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Determination of Carotenoids in Flour and Extruded Snacks from Blends of Biofortified Cassava, Orange-Fleshed-Sweet Potato and Plantain with Moringa Leaf

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Abstract

This work produced extruded baked snacks from composite flour blends of Yellow root cassava, Orange-fleshed-sweet potato and Plantain fortified with Moringa leaf powder. This research is aimed at developing extruded snacks from the composite flour of Yellow root cassava, Orange-fleshed-sweet potato and plantain with Moringa leaf as well as determining the carotenoid contents using High Performance Liquid Chromatography. Eight flour samples and eight composite snacks at different levels of Orange-fleshed-sweet potato, Yellow root cassava, and plantain with Moringa leaf flour formulations were prepared and evaluated for carotenoid content. The results indicated significant differences ($p < 0.05$) in the total β-carotene content of the flour samples with a range of 1.92 ± 0.00 µg/g in 95% Yellow root cassava + 5% Moringa leaf powder to 28.95 ± 0.00 µg/g in 95% OFSP + 5% moringa leaf powder. Total β-carotene for the extruded snacks ranged from 6.37 ± 0.00 µg/g in 95% Plantain + 5% moringa leaf powder to 18.17 ± 0.00 µg/g in 95% Orange-fleshed-sweet potato + 5% Moringa leaf powder. 13-Cis-β-carotene, β-cryptoxanthin, Trans-β-carotene and 9-Cis-β-carotene values were generally higher in the flour samples. The study showed that snacks with high carotenoid retention could be produced from local crops as a substitute for wheat.

Keywords

Carotene, Flour, Retention, Snacks, Vitamin A

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1. Introduction

Wheat flour has overtime being utilized in the manufacture of baked products like meat pie, doughnuts, sausage rolls, biscuits, cakes, and bread, due solely to the characteristics of protein found in wheat flour. But climatic reasons of the tropics such as Nigeria which are not suitable for the production of wheat has consequently increased the complete dependence on imported wheat for baked products manufacture in Nigeria [1]. However, gluten intolerance relative to certain cereals inclusive of which are barley, oats, rye and wheat have been discovered in some individuals. This intolerance causes intestinal absorption impairment thereby leading to malnourishment which has necessitated the use of composite flour. Composite flour has been defined as a mixture of different flours, with or without the addition of wheat flour and could be obtained from roots, cereals, tubers, and legumes [2]. These flours have extensively been used in baked foods production with a record of successes. However, cereal-tuber-legume combination of composite flour in the manufacture of various products has been reported. Some of the advantages of composite flour for developing countries like Nigeria stretch from reduction of

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wheat flour importation to encouragement of the use of domestic agricultural products like sweet potatoes, rice, soybean, plantain, maize, cassava, as flour [3].

Plantain (*Musa paradisiaca*) is largely produced in Nigeria and is traditionally used for preparation of gruel when processed into flour. It is also consumed as snacks in form of chips and gradually has been applied during the formulation of weaning food and preparation of composite flour [4]. Its flour has: a good prospect for use in bakery products as a functional agent; successfully been used as a composite of conventional wheat flour; high levels of Nitrogen, Phosphorus, Calcium, Potassium, Magnesium; vitamins B_1, B_2, B_3, B_6, A, and C. Although plantain has lower protein content, its gluten deficiency makes it suitable for those suffering from gluten intolerance [5].

Moringa oleifera is famous for its application in both external and internal health. According to Makkar et al. [6] moringa leaves are filled with various vitamins and minerals, particularly vitamins A and Calcium, Zinc, Magnesium, Iron, and Potassium. Its supplementation may help with improving cardiovascular health, glucose metabolism, eye and pulmonary health.

Cassava is a very popular root crop of the tropics. It has the yellow root as a new breed and the regular whte breed as a staple crop in tropical countries with about 300 million people relying on it for at least 10% of their caloric intake per day. Being a major food staple, biofortified cassava (β-carotene), can potentially alleviate the deficiency of vitamin A in Africa. This is because of the difference between biofortification and ordinary fortification, which focuses on nutrition contribution to plant foods as the plants are growing, rather than nutrient addition to the food during processing [7].

