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Changes in *β*-carotene Content of Thermally Processed Sweet Potato (*Ipomoea batatas*) Cultivar

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Authors' contributions

This work was carried out in collaboration between both authors. Author ANU carried out the analysis and wrote the manuscript with the literature references. Author PCO designed the study and interpreted the data. Both authors read and approved the final manuscript.

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ABSTRACT

This research was conducted to evaluate the changes in *β*-carotene (the major pro-vitamin A) associated with processing of sweet potatoes, Total *β*-carotene of a sweet potato cultivar (Ex-Igbariam) was quantified using High Performance Liquid Chromatography (HPLC). The level of retention (%R) of *β*-carotene was calculated. The all-trans and cis isomers of *β*-carotene were also quantified. Processing methods used were boiling, roasting, deep fat-frying and oven drying. *β*-carotene retention after oven drying and roasting was highly significant (P<o.o5) when compared to boiling and deep fat-frying. The total *β*-carotene concentration for the oven dried (29.25 µg/g) and roasted samples (23.53 µg/g) were about twice the concentration of the unprocessed (13.08 µg/g). Processing by boiling showed low *β*-carotene retention (38%) when compared with the unprocessed (100%). It also showed higher levels of the cis isomers of *β*-carotene which has less vitamin A activity. The all-trans geometrical isomer of *β*-carotene was greater than the cis geometrical isomer fractions in both the oven dried and roasted samples. The overall results show that oven drying and roasting improved the retention of pro-vitamin A activity in this sweet potato cultivar and that the all-trans configuration which is associated with higher nutrient value is still

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largely retained even after using these processing methods. There is the need to develop an appropriate method of identifying the isomers formed after processing by frying since the method applied in this research could not separate different isomers of fried samples.

Keywords: Total β-carotene; β-carotene retention; trans-cis isomers; boiling; roasting; deep fat-frying; oven drying.

1. INTRODUCTION

Sweet potato (*Ipomoea batatas (L) Lam.*) (convolvulaeae) is a tropical root crop of immense nutrition and health benefits. It came into prominence worldwide since the Sweet potato Symposium held in Taiwan in 1981 [1]. According to International Sweet potato Centre (CIP) [2], more than 135 million metric tons of sweet potatoes are produced annually. This root crop has a long history of saving lives because of its ability to mature fast. Sweet potato has a great potential to be an efficient and economic source of energy, providing over 90% of the nutrient per calorie required by most people [3]. In some varieties, both the roots and the leaves are good source of the B-group of vitamins, vitamin C, calcium, iron, potassium, sodium and *β*-carotene [4]. Sweet potato has high dietary fiber with smooth texture. The potentials of different sweet potato varieties to provide nutrients vary. Ex-Igbariam, an orange- fleshed sweet potato has a nutrient content of 6.13% (dwb) protein, 2.10% fiber, 2.0% ash, 1.40% fat, 27.37% carbohydrate and 61% moisture [5], but its potentials for alleviation of vitamin A deficiency has not been evaluated. Its content of pigment with health benefits such as isoflavones and flavonoids have also not been determined.

Due to its moderate to high content of pro-vitamin A, sweet potato has been identified as an important nutritious and health food necessary to reduce high incidence of vitamin A deficiency particularly in developing countries [6,7]. *β*-carotene is non-polar, highly conjugated, deeply colored and very lipophilic. *β*-carotene has been linked with enhancement of immune function and reduction of cardiovascular disorders [8-10].

Sweet potato can be used in conjunction with pulses and vegetables to formulate balanced meals for the entire family. It can be cooked, roasted, fried and processed in various other ways to give delicious dishes [11]. Sweet potato can also be processed into flour for confectionery.

