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RESPONSE SURFACE METHODOLOGY FOR THE OPTIMIZATION OF SWEET POTATOES (Ipomoea batatas) DRYING PROCESS CONDITIONS

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Abstract. The aim was optimization of sweet potatoes (*Ipomoea batatas*) drying process conditions with RSM to obtain high quality product is very vital as improper drying conditions can affect the composition of the dried sweet potatoes and thereby increases the risk of running into deterioration of the nutrient contents of the product and loss. Matured sweet potatoes were processed by washing, peeling and cut into required size. Samples obtained were dried in triplicate using DHG-9101 laboratory drying oven at different temperatures of 60, 65, and 70$°C$ and time of 480, 540 and 600 minutes at thickness size of 4, 5 and 6 mm by employing Design of Experiment (DOE). Statistical analysis based on central composite design was carried out. The significant factors were identified. The optimum conditions obtained were at a temperature of 60$°C$, time of 480 minutes and thickness of 4 mm which resulted in final moisture content of 13.96%. From these results obtained, the use of response surface methodology in drying operation for optimizing sweet potatoes could be used. For further research, higher temperatures at lower drying time could be implemented. Also, other drying methods such as freeze drying and osmotic drying can be explored.

Keywords: Sweet potatoes, response surface methodology, oven, drying, process conditions.
AMS Subject Classification: 62M20, 80M50.
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1 Introduction

Sweet Potato (*Ipomoea batatas L.*) is a tuberous crop of great importance in the world economy and feeding. It is widely consumed fresh, and its industrialization is on the rise, especially in the production of starch and chips. Sweet Potatoes are also the fourth most important vegetable crop for human nutrition in the world (Ozturk et al., 2012; Tokusoglu et al., 2012). Nigeria is among the major producers of sweet potatoes, others are Uganda, China, Indonesia and Viet Nam. Several investigators had proposed numerous mathematical models for the thin layer drying of many agricultural products and porous materials (Inyang et al., 2019).

More so, sweet potato is rich in many kinds of nutritional components, such as starch, protein, dietary fiber, phenolics, vitamins, and minerals, etc, but lower fat content (Ozturk, 2012). It also exhibits some physiological properties, for example, regulating blood glucose and lipid, improving immunity, protecting from cancers and oxidation, etc., thus gaining much more

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extensive attention and researches in recent years (Wang et al., 2016; Feina et al., 2019).

Response surface methodology (RSM) is an effective technique which is widely used for optimizing the process parameters. The significant advantage of RSM is that it allows the evaluation of the independent variables and their interactions on the dependent variables with the reduced number of trials. RSM is often used to optimize the processing parameters and has the advantages of fewer experiments and higher accuracy(Feina et al., 2019). However, Response Surface Methodology (RSM) techniques were employed for analysis using Design Expert software. Response Surface Methodology (RSM) is one of the experimental designing methods which can surmount the limitations of conventional methods collectively and has an advantage that it reduces the number of experimental trials needed to evaluate multiple parameters and their interactions (Inyang et al., 2019).

Different processing drying methods are there Inyang et al. (2017b) for the processing of agricultural products and this may have great effect on the qualities of dried products but oven technique was chosen for the drying of sweet potatoes due to the convenient, cleanliness, ease to used, easy to regulate, drying system is less time consuming and also cost is relatively cheap.

However, the optimal drying conditions for sweet potato have not been reported widely by oven technique using RSM. Therefore, it is crucial to evaluate the process conditions around our vicinity with our local species. In this study, RSM was used to study the effects of drying process conditions parameters, such as temperature time, and determine the optimal conditions.