Sweet potatoes (*Ipomea batatas* L.) belong to the botanicial family convolvulaceace. In Nigeria, sweet potato is a major diet composition of the populace, eaten boiled, fried for breakfast or as sweet potato chips [8]. It is an excellent source of protein, iron and vitamin A, B_2 and C. Their extracts are high in carotenoids and phenolic compounds with anti-cancer, anti-mutagenic and anti-bacteria properties [9]. Although, majority of sweet potatoes' varieties are high in carbohydrate, orange-fleshed-sweet potato (OFSP) varieties also provide vitamins A and C. The β- carotene concentration ranges from 0.2 µg/g in white fleshed sweet potato, to 218 µg/g in orange-fleshed-sweet potato. β-carotene, a potent vitamin A with 100% source of provitamin-A bioactivity has been adjudged to have a connection with decrease in the risk of degenerative disease and immune functionalities. Vitamin A also plays crucial roles in vision, cellular differentiation and morphogenesis, haemopoisis, skeletal growth and fertility in man [10].

This research aims at getting composite flour from local crops (orange-fleshed-sweet potato, biofortified-cassava, plantain-blended with moringa olifera) to replace wheat and combining its qualities in the production of an extruded snack whose carotenoid content was evaluated with High Performance Liquid Chromatography.

2. Methodology

2.1. Raw Material Procurement

Unripe plantain (*Musa paradisiaca* Normalis) which served as a raw material for this study was obtained from Ndi-oru market in Umuahia, Abia State. (*Manihot esculenta* Cranz) Orange-fleshed-sweet potatoes (*Ipomoea batatas* Lam*)* and UMUCASS 45 variety of Yellow root cassava were obtained from the National Root Crop Research Institute (NRCRI) Umudike. Micheal Okpara University of Agriculture, Umudike (MOUAU) provided the Moringa leaves used in this research. Figure 1 and 2 shows the schematic flow diagram for the production of Yellow root cassava, Orange-fleshed-sweet potato and Plantain flour respectively.

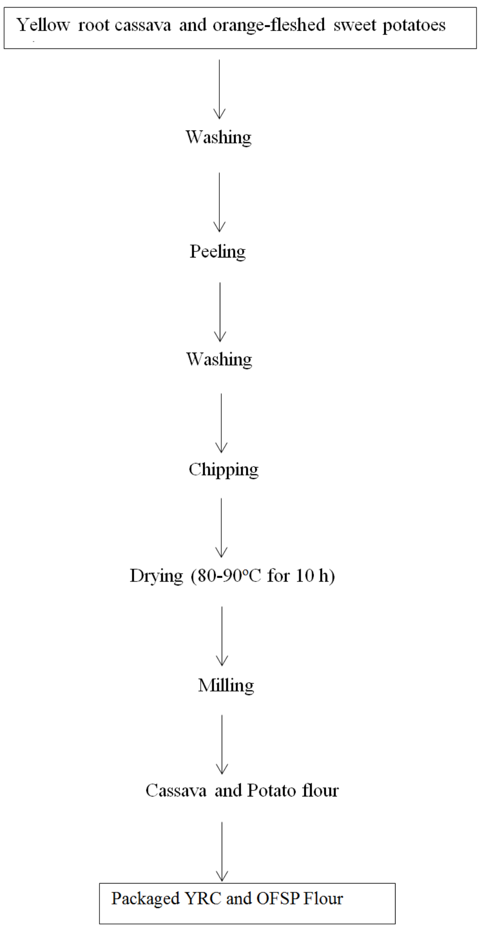

Figure 1. Schematic flow diagram for the production of orange-fleshed sweet potato and yellow root cassava flour.

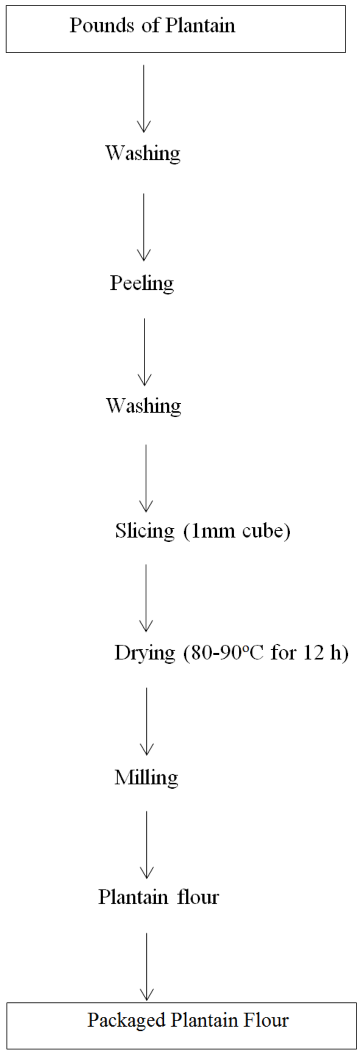

Figure 2. Schematic flow diagram for plantain flour production.

