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Optimization of Processing Conditions on Some Selected Mechanical Properties of Cookies from Wheat-Cocoyam Flour Using Response Surface Methodology (RSM)

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Abstract This study investigated the optimization of processing conditions on some selected mechanical properties of cookies from wheat-cocoyam flour using response surface methodology. The purpose of this research is the utilization of cocoyam crops in the production of cookies. A central composite rotatable experimental design with two factors and five levels was used. The independent variables were baking temperature and time. The responses are moisture (Y_1), energy to break (Y_2), break strength (Y_3), force at break (Y_4) and overall acceptability (Y_5). Thirteen baking trials were performed with five central points and eight non central points. The results shows that moisture, energy to break, break strength, force at break and overall acceptability ranged from 4.43-8.94%, 0.0027-0.422N/m, 0-0.90.83N/mm^2, -6-90.83N, 3.50-8.80 respectively. The results indicated that there were significant difference ($P<0.05$) in the moisture content and mechanical properties of the cookies and were all affected by baking temperature and time. The cookies produced at 210°C for 30 minutes were most preferred by the panelists. The best processing conditions were samples baked at 190.15°C at 27 minutes with desirability of 0.700. In conclusion, the production of cookies using 10% inclusion increases the usage of underutilized cocoyam crops and also leads to the development of more cookies to meet people's demand.

Keywords: *cookies, baking temperature, baking time, RSM (Response surface methodology)*

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1. Introduction

Cocoyam (*Colocasia spp and Xanothosoma spp)* is grown in the tropics and sub-tropical region of the World particularly in Africa for human nutrition, animal feed and cash income for both farmers and traders [1]. It is commonly used for food and grown among small scale farmers in Nigeria [2]. The World leading producer of cocoyam is Nigeria, producing estimately 3.7 million metric tonnes annually [3]. The underground cormels provide easily digestible starch with lots of minerals, vitamins and thiamine [4].

In Nigeria, the annual increase of wheat importation has been reported and the current value is around N635 billion [5]. To reduce importation of wheat and to utilized indigenous crop such as root and tuber crops, the Federal Government implemented 10% cassava/wheat composite flour in the baking industry [6]. However, cocoyam is underutilized.

A cookie is an important snack due to its taste, crispness and eating convenience [7]. It is common among age groups especially in children. Cookies are made from wheat flour and could also be a preferred way to use composite flour [8]. Studies have been conducted by different authors on the composite flour in the production of cookies [7,8,9,10,11]. It was reported that baking time and temperature were among the factors affecting the quality characteristics of cookies [12]. Therefore, the aim of this research work was to blend 10% cocoyam and 90% wheat flour in the production of cookies and to determine the best processing conditions using response surface methodology.

2. Materials and Methods

2.1. Materials

2.1.1. Processing of Cocoyam Flour

Cocoyam cormels (Tannia) and wheat flour were obtained from Ogijo Market in Ogun State, Nigeria. Cocoyam flour was produced using the method described by Okpala and Okoli [13]. The cormels were washed with portable water to remove dirt, peeled with knife, sliced to reduce the surface area and blanched at 80^{o}C for 4 minutes. The blanched slices were dried in the oven, milled and sieved through 100µm mesh size.

2.1.2. Production of Cookies

Cookies were produced using modified recipe described by Okaka, [14]. The fat and sugar were mixed until fluffy. Egg and milk were added while mixing continued for about 40 minutes. Appropriate amount of flour, baking powder, nutmeg, vanilla, flavouring and salt were introduced into the mixture. The dough were cut into shapes and baked in the oven.

Table 1. Production Recipes Used in Dough Formation

INGREDIENT	QUANTITY
Flour	500g (wheat 450g, cocoyam 50g)
Fat	200g
Sugar	125g
Salt	5.0g
Egg	$2^{1/2}$ whole eggs
Milk powder	$7^{1/2}$ teaspoonful
Nut meg	1.5g
Vanilla flavouring	$2^{1/2}$ teaspoonful
Baking powder	5g

Source: Okaka, [14].

