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Full Length Research Paper

Effect of Temperature, Drying time and Thickness of Sliced Yam on Weight Loss of Yam during Drying

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Abstract
Drying is one of the most effective post harvest operations being carried out on agricultural products especially on tubers to preserve its shelf life. In this research, drying process in yam was investigated using drying temperature, time of drying and the thickness of the sliced tuber. The Response Surface Methodology (RSM) was employed to analyzed the result of the investigation. Empirical results shows that the linear effect of thickness of sliced tubers, and the interaction of temperature and time of drying had significant effect on weight loss of the sliced tubers at $p < 0.05$. Furthermore, the quadratic effect on the drying time and temperature had significant effect on weight loss. The three factors manipulated during the drying process accounted for 94.2% of the variations observed in the final weight loss of the dried chips.

Keywords: Drying, RSM, Temperature, Thickness, Yam

Introduction

Drying food product is one of the oldest methods of preservation. Dried yam when kept well could have their shelf lives extended for considerable long period without spoilage. Preservation by drying is based on the fact that moulds, yeasts, and bacterial cannot grow on dry materials and these activities of enzymes and various other determinant chemical reactions are retarded or prevent when the moisture content is lower than 10 percent on wet basis.

To be considered *"dried",* the final product must be solid in the form of a continuos sheet (e.g. paper) long pieces e.g. wood), particles (e.g. cereals grains or corn flakes) or powder (e.g sand, salt, washing powder, milk powder) (Greensmith, 2008). Drying can be technologically said to be the mass transfer process resulting in the removal of water (moisture content) from another solvent by evaporation form solid, semi-solid or liquid state to end in solid state. To achieve this, there must be a source of heat transfer through conduction, convection or radiation. The application of heat depends largely on the type nature and the life span of the materials or to be dried (Greensmith, 2008).

Processing into staple, non-perishable and easily transportable produce offers an alternative to storage in the fresh form. They are best preserved in the dried form by processing into flour, chips and pellet for both human and livestock consumption. The operation involved in producing these pellet include washing, peeling, size reduction (slicing) and drying (Adubuola, 2002).

It was found out that peeling and slicing (which can be done in form of punching into cube shape or round shape) of tuber are done manually while reported that there has been efforts at mechanizing tuber processing in the very few processing plant in Nigeria (Adubuola, 2002).

The main purpose of drying is therefore the reduction of moisture in a produce to a level that will substantially diminish the activities of agents of deterioration so that spoilage will not occur before the agricultural produce in ready for utilization. In this modern age, the demand for tuber products for livestock and human consumption cannot be underrated in which the manual method of processing cannot meet the demand. While in the olden days, the traditional method of processing adopted area tedious and time wasting. (Mujumdar, 2010).

White yam *(Dioscorea rotundata poir)* originated in Africa and is the most widely grown and preferred yam species. The tuber is roughly cylindrical in shape, the skin is smooth and brown and the flesh usually white and firm. A large number of white yam cultivate exist with differences in their production and post-harvest characteristics.

The world production of yam was estimated at 28.1 million tons in 1993. Out of this total production, 96% come from West African the main producer being Nigeria with 71% of the world production, Coted'lvoire 8.1% Benin 4.3% and Ghana 3.5%. In the humid tropic countries of West African, both in the rain forest and in the savannah yams are one of the most highly regarded food products and closely integrated with the social, cultural, economic and religious aspect of life. Traditional ceremonies still accompany yam production, indicating the high status given to the plant (Food – into net).

In the addition yam *(Dioscorea spp)* predetermined thickness is called chuck. It is produced nationwide and harvested between June and December annually. It is a tuber crop of over 600 species and it highly perishable when fresh, primarily because of its high moisture content (50-80%) wet basis). (Degrass and Osunde 2008).

They are planted on mounds rather than flat slopes depending on the hydromorphic nature of the soils which are generally of loose soil suitable to grow roots and tuber crops. White yam (Dioscorea spp) has high carbohydrate content (low in fat and protein) and provides a good source of energy. Unpeeled yam has vitamin C. Yam, sweet in flavor is consumed as boiled yam (as cooked vegetable) or fufu or fried in oil, then consumed (Food into net).

The main objective in crop drying is the reduction of the moisture content such that spoilage will not occur before the crops is ready for use. This article therefore investigates the effect of applied temperature, drying time, and thickness of sliced tuber of yam on the weight loss of sliced yam during drying, using response surface methodology (RSM).

