

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 flesh 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 orange fresh sweet potato. Fourteen experimental combinations were produced with six replicates at the center point to generate twenty (20) runs. Sweet potato was blanched at a temperature range of 60-90°C for 3-5 minutes and dried at a temperature ranging between 70-80°C. The result showed that the beta carotene content of fresh sweet potatoes was 8403µg and dried ones ranged from 4401µg to 2826µg. Sweet potato processed for 3mins (blanching time), at 90°C (blanching temperature) and 70°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 flesh 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]. Orange flesh sweet potato (OFSP) is a variety of sweet potatoes characterized by its orange or yellow coloured tubers. It is an important staple for the poor and less privileged considering its relative ease of cultivation, and poor utilization, and numerous health benefits, for children and pregnant women who desired these nutrients [2]. Presently, it is strongly emerging as the most popular commonly cultivated, and demanded specie because it is rich in vitamin A and beta carotene [3]. 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 [4].

The basic limitation of this root crop is that they are highly seasonal. 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 flavour, colour, 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.

Therefore, optimum blanching and drying conditions are required in order 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 the essential micronutrients will reduce the risk of chronic diseases associated with aging and increase lifespan [5].

2. MATERIAL AND METHODS

The orange-orange-fleshed sweet potatoes (Mother Delight) freshly harvested at the optimum maturity were used for this study. They 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°C for 3-5 minutes and dried at a temperature ranging between 70-80°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 [6]. Calcium and Iron content was determined using the AOAC method [7].

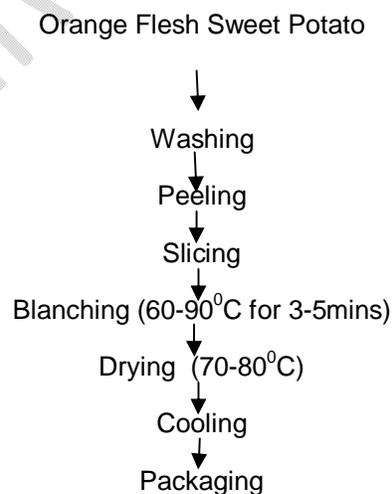


Fig. 1. Production of dried diced Orange Flesh Sweet Potato

2.2.1 Extraction and Determination of Beta Carotene

Beta carotene was determined using [the](#) colorimetric method [6]. 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 culettes and their respective absorbance were read in a spectrophotometer at 325nm with a reagent blank at zero.

Calculation:

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

2.2.2 Iron Determination

Iron content was determined according to AOAC [7] method. Exactly 1g of the dried sample was weighed into a digestion flask and added 20ml of the acid mixture (650ml conc. HNO₃). 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 [on-in](#) the instruction manual of the instrument.

2.2.3 Calcium Determination

Calcium [was](#) [determination](#) by AOAC [7]. Exactly 1g of the sample was weighed in a dried porcelain crucible, then ash for 2 hours at 500⁰C, and allowed to cool. Ten (10) drops of H₂O and 3-4 MI HNO₃ were added. The excess HNO₃ was evaporated using [a](#) hot plate set at 100-120⁰ C, the crucible was returned to the furnace and ash for [an](#) additional 1 hour at 500⁰C. 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 H₂O. Calcium content was analyzed using an inductively coupled [dd](#) 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 (X₁), blanching temperature (X₂), and drying temperature (X₃) on the parameters of interest. Fourteen experimental combinations were produced with six replicates at the [centre-center](#) point to generate twenty (20) runs. The independent variables and their variation levels are shown in [Tables](#) 1. The independent variables range studied for sweet potato were blanching time (3-5 mins), blanching temperature (60-90⁰C), and drying temp (70-80⁰C). Ranges were obtained after reviewing relevant literature.

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. (°C)	(X ₂)	50	60	75	90	100
Drying temp. (°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 [8]. 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:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3$$

Where b_0 = 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,

X₁= Blanching time,
 X₂= Blanching temperature,
 X₃= Drying temperature.
 The dependent variable (Y) in this study is beta-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

Regression analysis and analysis of variance (ANOVA) were conducted at a 95% confidence level for fitting the models. The adjusted R², model significance (p<0.05), and p-lack of a fit test[9] were used to test the adequacy of the model. For a good fit model [10] recommended that R² 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 [11], who reported fat content of 2.2% [12], observed that most plant tubers and leaves 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 fibre content of sweet potato tuber samples in this study was generally low and conforms to the work of [13].

The study also revealed that carbohydrate constitutes the highest nutrient in the tuber and are in line with previous reports [11]. 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 sweet potato. Beta carotene which is precursor 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 [12][14].

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.

Table 4: Values are means of triplicate determinations

Sample	Blanching time X ₁ (mins)	Blanching temp. X ₂ (°C)	Drying temp X ₃ (°C)	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 ^d
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°C, and drying temperature of 70°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°C, and drying temperature of 75°C. Variations in the beta carotene content of sweet potato dices at different treatments were shown in Table 4. It was observed that the beta carotene content of sweet potato samples ranged from 2826µg to

4401 μg , 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 (4401 μg) was recorded for the sweet potato sample subjected to 3mins (blanching time), 90°C (blanching temperature), and 70°C (drying temperature). While the lowest beta carotene content (2826 μg) was recorded for the sweet potato dices subjected to the blanching time 2mins, blanching temperature 75°C with drying temperature of 75°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. 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 8403 μg (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[15], 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, 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 \times blanching time and drying temperature \times drying temperature had a significant effect on beta carotene content. It was observed that the interaction effect of blanching time \times drying temperature and blanching temperature \times 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 which 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.

