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Physical Properties of Bread from Wheat– Cassava Flour Composite Using Response Surface Methodology (RSM)

Peluola-Adeyemi O.A*, Adepoju P.A, Lawal S.O

Department of Food Technology, Lagos State Polytechnic, Ikorodu, Lagos State, Nigeria
*Corresponding author: biodunpeluolaadeyemi@gmail.com

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Abstract Physical properties of bread prepared from 90% wheat and 10% cassava composite flour were investigated using response surface methodology. A central composite rotatable experimental design with two factors and five levels was used. The independent variables were baking temperature and time. Thirteen baking trials were performed with five central points and eight non central points. The results showed that the crumb moisture, specific loaf volume, crumb hardness and overall acceptability values ranged from 33 - 39.6%, 3.80 - 4.8cm^3/g, 63.00 - 70.25N and 6.2 - 8.1 respectively. There were significant differences ($p< 0.05$) in the physical properties of the bread samples and the physical properties were affected by the baking temperature and time. The bread samples baked at temperature of 195°C for 16.89 minutes were highly preferred by the panelists and the best processing conditions were baking temperature of 181.20°C at 24.18 minutes with desirability of 0.85. This research suggested that 10% inclusion of cassava in the production of bread would further increase the utilization of cassava flour, thereby promoting the economic value of the indigenous crop.

Keywords: *physical properties, wheat/cassava, baking temperature, time, bread*

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1. Introduction

Bread is a convenient food because it is ready-to-eat, easy to carry round, moderate moisture content food, its taste is highly acceptable [1] and it is part of the major daily diet calorie intake of many people all over the world [2]. It is a staple food that is prepared by baking dough of flour and water [3]. In choosing the appropriate flour type for non-wheat baking, full consideration should be given to the realities of the local agricultural resources prevalent in the area. Nations all over the world have developed their own bread specialties based on their available agricultural resources [4]. White bread is the most common type of bread produced in Nigeria and about 6.2 billion loaves are supplied by over 20,000 bakeries into Nigeria market annually [5]. In recent years the consumption of wheat bread has increase tremendously in many developing nations including Nigeria which could be due to increase in population, urbanization and changing in food habit [6]. Elemo *et al.* [5], reported that the recent annual value of wheat importation in Nigeria is N635 billion. To reduce the nation’s cost on importation of wheat and find wider application for the largely produced cassava roots, the Federal Government of Nigeria approved the use of composite cassava-wheat flour for baking by adding 10% cassava flour to wheat as reported by Shittu *et al.*, [7]. They also reported that the control of the baking parameters like baking temperature and time combination during baking as an engineering problem could be critical to the successful implementation of commercial flour baking technology [7].

Response surface methodology (RSM) is a collection of statistical and mathematical techniques used for development, improvement and optimization of processes or formulations [8,9]. It is used to examine the relative significance between a set of quantitative experimental factors and the response variable. Therefore, this study aimed in assessing the physical properties of bread from wheat-cassava composite flour using response surface methodology.

2. Material and Methods

Cassava (*Manihot esculenta*) and wheat flour (*Triticum spp*) were purchased at Sabo Market, Ikorodu, Lagos State, Nigeria.

2.1. Production of Cassava Flour

The method described by Shittu *et al.*, [7] was used. The cassava roots were manually peeled with knife and washed to remove sand and other dirt. The washed, peeled cassava roots were cut into round chips of uniform sizes. The wet chips were spread in stainless steel trays and sundried for 14 days. The dried chips were milled using attrition mill and sieved to separate coarse or fibrous particles from the fine flour and packaged in polyethylene films.

2.2. Production of Bread

The method described by Shittu, *et al*., [7] was used. The basic ingredients and the proportions required for the preparation of bread sample are 90% wheat and 10% cassava flour. Other ingredients include salt, yeast, sugar, EDC and water as shown in Table 1. Mixing was carried out manually according to the straight dough method. The dry ingredients, shortening and the activated yeast were added in a bowl and water and then kneaded until the dough was elastic and the required consistency was reached. After this, the dough was rounded and was kept in a bowl for the first proofing at the room temperature (30°C) for about 40 min. After the first proofing, the dough was punched and works lightly so that the excess gas could escape and the gas cells are redistributed. The dough was then shaped to fit lightly in greased bread pans. The dough was again kept for the final proofing for about 1 hour. Finally, after second proofing, the breads in pans were baked in oven at different experimental temperatures and time. After baking, the prepared bread samples were cooled for about 1 hour at room temperature and then analysis were carried out.