Materials and Methods

The selection of materials for drying is essential, therefore an highly efficient oven dryer should be used to obtain an appropriate results.

Sourcing of Materials

Tubers of yam was purchased at Oja Tuntun market Ilorin Kwara State with the moisture content of about (50-80%) wet basis.

Sample Preparation

The following materials were used for the drying of yam:

i. *Knife: It was used to peel and slice the measured thickness required for drying*
ii. *Venier caliper: This was used to measure the thickness required*
iii. *Stop watch: It was use to determine and monitor the exact time required to dry the sliced yam*
iv. *Digital weighing scale: It was used to weigh the final weight of the sliced yam.*

Description of the digital weighing scale used:

Manufacturer	-	*Elmakarus Postal Scale*
Model:	-	*El-5K02*
Size:	-	*227 x 61 x 229mm*
Power:	-	*9v Block battery*
Capacity:	-	*50lb*
Graduation:	-	*0.2 oz*

Technical parameters of DHG 9070B Blast Drying Oven used:

Model	-	*DHG-9070B*
Voltage	-	*220V 50Hz*
Power Consumption	-	*1500W*
Temperature Range	-	*RT + 10˜ 300^{0}C*
Temperature Resolution	-	*0.1^{0}C*
Temperature fluctuation	-	*±0.5^{0}C*
Liner Size (mm)	-	*450*
Dimension	-	*595*
Shelf	-	*3pcs*
Timing Range	-	*1˜9999mn*

Experimental Procedure

The yam was peeled and cleaned before slicing into selected thickness. The factors selected were based on literature reviews and preliminary tests in the laboratory. The thickness selected were (1cm, 1.5cm and 2cm) while the applied heating temperature selected were (100^{0}C, 150^{0}C, and 200^{0}C) respectively. The initial weight and final weight of the samples were obtained by digital weighing machine.

Experimental Design and Layout

The factors selected for this study were based on related literature search. They are thickness, temperature and time.
The thickness selected were 1cm, 1.5cm and 2cm. the temperature for the study are 100^{0}C, 150^{0}C and 200^{0}C. The times selected for the experiment were 30 mins, 60mins and 90mins.

Output Parameters

Weight losses

Wo = W_1-W_2 (kg)

Wo = weight losses between successive readings

W_1 = initial weight of slice (kg)

W_2 = final weight of slice (kg)

Statistic Analysis

Response surface methodology (RSM) is a collection of statistical and mathematical techniques that has been successfully used for developing, improving and optimizing process (Myers et al 2009). RSM enables a reduction in the number of experimental trials needed to evaluate multiple parameters and their interaction, thus, requiring less time and labour. RSM has been widely applied for optimizing processes in the food industry (Kumer et al 2009; Shih et al 2009, Sabukola et al 2009; Wang et al, 2010) (Mercali et al, 2011,suresh kumar and Devi 2011).

Cornel 1990, reported that RSM uses quantitative data from appropriate experimental design to determine and simultaneously solve multivariate equation, graphically represented as response surface which can be used in three ways.

(i) to describe how test variable affect the response

(ii) to determine the inter relationship among the test variable on the response.

(iii) to describe the combine affect of all the test of variable on the response

The nonlinear model of the RSM is.

$$Y= b0 + \sum_i bixi + \sum_i biix^2 + \sum \sum_{ik(k/j)} bjkXjXk$$

where;

bo = intercept

Y= response variable

xk, xj, xi = independent variable

bii, bjk, bi = regression co-efficients of the model

The experimental design, regression analysis and respoinse surface graphs were done with Matlab 7.1 software. (Cornell, 1990)

Results and Discussion

The Response Surface Methods (RSM) procedure and factor coding are presented in Table 1. The Box-Behnken design for 3 Factors adopted for this study naturally have 16 runs. Table 1 shows the complete runs of the factor coding and the response. The factor consider for this study are Thickness (cm) of the sliced yam, Temperature (ºC) applied to the various sliced yam and Time (min) of drying, while the response was the final weight loss of the yam.