2.2. Formulation of Raw Materials (Flour)

Orange-fleshed-sweet potatoes, Plantain, Cassava flour and Moringa leaves powder were blended in ratios as shown in Table 1, with the use of Hobart mixer. It shows different blend formulations of raw composite flour into eight (8) sample combinations. The blended formulations were stored at ambient temperature, using polyethylene bags.

Table 1. Composite Flour Blends of Orange-fleshed sweet potato (OFSP), Plantain, Yellow Root Cassava (YRC) and Moringa leaf.

Plantain (%)	YRC (%)	OFSP (%)	Moringa leaf powder (%)
20	65	10	5
15	70	10	5
10	75	10	5
10	80	5	5
5	85	5	5
-	95	-	5
-	-	95	5
95	-	-	5

Keynote:
OFSP – Orange-fleshed sweet potato
YRC- Yellow root cassava

2.3. Preparation of Extruded Snacks from the Flour Blends of Yellow Root Cassava, Orange-fleshed-sweet Potato and Plantain with Moringa Leaf

The production of puffed snacks was done using the method described by Uzoaga et al. [11]. The extruded baked snacks was produced from the flour blends of unripe plantain, orange-fleshed-sweet potato, yellow root cassava, with moringa leaf powder which served as a fortificant. A mixture of 100 g cassava flour, unripe plantain flour, orange-fleshed-sweet potato flour, and moringa leaf powder, 150 ml of water, 1g of mixed spices and 1g of salt was used to prepare the dough for the extruded blends. The flour was later mixed to consistency at temperature of 37°C thereby obtaining a malleable dough. 5 cm diameter of dough was formed into cylindrical rolls which was later filled in an extruder piped on a greased tray. Using a hot oven (Gallenkamp Co. Ltd. London, England), the extruded product contained in a greased tray was baked at 100°C for 30 minutes to moisture content of about 12%. The baked snacks was cooled using a kitchen paper and stored prior to analyses in an air tight container.

2.4. Determination of Carotenoid Using High Performance Liquid Chromatography (HPLC)

The method described by Tanumihardjo and Howe [12] was used. Fifteen (15) ml petroleum ether was taken and drained down under Nitrogen. Methanol/dichloroethane (1 ml, 50: 50 v/v) was used to reconstitute samples with the injection of 50 µl into the high performance liquid chromatography (HPLC). A water HPLC system (Water Corporation, Milford, MA) consisting of a guard column, C30 YMC carotenoid column (4.6 x 250 mm, 3 µm), water 626 binary HPLC pump, 717 auto sampler and a 2996 photo diode array detector was used for carotenoid determination. Solvent A: 100% Methanol, Solvent B: 100% Methyl tertbutyl ether (MTBE). Isocratic elution was performed at 1 ml/min and run time was for 15 min.

2.5. Statistical Analysis

Statistical analysis was carried out on all data using SPSS version 20.0 (IBM SPSS Statistics for windows, IBM Corporation Armonk, New York). The mean and least square deviation (LSD) triplicate analyses were calculated. ANOVA was performed for significant difference ($p < 0.05$) determination between group means while the new Duncan multiple range test was used to separate the means.

3. Results

Table 2. Retention of Provitamin-A Carotenoid of the Composite Flour of Plantain, Orange-Fleshed Sweet Potatoes and Yellow Root Cassava Blended with Moringa Oleifera Leaf.

