EFFECT OF TEMPERATURE AND TIME ON THE PHYSICAL PROPERTIES OF BREAD PRODUCED FROM WHEAT – COCOYAM FLOUR USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT

This study investigated the effect of baking temperature and time on the physical properties of bread from 10% cocoyam and 90% wheat flour. A central composite rotatable experimental design with two factors and five levels were used. The independent factors were baking temperature $(174.82 − 251.18°C)$ and baking time $(30 − 45min)$. The responses were specific loaf volume (Y_1), crumb moisture (Y_2), crumb hardness (Y_3) and overall acceptability (Y_4). Thirteen (13) baking trials were performed with five center points and eight non center points. The specific loaf volume $(3.35 − 3.9cm^3/g)$, crumb moisture content $(32.1 − 35\%)$, crumb hardness $(70 − 70.48N)$ and overall acceptability $(4.85 − 8)$ varied significantly $(P<0.05)$ with the baking temperature and time. The panelists preferred the bread baked at 186°C for 45min.

Keywords: Bread, 90% Wheat flour, 10% Cocoyam flour, Temperature, Time, Response surface methodology.

Contribution/ Originality

This study documents the effect of baking temperature and time on the physical properties of bread from wheat- cocoyam flour using response surface methodology and revealed that acceptable bread can be obtained from 90% wheat flour and 10% cocoyam flour at the baking temperature of 186ºC for 45mins.

1. INTRODUCTION

Bread is a product made from low protein wheat and is an important source of food in Nigeria. It is consumed extensively in homes, restaurants and hotels and usually contains several ingredients that would help improve the quality of the bread (Vicki, 1997). Bread is part of the major daily diet of Nigerians, contributing about 40% of the daily calorie intake (Bureng and Olatunji, 1992). The quality depends on the properties of raw material and on the technological parameters applied in the process of production. The basic ingredients are wheat flour, water, yeast, and salt (Martin, 2004; Sluimer, 2005). Other ingredients which may be added include flours of other cereals, fat, yeasts foods, milk (Kent, 1984). The major challenge in both flour milling industry and bakeries is the baking quality of flour, which is determined by the capacity of the dough prepared from it to retain gas. As a result of wide variations in the composition of flour, various treatments and supplements/ conditioning agents (flour/bread improvers) are added for strength during mixing, extensibility for molding and also to increase loaf volume and texture (Emeje *et al.*, 2010). However, several studies have shown deleterious effects of these improvers with potassium bromate being the most implicated hence necessitating its ban. It is not only carcinogenic but also has effects on the nutritional quality of bread degrading vitamins A2, B1, B2, E and niacin, which are the main vitamins available in bread (IARC, 1999).

Furthermore, the quality of bread does not depend only on the quality of flour, baking process and improver used but also depends mainly on the rate and amount of heat applied, the type of baking chamber and the baking time. It has been found that the baking temperature and time that bakers use in baking their bread varies as described by Jideani and Onwubali (2009).

Wheat (*Triticum spp*) is a cereal crop grown and cultivated Worldwide. It is an important staple food for humans, it is used to make flour for production of bread, cakes, biscuits, pastas and breakfast cereal (Chinma and Gernah, 2007). The wheat of commerce fall into three main groups: *Triticum vulgare, Triticum durum* and *Triticum compactum*. The first is the most suitable for making bread flours (Wheat Food Council, 2005).

Cocoyam is an annual plant with edible underground tubers. The plant is popular in the West Indies, West Africa and Asia (Cobley, 1988). The plant is adapted to flooding in dry areas, they can be grown in swampy places or with irrigation. In Nigeria, cocoyam is grown in almost every part of the country, the varieties and species differ with prevailing climatic conditions of the place of cultivation (Abbo *et al.*, 1985). Cocoyam is rich in digestible starch, good quality protein, Vitamin C, thiamin, riboflavin, niacin and high scores of protein and essential amino acids (Lewu *et al.*, 2009).

Response surface methodology (RSM) is a collection of statistical and mathematical techniques used for development, improvement and optimization of processes or formulations (Malcolmson *et al.*, 1993; Bas and Boyaci, 2007). It is used to examine the relative significance between a set of quantitative experimental factors and the response variables. In food research studies, response surface methodology (RSM) is very frequently used to optimize the efficiency of the ingredients such as composite flours (Shittu *et al.*, 2007) optimization in food processes like product development and functional food preparation (Gupta *et al.*, 2007).