For human nutrition applications, evaluation of retention of carotenoids in processed sweet potato should be in terms of the carotenoid concentrations in the food as consumed [12]. The all-trans form of *β*-carotene is a more potent source of vitamin A than the *cis* structural isomers. Vitamin A properties of the different *cis* transfigurations vary. For instance, 13-*cis*-*β*-carotene possess higher biological activity than 9-*cis*-*β*-carotene [13]. It becomes necessary to determine the carotenoid concentration of sweet potato given different processing and food preparation treatments in order to verify gains or losses in carotenoids during processing. The result can be used to make recommendations regarding the processing conditions that promote retention of *all-trans* isomer of *β*-carotene in sweet potato. The result can also be used to assist nutritional studies and to boost vitamin A availability in areas with a prevalence of vitamin A deficiency. Analysis was therefore performed to determine the retention of *β*-carotene in a sweet potato cultivar (Ex-Igbariam) given four different processing treatments, namely, boiling, roasting, deep fat frying and oven drying. The research also quantified changes in *β*-carotene content from *trans* to *cis* isoforms due to applied processing methods.

2. MATERIALS AND METHODS

A sweet potato cultivar (Ex-Igbariam), obtained from National Root Crop Research Institute (NRCRI), Umudike, Abia State, Nigeria was used for the research work.

2.1 Sample Preparation

The sample was washed with clean water, peeled, washed again and sliced to 1cm thickness [14]. The sample was packaged in aluminum foil, and stored at -80℃ to prevent enzymatic degradation of the carotenoid. Duplicate samples for both raw and processed were taken from this batch for subsequent *β*-carotene analysis.

2.2 Processing Methods

Modified methods from Padmavati et al. [15], were adopted.

2.2.1 Boiling

About three (3) grams of the sample was boiled in 100 mL of water at 98℃ for 5 minutes.

2.2.2 Roasting

About three (3) grams of the sample was roasted in electric oven (Continental) at 120℃ for 10 minutes.

2.2.3 Deep fat frying

About three (3) grams of the sample was fried in Turkey brand pure vegetable oil for 5 minutes at 240℃.

2.2.4 Oven drying

About three (3) grams of the sample was oven dried in a hot box oven (Gallemkamp Model OV-440) at 60℃ for 24 h.

2.3 Carotenoid Extraction and *β*-carotene Analysis

About three (3) grams of the duplicate samples (raw and processed) were used for carotenoid extraction according to the method of Rodriguez-Amaya and Kimura [12]. The analysis of *β*-carotene in this sweet potato using HPLC was according to the method of Howe and Hanumiharjo [16]. The concentrated and dried *β*-carotene samples were reconstituted in methanol dichloroethane (1000 µl, 50:50v/v) and injected (10 µl) into the HPLC. The HPLC consisted of a guard column, C_{30} YM Ccarotenoids column (4.6 x 2.50 mm, 3 µm), 626 HPLC pump, 717 auto sampler, and a 2996 photodiode array detector (Waters Corporation, Milford M.A). Solvent A consisted of 100% methanol. Solvent B consisted of 100% methyl tert-butyl ether. The isocratic elution was carried out with 50% of solvent A and 50% of solvent B at 1ml/minute for 15 minutes. Isomers of *β*-carotene were eluted between 6-8 minutes. Chromatograms were generated at 450 nm. Identification of trans and cis isomers of β-carotene was done using standards for authentication of their absorption spectrum. Internal standards for identification of isoflavones and bioflavonoids were not available. The calculation of % *β*-carotene retention was carried out according to Murphy et al. [17].

3. RESULTS

3.1 Retention of *β*-carotene in Thermally Processed Sweet Potato Samples

Figs. 1, 2, and 3 show the effect of thermal processing on the total *β*-carotene and *β*-carotene retention of Ex-Igbariam sweet potato cultivar. The result indicates significant ($P<0.05$) differences in the total *β*-carotene content of the samples given different processing treatments. Processing by oven drying led to the highest *β*-carotene retention values (29.25 µg/g, and 92%).

This was followed by roasting with total *β*-carotene and *β*-carotene retention concentration of 23.53 µg/g and 87% respectively. Processing by boiling showed a significant decrease in total *β*-carotene and low *β*-carotene retention (4.64 µg/g and 38%) when compared with oven drying and roasting methods (Figs. 1, 2 and 3). The HPLC Chromatograms of the boiled, roasted and oven dried samples are shown in the Figs. 1,2 and 3 with identified major peaks, namely, peak 1, *all-trans-β*-carotene, peak 2, 9-*cis-β*-carotene and peak 3, *13-cis*-β-carotene respectively.

