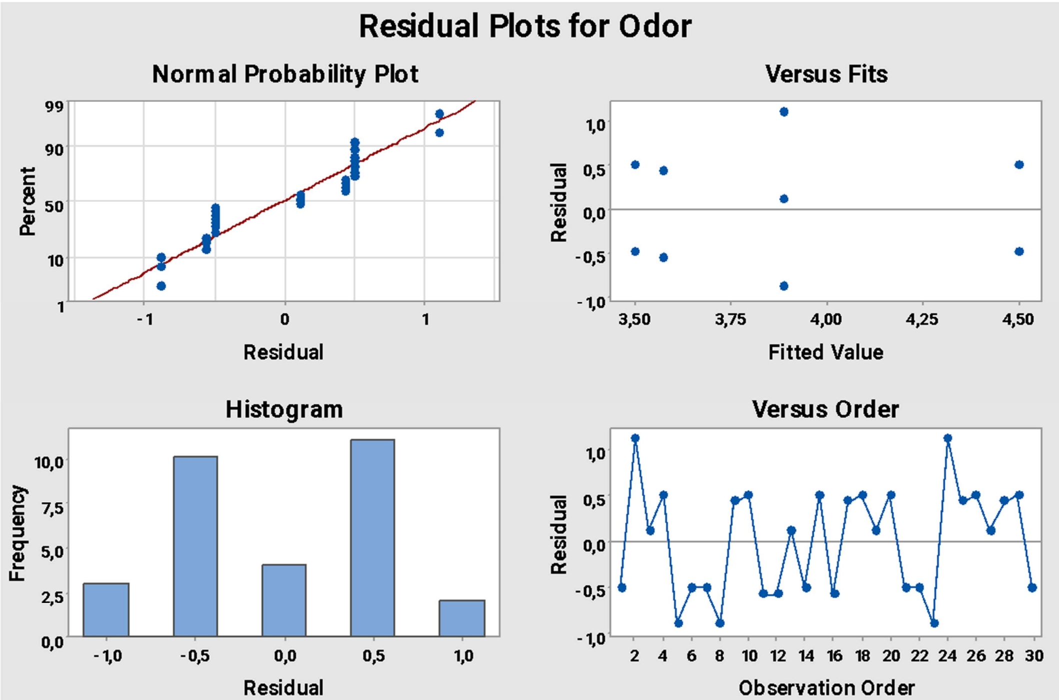

Figure 11. *Residual plots for smell with bread baking duration and humidification.*

