PERFORMANCE EVALUATION OF ROASTING PROCESS USING CENTRAL COMPOSITE DESIGN (CCD)

[1]Adebesin, A.A. & [2]Ganiyu, Y.O
Department of Mechanical Engineering & Nigerian Institute of Leather and Science Technology,
The Federal Polyechnic, Ilaro Ogun State, Nigeria & Zaria, Kaduna State, Nigeria
akeem.adebesin@federalpolyilaro.edu.ng & yusuffg470@gmail.com

Abstract

The research work is geared towards development of an acceptable limit for selected roasted food in a control process using Smart temperature controlled roasting device. Sensory qualities of roasted samples were evaluated through organoleptic experiment to accesses the important roasting characteristics (aroma, taste, colour and texture) that influence human for consumption and analyzed using Response Surface Methodology (RSM) of Design Expert-10 at different roasting temperatures (1600C to 2400C), roasting times (10min to 50min) and roasting distances (50mm to 150mm). The results show that roasting temperature, time and distance significantly (p<0.05) affected sensory qualities of roasted plantain while that of yam significantly (p<0.05) affected by temperature and time and attributes of roasted groundnut significantly (p<0.05) affected by temperature only. The correlation coefficients (R2) of the proposed equations for all quality indicator of roasted samples was more than 0.7, with the lack of fit being insignificant (p<0.05). Interaction of roasting factors become more significant (p<0.05) in the preparation of roasted plantain and yam than groundnut. The optimized roasting parameters for individual roasted food items are 160^{0}C, 11min and 150mm, were found to be the optimal parameters for roasting Groundnut with roasting efficiency of 68.4% but 220^{0}C, 36min and 138mm for roasted yam, and 186^{0}C, 38min and 149mm for roasting plantain with roasting efficiency of 66.1% and 94.1% respectively.

***Keywords**: Groundnut, Plantain, Yam Roasting, Sensory qualities, Temperature, Time, Distance, Physicochemical properties, Organoleptic.*

Introduction

Roasting or grilling is the process of applying of heat for cooking foods. This process involves the evaporation of the moisture content of any type of food, shrinking the fibre and making the food tough (Onwukeme *et al.,* 2016). This processing involves application of engineering technology with the aid of food science, to change or alter the appearance, taste, aroma, shape, or colour of selected agricultural food produce in order to satisfy human daily needs of food. Various techniques are available for food processing, most of which are applied in the food industry. These techniques involved temperature processing with the raw material preparation, which include size reduction, mixing, and processing by application of heat (Fellows, 2009). Generally, the size of food materials is often reduced during processing due to reasons; chief among are: reduces the drying time, exposing more surface area to the hot air and gives rise to faster cooking (Manguiat and Fang 2013).
Yam is another economically useful plants belonging to the *genes dioscorea*, or the tubers or rhizomes of these plants (Jimoh, *et al.,* 2008). The yam tuber is prepared for consumption in a variety of ways including boiling, frying, baking and roasting.

Roasted plantain, yam, and groundnut are becoming popular as form of refreshment and sometimes-major food in Nigeria. Sellers position themselves close to government ministries and agencies or other private organizations for easy accessibility (Mato and Onajin-Obembe, 2008; (Oke, 2014). However, the sensory qualities (like colour and appearance, taste and aroma) of roasted food in relation to temperature, time and distance variation has not been demonstrated. This study was carried out to determine the sensory values of roasted groundnut, ripped plantain and slice yam at control roasting conditions, and then establish optimal parameters, main and interaction effect, and sensory qualities model.

Methodology

Freshly harvested groundnut, ripe plantains and Yam, *white type*) were purchased from Samaru central market, Zaria, Kaduna. The foods were separated from their external coat and sliced in case of yam to prepare the direct surface of food in contact with hot air.

Methods

Experimental Design

Two well known software named Design Expert (2010 version) and Rapid Surface Methodology (RSM) were used in this research study. It generates a nonlinear multivariate model which can be used to provide sufficient and reliable response values, develop a mathematical model from the experimental design so that the data obtained can fit in order to determine the optimum value of the independent variables. Each independent variable has five level: $-\alpha$, -1, 0 +1 and $+\alpha$ (Boundary conditions: $-\alpha$ and $+\alpha$; low and high respectively: -1 and +1 while 0 is center) as shown in Table 1 while signal to noise ratio (S/N) for levels were measured according to equation 1 in order to minimize the variances in sensory attribute values

$$\frac{S}{N} = -10Log\left[\frac{1}{n}\sum\frac{1}{Y^2}\right] \quad \text{Eq. (1)}$$