Table 1. Recipe used in dough formulation

Material	Composition
Cassava flour	30.0g
Wheat flour	270.0g
Salt	1.5%
Sugar	6.0%
Yeast	5.0%
Vegetable oil	3.0%
EDC	0.3%

% values are based on the total flour weight (300g)
Source: Shittu *et al*., [7].

2.3. Experimental Design and Modeling for Optimization

Response Surface Methodology comprising of a central composite design with two-factors and five-levels was used. The two independent variable factors used are baking temperature (X_1) and baking time (X_2) and the four dependent variables (responses) are crumb moisture (Y_1), loaf specific volume (Y_2), crumb hardness (Y_3) and overall acceptability (Y_4). Thirteen baking trials were performed with five central points and eight non central points. The coded values of the independent variables are presented in Table 2.

Table 2. Coded Values of the Independent Variable

Variables	-α	-1	0	+1	+α
X_1(°C)	173.79	180	195.0	210	216.21
X_2 (min)	16.86	20	27.50	35	38.11

Where: α =1.414, X_1=Baking Temperature, X_2=Baking Time.

2.4. Physical Properties of Bread

2.4.1. Determination of Moisture Content

This was determined according to the method described by AACC [10] using the oven dry method, 1g of the sample (bread) was weighted into a silica dish; the silica dish with the sample was place in the oven at 105°C for 24 hours. It was cooled in the desiccator at room temperature. The content with the container was weighed and later placed back in the oven for another 24 hours to ensure complete drying. The cooling process in the desiccator was repeated before taking final weight.

$$\% \ moisture\ content = \frac{\left[\begin{array}{l} Initial\ weight\ of\ the\ sample\ (w_1) \\ -Final\ weight\ of\ the\ sample\ (w_2) \end{array}\right]}{Initial\ weight\ of\ the\ sample\ (w_1)} X100.$$

2.4.2. Specific Loaf Volume

The specific volume analysis was determined by the modified method of Greene and Bovell-Benjamin [11]. Samples were placed on the laboratory bench before the commencement of the analysis for few minutes. Beans were poured to cover the bottom of the borosilicate container of a known volume. The bread was placed in the container and the remainder of the beans was poured into the available space in the container using laboratory spatula. The leftover of the beans that were not required for the experiment were measured in a graduated cylinder and represented the volume of the bread.

The specific volume was obtained as a ratio of the volume of the bread to the weight of the bread.

$$Specific\ volume\ \left(cm^3/g\right) = \frac{loaf\ volume}{loaf\ weight}.$$

2.4.3. Crumb Hardness

The hardness of the bread crumb was measured using Universal Testing Machine, Table Model (ERWEKA TBA 200), about 2.5x1.5 cm^3 crumb slice was obtained from each loaf at the crumb center. Each slice was placed at the middle of a flat surface hardness tester receptacle. The plunger head was touched with the surface of the crumb slice. Thereafter, the plunger was driven 40 rpm into crumb until fracture. The maximum force require to cause failure (measured in N) is read off the dial gauge attached to the instrument.

2.5. Sensory Evaluation

Twenty panelists accessed the attributes of the bread produced such as taste, colour, texture, appearance and overall acceptability using nine point hedonic scale, 1= dislike extremely and 9=like extremely [12].

2.6. Statistical Analysis

Second order polynomial model was fitted to determine relationship between dependent variables, specific loaf volume (Y_1), crumb moisture (Y_2), crumb hardness (Y_3), overall acceptability (Y_4) and independent variable (X).

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{11} X_1^2 + \beta_{22} X_{22}^2 + \beta_{12} X_1 X_2 \quad (1)$$

Where β_0, β_1- β_2, β_{11}- β_{22} and β_{12} are regression coefficients for interception, linear, quadratic and interaction coefficients respectively, X_1-X_2 are coded independent variable and Y is the responses [13]. An ANOVA test was carried out using design expert 6.0.8 (Stat-East Inc., Minneapolis, USA) to determine the significance at different levels (0.1%, 1% and 5%).

3. Results and Discussion

3.1. Effect of Baking Temperature and Time on the Crumb Moisture Content of Bread

The effect of baking temperature and time on the crumb moisture content of bread samples are presented as contour plot in Figure 1. The crumb moisture content of the bread samples ranged from 33.0-39.6%. As the baking temperature and time increases the moisture content of the bread decreases. The model for the moisture content (R^2=0.78) had a positive quadratic terms (baking temperature and time) and a positive linear terms. The crumb moisture content was significantly affected by X_1^2 (quadratic effect of baking temperature). Moisture content is the amount or quantity of water presents in a food sample, the lower the moisture the longer the shelf-life. The amount of moisture in bread crumb has some implication on the mechanical [14] and keeping qualities [15].