2.2. Experimental Design

RSM was used to optimize the baking temperature and time. The two independent variables in this procedure are baking temperature (X_1) and baking time (X_2). Thirteen combinations (5 centre points and 8 non centre points) were performed in random order according to a central composite rotatable experiment design configured for two factors and five levels.

Table 2. CODED LEVELS OF INDEPENDENT VARIABLES

VARIABLES	-α	-1	0	+1	+α
X_1 (°C)	149.69	160	185.00	210	220.36
X_2 (Min)	11.89	15	22.50	30	33.11

Where: $\alpha = 1.4141$, X_1 = baking temperature, X_2 = baking time.

2.3. Methods

2.3.1. Moisture Content

1.0g of the crushed sample was weighed into the sliced dish. The silica dish and the content were placed in the oven at 105°C for 24 hours. It was cooled in the desiccators to the room temperature. The content with the container was weighed and later placed back in the oven for another 24 hours to ensure complete drying [15].

2.3.2. Mechanical Properties

The selected mechanical properties investigated were force at break, energy to break and break strength. They were carried out using universal texturometer.

2.3.3. Sensory Evaluation

The method described by Iwe [16] was employed. The cookies were assessed by 20 panelists and evaluated on 9-point hedonic scale where 9 represented like extremely and 1 represents dislike extremely.

2.4. Statistical Analysis

Second order polynomial model was fitted to determine relationship between dependent variables, moisture content, force at break, energy at break, break strength, overall acceptability and independent variables (X) as shown in Eq. 1

$$Y = \beta o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{33} X_3^2 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 \quad (1)$$

Where $\beta o+\beta_1-\beta_2$, $\beta_{11}-\beta_{22}$ and β_{12} are regression coefficient for interception, linear, quadratic and interaction coefficients respectively, X_1-X_2 are coded independent variable and Y is the responses [17].

2.5. Optimization of Processing Variables

According to the method of Stat-Ease, [17], response 1(moisture content), response 2 (force at break) and response 3 (energy at break) were used for the optimization of processing variables.

3. Results and Discussion

3.1. Effect of Baking Time and Temperature on Moisture Content of Cookies

The effect of baking time and temperature on the moisture content of cookies are presented as 3D surface plot in Figure 1. The moisture content of the cookies ranged from 4.43 - 8.49%. There was significant decrease in the moisture content of the cookies as the baking time and temperature increases. The model for the moisture content (R^2=0.82) had a positive quadratic terms (baking temperature), a negative quadratic terms (baking time) and a positive linear terms. The moisture content was significantly ($P<0.05$) affected by X_1 and X_2^2 (baking temperature and quadratic effect of baking temperature). Moisture content is the amount or quantity of water present in a food sample, the lower the moisture content of a food sample, the longer the shelf life. It could be determined by the extent of gelatinization of starch in dough during baking. It was discovered that the effect of the temperature on the residual moisture content in the cookies was more significant than that of time. Slade and Levine [18] reported the amount of moisture in cookies could have some implication on the mechanical properties and the overall acceptability.

3.2. Effect of Baking Time and Temperature on Force at Break of Cookies

The effect of baking time and temperature on the cookies are presented as 3D surface plot in Figure 2. The force at break of the cookies ranged from -6 - 90.83N. The force at break significantly increases with the baking time and temperature. The model for force at break (R^2=0.94) had a positive quadratic terms (baking time and temperature) and a positive linear terms. The force at break was significantly ($P< 0.05$) affected by X_1 and X_2 (baking time and temperature) and X_2^2 (quadratic effect of baking temperature). The force at break is the force required or needed to be applied on a sample to make it break. This could be affected by the width, thickness and the moisture content of the samples. It was discovered that as the moisture content increased, the force at break decrease and as the moisture content decreased, the force are break increase.