Table 1: Central Composite Level for Independent Variables

PARAMETERS	UNIT	LOW	HIGH	$-\alpha$	$+\alpha$
Roasting Temperature	Degree	180	220	160	240
Roasting Time	Min	20	40	10	50
Roasting Distance	mm	75	125	50	150

Process parameters, which are independent variables, were selected with respect to a Central Composite Design (CCD) of Response Surface Methodology (RSM) by the Design Expert. Other independent variables like temperature (X1), time (X2) and distance (X3) were varied from 160^0C to 240^0C roasting temperature, 50mm to 100mm roasting height and 10 minutes to 50 minutes roasting time respectively are ranges commonly used in convectional roasting.

$$Y = \beta_o + \sum_{i=1}^{k}\beta_i X_i + \sum_{i=1}^{k}\beta_{ii}X_i^2 + \sum_i^k\sum_j^k\beta_{ij}X_iX_j + e \quad \text{Eq. (2)}$$

Where;

β_0 is the regression coefficient,

$$N = k^2 + 2k + c_p \quad \text{Eq. (3)}$$

N = Number of joints

X = Independent variable

Y = Dependent variable

S/N = Noise ratio

n = Number of experimental run

e = Pure error

DOE = Design of Experiment

CCD = Central Composite Design

ANOVA = Analysis of Variance

+ α (Alpha) and – α (Alpha) = High variable factor and Low variable factor.

+ 1 and – 1 = Intermediate factor

0 = Centre factor

β = Beta (Regression coefficient)

A detailed ANOVA framework for assessing the significance of the process parameters is also provided in this study. The degree of significance for all the terms in the model were determined statistically at probability ($p<0.05$) and all the statistical analyses were performed using Design Expert Software (DOE, 2010).

Sensory Analysis

The sensory quality of roasted food is the summation of all physical and chemical characteristics of the edible roasted samples that influences human senses and results in acceptability judgments by the consumer (Mridula *et al*., 2007). Sensory measurands such as colour and appearance, taste and aroma for different samples were collected and assessed through organoleptic experiment using hedonic scale. Fifty trained panelists were selected for organoleptic experiment as means of data collection and the selection was based on medical history, educational level and field of specialization, and favorite roasted food. In order to combine effects of the independent variables on the responses, a controlled experimental set- up was chosen according to CCD setting for three mutually independent variables. The experimental set- up of actual level of the variables is shown in Table 2.

Table 2: Experimental Table

Std	Run	Space Type	A(X1)	B(X2)	C(X3)	Sensory attributes (groundnut)	Sensory attributes (yam)	Sensory attributes (plantain)
			degree	min	mm			
2	1	Factorial	220	20	125	23.0771	24.7281	23.4011
4	2	Factorial	180	20	75	25.5616	24.3482	25.3569
5	3	Axial	160	30	100	24.2646	20.8194	23.3277
9	4	Axial	200	30	50	20.2663	25.8574	24.4
8	5	Axial	200	50	100	23.6208	24.7712	22.5882
1	6	Factorial	220	40	75	20.435	24.7353	21.991
7	7	Axial	200	10	100	24.2535	21.1461	25.7321
6	8	Axial	240	30	100	17.4077	22.7473	20.8194
10	9	Axial	200	30	150	22.4484	25.1923	25.1511

3	10	Factorial	180	40	125	24.3048	22.4413	25.1511
11	11	Center	200	30	100	20.3763	25.2151	24.93

Roasting Procedures for Smart Temperature Controlled Roaster

Groundnut cobs (2900g), plantain (1160g) and slice yam (3000g) were placed one after the other into the rotary mesh, which was enclosed in a roasting chamber of smart temperature controlled roaster and was subjected to roasting under roasting conditions set for each experimental runs prepared by Design Expert (Table 2). To ensure that the conditions were stable, the roaster left to attain required roasting temperature prior the placement of food in the rotary mesh. The velocity of the rotating mesh was at a constant value of 1150rpm and as the measured value for roasting reached setting point, food was loaded and temperature of the measured value dropped because of thermal differences between raw food and hot chamber but in most cases, the temperature drop was not below desire temperature setting value to activate temperature control fan installed in the chamber. Therefore, fan continues working throughout the process.