The potentials of the cocoyam for food security, income generation and nutritional enhancement in the households are grossly underutilized (Ogunlakin *et al.*, 2012). Presently few studies have been conducted on the baking temperature and time on the quality of bread (Datta, 2006; Josoh *et al.*, 2007). In order to reduce the expense on wheat importation and find wider utilization for the increasingly produced root and tubers, the Federal Government of Nigeria mandated the use of composite cassava-wheat flour for baking by adding minimum of 10% cassava flour (Shittu *et al.*, 2007). However, for the utilization of cocoyam flour, the objective of this research work was to produce bread from 90% wheat : 10% cocoyam (*Xanthosoma sagittifolium*) flour, to determine the effect of baking temperature and time on the quality of bread and evaluate the sensory properties of wheat-cocoyam composite bread.

2. MATERIALS AND METHODS

Cocoyam (*Xanthosoma sagittifolium*), wheat flour (*Triticum spp*) baker's yeast were obtained from Sabo market, Ikorodu, Lagos, Nigeria.

2.1. Methods
2.1.1. Processing of Cocoyam Flour

The harvested cocoyam cormels were sorted to remove immature cormels and foreign materials. The cocoyam cormels were peeled with knife washed to remove sand and dirt. The washed peeled cormels were cut into round chips of uniform sizes, blanched in water bath for 100^0C for 5minutes.The blanched chips were spread in stainless steel trays and sundried for seven days to a low moisture level. The dried chips were milled using attrition milling machine, sieved and the flour was packaged into polyethylene films prior to analysis (Iwe and Egwuekwe, 2010).

2.1.2. Production of Bread

The basic ingredients and proportions required for the preparation of bread samples was 90% wheat flour and 10% cocoyam flour. Other ingredients included salt, yeast, sugar, EDC and water as shown in Table 1. The dry

ingredients, shortening and the activated yeast were added in a bowl of water and kneaded until the dough became elastic and the required consistency reached. After this, 200g of dough was rounded and kept in a bowl for the first proofing at room temperature (30°C) for about 40minutes. The bowl was covered with a wet cloth to maintain a relative humidity of 80-90%. After the first proofing, the dough was punched and worked lightly so that the excess gas could escape and the gas cells redistributed. The dough was then shaped to fit into lightly greased bread molds. The dough again was kept for the final proofing for about 1hour. Finally, the dough in molds was baked in electric oven at different experimental temperatures and time (Table 2). After baking, the prepared bread samples were cooled for about 1hour at room temperature (Lipi *et al.*, 2012).

Table-1. Recipe Used In Dough Formulation

Materials	Composition
Cocoyam flour	3.0g
Wheat flour	270g
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.* (2007)

Table-2. Coded Levels of the Independent Variable

Variables	$-\alpha$	-1	0	$+1$	$+\alpha$
X_1(°C)	174.82	186	213.00	240	251.18
X_2(min)	37.5	30	37.5	45	48.11

Where

$\alpha= 1.414$

X_1 = Baking Temperature

X_2 = Baking Time

Table-3. Treatment Schedule for Two Factors of Centered Composite Design and Responses

TRIAL	Baking temperature(°C) (X_1)	Baking time(min) (X_2)	Loaf volume(Y_1)	Crumb moisture(Y_2)	Crumb hardness(Y_3)	Overall acceptability(Y_4)
1	186	30				
2	240	30				
3	186	45				
4	240	45				
5	174.82	37.5				
6	251.18	37.5				
7	213	26.89				
8	213	48.11				
9	213	37.5				
10	213	37.5				
11	213	37.5				
12	213	37.5				
13	213	37.5				

Source: Stat-Ease (2002)

2.1. 3. Experimental Design

RSM comprising of a central composite design with two-factor and five-levels was used. The two independent variables (factors) used are baking temperature (X_1) and baking time (X_2) and the four dependent variables(responses) are loaf specific volume (Y_1),crumb moisture (Y_2),crumb hardness (Y_3), overall acceptability (Y_4). Thirteen (13) baking trials were performed with five center points. The coded level of independent variable and treatment schedule are shown in Table 2 and 3.