Samples	β-CryP (μg/g)	13-Cis Beta (μg/g)	Trans-Beta (μg/g)	9-Cis (μg/g)	TBC (μg/g)
A_{cf}	2.12^{e}±0.00	2.96^{d}±0.00	9.73^{b}±0.00	1.25^{d}±0.00	13.94^{c}±0.00
B_{cf}	4.86^{b}±0.00	3.73^{c}±0.00	7.16^{c}±0.00	2.48^{bc}±0.00	13.38^{d}±0.00
C_{cf}	3.61^{c}±0.00	5.89^{b}±0.00	18.20^{a}±0.00	2.64^{b}±0.00	26.74^{b}±0.00
D_{cf}	1.66^{f}±0.00	2.09^{e}±0.00	5.66^{e}±0.00	1.38^{d}±0.00	9.13^{e}±0.00
E_{cf}	3.33^{d}±0.00	3.52^{c}±0.00	0.64^{g}±0.00	2.14^{c}±0.00	6.29^{f}±0.00
F_{cf}	0.64^{g}±0.00	0.14^{f}±0.00	0.97^{g}±0.00	0.81^{e}±0.00	1.92^{h}±0.00
G_{cf}	0.06^{g}±0.00	0.24^{f}±0.00	2.45^{f}±0.00	0.27^{e}±0.00	2.96^{g}±0.00
H_{cf}	10.51^{a}±0.00	18.88^{a}±0.00	6.61^{d}±0.00	3.45^{a}±0.00	28.95^{a}±0.00
Mean values are of triplicate determinations and expressed as mean ± SD. Values with the same superscripts in the same column are not significantly different (p > 0.05)					

YRC = Yellow Root Cassava, OFSP= Orange-fleshed Sweet Potato cf = Composite flour
Acf = 65% YRC + 10% OFSP + 20% Plantain + 5% Moringa leaf powder, Bcf = 70% YRC + 10% OFSP + 15% Plantain + 5% Moringa leaf powder, Ccf = 75% YRC + 10% OFSP + 10% Plantain + 5% Moringa leaf powder, Dcf = 80% YRC + 5% OFSP + 10% Plantain + 5% Moringa leaf powder, Ecf = 85% YRC + 5% OFSP + 5% Plantain + 5% Moringa leaf powder, Fcf = 95% YRC + 5% Moringa leaf powder, Gcf = 95% Plantain + 5% Moringa leaf powder, Hcf = 95% OFSP + 5% Moringa leaf powder.

Table 2 showed the quantification and identification of carotenoid in the composite flour from Yellow root cassava, Orange-fleshed-sweet potato, Plantain and Moringa oleifera leaf. β-cryptoxanthin for the flour samples ranged between 0.06 to 10.5 µg/g with sample H_{cf} which is the blend of 95% OFSP + 5% Moringa leaf powder being the highest (10.5 µg/g) and sample G_{cf} which is a blend of 95% Plantain + 5% Moringa leaf powder (0.64) being the lowest.

Table 3. Retention of Provitamin-A Carotenoid of the Extruded Baked Snacks from Yellow Root Cassava, Orange Fleshed Sweet Potatoes, Plantain Blend with Moringa Oleifera Leaf.

Samples	β-CryP (μg/g)	13-Cis Beta (μg/g)	Trans-Beta (μg/g)	9-Cis (μg/g)	TBC (μg/g)
I_{es}	1.35^{c}±0.00	2.17^{c}±0.00	8.50^{a}±0.00	2.62^{c}±0.00	12.28^{e}±0.00
J_{es}	1.76^{b}±0.00	2.39^{c}±0.00	5.65^{d}±0.00	2.49^{cd}±0.00	10.54^{d}±0.00
K_{es}	1.85^{b}±0.00	3.22^{d}±0.00	8.17^{b}±0.00	5.62^{b}±0.00	17.01^{b}±0.00
L_{es}	0.06^{e}±0.00	5.19^{e}±0.00	2.20^{f} ±0.00	0.35^{e}±0.00	7.74^{f} ±000
M_{es}	1.29^{c}±0.00	2.76^{f} ±0.00	6.24^{cd}±0.00	2.86^{c} ±0.00	11.87^{c}±0.00
N_{es}	1.35^{c}±0.00	2.04^{a} ±0.00	3.72^{e} ±0.00	1.92^{e} ±0.00	7.68^{f} ±000
O_{es}	0.89^{cd}±0.00	2.48^{g} ±0.00	1.83^{g} ±0.00	2.06^{d} ±0.00	6.37^{g} ±0.00
P_{es}	16.63^{a}±0.00	3.39^{b} ±0.00	6.99^{c} ±0.00	7.78^{a} ±0.00	18.17^{a}±0.00
Mean values are of triplicate determinations and expressed as mean ± SD. Values with the same superscripts in the same column are not significantly different ($p > 0.05$)					

