Original Research Article

Optimization of process conditions (blanching time and temperature) on the beta carotene content of Diced Orange Flesh Sweet Potato

ABSTRACT

Optimization of process condition (blanching and drying) on the beta-carotene content of orange fleshed sweet potato (mother delight) using response surface methodology was studied. Sweet potatoes were washed, peeled, diced, blanched, and dried at various temperature ranges. Nutritional composition of the fresh and dried samples was determined using standard methods. A three-factor central composite rotatable design (CCRD) was used to study the effects of blanching time (X_1), blanching temperature (X_2), and drying temperature (X_3) on the beta-carotene content of the orange fresh sweet potato. Fourteen experimental combinations were produced with six replicates at the center point to generate twenty (20) runs. The sweet potato was blanched at a temperature range of 60-90^{0}C for 3-5 minutes and dried at a temperature ranging between 70-80^{0}C. the result showed that the beta-carotene content of fresh sweet potatoes was 8403µg and dried ones ranged from 4401µg to 2826µg. Sweetpotato processed for 3mins (blanching time), at 90^{0}C (blanching temperature) and 70^{0}C (drying temperature) produced the maximum beta carotene. The experimental data was fitted to a second-order polynomial equation using multiple regression analysis and the quadratic model was highly significant ($p<0.05$).

Keywords: Blanching, optimization, carotene, orange flesh sweet potato

1. INTRODUCTION

"Orange fleshed sweet potato (Ipomoea batatas) is one of the world's most important root crops and an important staple in Nigeria and other developing countries" [1]**. "**In the year 2017 worldwide,494.6million tons of roots and tubers (including potato) are produced" [2]. "Orange flesh sweet potato (OFSP) is a variety of sweet potatoes characterized by its orange or yellow colored tubers. It is an important staple for the poor and less privileged considering its relative ease of cultivation, poor utilization, and numerous health benefits, for children and pregnant women who desired these nutrients" [3]. "Presently, it is strongly emerging as the most popular commonly cultivated and demanded specie because it is rich in vitamin A and beta carotene" [4]. "Orange flesh Sweet potato roots are also a good source of dietary fiber, stimulating feelings of fullness, and cooked sweet potatoes have a medium glycemic index" [5].

Fundamentally, root crops are highly seasonal and limited to its harvesting season. Therefore, they are processed to create varieties and to make it available all year round. Conversely, this processing tends to destroy micronutrients content of root crops. Food processing techniques such as blanching, drying, freezing etc have the potential to alter the micronutrient quality of root crops [6]. Root crops are therefore subjected to various processing steps such as blanching and drying to increase their shelf life and as well provide varieties. Blanching as one of the processing techniques helps to stop enzyme actions that are capable of causing loss of flavor, color, and texture. It also helps to retard the loss of vitamins. "The effectiveness of blanching is dependent on the blanching temperature and time. Blanching time has to be just sufficient to inactivate enzymes catalase and peroxidase and assure elimination of air from tissues" [7].

Therefore, optimum blanching and drying conditions are required to retain the quality and level of micronutrients available in them during processing. This will go a long way in solving issues related to blindness, cancer treatment, and other immune system malfunctions. The triage theory predicts that optimizing the intake of essential micronutrients will reduce the risk of chronic diseases associated with aging and increase lifespan [8]. This work is therefore aimed at employing the techniques of response surface methodology to study and optimize the effects of blanching and drying on beta carotene, towards ensuring maximum retention of beta-carotene after processing. If achieved, it will ensure availability of beta-carotene which are abound in orange flesh sweet potato and will also help to eradicate numerous defects caused by lack of vitamin A in our system.

The objective of this work is to study and optimize the effects of blanching and drying on the beta-carotene and other mineral content of diced dried orange fleshed sweet potato.

2. MATERIAL AND METHODS

The orange-fleshed sweet potatoes (Mother Delight) freshly harvested at the optimum maturity were used for this study. The materials were purchased from National Root Crops Research Institute Umudike, Abia State, Nigeria.

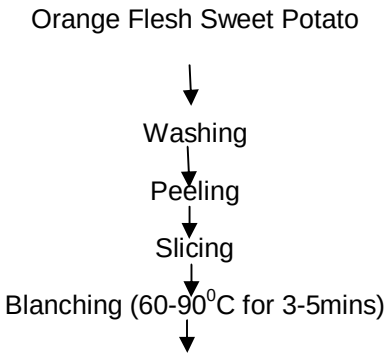
2.1 Sample Preparation

The sweet potato was sorted and properly washed to remove dirt and contaminants. The sweet potato was peeled and cut manually into thin dices using stainless knives. The diced sweet potato was blanched at a temperature range of 60-90^{o}C for 3-5 minutes and dried at a temperature ranging between 70-80^{o}C.