Table 1. Variables Used in the Design

	Low	Medium	High
Independent variables	-1	0	1
Thickness (cm)	1	1.5	2
Temperature (ºC)	100	150	200
Time (min)	30	60	90

Table 2. Design Matrix and observed response values for the RSM

Exp #	*Thickness (cm)*	*Temperature (ºC)*	*Time (min)*	*Weight Loss*		
				R1	*R2*	*R3*
1	0	1	0	0.10	0.10	0.10
2	-1	-1	-1	0.00	0.01	0.01
3	1	1	-1	0.01	0.00	0.00
4	1	0	0	0.01	0.01	0.01
5	1	-1	-1	0.00	0.00	0.00
6	-1	1	-1	0.01	0.00	0.01
7	0	0	0	0.01	0.01	0.01
8	1	1	1	0.15	0.15	0.20
9	-1	1	1	0.10	0.10	0.15
10	-1	-1	1	0.01	0.01	0.01
11	0	0	0	0.01	0.01	0.01
12	0	0	1	0.10	0.10	0.10
13	0	-1	0	0.01	0.00	0.01
14	-1	0	0	0.01	0.01	0.01
15	0	0	-1	0.00	0.01	0.00
16	1	-1	1	0.01	0.01	0.01

Effect of Experimental Variables on Weight loss of Dried Yam

The effect of applied temperature (α), thickness of the yam chip (γ) and time of drying (β) on the final weight of loss of the dried yam chips was estimated as presented in Table 2. The reliability of the RSM model was examined using analysis of variance (ANOVA). The ANOVA tests for Significance of the RSM model from statistical perspectives. Table 3 shows the analysis of variance for the RSM model. The analysis of variance tests was significance at 5% level. The null hypothesis of no functional relationship is rejected. This implies that there exist a functional and significant relationship between the process input (temperature, thickness and drying time) and the final weight loss of dried yam chips.

Table 3. The Analysis of Variance Table for Weight Loss

Source	SS	MS	F	F- Sig.	df
Regression	0.05577	0.00930	41.31	0.001	6
Residual	0.00203	0.000225			9
Total	0.05780				15

Table 4 shows the regression coefficients and their t-ratios. The coefficients of the models developed were significant at 5% levels of significance as shown by their associated probability values (p value). This implies that the linear effect of applied temperature and time of drying of the yam chips, and the interaction of temperature and time of drying of the yam chips had significant effect on the final weight loss of the dried yam chips at 5% significant level. Also, the quadratic effect of applied temperature, thickness of the chips and the time of drying had significant effect on the final weight loss of the dried yam chips. The three factors manipulated during the drying process accounted for 94.2% of the variations observed in the final weight loss of the dried chips. This implies that only a negligible fraction of about 5.8% variations was not accounted for.

Table 4. The Estimated Regression Coefficients for Weight loss

	Coeff.	P value	Std Error	t Stat
Constant	0.02276	0.0107	7.10E-03	3.20E+00
α	0.04200	0.0010	4.74E-03	8.85E+00
β	0.04500	0.0010	4.74E-03	9.49E+00
γ^2	-0.01914	0.0482	9.24E-03	-2.07E+00
α^2	0.02586	0.0207	9.24E-03	2.80E+00
β^2	0.02086	0.0503	9.24E-03	2.26E+00
$\alpha\beta$	0.04125	0.0010	5.30E-03	7.78E+00

α =temperature, β=time and γ=thickness

RSM Surface Plot of the Relationship between Process Inputs and Response

Figures 1 to 3 show the surface plots of the paired process inputs with the response.

Inference from figure 1 shows that the final weight loss of dried yam chips increase with increased in the levels of temperature and thickness of the slices of yam. The maximum final weight loss of the dried yam chips of 0.10kg was observed at a temperature of 200ºC and a thickness of 1.5cm.

Similarly, in figure 2, final weight loss of dried yam slices also increases as both thickness of yam slices and time of drying increase. With optimum thickness of 1.5cm and drying time of 90mins, a maximum final weight loss of 0.11kg of the dried yam slices was recorded.

Finally, figure 3 show a maximum final weight loss of 0.17kg of dried yam slices being observed at temperature of 200ºC and a drying time of about 90mins. Both temperature and drying time have a proportionate effect on the final weight loss of the dried yam slices.