YRC = Yellow Root Cassava, OFSP= Orange Fleshed Sweet Potato $_{es}$ = Extruded snacks
I_{es} = 65% YRC + 10% OFSP + 20% Plantain + 5% Moringa leaf powder, J_{es} = 70% YRC + 10% OFSP + 15% Plantain + 5% Moringa leaf powder, K_{es} = 75% YRC + 10% OFSP + 10% Plantain + 5% Moringa leaf powder, L_{es} = 80% YRC + 5% OFSP + 10% Plantain + 5% Moringa leaf powder, M_{es} = 85% YRC + 5% OFSP + 5% Plantain + 5% Moringa leaf powder, N_{es} = 95% YRC + 5% Moringa leaf powder, O_{es} = 95% Plantain + 5% Moringa leaf powder, P_{es} = 95% OFSP + 5% Moringa leaf powder

Table 3 showed the quantification and identification of carotenoid in extruded baked snacks from Yellow root cassava, Orange-fleshed-sweet Potato, Plantain and Moringa oleifera leaf. Among the baked snacks, sample P_{es} was predominant in β-cryptoxanthin (16.63 µg/g), 9-cis (7.78 µg/g) and total β-carotene (18.17 µg/g) while sample L_{es} was the least in β-cryptoxanthin (0.06 µg/g) and 9-cis (0.35 µg/g). A significant difference ($p < 0.05$) exists in the β-cryptoxanthin content of the samples while samples J_{es} and K_{es} as well as samples I_{es} M_{es} N_{es} and O_{es} did not vary significantly.

Table 4. Retention of Provitamin-A Carotenoid in Fresh Yellow Root Cassava, Orange Fleshed Sweet Potatoes and Plantain.

Samples	β-CryP (μg/g)	13-Cis Beta (μg/g)	Trans-Beta (μg/g)	9-Cis (μg/g)	TBC (μg/g)
Q	0.31^{a}±0.00	0.78^{b}±0.00	2.15^{b}±0.00	1.28^{a}±0.00	4.21^{b}±0.00
R	0.03^{c}±0.00	0.82^{a}±0.00	1.44^{c}±0.00	0.29^{c}±0.00	2.54^{c}±0.00
S	0.06^{b}±0.00	1.31^{c}±0.00	4.19^{a}±0.00	1.06^{b}±0.00	6.57^{a}±0.00
Mean values are of triplicate determinations and expressed as mean ± SD. Values with the same superscripts in the same column are not significantly different (p>0.05)					

YRC = Yellow Root Cassava, OFSP= Orange-Fleshed Sweet Potato,
Q = 100% YRC,
R = 100% Plantain
S = 100% OFSP

For Table 4, the highest total β-carotene value was observed in sample S (6.57 μg/g), followed by sample Q (YRC 4.21 μg/g) and sample R (Plantain 2.54 μg/g). The three variants of provitamin A recorded highest values in samples S and Q. Samples S had the highest values for 13-Cis Beta-carotene, Trans-Beta-carotene and total Beta-carotene while Q was highest for Beta-cryptoxanthin and 9-Cis carotene.

4. Discussion

The values for β-cryptoxanthin in this study were lower than the value of 21.20 μg/gdb reported by Kim et al. [13]. However, this does not agree with the result obtained by Stinco et al. [14] and Tomlins et al. [15] whose report showed a total carotene content of 61.7 μg/g and 41.26 μg/g respectively with no detection of β-cryptoxanthin. β-cryptoxanthin is the prevalent dietary carotenoid in fruits and vegetables and is a provitamin-A carotenoid (PVAC) along with α-carotene and β-carotene [16]. Lower concentrations of high density lipoproteins (HDL) in the human body were observed to be associated with β-cryptoxanthin intake by food with current experimental research reporting a positive β-cryptoxanthin correlation with osteoporosis prevention [17]. There was an observable significant difference ($p > 0.05$) between the samples except samples F_{cf} and G_{cf}.