Results and Discussion

Statistical analysis

A summary of linear terms, and quadratic and cross products terms as shown in Table 3 and Table 4 respectively. The cross product (X_1X_2, X_1X_3 and X_2X_3) and quadratic ($X^2{}_1$, $X^2{}_2$ and $X^3{}_2$) terms were highly important for the roasting preparation of yam and plantain whereas linear terms (X_1, X_2 and X_3) were important for roasting preparation of all three foods (groundnut, yam and plantain). The significant effect of roasting parameters on sensory qualities of roasted groundnut, yam and plantain are shown in Table 3. This implies that the grilling temperature, time and distance significantly ($p<0.05$) affected sensory qualities of roasted plantain while that of yam significantly ($p<0.05$) affected by temperature and time and attributes of roasted groundnut significantly ($p<0.05$) affected by temperature only. The correlation coefficients (R^2) of the proposed equations for all quality indicator of roasted samples was more than 0.7, with the lack of fit being insignificant ($p<0.05$) (Figure 1) and the regression coefficients (Table 5) for the model showing the relationship between roasting conditions and sensory qualities variations. These results indicate that the proposed model equations (4) and (5 and 6) were linear and polynomial respectively.

$$Y_{maize} = \beta_1 X_1 + e \quad \text{Eq. (4)}$$

$$Y_{yam} = \beta_1 X_1 + \beta_2 X_2 + \beta_{11} X_1^2 + \beta_{12} X_2^2 + \beta_{13} X_1 X_3 \quad \text{Eq. (5)}$$

$$Y_{plantain} = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{23} X_2 X_3 + \beta_{13} X_1 X_3 \quad \text{Eq. (6)}$$

Table 3 showed that interaction of factors become more significant ($p<0.05$) in the preparation of roasted plantain and yam than groundnut. A comparative (ANOVA) test carried out revealed the most effective process parameters, which influence the sensory attribute of roasted food. This research study could be likened to the work of Adisa, (2018) who designed and development a Charcoal Fired Plantain Roasting Machine and determined the roasting time with reference to its sensory quality. The Analysis of Variance indicated that the process parameter(s) has/have significance ($p<0.05$) contribution to the model. Values above 0.1 indicate the model terms are not significant.

Table 3: Linear Effect of Process Conditions on Sensory Qualities

Source	Sum of Square					
	df	Groundnut (S.Q)	Df	Yam (S.Q)	df	Plantain (S.Q)
Roasting Temperature	1	48.28*	1	1.87**	1	3.15*
Roasting Time	1	2.22	1	6.57**	1	4.94*
Roasting Distance	1	0.3337	1	0.22	1	0.28**

*, **, ***, Significant at p<0.01, p< 0.05 and p<0.1 respectively. (S.Q)-Sensory Qualities

Table 4: Interaction Effect of Process Conditions on Sensory Qualities

Items	Sum of Square					
	X1X2	X1X3	X2X3	X^21	X^22	X^23
Yam	0.26	5.09**	0.093	16.12*	7.42*	
Plantain	0.034***	0.39**	1.13*	5.57*	0.40**	0.016***

*, **, ***, Significant at p<0.01, p< 0.05 and p<0.1 respectively.

Table 5: Regression Coefficients of Relationship between Roasting Conditions and Quality Changes in Foods.

Coefficient	Groundnut (S.Q)	Yam (S.Q)	Plantain (S.Q)
β_0	22.5469	25.4919	24.924
β_1	-0.00573*	0481975**	-0.627075*
β_2	-0.430358	0.906275**	-0.785975*
β_3	0.479125	-0.166	0.187775**
β_{12}		0.31225	-0.1133***
β_{13}		1.3812**	-0.328**
β_{23}		-0.1865	0.6519*
β_{11}		-0.91395*	-0.71336*
β_{22}		-0.62013*	-0.19171**
β_{33}			-0.0378***

*, **, ***, Significant at p<0.01, p< 0.05 and p<0.1 respectively. (S.Q)-Sensory Qualities

Table 6: Analysis of Variance for Roasted Qualities of Groundnut, Yam and Plantain

Source	Sum of Square					
	Df	Groundnut (S.Q)	Df	Yam (S.Q)	Df	Plantain (S.Q)
Model	3	53.25**	8	29.90**	9	25.35*

Residual	7	17.89	2	0.13	1	2.358e004
R^2		0.7485		0.9970		1.0000
Cor Total	10	71.14	10	30.03	10	25.35

*, **, ***, Significant at p<0.01, p< 0.05 and p<0.1 respectively. (S.Q)-Sensory Qualities