2.2. Analysis

2.2.1. Specific Volume

The specific volume analysis was carried out by the following modified method of Greene and Bovell (2004). Samples were placed on the laboratory bench before the commencement of the analysis in 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 that contained the bread. The beans were leveled on the surface of the container using a laboratory spatula. The left-over of the beans that were not required for the experiment were measured in a graduated cylinder which 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.
The same procedure was followed for other samples.

$$\text{Specific volume (cm}^3/\text{g)} = \frac{Loaf\ volume}{Loaf\ weight} \quad \text{........................} \quad (1)$$

2.2.2. Crumb Moisture

Bread moisture was determined by weighing 1.0g of the sample into the silica dish. The silica and the content placed in the oven for 24 hours at 105ºC (AACC, 2000). It was cooled in the dessicator to room temperature. The content with the container were weighed and later placed back in the oven for another 24hours to ensure complete drying. The cooling process in the dessicator was repeated before taking the final weight.
The same procedure was followed for other samples.

$$\%\text{Moisture content} = \frac{Initial\ weight\ of\ the\ sample\ (W1) - Final\ weight\ of\ the\ samples\ W2}{Initial\ weight\ of\ the\ sample\ (W1) \times 100} \quad \text{.........} \quad (2)$$

2.2.3. Crumb Hardness

The hardness of the bread crumb was measured using Universal Testing Machine, Table Model (ERWEKA TBA 200). About 2.5cm³ crumb slice was obtained from each loaf at the crumb center. Each slice was placed in the middle of a flat surface hardness tester receptacle. The plunger head was touched with the surface of the dried crumb slice. Therefore, the plunger was driven 40rpm into crumb until fracture. The maximum force required to cause fracture (measured in N) was read off the dial gauge attached to the instrument.

2.3. Statistical Analysis

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

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

Where β_0, $\beta_1 - \beta_2$, $\beta_{11} - \beta_{22}$ and β_{12} are regression coefficients for interception, linear, quadratic and interaction coefficients respectively, X_1-X_2 are coded independent variables and Y is the response (Stat-Ease, 2002). An Anova test was carried out using Design Expert 6.0.8 (Stat- Ease inc., Mnneapolis, USA) to determine the significance at different levels (1% and 5%) (Stat-Ease, 2002).

3. RESULTS AND DISCUSSION

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

The effect of baking temperature and time on specific volume of bread samples are presented as 3D surface plots in figure 1. The specific volume of the bread samples ranged from 3.35 - 3.9cm³/g. As the baking temperature and time increases, the loaf specific volume decreases. The model for the specific volume ($R^2=0.81$) had a negative quadratic terms (baking temperature and time) and also negative linear terms. The loaf volume was significantly affected by X_2 (baking time) and X_1^2(quadratic effect on temperature). Specific loaf volume is the ratio of volume of the bread to the weight of the bread which is more precise measurement of loaf size. The results obtained showed that higher baking temperature or higher baking time produced bread with low specific loaf volume. This could be as a result of shrinking of the dough. According to Ragaee and Abel-Aal (2006) variations in loaf specific volume could probably be affected by the protein content of the flour as well as the proofing time, temperature and also the differences in the rate of gas evolution.

3.2. The Effect of Baking Temperature and Time on Crumb Moisture Content of Bread

The effect of baking temperature and time on the crumb moisture content of bread samples are presented as 3D surface plots in figure 2. The crumb moisture ranged from 32.1 - 35%. Increase in baking temperature and time led to decrease in the crumb moisture content. The model for the crumb moisture content ($R^2=0.84$) had a positive quadratic terms (baking temperature and time) and a positive linear terms. The crumb moisture content was significantly affected by X_1 (baking temperature), X_2 (baking time) and X_2^2 (quadratic effect on time). Moisture content is the amount or quantity of water present in a food sample. Moisture content in bread should be controlled because it determines the shelf-life of the bread. The results obtained showed that high baking temperature or time produced bread with low moisture content but high baking temperatures had more effect on the crumb moisture content than the baking time. This could be as a result of evaporation of water content in the dough during baking. Zghal et al. (2002) reported that the moisture content of the bread crumbs may be governed by the extent of gelatinization of starch in dough during baking. The crumb moisture content has some implication on the mechanical and keeping qualities.

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

Hardness is an important factor in bakery products and is strongly related with the consumer's perception of bread freshness (Ahlborn et al., 2005). The effect of baking temperature and time on crumb hardness of bread are presented as 3D surface plots in figure 3. It depends on both baking temperature and time and the values ranges from 70 - 70.48N. Hardness of the bread samples increased with increasing baking temperature and time. The model for the crumb hardness ($R^2=0.79$) had a positive quadratic terms (baking temperature and time) and also positive linear terms. The crumb hardness was significantly affected by X_2 (baking time) and X_2^2 (quadratic effect on time). Crumb hardness is the maximum force required to cause failure of the crumb. The results obtained showed that higher baking temperatures or time produced bread with high crumb hardness. According to Ahlborn et al. (2005) this could probably as a result of high rate of water evaporation from the surface of the bread at higher temperature.