2.2 Method of Analyses

The analyses conducted on the samples were proximate composition, minerals and vitamins.

Beta carotene was done using the colorimetric method [9]. Calcium and Iron content was determined using the Association of Official Analytical Chemists (AOAC) method [10].



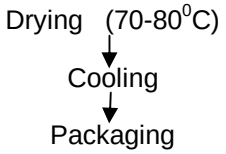


Fig. 1. Production of dried diced Orange Flesh Sweet Potato

2.2.1 Extraction and Determination of Beta Carotene

Beta carotene was determined using the colorimetric method [9]. A measured weight (1g) of the sample and standard was mixed with 30ml of absolute alcohol and 3ml of 5% KOH solution was added to it and boiled gently for 30mins under reflux, after washing with distilled water, vitamin A was extracted with 50ml of diethyl ether. The extract was evaporated to dryness at low temperature and then dissolved in 10ml of isopryl alcohol, 1ml of standard vitamin A solution prepared, and that of the dissolved extract were transferred to separate curettes and their respective absorbance were read in a spectrophotometer at 325nm with a reagent blank at zero.

Calculation:

$$\text{Conc. of beta carotene in sample} = \frac{\text{Absorbance of sample x conc. of standard}}{\text{Absorbance of standard}}$$

2.2.2 Iron Determination

Iron content was determined according to Association of Official Analytical Chemists (AOAC) [10] method. Exactly 1g of the dried sample was weighed into a digestion flask and added 20ml of the acid mixture (650ml conc. HNO_3). The flask was heated until a clear digest was obtained. The digest was diluted with distilled water up to the 500ml mark. Calibration curves were prepared using a standard solution. The appropriate lamps and correct wavelength are usually specified in the instruction manual of the instrument.

2.2.3 Calcium Determination

Calcium was determined by Association of Official Analytical Chemists (AOAC) [10]. Exactly 1g of the sample was weighed in a dried porcelain crucible, then ash for 2 hours at 500^{0}C, and allowed to cool. Ten (10) drops of H_2O and 3-4 MI HNO_3 were added. The excess HNO_3 was evaporated using a hot plate set at 100-120^0 C, the crucible was returned to the furnace and ash for an additional 1 hour at 500^{0}C. It was cooled again in the desiccator, the ash was dissolved in 5ml HCl, and was transferred into a 25ml volume flask and diluted to volume with H_2O. Calcium content was analyzed using an inductively coupled plasma atomic emission spectrophotometer.

2.3 Experimental Design and Optimization

A three-factor central composite rotatable design (CCRD) was used to study the effects of blanching time (X_1), blanching temperature (X_2), and drying temperature (X_3) on the parameters of interest. Fourteen experimental combinations were produced with six replicates at the center point to generate twenty (20) runs. The independent variables and their variation levels are shown in Table 1. The independent variables range studied for sweet potato were blanching time (3-5 mins), blanching temperature (60-90^{o}C), and drying temp (70-80^{o}C).

Table 1: **Independent variables and levels used for a central composite rotatable design for sweet potato**

	Coded	Variable	Level			
	Code	**-1.68**	**-1**	**0**	**+1**	**+1.68**
Blanching time (mins)	(X_1)	2	3	4	5	6
Blanching temp. (^{0}C)	(X_2)	50	60	75	90	100
Drying temp. (^{0}C)	(X_3)	67	70	75	80	83

The experiments were run in random order to minimize the effects of unexplained variability in the observed response due to extraneous factors [11]. The outlines of the experimental designs with the coded and actual values are shown in Table 2

Table 2: **Experimental design for the experiment for sweet potato in coded and actual units**

Independent variables in coded forms			**Experimental variables in their actual**		
Design point	**(X_1)**	**(X_2)**	**(X_3)**	**(X_1 mins)**	**(X_2 ^{0}C)**	**(X_3 ^{0}C)**
1	-1	-1	-1	3	60	70