There were unidentified minor peaks due to lack of internal standards which may represent the xanthophyll fractions.

3.2 Effects of Processing on *Cis-trans* Isomers of *β*-carotene

Table 1 shows the effect of processing methods on the formation of *cis-trans* isomers of *β*-carotene. The *trans* isomers from the roasted and oven dried samples are quantitatively significantly ($P<0.05$) different from the boiled and unprocessed samples (Table 1). This was followed by 9-*cis-β*-carotene, 13-*cis-β*-carotene and 15-*cis-β*-carotene respectively. The unstable nature of carotenoids provoked trans-cis isomerization during processing. The *cis*-isomers contribute to lower Vitamin A activity than the all trans-isomers. Stahl et al. [18] and Ben-Amotz and Levy [19] reported preferential absorption of trans-isomers of β-carotene in humans. The higher concentration of all *trans-β*-carotene obtained in this work means more biologically available Vitamin A in the sweet potato metabolism in the body, giving that 6µg *β*-carotene is one (1) retinol equivalent.

Edible portion of Ex-Igbariam sweet potato cultivar contained 39 g/100 g dry matter; 61 g/100 g moisture; 6 g/100 g protein; 2 g/100 g ash; 2 g/100 g fiber; 1.4 g/100 g fat and 27.3 g/100 g carbohydrate respectively. The mineral content was as follows: phosphorus-19 mg/kg; potassium-260 mg/kg; sodium-59mg/kg; calcium-80 mg/kg; and magnesium-24.3 mg/kg [5].

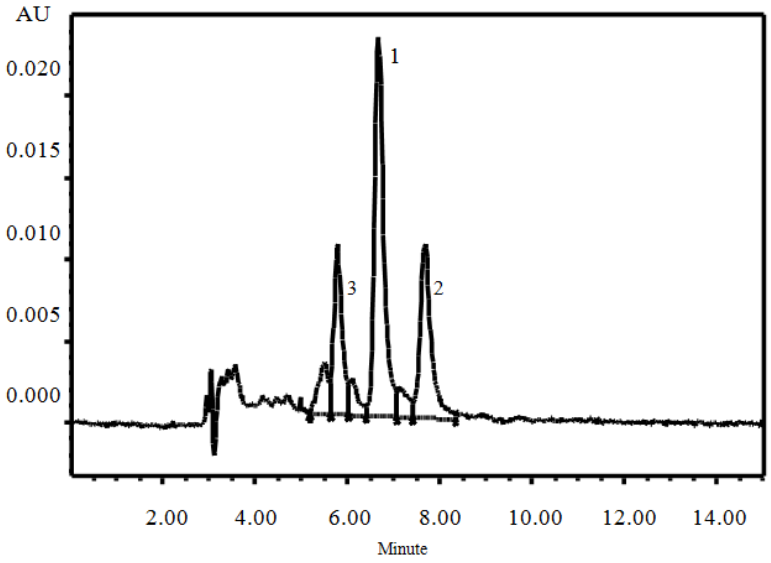

Fig. 1. HPLC chromatogrm of boiled sweet potato sample (Ex-Igbariam cultivar) peaks (1) All-trans-β-carotene (2) 9-cis- β-carotene (3) 13-cis- β-carotene