The values for 13-Cis-β-carotene ranged from 0.14 μg/g (sample F_{cf}) to 18.8 μg/g (sample H_{cf}). Sample H_{cf} which is the blend of 95% Orange-fleshed-sweet potato flour + 5% moringa leaf powder, indicated highest in value of 13-Cis-β-carotene followed by sample C_{cf} (5.89 μg/g) which is the blend of 75% YRC + 10% OFSP + 10% Plantain + 5% Moringa leaf powder while sample F_{cf} which is the blend of 95%YRC + 5% Moringa leaf powder indicated least in value. Regarding the isomers, there was a significant difference ($p < 0.05$) among the blends with respect to 13-Cis-β-carotene concentration in the flour samples except sample B_{cf} which did not vary significantly ($p > 0.05$) with sample E_{cf} as well as sample F_{cf} which was not significantly different ($p > 0.05$) from sample G_{cf}. However, these values did not differ from 0.42 μg/g and 0.39 μg/g obtained for cassava root as reported by Ronielli et al. [18].

The values for samples A_{cf} and D_{cf} were similar to the values of 2.39 μg/g and 2.47 μg/g for 14 WAP and 8 WAP of Orange-fleshed-sweet potato vine varieties as reported by Emetole [19] but differed from 1.46 μg/g reported for TIS 87/0087 sweet potato variety by Ukom et al. [20]. There has been reports of higher biological availability of all trans forms than their cis-counterpart, while the β-carotene and β-apo-12-carotenoid show the highest rate of bioconversion [21].

Islam et al. [22] reported cis-β-carotene value of 3.5 − 23.44 μg/g for orange-fleshed-sweet potato which was higher than the values obtained for both 13 and 9-cis in this study except samples B_{cf}, C_{cf}, and E_{cf} in respect of 13 cis-β-carotene. Berni et al. [16] reported a value of 3.8 – 9.0 μg/g for 13-cis which was lower than the value of 18.08 μg/g for sample H_{cf} (95% OFSP). Also, the value of 0.06 – 9.8 μg/g for 9-cis reported by Liu et al. [23] was in agreement with the values obtained for 9-cis in this study.

These values were similar to the values obtained for total carotenoid on five cassava genotype processed flour reported by Oliveria et al. [24]. Ukom et al. [20] reported concentration of 3.82 μg/g for CIP Tanzania sweet potato variety which was very low as compared to the value obtained for sample H_{cf} [28.95 μg/g (composite flour of Orange-fleshed-sweet potato and Moringa oleifera)]. β-carotene are the most potent and widespread provitamin-A. It has 100% vitamin A activity. Trans-β-carotene has 100% biopotency as provitamin-A. It is preferentially absorbed over the cis-isomers in human [25].

There was no significant difference ($p < 0.05$) among samples B_{cf} and E_{cf} as well as sample F_{cf} and G_{cf}. Sample H_{cf} presented the highest score in respect of 13-Cis β-carotene (18.88 μg/g) followed by sample C_{cf} (5.89 μg/g). The values for samples F_{cf} (0.14 μg/g) and G_{cf} (0.24 μg/g) fall within the range (0.22 – 1.24 μg/g) reported by Oliveira et al. [24] on the evaluation of 12 varieties of yellow bitter cassava pulp for 13-Cis β-carotene.

The value of trans-β-carotene was highest (18.20 μg/g) in sample C_{cf}, followed by sample A_{cf} (9.73 μg/g), B_{cf} (7.16 μg/g), H_{cf} (6.6.61 μg/g) and D_{cf} (5.66 μg/g) respectively. A significant difference ($p < 0.05$) was observed among the composite flour. Bengtsson et al. [26] reported a range of 4.7 – 94.0 μg/g for 13-cis while kim et al. [13] reported a range of 7.4 – 61.8 μg/g for 9-cis which differ from the figures obtained in this study. The varying carotenoid concentrations of isomers found in Orange-fleshed-sweet potato may be due to the location or methods used during processing. Orange-fleshed-sweet potato is considered as a good source of carotenoid for combating ventricular assist device problems in developing countries. Stinco et al. [14] reported a value of 13.11 μg/g while Huang et al. [27] reported a range of 1 – 15.0 μg/g for β-carotene in Orange-fleshed-sweet potato which was lower than the range value (6.37 – 18.17 μg/g) obtained in this study.