4.5.2 Statistical Properties of Model

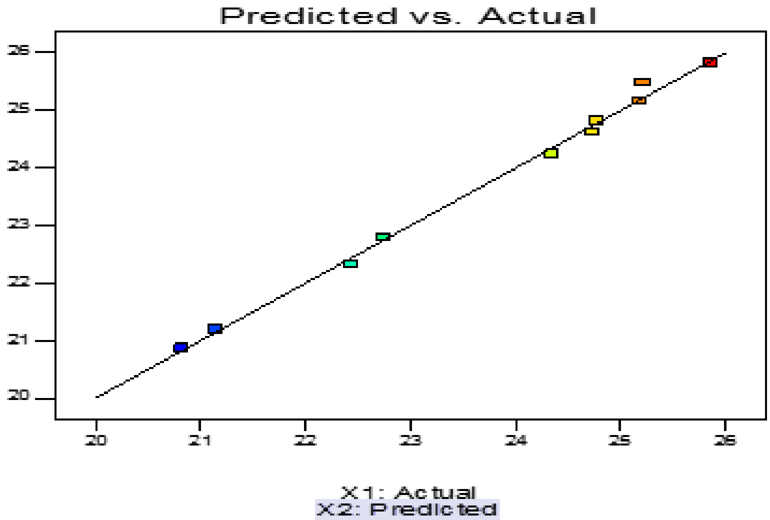

Figure 1: Predicted vs Actual of roasting effect on Sensory Quality of Groundnut

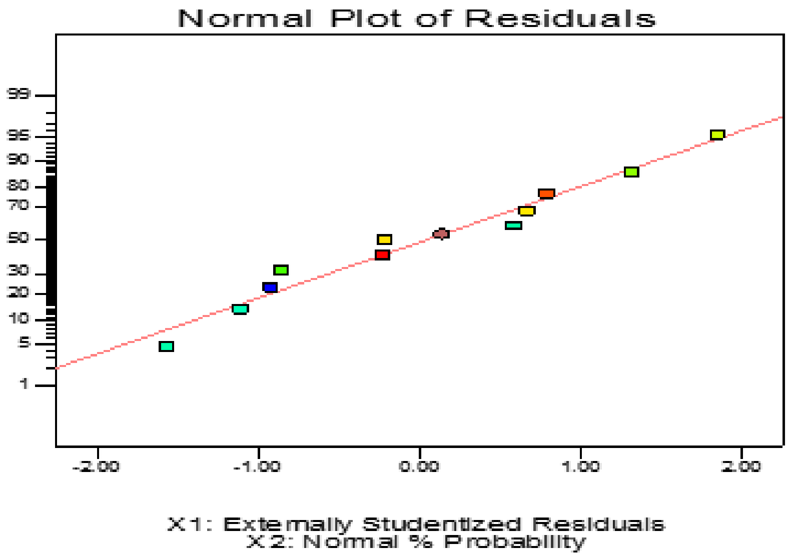

Figure 2: Predicted vs Actual of roasting effect on Sensory Quality of Yam

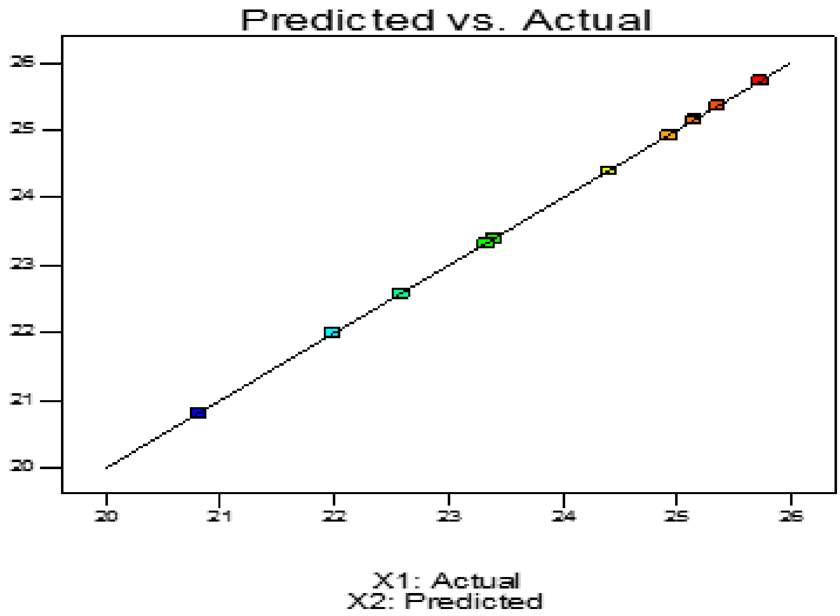

Figure 3: Predicted vs Actual of roasting effect on Sensory Quality of Plantain

Conclusion

Temperature, time and roasting height are three major factors that affect the sensory quality of roasted plantain at ($p<0.05$) significance level but roasted yam is significantly affected at ($p<0.05$) by temperature and time only. The optimized grilling parameters for individual food items including: 160^0C, 11min and 150mm have found to be the optimal parameters for roasting Groundnut but 220^0C, 36min and 138mm for roasted yam while 186^0C, 38min and 149mm found as optimal for roasting plantain. It was also concluded from the results that model formulated to predict sensory qualities of groundnut was simple linear regression and that of yam and plantain were polynomial.

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