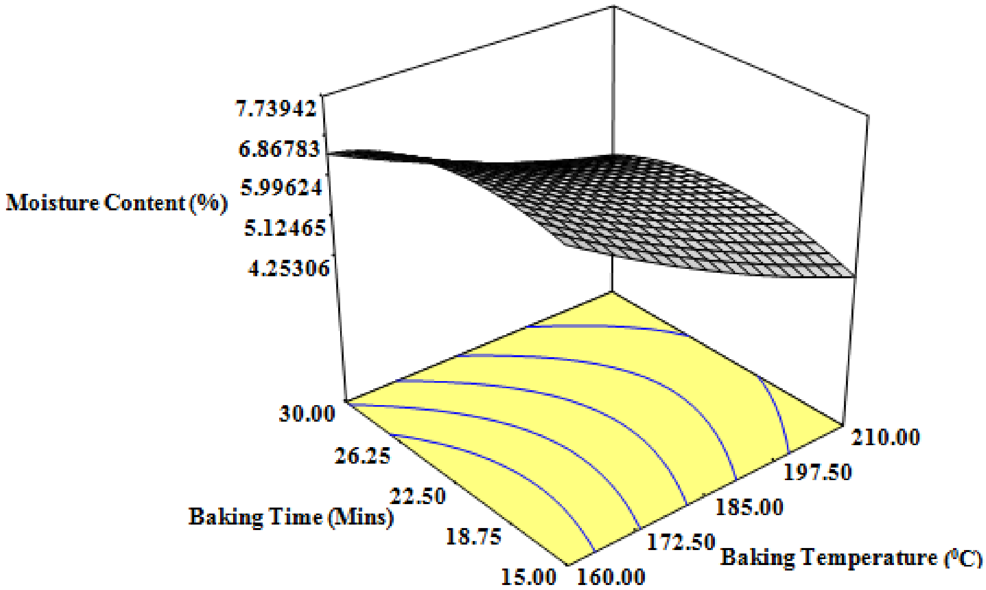

Figure 1. Effect of baking time and temperature on moisture content of cookies

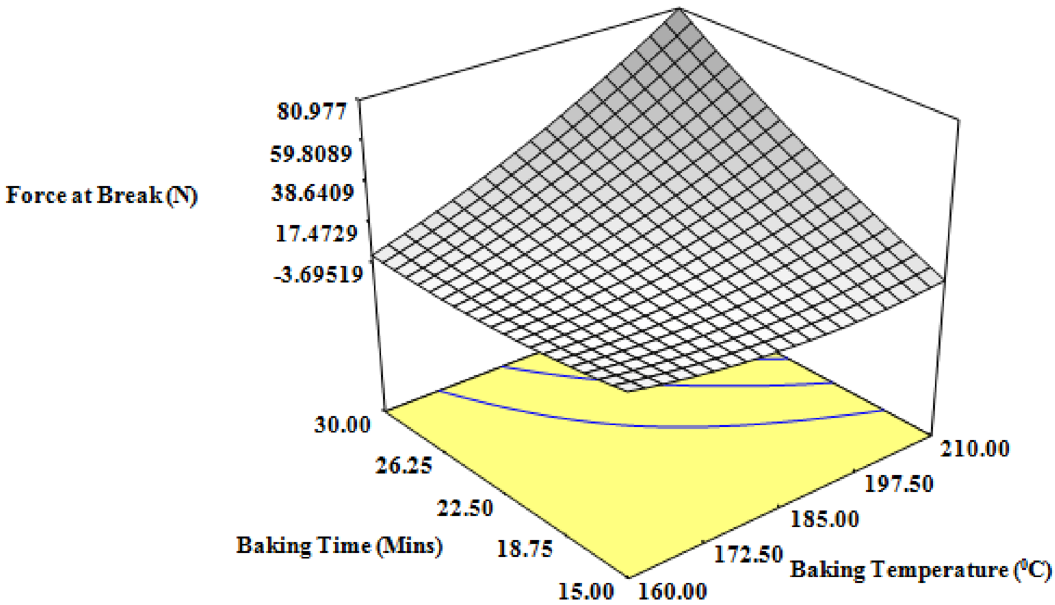

Figure 2. Effect of baking time and temperature on force at break of cookies

3.3. Effect of Baking Time and Temperature on Energy to Break of Cookies

The effect of baking time and temperature on energy to break of cookies are presented as 3D surface plots in Figure 3. The energy to break of the cookies depends on both baking temperature and time and the value ranged from 0.0027 - 0.422N/m. The energy required to break the cookies significantly increases with baking time and temperature. The model (R^2=0.77) had a positive quadratic terms (baking time and temperature) and positive linear terms. The energy to break was significantly ($P<0.05$) affected by X_2 (baking time). The energy to break shows how strong the sample was or hold up well under stress, which was highly dependent on the moisture content of the samples. The values observed in this work was similar to the values reported by Yadav *et al.,* [19].

3.4. Effect of Baking Time and Temperature on Break Strength of Cookies

The effect of baking time and temperature on break strength of cookies are presented as 3D surface plot in Figure 4. The breaking strength depends on both baking time and temperature as the values ranged from 0 - 0.90.83N/mm^2. Break strength of cookies increased significantly with increase in baking time. The model for the break strength (R^2=0.96) had a positive quadratic linear terms (baking temperature and time) and a positive linear terms. The break strength was significantly ($P<0.05$) affected by X_1 and X_2(baking temperature and time) and X_1^2 and X_2^2 (quadratic effect of temperature and time). It was observed that the effect of the temperature on the cookies was more significant than the time. The values obtained were lower compared to the values reported by Yadav *et al.,* [19].