2	+1	-1	-1	5	60	70
3	-1	+1	-1	3	90	70
4	+1	+1	-1	5	90	70
5	-1	-1	+1	3	60	80
6	+1	-1	+1	5	60	80
7	-1	+1	+1	3	90	80
8	+1	+1	+1	5	90	80
9	-1.68	0	0	2	75	75
10	+1.68	0	0	6	75	75
11	0	-1.68	0	4	50	75
12	0	+1.68	0	4	100	75
13	0	0	-1.68	4	75	67
14	0	0	+1.68	4	75	83
15	0	0	0	4	75	75
16	0	0	0	4	75	75
17	0	0	0	4	75	75
18	0	0	0	4	75	75
19	0	0	0	4	75	75
20	0	0	0	4	75	75

The generalized polynomial model proposed for predicting the response variable is given as:

$$Y=b_o + b_1X_1 + b_2X_2+b_3X_3+b_{11}X_1^2 + b_{22}X_2^2+ b_{33}X_3^2+ b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3$$

Where b_o= Intercept,
b_1, b_2, b_3 are linear,
b_{11}, b_{22}, b_{33} are quadratic,
b_{12}, b_{13}, b_{23} are interaction regression coefficient terms,
X_1= Blanching time,
X_2= Blanching temperature,
X_3= Drying temperature.
The dependent variable (Y) in this study is beta-carotene.

Optimization was carried out using the numerical optimization technique using the desirability function. The desired goal was to maximize the beta-carotene content.

Statistical Analysis

Simple regression analysis was used in order to make estimates for dependent variable and analysis of variance (ANOVA) were conducted at a 95% confidence level to find a common mean between variables of different groups and for fitting the models. The adjusted R^2, model significance ($p<0.05$), and p-lack of a fit test [13] were used to test the adequacy of the model. A good fit model recommended that R^2 should be at least 0.80. Minitab Version 17.3.1 was used for the statistical analysis. Surface plots for each response were generated with the help of the statistical software.

3. RESULTS AND DISCUSSION

3.1 Composition of Orange Flesh Sweet Potato (Mother Delight)

The result of the chemical composition of sweet potato as shown in Table 3 revealed a fat content of 2.17% which is in agreement with the work of [14], who reported fat content of 2.2% [15], observed that

most plant tubers and leaves co contain low level of fat, but its consumption should be encouraged since it is a type of fat that is easily used by the body system. The crude fiber content of sweet potato tuber samples in this study was generally low and conforms to the work of [16].

The study also revealed that carbohydrate constitutes the highest nutrient in the tuber and are in line with previous reports [14]. These authors agreed that if sweet potato is steadily available for consumption, it will reduce the rate of energy malnutrition in humans. The mineral analysis showed a relatively low level of iron although the bioavailability was not tested.

Table 3: **Chemical composition of fresh sweet potato**

Parameter	Mean
Moisture (%)	67.67 ±0.57
Ash(%)	2.10 ±0.01
Fat(%)	2.17 ±0.06
Protein(%)	4.02 ±0.01
Fibre(%)	1.91 ±0.01
Carbohydrate(%)	22.47 ±0.59
Calcium(mg)	33.43 ±0.59
Iron(mg)	0.94 ±0.01
Beta carotene (µg)	8403 ±0.05

Values are means of triplicate determinations ± standard deviation

The result revealed a high beta carotene content in orange flesh sweet potato. Beta-carotene which is pre cursor of vitamin A is known for its ability to stimulate the immune system and improvement of sight. Nevertheless, it should be noted that many Nigerians depend on plant sources for minerals and Vitamins. Calcium in this study can be compared with the work of previous authors [15][17].

3.2 Effect of Blanching Time, Blanching Temperature, and Drying Temperature On The Beta Carotene Content Of Sweet Potato

The effect of the variables – blanching time, blanching temperature and drying temperature interactions on beta carotene content is presented in Table 4.

Sample	Blanching time X_1(mins)	Blanching temp. X_2(^oC)	Drying temp X_3 (^oC)	Beta carotene (µg)
1	3	60	70	3251^m
2	5	60	70	3068^o
3	3	90	70	4401^b
4	5	90	70	3622^i

5	3	60	80	3425[l]
6	5	60	80	3845[g]
7	3	90	80	3158[n]
8	5	90	80	3870[f]
9	2	75	75	2826[p]
10	6	75	75	3489[k]
11	4	50	75	4026[d]
12	4	100	75	3956[e]
13	4	75	67	3734[h]
14	4	75	83	3578[j]
15	4	75	75	4149[c]
16	4	75	75	4149[c]
17	4	75	75	4149[c]
18	4	75	75	4149[c]
19	4	75	75	4149[c]
20	4	75	75	4149[c]
Control	0	0	0	8403[a]

Table 4: Values are means of triplicate determinations
Means followed with the same superscript in the column are not significantly different at ($p<0.05$)