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

The effect of baking temperature and time on overall acceptability of the bread samples are presented as 3D surface plots in figure 4. Overall acceptability of bread depends on both baking temperature and time and the values ranges from 4.85 - 8. Overall acceptability of the bread samples decreased with increase in baking temperature and time. The model for the overall acceptability of the bread ($R^2=0.86$) had a positive quadratic terms (baking

temperature and time) and positive linear terms. The overall acceptability was significantly affected by X_2^2 (baking temperature) and X_2^2 (quadratic effect on temperature).
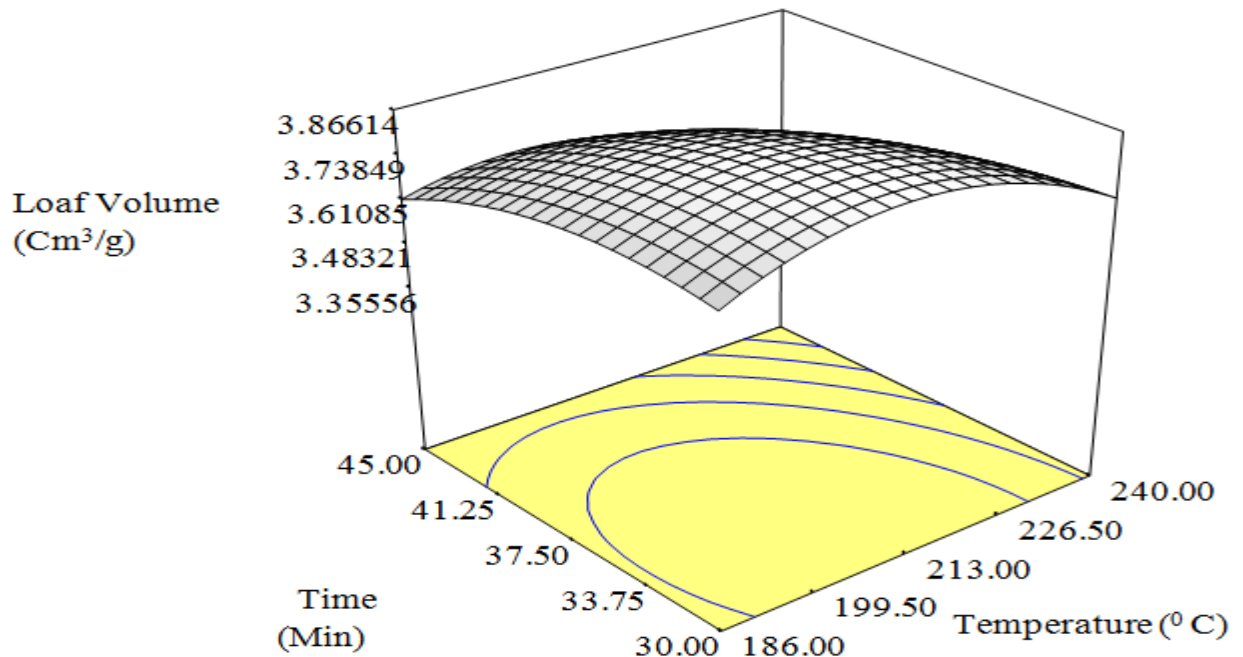