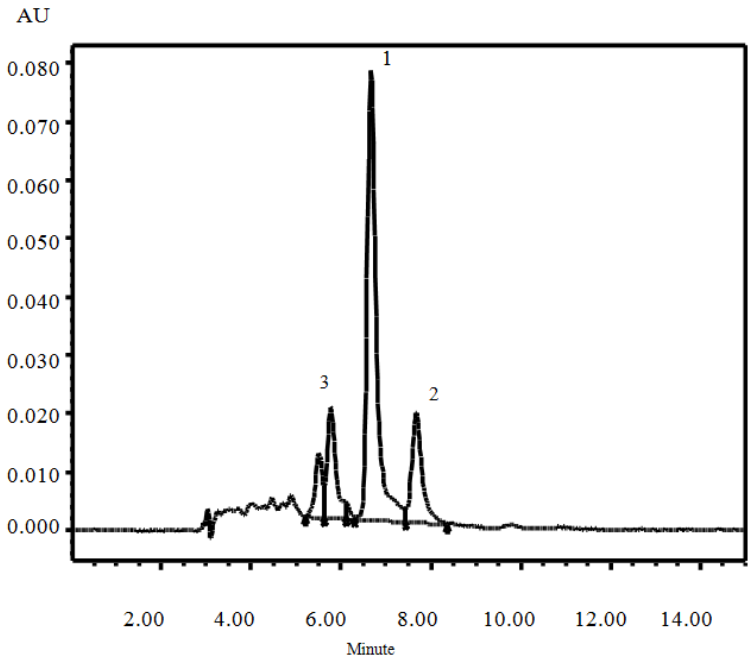

Fig. 2. HPLC chromatogram of roasted sweet potato sample (Ex-Igbariam cultivar) peaks (1) All-trans-β-carotene (2) 9-cis- β-carotene (3) 13-cis- β-carotene

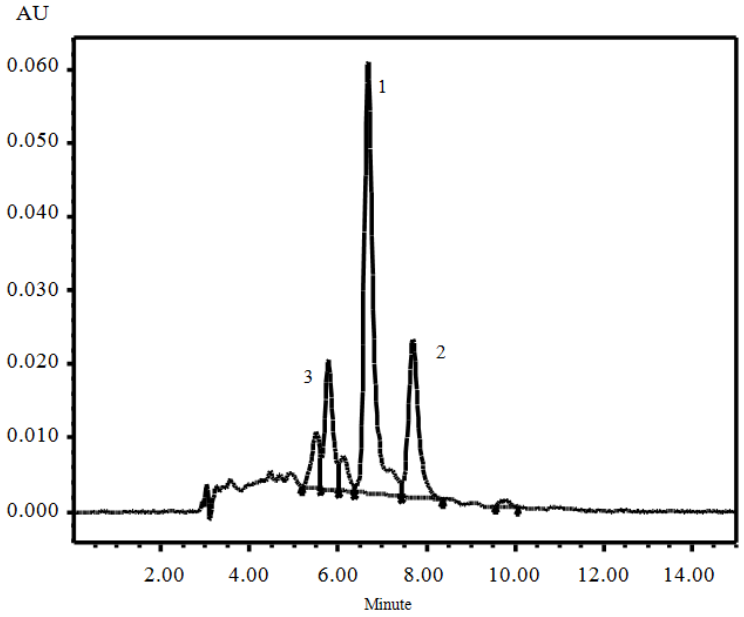

Fig. 3. HPLC chromatogrm of oven-dried sweet potato sample (Ex-Igbariam cultivar) peaks (1) All-trans-β-carotene (2) 9-cis- β-carotene (3) 13-cis- β-carotene

Table 1. Effect of processing on the *Trans* and *cis* isomers of *β*-carotene and % *β*-carotene retention of Ex-Igbariam sweet potato cultivar

Isomers	Raw	Boiled	Roasted	Oven dried
9-cis	3.95^{b}±0.04	1.25^{c}±0.02	5.09^{ab}±0.91	7.0^{a}±1.18
13-*cis*	2.66^{b}±0.04	1.01^{c}±0.06	3.95^{a}±0.092	4.74^{a}±0.76
15-*cis*	0.26^{b}±0.0	0.27^{b}±0.i4	0.66^{a}±0.071	0.65^{a}±0.09
All *trans*	6.13^{c}±0.11	2.08^{d}±0.11	13.84^{b}±0.91	16.89^{a}±2.18
Total carotene	13.02^{c}±0.18	4.6^{d}±0.21	23.53^{b}±0.17	29.26^{a}±0.45
%*β*-carotene retention	100.0^{a}±0.0	38.0^{d}±1.41	87.0^{c}±1.41	92.0^{b}±2.83

Values in the same row with similar superscript are not significantly different (P<0.05)