2 Materials and Methods

2.1 Preparation of samples

Fresh sweet potatoes were purchased at Use market, Uyo Local Government Area in Akwa Ibom State. The sample was then taken to the Engineering Laboratory, University of Uyo for the drying experiment. Samples was prepared same day, after washing to remove any form of dirt, the washed sample was left in a sieve to remove excess water then the outer skin was trimmed off. After, the sample was sliced into different thickness levels ranging between 2 - 6 mm. It was then weighed to obtain the initial weight before the start of drying operation which was done using DHG-9101 Laboratory Drying Oven. The thicknesses of sliced samples were measured using a Vernier slide Caliper to confirm the actual thickness of the samples which were then oven-dried at different temperatures.

2.2 Design of Experiment

Response surface methodology based on central composite design (CCD) was used to plan and design the experiment analysis using Design Expert software. The dependent variable was the moisture content (%) of the dried sweet potatoes and the independent variables were the drying temperature ($^{\circ}C$), drying time (min) and thickness (mm). The factors were varied with three elements as factorial points, axial/star point and center runs. The input factors and their levels are presented in Table 1. The range of the variables that were optimized is shown in Table 1. The experimental design made up of 20 runs was developed using Design Expert® 7.0.0 (Stat-ease, Inc. Minneapolis, USA). The results of the 20 experimental runs are shown in Table 2. The model parameters were estimated by applying multiple linear regression while analysis of variance (ANOVA) was used to assess the fit of the model.

The method of analysis and interaction of the independent and dependent variables was adopted from Amenaghawon et al. (2015) to establish the effect of the process parameters on the response.

Table 1: Factors and levels for the CCD experimental design plan

Factor	Name	Units	Type	Minimum	Maximum
A	Temperature	$^{\circ}C$	Numeric	56.59	73.41
B	Thickness	mm	Numeric	3.32	6.68
C	Time	min	Numeric	439.09	640.91

Table 1 Cont'd

Factor	Coded Low	Coded High	Mean	Standard Deviation
A	-1 $\leftrightarrow$ 60.00	+1 $\leftrightarrow$ 70.00	65.00	4.24
B	-1 $\leftrightarrow$ 4.00	+1 $\leftrightarrow$ 6.00	5.00	0.8478
C	-1 $\leftrightarrow$ 480.00	+1 $\leftrightarrow$ 600.00	540.00	50.87

Table 2: Generated values after experimental runs

Run	Drying Temperature($^{\circ}C$)	Thickness(mm)	Drying Time (min)	Moisture Content (%)
1	70	4	480	12.01
2	60	4	600	11.5
3	65	5	540	18.5
4	65	5	540	15.9
5	70	4	600	9.2
6	65	6.69	540	17.5
7	60	6	480	16.54
8	60	6	600	15.1
9	60	4	480	14.13
10	65	5	540	18.2
11	70	6	480	12.4
12	65	5	540	14.1
13	56.60	5	540	14.85
14	73.41	5	540	10
15	65	3.32	540	11.3
16	70	6	600	9.9
17	65	5	540	13.5
18	65	5	640.91	14.32
19	65	5	439.10	17.17
20	65	5	540	17.43

3 Result and Discussion

3.1 Model Fitting and Analysis of Variance

The results of the 20 experimental runs are shown in Table 2. Equation 3 is the second order statistical model obtained after applying multiple regression analysis to the experimental data. The equation represents Moisture content as a function of drying temperature (A), Thickness (B), and drying time (C).

$$\begin{aligned}\text{Moisture Content} &= +16.319 + -1.60481 * A + 1.28339 * B + -1.0378 * C + \\ &\quad -0.615 * AB + -0.155 * AC + 0.1875 * BC + -1.66941 * A^2 + \\ &\quad -0.971143 * B^2 + -0.495614 * C^2.\end{aligned}$$

The results obtained after performing ANOVA are presented in Table 3. The model F value of 4.24 implies that the model is significant. Also, the model F value of 4.24 have very low probability value ($p = 0.0171$) implies significant model fit. From the regression model, A, B, A^2 are significant model terms. The lack of fit value of 0.47 implies that the lack of fit is not significant relative to the pure error and non-significant lack of fit is good.