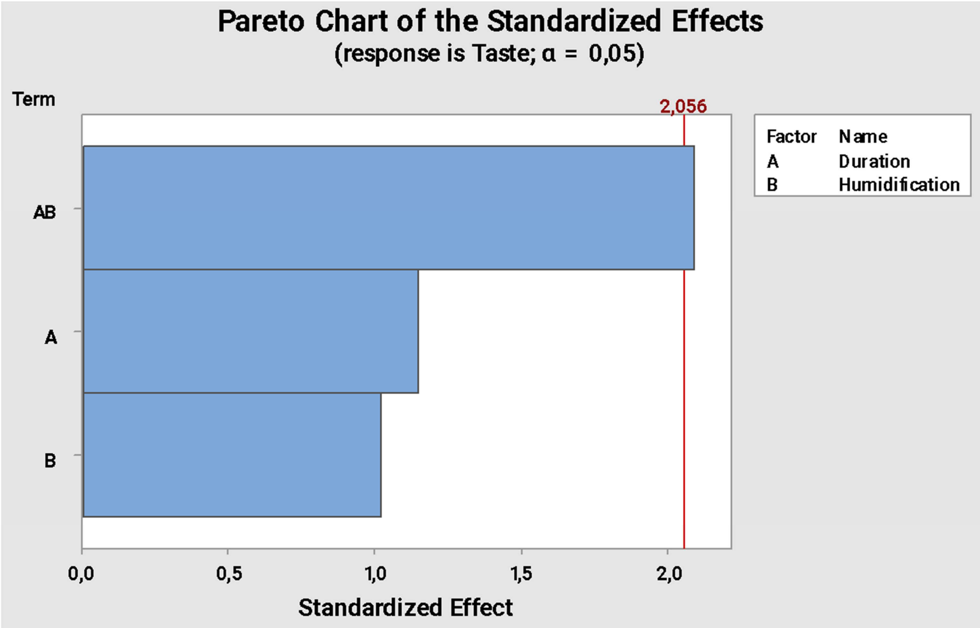

Figure 12. *Pareto chart of standardized effects (response is taste).*

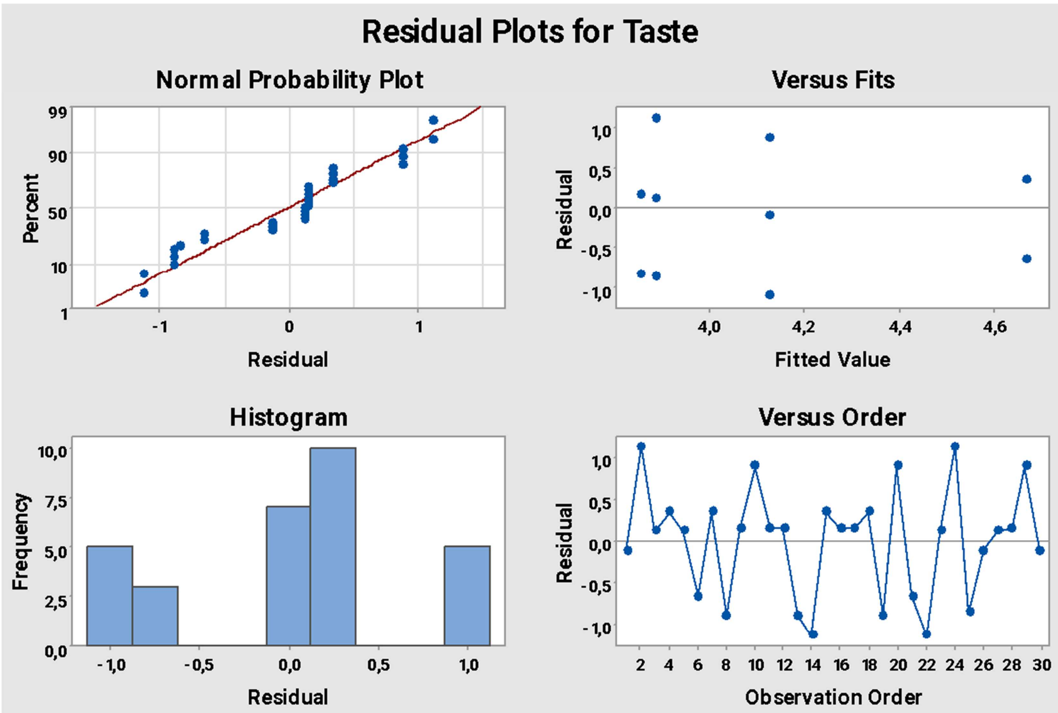

Figure 13. *Residuals plot for taste with bread baking duration and humidification.*

In addition, there is no particular trend in the values adjusted according to the residual values; and no correlation between the time and humidification variables. The coefficients of determination is R squared = 27.64% R squared (adj) = 22.28% R squared (pred) = 11.17% for smell and R squared = 18.68% R squared (adj) = 9.29% R squared (pred) = 0.00% for taste. These coefficients are low. However, correlations between the values of the factors and those of the smell response do exist. Which is justified by the p -value = 0.015 for the linear regression of the smell score expressed as follows:

$$\text{Smell} = 6.957 + 0.307\ \text{Time} + 0.593\text{Humidification}$$

There is no significant regression between the time and humidification variables and the taste score, although the interaction between these two factors is significant (figure 12). So, we decided to further analyze the factorial design stepwise while not requiring the hierarchical model. After deleting the terms A and B, We obtained the R squared = 45.81% R squared (adj) = 43.55% R squared (pred) = 36.32% and the following equation:

$$Taste = 4.1488 + 0.4345 Time * Duration$$

The results of the combined optimization of the two characteristic scores, shown in figure 14, predict the maximum score values of 4.125 (Taste) and 4.500 (Smell) if the factors time and humidity level are both set at their upper levels: baking time 35 min and bread humidified before baking.