It was observed that the beta carotene content of the samples were significantly ($p<0.05$) affected by the different combinations of variables. The table showed that the highest beta carotene yield was observed at a blanching time of 3mins, blanching temperature of 90^{o}C, and drying temperature of 70^{o}C. At these combinations, beta carotene content was 4401µg. The lowest beta carotene content of 2826µg was observed at a blanching time 2mins, blanching temperature 75^{o}C, and drying temperature of 75^{o}C. Variations in the beta carotene content of sweet potato dice at different treatments were shown in Table 4. It was observed that beta the carotene content of sweet potato samples ranged from 2826µg to 4401µg, indicating that blanching temperature, time of blanching, and drying temperature has a significant impact on the quantity of beta carotene after processing. The highest beta carotene content (4401µg) was recorded for the sweet potato sample subjected to 3mins (blanching time), 90^{o}C (blanching temperature), and 70^{o}C (drying temperature). While the lowest beta carotene content (2826µg) was recorded for the sweet potato dices subjected to the blanching time 2mins, blanching temperature 75^{o}C with drying temperature of 75^{o}C. Depending on the time-temperature regime, blanching and drying of sweet potato strongly affected the beta carotene content when compared with the fresh sample [18]. Time and temperature of blanching played a vital role in retention of beta carotene in sweet potato. The beta carotene content of the fresh sweet potato used in this investigation is 8403µg (Table 4) which is significantly higher than the beta carotene content of processed samples. The decrease in beta carotene quantity may be attributed to the temperature and time of blanching. Also, leaching of the pigments as the osmotic stress increased as a result of breakage of the cell structures [19], may also be a factor.

3.3 Analysis of variance for response surface quadratic model

Regression analysis for orange flesh sweet potato was carried out to fit a statistical model to the experimental data. The result of the analysis of variance (ANOVA) is shown in Table 5. The table showed that the response surface quadratic model was significant ($p=0.001$). The model exposed the results of the linear effect, and quadratic effect as well as the interaction effect of the variables on the parameter of interest. The result indicates that the linear effect of blanching time, blanching temperature and drying temperature had no significant effect on the beta carotene content. The quadratic effect of blanching time

× blanching time and drying temperature × drying temperature had significant effect on beta carotene content. It was observed that the interaction effect of blanching time × drying temperature and blanching temperature × drying temperature had a significant effect on the beta carotene content. The lack of fit test measures the failure of the model to represent the data in the experimental domain at points that are not included in the regression. As shown in Table 5, the *F*-value and *P* value of the lack of fit test were 4.74 and 0.056 respectively, which implies it was not significant and shows that the model equation was adequate for predicting the retention of beta carotene in sweet potato. The fitness of the model was also confirmed by a satisfactory value of the coefficient determination (R^2), which was 89%, indicating that 89% of the variability in the response could be predicted by the model. The model generated coefficients that can be substituted in the equation to obtain beta carotene without practically carrying out the analysis. The curved shape of the response surface plot and the oval features of the lines in the contour plot confirm the fact that a second-degree polynomial model equation is appropriate to describe the rate of retention of beta carotene.

Table 5: Analysis of variance for response surface quadratic model

Source	DF	Adj SS	AdjMS	f-value	p-value
Model	9	3.39062	0.37674	9.23	0.001 sig
Linear	3	0.14383	0.04794	1.17	0.368
blanching time	1	0.00474	0.00474	0.12	0.740
blanching temp	1	0.13312	0.13312	3.26	0.101
drying temp	1	0.00598	0.00598	0.15	0.710
Square	3	1.96905	0.65635	16.08	0.000 sig
blanching time*blanching time	1	1.62240	1.62240	39.74	0.000 sig
blanching temp*blanching temp	1	0.02368	0.02368	0.58	0.464
drying temp*drying temp	1	0.36992	0.36992	9.06	0.013 sig
2-Way Interaction	3	1.03450	0.34483	8.45	0.004 sig
blanching time*blanching temp	1	0.01280	0.01280	0.31	0.588
blanching time*drying temp	1	0.55125	0.55125	13.50	0.004 sig
blanching temp*drying temp	1	0.47045	0.47045	11.52	0.007 sig
Error	10	0.40830	0.04083		
Lack-of-Fit	5	0.33722	0.06744	4.74	0.056
Pure Error	5	0.07108	0.01422		
Total	19	3.79892			

3.4 Model Fitting For Beta Carotene Content of Sweet Potato

Regression analysis and analysis of variance were carried out to determine the statistical significance of the model terms. Presented in Table 5 are the results of fitting the linear, quadratic and interaction models to data obtained from beta carotene. The result revealed that linear model has no significant effect on the beta carotene content. The quadratic model of blanching time × blanching time and drying temperature × drying temperature had significant effect on beta carotene content. It was observed also that interaction model of blanching time × drying temperature and blanching temperature × drying temperature had significant effect on the beta carotene content.