Table 3: ANOVA Results for model representing Moisture content

Sources	Sum of Squares	df	Mean Square	F-value	p-value	
Model	126.45	9	14.05	4.24	0.0171	Significant
A-Temperature	35.17	1	35.17	10.61	0.0086	
B-Thickness	22.49	1	22.49	6.78	0.0263	
C-Time	14.71	1	14.71	4.44	0.0614	
AB	3.03	1	3.03	0.9125	0.3620	
AC	0.1922	1	0.1922	0.0580	0.8146	
BC	0.2813	1	0.2813	0.0848	0.7768	
A^2	40.16	1	40.16	12.11	0.0059	
B^2	13.59	1	13.59	4.10	0.0704	
C^2	3.54	1	3.54	1.07	0.3258	
Residual	33.16	10	3.32			
Lack of Fit	10.60	5	2.12	0.4697	0.7868	not significant
Pure Error	22.56	5	4.51			
Cor Total	159.61	19				

Table 4: Statistical information for ANOVA for Moisture Content

Parameter	Value
R-squared	0.7922
Adjusted R-squared	0.6053
Predicted R-squared	0.2934
Mean	14.18
Standard Deviation	1.82
C.V%	12.84
Adequate Precision	6.5883

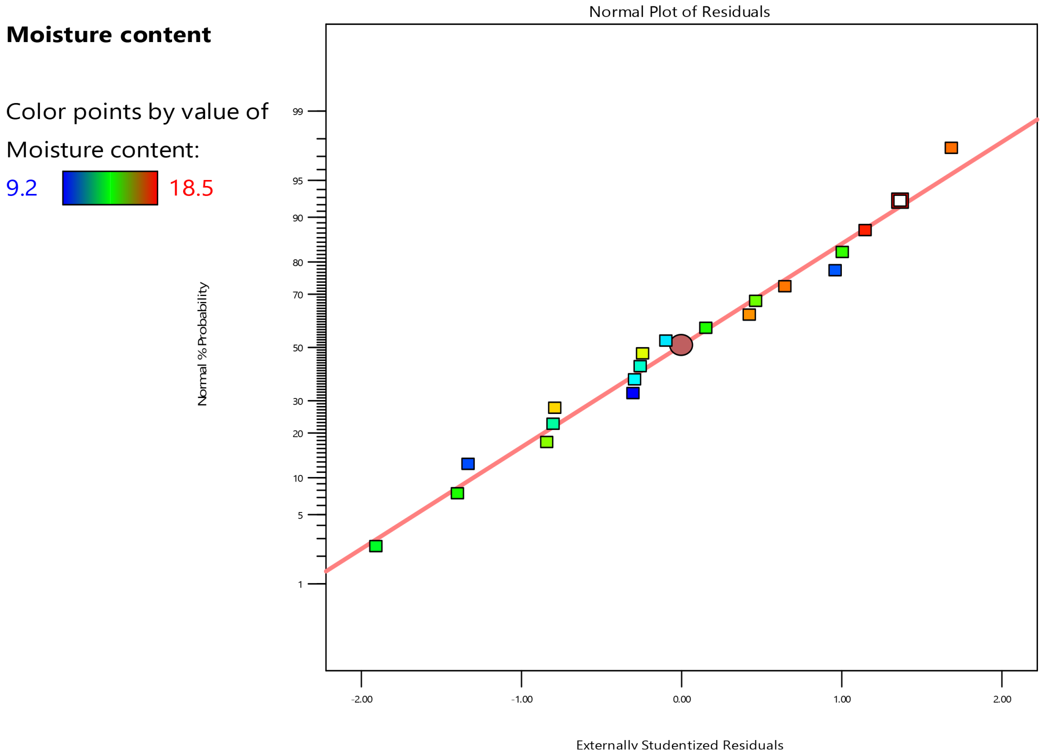

Figure 1: Normal probability plot for Moisture Content

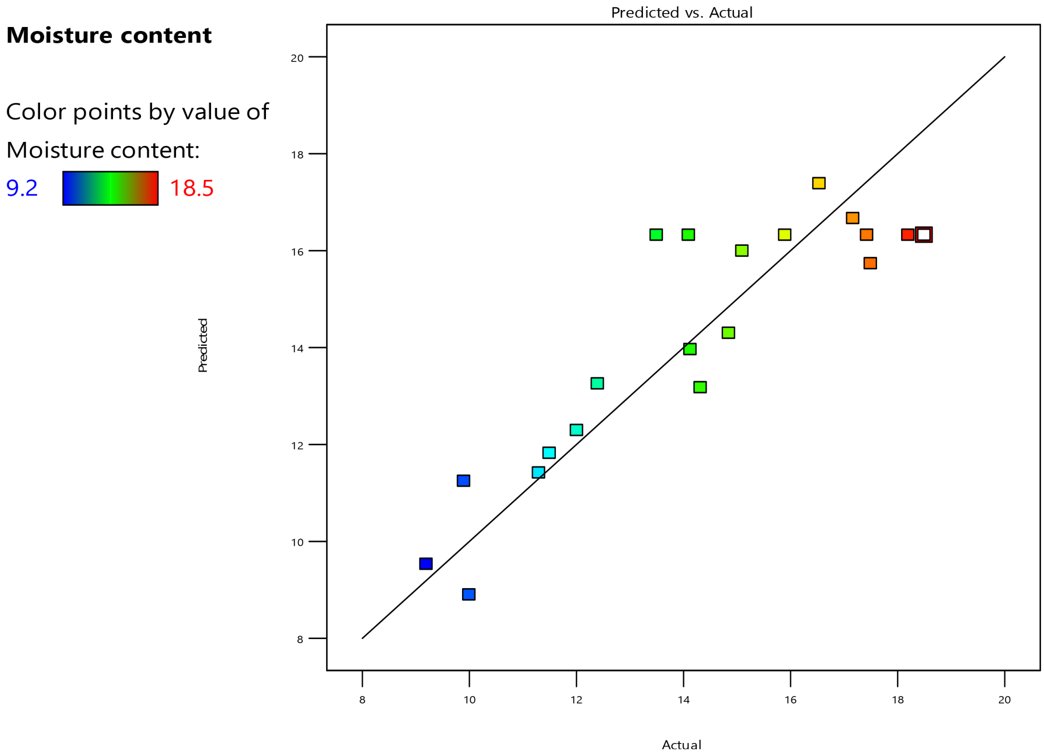

Figure 2: Parity Plot for Moisture Content Model

Table 4 shows that the coefficient of determination (R^2) of the model was 0.7922 indicating that the model adequately represented the relationship between the independent variables and the chosen response. An R^2 value of 0.7922 shows that the model was able to account for 79.22% of the variability observed in the response and the remaining 20.78% was as a result of chance.

The coefficient of variation (C.V.) was obtained as 12.84. This parameter indicates the degree of precision with which the experimental runs were carried out. Montgomery, 2005 reported that a low value of C.V indicates a high reliability of the experiment. The Adequate precision value was obtained as 6.5883. According to Cao et al. (2009), this parameter measures the signal to-noise ratio, and a ratio greater than 4 is generally desirable.

The adequacy of the quadratic model was further verified by running diagnostics on the model. The normal probability plot for the model representing moisture content is presented in Figure 1. The normal probability plot indicates whether the residuals follow a normal distribution, i.e. follow the straight line. The clustering of the points around the straight line as shown in Figure 1 shows that the residuals indeed follow a normal distribution.

Furthermore, Figure 2 shows the parity plot of the response for Moisture content. It is a plot of the predicted response values versus the experimental response values. The purpose is to detect a value, or group of values, that are not easily predicted by the model. Comparison of the experimental values of the response and those predicted by the statistical model showed that there was an acceptable level of fit between the experimental and model predicted results. This is evident from the fact that the data points all clustered around the 45° diagonal line showing that there was minimal deviation between experimental and predicted values thus indicating optimal fit of the model.