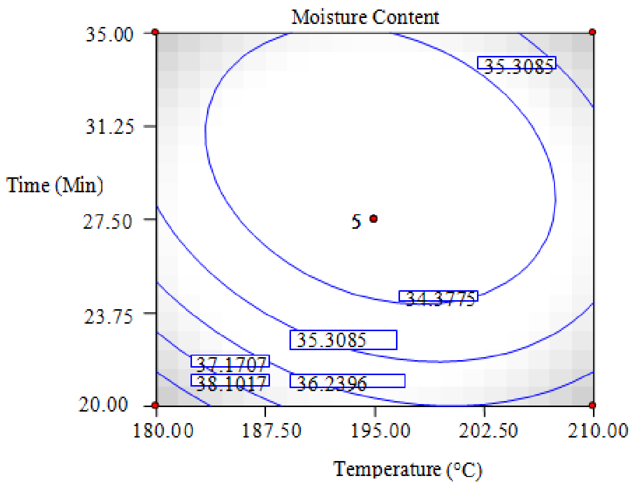

Figure 1. Contour plot showing the effect of baking temperature and time on crumb moisture content of bread samples

3.2. Effect of Baking Temperature and Time on Specific Loaf Volume of Bread

The effect of baking temperature and time on the specific loaf volume of bread samples are presented as contour plot in Figure 2. The specific loaf volume of the bread samples ranged from 3.80-4.80 cm^3/g. The specific loaf volume of the bread samples were influenced by baking temperature and time. As the baking temperature and time increases, the specific loaf volume of the bread samples decreases. The model for the specific loaf volume (R^2=0.84) had a negative quadratic terms (baking temperature and time) and a positive linear terms. The specific loaf volume was significantly (P<0.05) affected by X_1^2 and X_2^2 (quadratic effect of baking temperature and time). All the bread samples are within the recommended standard for specific loaf volume (3.5-6.0 cm^3/g) given by China Grain Product Research and Development Institute [16]. Since the bread samples are produced from the same formulation, the variation of the specific loaf volume could be attributed mainly to different rate of gas evolution. The extent of starch gelatinization could be due to differences in baking temperature and time as reported by Eggleston *et al*., [17]. Ragaee and Abdel-Aal [18], reported that higher loaf volume has positive effect on bread at retail end. Hence, decrease in loaf weight during baking is an undesirable economic quality to the bakers as consumers often get attracted to bread loaf with higher weight and volume.

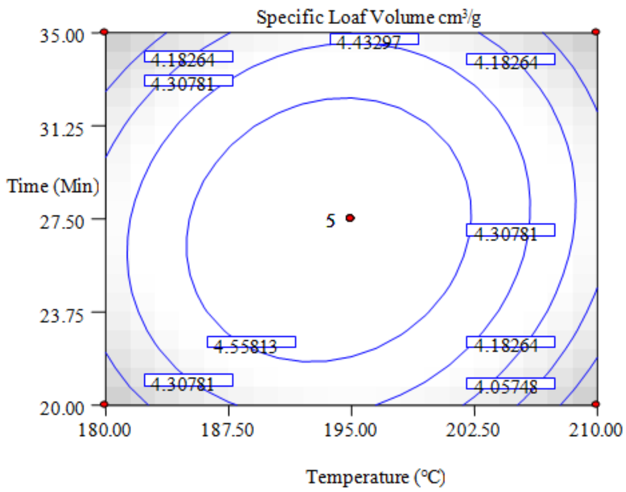

Figure 2. Contour plot showing the effect of baking temperature and time on specific loaf volume of bread samples

3.3. Effect of Baking Temperature and Time on the Crumb Hardness (Texture) of Bread

The effect of baking temperature and time on the crumb hardness of bread samples are presented as contour plot in Figure 3. The hardness depended both on the baking temperature and time, and the values ranged from 63.0-70.25N. Hardness of the bread crumb increases with increase in baking temperature and time. The model for the crumb hardness (R^2=0.88) had a positive quadratic terms (baking temperature and time) and a positive linear terms. The crumb hardness was significantly (P<0.05) affected by X_1^2 and X_2^2 (quadratic effect of baking temperature and time). Crumb hardness depends on crust thickness. The hardness test was used to determine the amount of energy that may be required to fracture a given volume of dried crumb. As the baking proceeded, the crust thickness increases with increase in baking temperature and time which could be due to the evaporation of moisture from the surface of the bread. Hardness is an important factor in bakery products and it is strongly related with the consumer's perception of bread freshness [19].