Figure-1. Effect of Baking Temperature and Time on the Specific Loaf Volume of the Bread
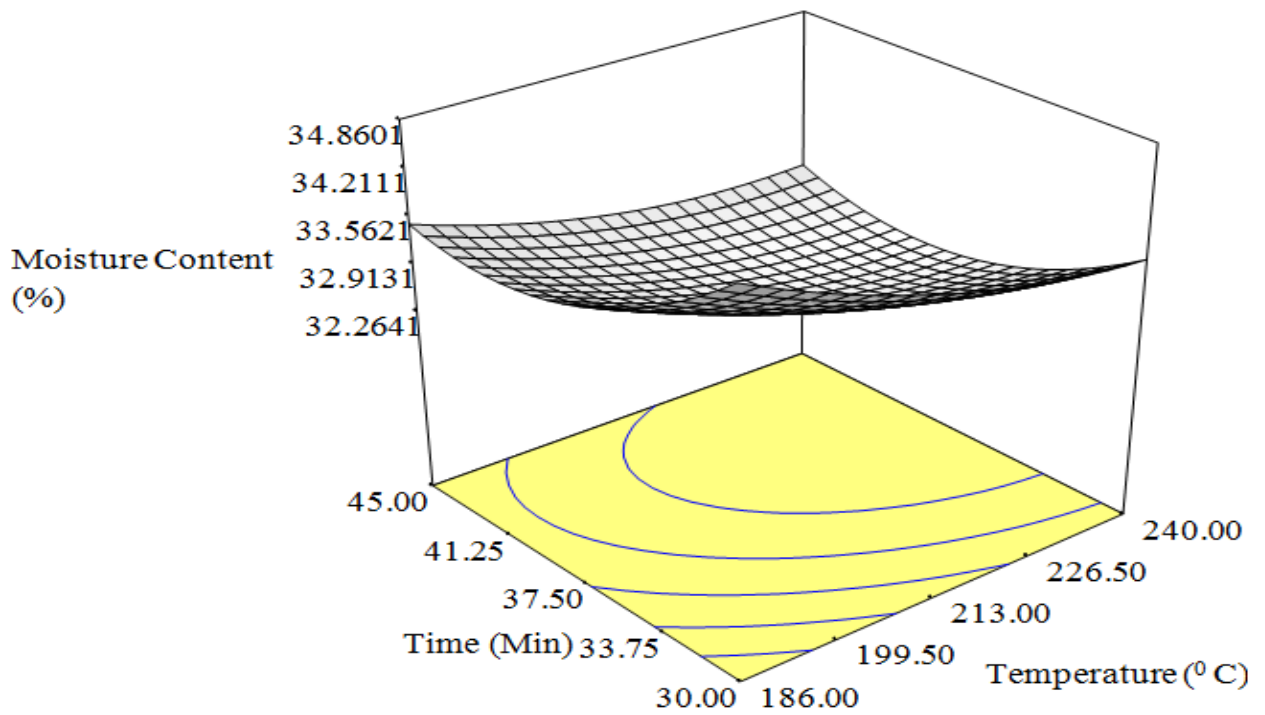

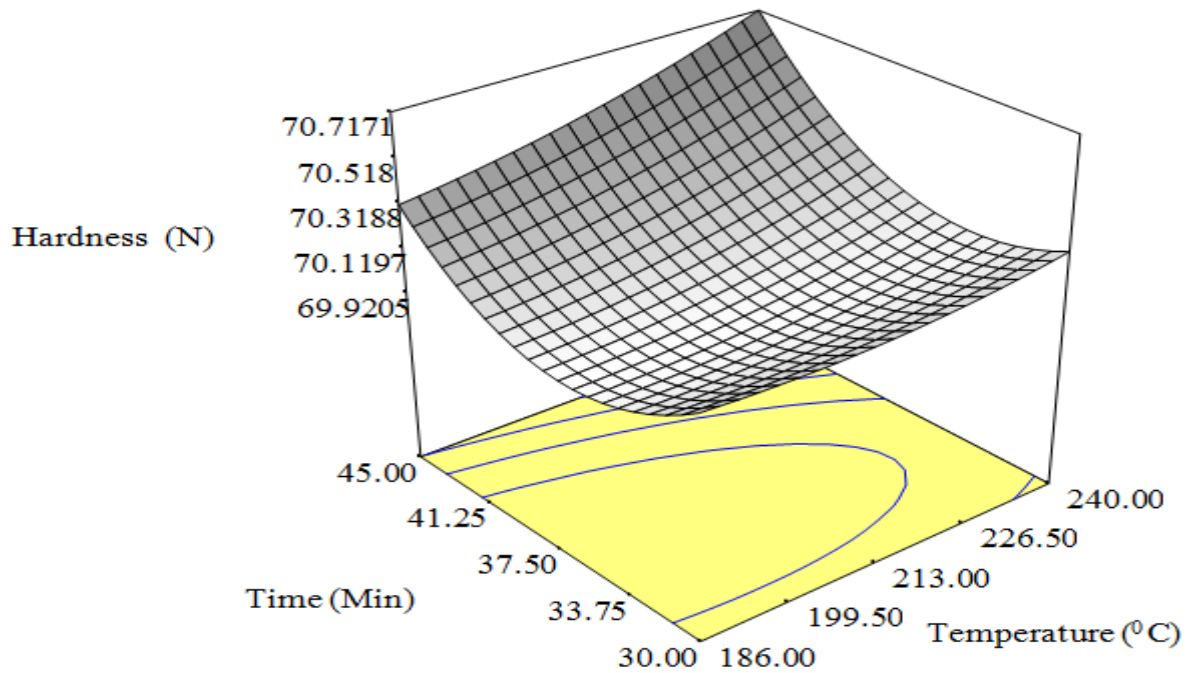**Figure-2.** Effect of Baking Temperature and Time on the Crumb Moisture Content of the Bread