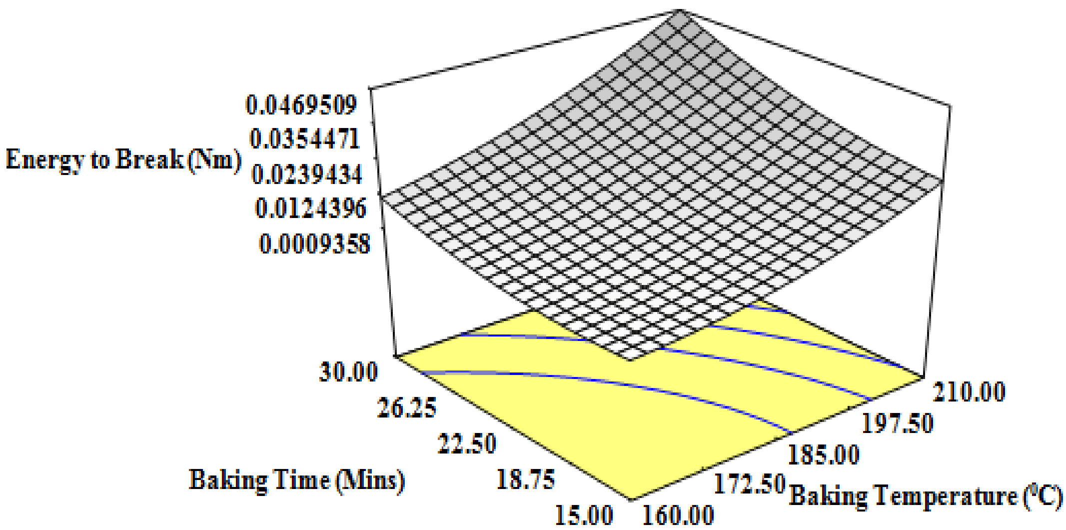

Figure 3. Effect of baking time and temperature on energy to break of cookies

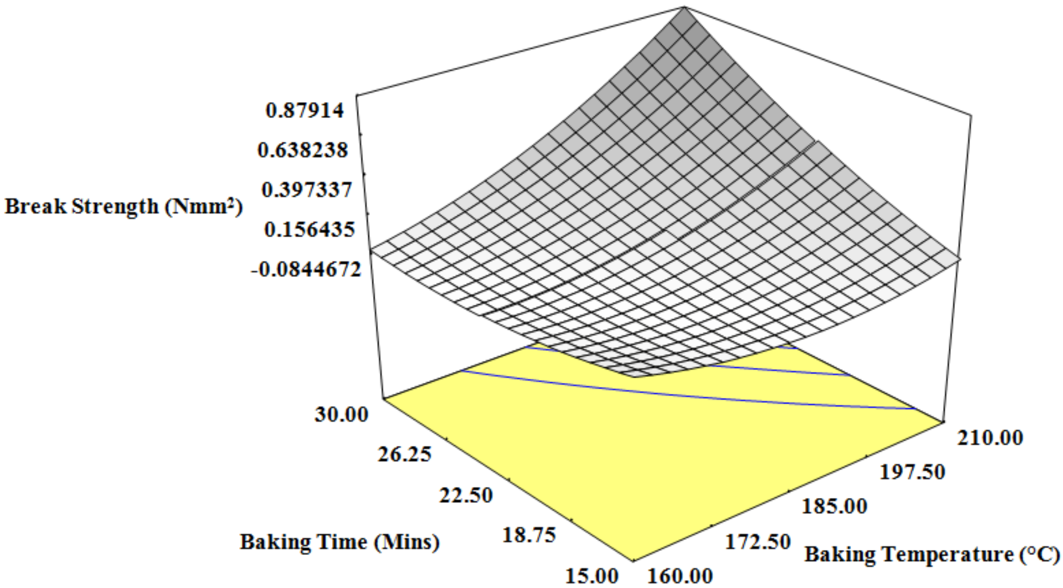

Figure 4. Effect of baking temperature and time on overall acceptability of cookies