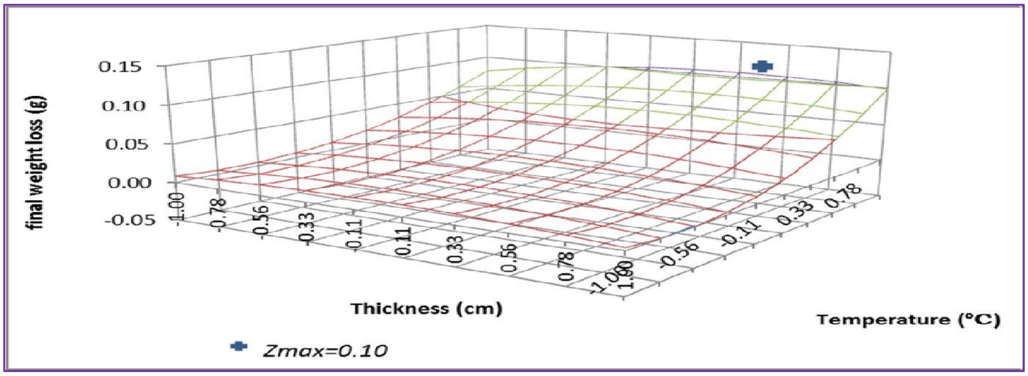

Figure 1: Response Surface Curves of the Effects of Temperature and Thickness of yam slices on the final weight loss of yam chips during drying

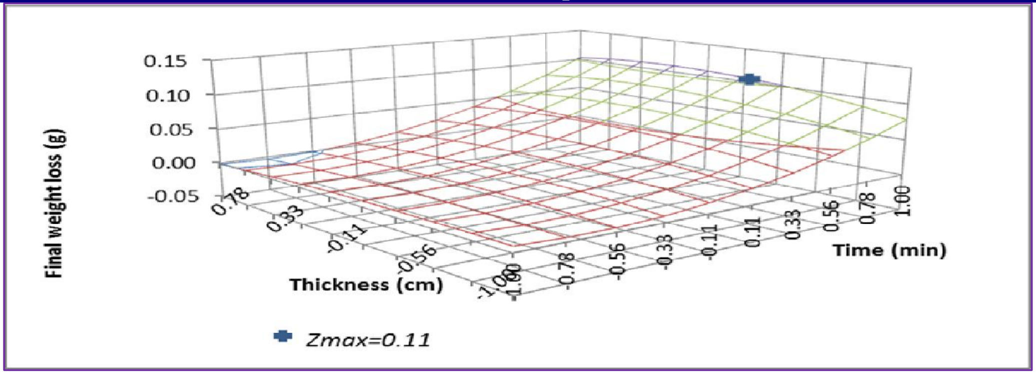

Figure 2: Response Surface Curves of the Effects of Thickness of yam slices and Time of Drying on the final weight loss of yam chips during drying

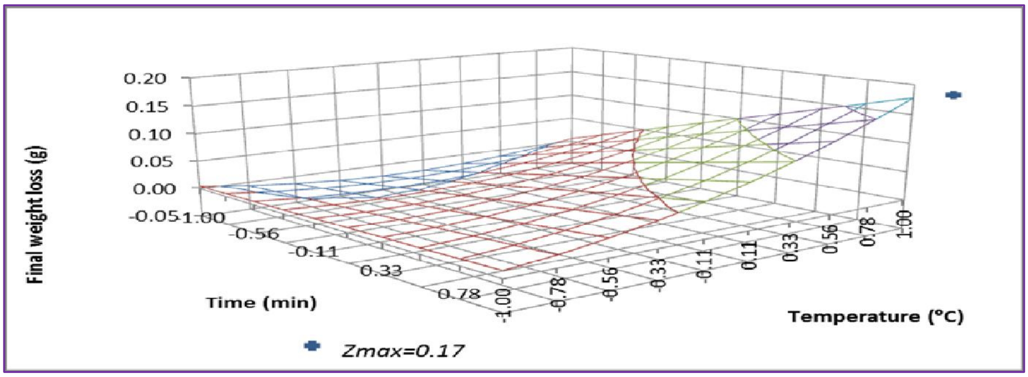

Figure 3: Response Surface Curves of the Effects of Temperature and Time of Drying on the final weight loss of yam chips during drying

Conclusion

The drying of sliced yam is influenced by such factors as applied temperature, thickness of the sliced yam (chips) and time of drying. Most importantly, the drying of yam is influence by temperature and time of drying. Higher temperature and moderate thickness proportionally affect the drying condition of sliced yam.

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