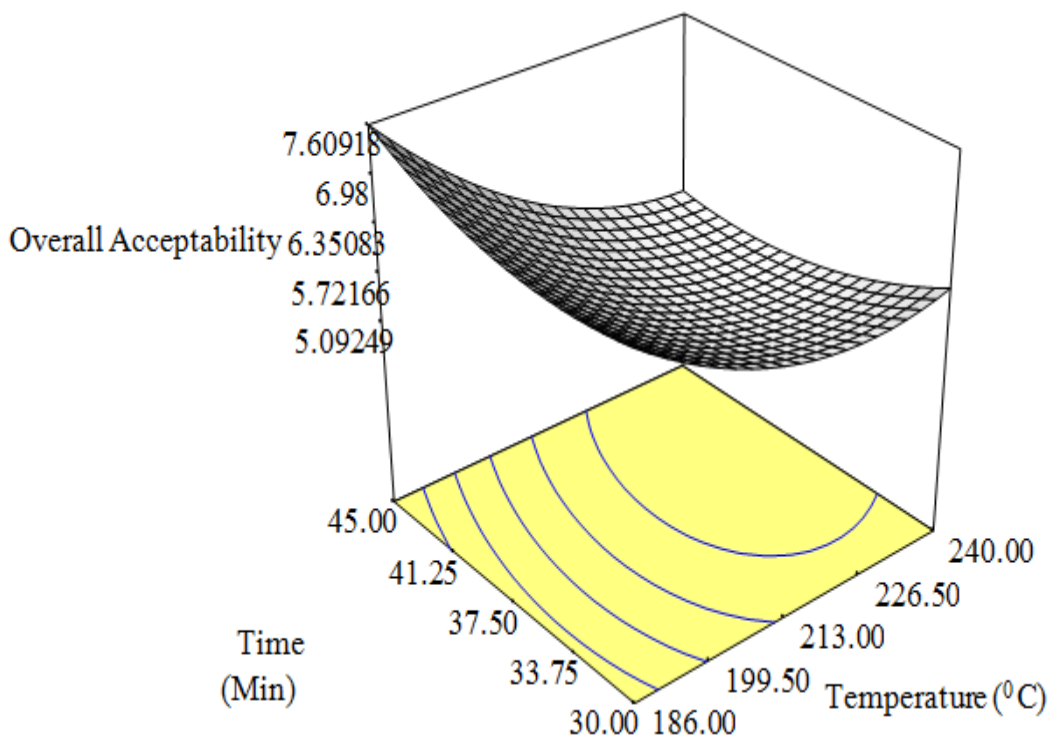**Figure-3.** Effect of Baking Temperature and Time on Crumb Hardness of the Bread

Figure-4. Effect of Baking Temperature and Time on Overall Acceptability of the Bread

4. CONCLUSION

The study showed that there were significant changes in the physical characteristics of composite bread made from 10% cocoyam and 90% wheat flour due to different temperature and time combination during baking. All the responses were significantly affected by the varying factors. Therefore, the best baking conditions obtained were baking temperature of 186°C and time of 45min.

Regression coefficients, coefficient of Determination (R²) and Analysis of variance of Regression models

Coefficients	Loaf specific volume (Y₁)	Crumb moisture (Y₂)	Crumb hardness (Y₃)	Overall acceptability (Y₄)
β_0	-7.96*	82.30**	81.74*	44.72**
X₁	0.09	-0.23**	-0.04	-0.31**
X₂	0.14*	-1.15*	-0.46*	-0.12
β_{11}	-0.00**	0.00	0.00	0.00**
β_{22}	-0.00	0.01**	0.00**	0.00
β_{33}	-0.00	0.00	0.00	0.00
R²	0.81	0.84	0.79	0.86
F-value	5.94	7.30	5.31	8.84

Significant level

***0.001

**0.01

*0.1

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