3.2 Response Surface Plots

Response surface plots were generated from the statistical models to examine the interactions between the independent variables and to determine the optimum levels of the variables. The plots show how drying temperature, thickness and drying time affect the moisture content in sweet potatoes. Figure 3 shows moisture content as a function of temperature and thickness. At constant Temperature, an increase in thickness results in an increase in moisture content. The negative effect of an increase in moisture content is the reduction in shelf life of the sweet potatoes. Also at constant thickness, an increase in temperature results in a decrease in moisture content. With increasing Thickness and Temperature, the moisture content showed a significant decrease.

Figure 4 shows moisture content as a function of time and temperature. At constant temperature, an increase in time shows a slight decrease in moisture content. The negative effect of this would be the time wasted for a little or no change in moisture content. But varying (increasing) temperature at constant time shows a significant decrease in moisture content. Temperature in both cases had significant effect in the reduction of moisture content while thickness of the sweet potatoes also determines the loss in moisture content.

Numerical optimization of the response was carried out to optimize the moisture content. The values of the independent variables during numerical optimization were fixed within the experimental range as shown in Table 1. After evaluating the model graphs and the solutions suggested by the numerical optimization package, the optimum conditions were chosen as the one with the highest desirability value. The optimization results revealed that the optimum moisture content was obtained as 13.960 at optimum conditions of temperature ($60°C$), thickness (4 mm) and time (480 min). Similar results for Oven drying of various food products has been recorded for plantain Inyang et al., 2019, bell pepper Odewole & Olaniyan 2016.