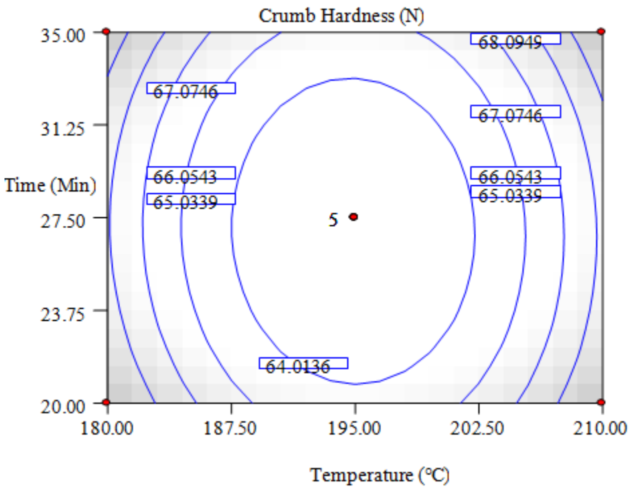

Figure 3. Contour plot showing the effect of baking temperature and time on crumb hardness of bread samples

3.4. Effect of Baking Temperature and Time on the Overall Acceptability of Bread

The effect of baking temperature and time on overall acceptability of bread samples are presented as contour plot in Figure 4. The overall acceptability of the bread ranged from 6.2-8.1. From the sensory evaluation, it was noticed that the baking temperature and time affected the final bread quality. As the baking temperature and time decreases, the overall acceptability of the bread increases. The model for the specific loaf volume (R^2=0.76) had a negative quadratic terms (baking temperature and time) and a negative linear terms. The overall acceptability was significantly affected by X_1^2 (quadratic effect of baking temperature). Bread baked at 195^{0}C for 16.89 minutes had the highest overall acceptability in terms of taste, colour, and texture, while the bread baked at 210^{0}C for 35 minutes was least accepted in terms of taste, colour and texture.

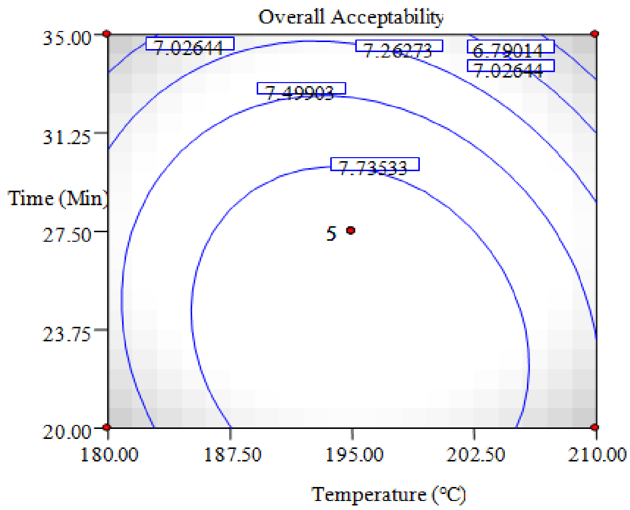

Figure 4. Contour plot showing the effect of baking temperature and time on overall acceptability of bread samples

3.5. Optimization Conditions

The optimization conditions for the production of bread are presented as contour plot in Figure 5. The best conditions for the production of bread are baking temperature of 181.20°C at 24.18 minutes with desirability of 0.85, indicating that the bread produced from 90% wheat and 10% cassava flour are of good quality.

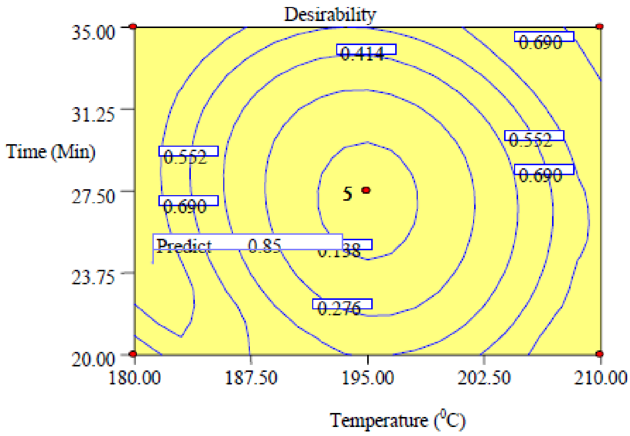

Figure 5. Effect of baking temperature and time on desirability of the bread samples

4. Conclusion

Response surface methodology was successful used to optimize the physical properties of bread produced from 90% wheat and 10% cassava flour. The baking temperature and time had a significant effect on the physical properties of the bread. The bread baked at 195°C for 16.89 minutes was highly preferred by the panelists. The best conditions for the production of bread are baking temperature of 181.20°C at 24.18 minutes with desirability of 0.85. In conclusion, the study showed that good quality bread could be produced from wheat-cassava composite flour without compromising the quality of the bread.

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