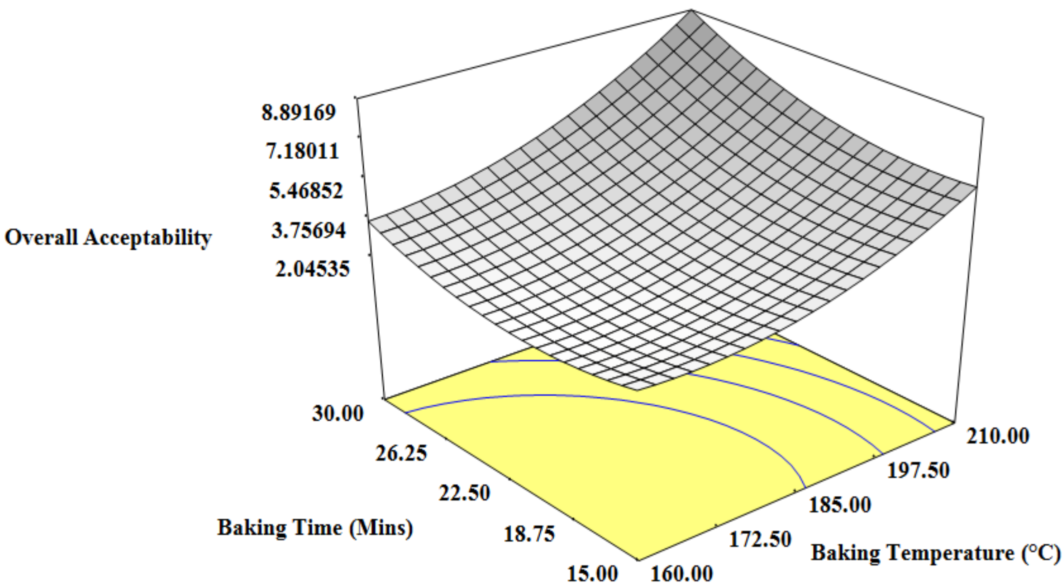

Figure 5. Effect of baking temperature and time on overall acceptability

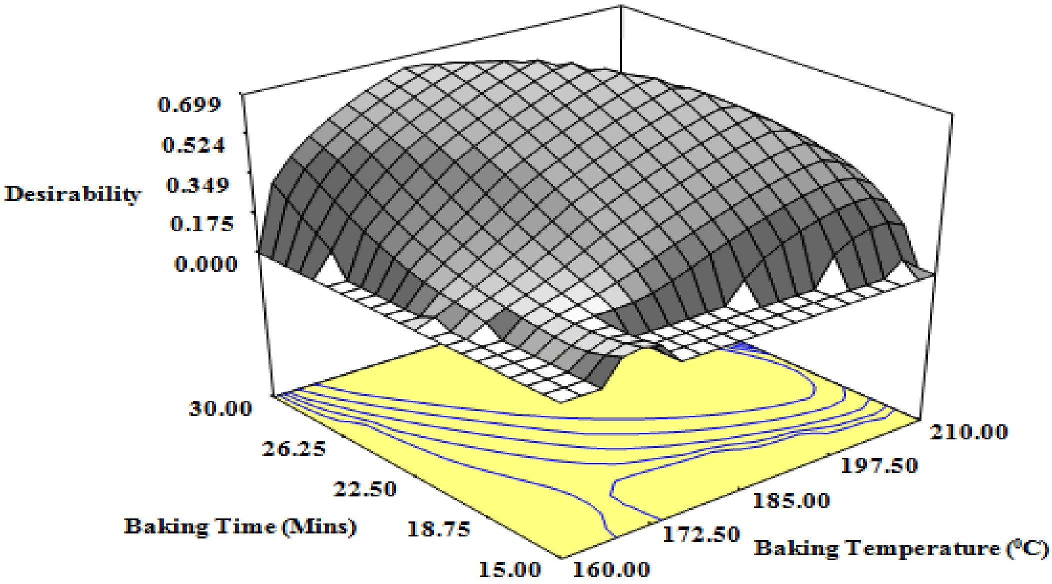

Figure 6. Effect of baking temperature and time on desirability of cook

Table 3. Regression coefficients, coefficient of determination (R^2) and analysis of variance of regression models for baking temperature and time for cookies

Coefficients	Moisture Content	Force at Break	Energy to Break	Break Strength	Overall Acceptability
β^o	28.31**	742.59***	0.23*	11.37***	67.61***
X_1	- 0.21***	- 6.05***	-0.00**	- 0.10***	- 0.66***
X_2	0.22	- 23.49***	- 0.00*	- 0.28**	- 1.18**
X_1^2	0.00	0.01*	0.00	0.00**	- 0.00***
X_2^2	0.00*	0.08	0.00	0.00*	0.02**
AB	0.00	0.12***	0.00	0.00*	0.02**
R^2	0.82	0.94	0.77	0.98	0.93
F Value	6.56	20.95	4.82	31.58	18.86

Significant levels *** 0.001, ** 0.01, * 0.1.

3.5. Effect of Baking Temperature and Time on the Overall Acceptability of Cookies

The effect of temperature and time on overall acceptability of cookies are presented as 3D surface plots in Figure 5. The values ranged from 2.20 - 8.80. From the sensory evaluation, it was observed that the baking temperature and time affected the final quality. As the baking temperature and time increased, the overall acceptability of the cookies significantly increases. The model (R^2=0.93) had a positive quadratic terms (baking temperature and time) and a negative linear terms. The overall acceptability was significantly ($P<0.05$) affected by X_1 and X_2 (baking temperature and time) X_1^2 and X_2^2 (quadratic effect of baking temperature and time).

3.6. Optimization of the Process Variables

The optimization conditions for the production of cookies are shown as 3D in Figure 6. The best processing conditions are baking temperature of 190.15°C and baking time at 27.00 Minutes with desirability of 0.700.

4. Conclusion

This research has been able to show that the varying temperature and time combinations significantly affect the moisture content and the mechanical properties (break strength, force at break and energy at break) and overall acceptability of the cookies, it was discovered that the effect of the temperature was more significant than the time in all properties studied. The optimum conditions for the processing variables were baking temperature of 190.15°C and baking time of 27 minutes with desirability of 0.700. The 10% inclusion of cocoyam flour to wheat flour will not only increase the utilization of underutilized cocoyam crops but create more varieties of cookies in the baking Industry and also meet the demand of the growing populace.

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