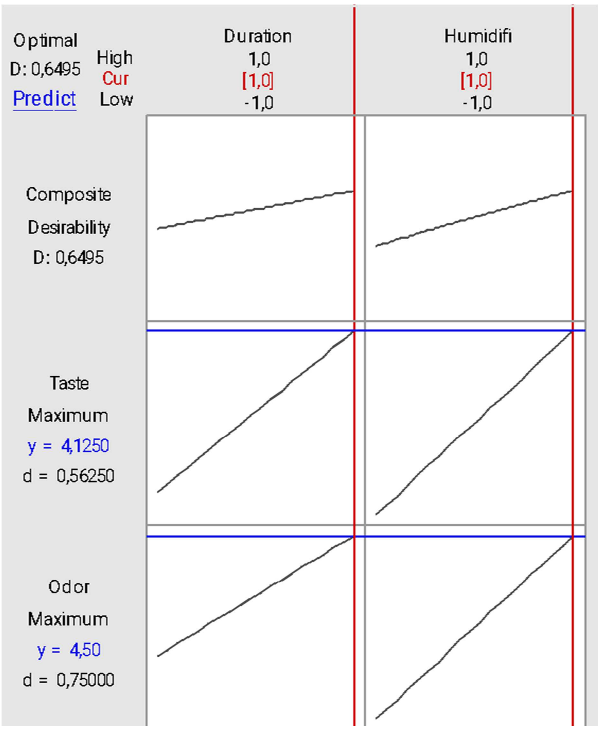

Figure 14. *Taste and smell optimization plot for baking time and humidification (on the 1 to 5 scale basis).*

3.4. Optimal Process

The optimal process parameters are shown in Tables 11 and 12.

Table 11. *Optimal formulation.*

Ingredients	Quantities (g)	%
Malted corn flour	18.00	11
Wheat flour	80.00	48
Water	58.00	35
Fat	3.00	2
Salt	2.12	1
Yeast	1.50	1
Sugar	3.88	2

Table 12. *Mean scores of sensory characteristics of optimal bread.*

Factor	N	Mean	EcTyp	95% CI
Color	19	7.632	1.065	(7.080; 8.183)
Smell	19	7.421	1.071	(6.869; 7.973)
Taste	19	7.158	0.898	(6.606; 7.710)

3.5. Quality of the Prototype Bread

3.5.1. Sensory Quality

The results of the sensory evaluation of the optimal bread are summarized in Table 12. The mean scores for the characteristics evaluated vary between 6.8 and 7.6. These values confirm the predictions of the optimizations. The differences between these scores are not significant.

3.5.2. Physicochemical Quality

The results of the physicochemical analyzes of the bread of the optimal formulation are shown in Table 13. It emerges that the water content was 22.76% followed by the protein content (10.18%, ash (3%), lipids (1.4%), phosphorus The levels of calcium, magnesium, iron phosphorus were respectively 0.01%, 0.04% and 0.06%.

Table 13. *Physicochemical characteristics of optimal bread (2 replications).*

Humidity	Proteins	Lipid	Fibers	Calcium	Magnesium	Iron	Phosphorus	Ashes
22.76±0.16	10.18±0.03	1.43±0.04	0.39±0.03	0.04±0.00	0.06±0.01	0.01±0.00	0.04±0.00	3.03±0.01

4. Conclusion

In accordance with the results obtained, it emerges that the components of unmalted maize flour and malted maize flour significantly influenced the color and taste characteristics unlike the smell; some samples received maximum scores of 9 (extremely like). The optimization results showed that average scores of 7 are predictable, for these two characteristics, only with the 18 g fraction of malted maize flour.

Sugar and salt mixtures only had significant effects on taste and not on color and smell. Thus, the optimization results gave a predictable score of 6 with a mixture of 2.121 g of salt and 3.879 g of sugar.

The results also showed that the humification factor and the moistening *cooking time interaction have significant effects on the color and taste characteristics respectively. The optimization made it possible to predict scores of 7 for taste and 8 for smell when the dough pieces are moistened by sprinkling water before placing in the oven and cooked for 35 min.

The combination of these results made it possible to establish an optimal formulation containing 18 g of germinated maize flour, 2.121 g of salt 3.879 g of sugar, in addition to wheat flour (80 g, water (58 g), fat (3 g) and yeast (1.5 g), This formulation gave a bread appreciated by the assessors in accordance with the predictions of the optimization with average scores of 7.

The values of the physicochemical characteristics are: 22.76% water content, 10.18% protein, 1.4% lipids, 039% fiber and 3% ash. The calcium, magnesium, iron and phosphorus contents vary between 0.01 and 0.06%.

ORCID

0000-0002-4225-1778 (Mikolo Bertin)
0009-0007-8179-6467 (Tsoumou Kedar)

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Conflicts of Interest

The authors declare no conflicts of interest.

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