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 the linear model has no significant effect on the beta carotene content. The quadratic model of blanching time \times blanching time and drying temperature \times drying temperature had a significant effect on beta carotene content. It was observed also that the interaction model of blanching time \times drying temperature and blanching temperature \times drying temperature had a 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

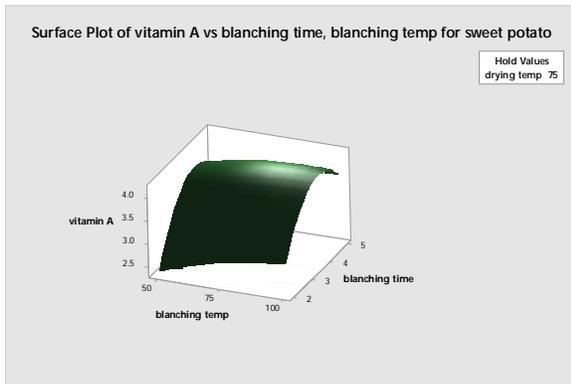
potatoes. The fitness of the model was also confirmed by a satisfactory value (89.25%) of the determination coefficient (R^2).

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:

$$\text{Beta carotene} = -44.6 - 0.3478X_1^2 - 0.00691X_2^3 + 0.0525X_1X_3 - 0.003233X_2X_3$$

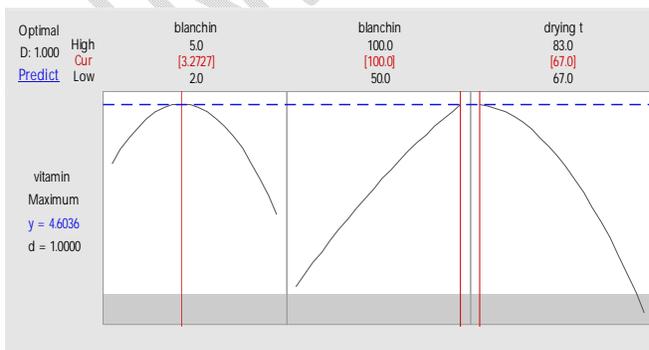
Where X_1 , X_2 , and X_3 are blanching time, blanching temperature, and drying temperature, respectively. The surface plot of vitamin A vs blanching time, and blanching temperature for orange flesh sweet potato can be found in graph 1



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°C blanching temperature, and 67°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 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°C, and drying temperature of 67°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 the processed ones. It was observed that orange flesh sweet potato processed at blanching time 3mins, blanching temperature 100°C, and drying temperature 46°C produced the maximum beta carotene yield. 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.

REFERENCES

1. University of Washington, (UW). Evans School Policy Analysis and Research (EPAR): Nigeria Sweet Potato Value Chain. Retrieved from www. (EPAR) un Request 220 Nigerian sp valuechain.org. Retrieved on 8th July, 2017
2. Fessehaye HD, Rungarun S. Effect of drying temperature on functional and digestive properties of sweet potato flour. Proceedings of 63rd IRES International conference Bangkok, 5-6th March 2017; 978-93-86291-88-2
3. Food and Agriculture Organization. Statistical Yearbook. Rome: Food and Agriculture Organization. 2004
4. Allen JC, Corbitt AD, Maloney KP, Butt MS, Truong VD. Glycemic index of sweet potato as affected by cooking methods. Open Nutr. J. 2012;6:1-11. doi: 10.2174/1874288201206010001
5. Ames BN. Low micronutrient intake may accelerate the degenerative diseases of aging through allocation of scarce micronutrients by triage. Proc Natl Acad Sci U S A. 2006
6. Kirk RS, Sawyer R. Pearsons composition and analysis of foods 9th Edition. Addison Wesley Longman Ltd, England pp 1998; 609-655 (2012)
7. AOAC. (2014) Official Methods of Analysis, Association of Official Analytical Chemists 2014.
8. Capanzana, Buckle. Optimization of germinated conditions by response surface methodology of a high amylase rice (*Oryza sativa*) cultivar. LWT. 1997; 30:155-163.
9. Lee J, Ye L, Landen WO, Eitenmiller RR. Optimization of an extraction procedure for the quantification of vitamin E in tomato and broccoli using response surface methodology. Journal of Food Composition and analysis 2000; 13:45-57
10. Joglekar AM, May AT. Product excellence through design of experiments. Cereal Foods World 1987; 32: 857- 868.
11. Velmurugu O, Ganeshavance R, Ramiah S, Sundara BK. J. Agric. Food 1995; 43:2546-2551
12. Anita BS, Akpan EJ, Okon PA, Umoren IU. Nutritive and antinutritive evaluation of sweet potato leaves, journal of Nutrition 2006; 5(2) 166-168.
13. Hiroshi I, Hirorko S, Noriko SO, Satoshi I, Tadahiro T, Akio M. Nutritive Evaluation of chemical composition of leaves stalks and stem of sweet potato (*Ipomea batatas*). Food Chemistry 2000; 68:350-367.

14. Ojeniyi T, Tewe OO. Processing and Utilization of sweet potato for food and livestock in Nigeria. Proceeding of 8th STRC, AB Symposium, Ibadan. 2001.
15. Teferra FT, Solomon A, Solomon W. Nutritional and Sensory Properties of Solar-Dried Carrot Slices as Affected by Blanching and Osmotic Pre-Treatments. International J. Food Sci. Eng., 2015; 5(1):24-32.

UNDER PEER REVIEW