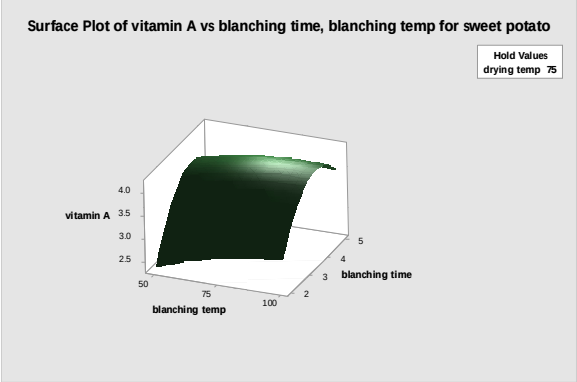
As shown in Table 5, the *F*-value and *P*-value of the lack of fit test were 4.74 and 0.056 respectively, which shows that the model equation was adequate for predicting the retention of beta carotene in sweet potatoes. The fitness of the model was also confirmed by a satisfactory value (89.25%) of the determination coefficient (R^2).

3.5 Equation for beta carotene content in sweet potato

The regression equation describing the effects of blanching time, blanching temperature and drying temperatures on Vitamin A content is given by:

$$\text{Beta carotene} = -44.6 - 0.3478X_1^2 - 0.00691X_3^2 + 0.0525X_1X_3 - 0.003233X_2X_3$$

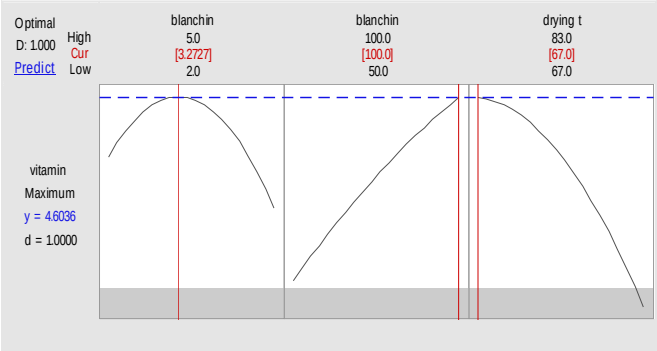
Where X_1, X_2 and X_3 are blanching time, blanching temperature, and drying temperature, respectively. The surface plot of vitamin A vs blanching time, and blanching temperature for orange flesh sweet potato can be found in graph 1



Graph 1. Surface plot of vitamin A vs blanching time, blanching temp for orange flesh sweet potato

Optimization of process variables

The process variables were optimized in order to improve the performance of the system and to increase the yield of the process. The response optimization variables are shown in graph 1. It was revealed that sweet potato processed at 3mins blanching time, 100^{o}C blanching temperature and 67^{o}C drying temperature will yield beta carotene content of 4603µg.



Graph 2. The optimization graph

3.6 Optimization of the process conditions

Orange fleshed sweet potatoes were subjected to various processing conditions to ascertain the best condition that will produce maximum retention of beta carotene in sweet potatoes. Figure 1 shows the optimization plot for orange fleshed sweet potato. The optimum conditions for the retention of beta carotene in sweet potato predicted by the regression model were as follows: blanching time of 3mins, blanching temperature of 100^{o}C, and drying temperature of 67^{o}C.

4. CONCLUSION

Generally, food quality is greatly affected by the type and extent of processing. The findings of this work revealed that processing technique such as blanching time, blanching temperature and drying temperature has great effect on the beta carotene content of orange flesh sweet potato. Raw sweet potatoes had higher beta carotene content than processed ones. It was observed that orange flesh sweet potato processed at blanching time 3mins, blanching temperature 100^{0}C, and drying temperature 46^{0}C produced the maximum beta carotene yield. For maximum retention of nutritional compositions and beta carotene content of orange flesh sweet potato after processing, these processing conditions were found to be the most suitable method for producing diced dried and sweet potato.
The results of this study suggest that orange flesh sweet potato is a good source of beta carotene and other minerals therefore increased inclusion in our meals will improve the nutritional status of the consumers and thus, contribute to alleviating dietary deficiency of vitamin A.

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