4. DISCUSSION

The major carotenoid found in the raw and processed samples was pro-vitamin A carotenoids, namely, all trans-β-carotene, followed by 9-*cis*-*β*-carotene, 13-*cis*-*β*-carotene and lastly *15*-cis-β-carotene respectively. The result of total *β*-carotene obtained from oven dried (29.25 µg/g) and roasted (23.53 µg/g) methods are about twice the concentration of total *β*-carotene content of the unprocessed (13.08 µg/g) sample (Table 1). On the other hand, the result obtained from boiling (4.64 µg/g) was about thrice less the concentration of the unprocessed (13.08 µg/g) (Table 1). Similarly, the all *trans* and isomeric forms of *β*-carotene in the roasted and oven dried methods doubled their concentrations in relation to the unprocessed tuber while the case was the opposite in the boiled method. The processing conditions employed affected the sweet potato matrix differently, resulting to significant (P<0.05) variation in concentrations of *β*-carotene. This means that the stability of *β*-carotene and the isoforms seem to be dependent on the processing method. Absorption of oil by the product during the deep fat frying process may have resulted into peak broadening in the reverse-phase HPLC thus, causing poor separation of the all and *cis* *β*-carotene isomers in the deep fat frying [16]. The *β*-carotene content and its isomeric forms of deep fat fried food products could not be quantified using the experimental procedures employed in the present research. There is need for the development of a better separation method for deep fat fried samples.

The results obtained in this research for % *β*-carotene retention (Table 1) are comparable to

results obtained using HPLC for other cultivars of processed sweet potato and other sources of *β*-carotene by other researchers. In this study, % *β*-carotene retention for oven dried (92%) and roasted (87%) methods were higher and significantly ($P<0.05$) different from the boiled/cooked (38%) method (Table 1). Reddy et al. [20] observed 21-36% β-carotene retention for cooked sweet potato. Oven drying at 60℃ for 12h resulted in 96-98% β-carotene retention of a vegetable (Pak Sak) and 90% β-carotene retention in *Methithelpla,* (chopped and roasted) [15]. Also stripped blanching of sweet potato at 100℃ for 10 minutes resulted in 93% retention of all *trans β*-carotene [21]. True retention values greater than 100% was reported for SPK-004 and Salyboro sweet potato varieties after boiling and for Zapallo after roasting [22]. They attributed this to higher chemical extractability of *β*-carotene due to changes in the cell wall structure during heat treatment. Deep fat frying of chopped vegetable [15] resulted into 15% *β*-carotene retention. Severe heat treatment (240℃) and lipid solubility in the deep frying method and/or absorption of excess oil may result into peak broadening and non-separation of the *trans* and *cis*-*β*-carotene [16,23].

Provitamin A (*β*-carotene) was higher in processed than in unprocessed food samples. Processing denatures protein and soften cell walls, facilitating the release of carotenoids from the food matrix and/or carotenoids bound to protein, thereby, making more carotenoids biologically available for nutrition and health. Absorption of *β*-carotene is enhanced if eaten with fats since the pigment is fat soluble. However, the *β*-carotene retention of the boiled sample (4.6 µg/g and 38%) was about thrice lower than the unprocessed (13.02 µg/g) value. This loss of *β*-carotene may be due to the sweet potato matrix and solubilization of carotenoid in the cooking water during the boiling process. Blanching (100℃ for 3 minutes) was found to improve the *β*-carotene content of okra [24]. Short time blanching treatment might alter the nature of the carotenoid-protein complex improving bioavailability of the carotenoid [25]. Processing sweet potato by oven drying and roasting methods contributed to higher concentration of *β*-carotene and % *β*-carotene retention in this work and may serve as a recommendation.

5. CONCLUSION

Oven drying and roasting of sweet potato were found to yield higher values of *β*-carotene than boiling/cooking. The afore mentioned processing methods also led to better retention of all trans configuration of *β*-carotene which is associated with higher vitamin A activity. There is need to find alternative methods for quantifying *trans* and *cis* isomers formed during deep fat frying of sweet potatoes. The method used in the present research could not separate the isomers for quantitative analysis. Compositional analysis indicates that the edible portion of this sweet potato cultivar is rich in potassium and calcium.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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