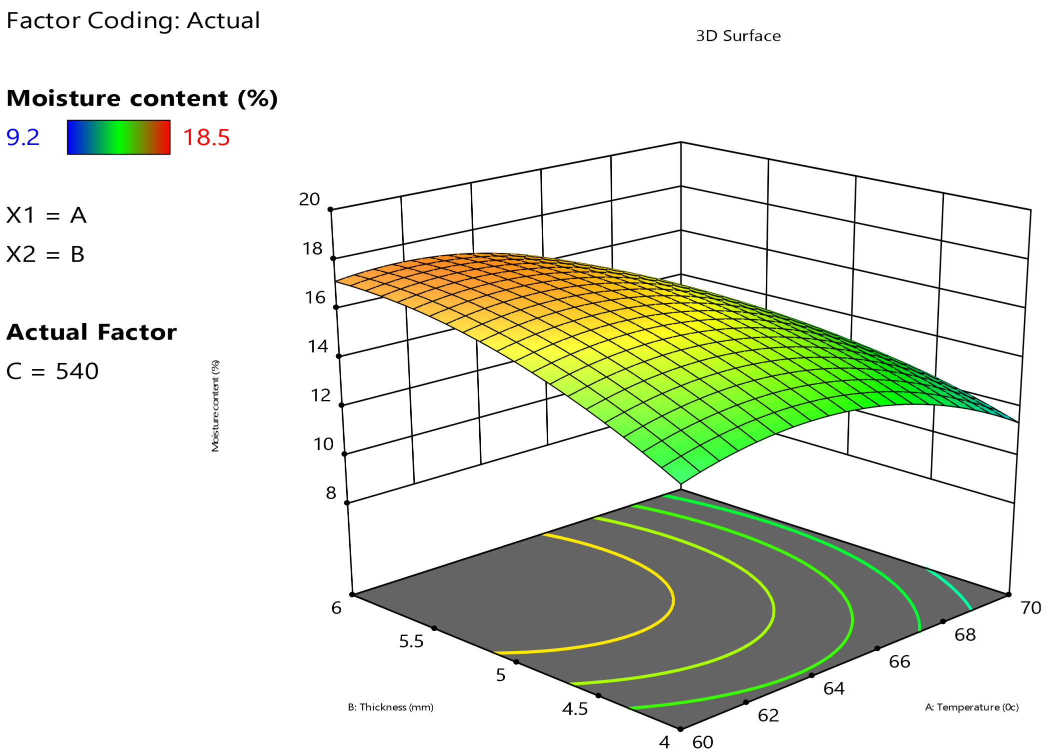

Figure 3: Response surface plot showing the effect of Temperature and thickness

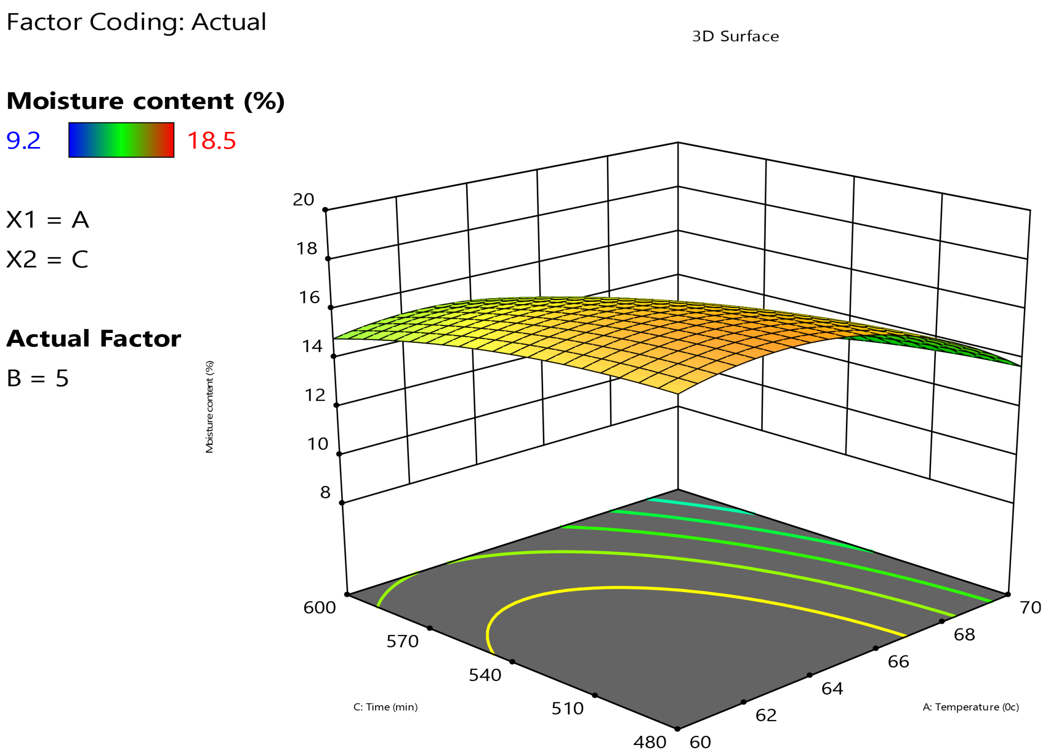

Figure 4: Response surface plot showing the effect of Temperature and Time

4 Conclusion

The modeling and optimization of the Moisture content in sweet potatoes (*Ipomoea batatas*) drying was carried out using a three variable central composite design for response surface methodology. The second order statistical model developed was statistically significant and did not show lack of fit. The moisture content in the sweet potatoes was significantly affected by temperature, thickness and time. Optimum moisture content value of 13.960% was obtained at optimum conditions of temperature ($60°C$), thickness (4 mm) and time (480 min).Validation of the model indicated no significant difference between experimental observations and model prediction. The Model F-value of 4.24 implies that the model is significant. Also, the model P-values ($I = 0.05$) indicates that model terms are significant. Also, lack of fit F-value of 0.47 shows that the lack of fit is not significant relative to the pure error. Further research could explore with other drying methods such as freeze drying and osmotic drying; lower temperatures or higher than what were used and lesser thickness can be employed.

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