β-cryptoxanthin is a xanthophyll with 50% provitamin-A activity of β-carotene [28]. A 24 μg of β-cryptoxanthin will metabolize to 1 μg of retinol when consumed via food into the human body. Medical studies reported a reduction of 20%

in the risk of pulmonary cancer with the consumption of β-cryptoxanthin [29]. Studies have shown that increased consumption of carotenoids (β-cryptoxanthin and lycopene) possess promising connection with a reduction in the risk of mouth cancer [30]. Chen and Huang [31] reported that heating in a reflux converts β-carotene to all trans and 13-cis beta-carotene. Pasturized and sterilized carrot juice was reported to have high concentrations of 13-cis beta-carotene while 9-cis beta-carotene was reportedly seen in blanched conditions. Moreover, 9-cis and 13-cis beta-carotene were reported to have been produced independently from cis bases due to the non-enzymatic actions of all trans forms [32].

The total β-carotene presented highest content in all baked snacks I_{es} – P_{es} than β-cryptoxanthin, 13-cis, 9-cis and trans-beta carotene which varied from 6.37 – 18.17 µg/g. These values were higher than the value of 4.55 µg/g reported after cooking Hibrido 2003 14 11 cassava cultivar [33]. According to Degrass [34], β-carotene, α-carotene and β-cryptoxanthin are the important precursors of vitamin A (in human nutrition) amongst the plant carotenoids found in nature. The most essential pro-vitamin A component in foods rich in carotenoid is β-carotene. Studies in Brazil have shown the predominance of trans β-carotene in the provitamin-A content of Orange-fleshed-sweet Potato [28]. Trans-isomers significantly increased on the baked snack products for samples D_{es} - L_{es} (2.09 µg/g- 5.19 µg/g), F_{es}- N_{es} (0.14 µg/g - 2.04 µg/g), G_{es} - O_{es} (0.24 µg/g - 2.48 µg/g). Thakkar et al. [35] observed that garri processing was associated with a decline in all trans β-carotene during toasting than during grating. As it happened in trans-β-carotene in sample product, there was a reduction among samples I_{es} (8.50 µg/g), J_{es} (5.68 µg/g), K_{es} (8.17 µg/g). The extruded baked sample presented total carotenoid content between 6.37 µg/g (sample $O_{es)}$ and 18.17 µg/g (sample P_{es}) which varied according to the blend ratio of Yellow root cassava, Orange-fleshed sweet potato and Plantain while Moringa oleifera leaf was constant. The study showed that sample P_{es} contained more total beta carotene than other samples. The work done by Carvalho et al. [33], studied true retention of total carotenoid and β-carotene on seven cooked cassava genotypes, reporting values which were (32.7 µg/g) higher than the values obtained from this work with the highest [sample P (18.17 µg/g)] being inclusive. In carrot, β-carotene was reduced to 27% after cooking under pressure for 10 min and to 16% when cooked in covered pot [36]. A reduction in the β-carotene content of a standard solution at 98°C for 60 minutes was observed by Aman et al. [37]. The reduction in total beta-carotene was observed both in blend sancks and the 95% blends which may be as a result of heat applied during processing and baking as heat reduces the vitamin A content. However, indication of total beta-carotene from this study can possibly be used as a means to minimize 25% Vitamin A deficiency. Despite the carotenoid degradation during processing, the concentration of these compounds in extruded snacks was superior when compared with fresh roots due to the removal of water during the drying process. The carotenoid retention depends on the genotype and the processing method used. Processing breaks the plants matrix with the inclusion of cellular compartments and the binding characteristics of protein that serves as carotenoids protection and stabilizer [38].

Vitamin A is needed in small amounts by humans as an essential nutrient for proper functioning of sight, epithelial cells integrity maintenance, reproduction and functionality of immune system. These vitamin A dietary needs are usually provided in the form of provitamin-A carotenoids and performed retinol [39]. VEB (Vitamin A equivalence of beta-carotene) connotes the amount in microgram (µg) of ingested β-carotene that will be absorbed and converted in the human body, into 1 µg retinol [40] and the VEB for a diet mixed with vegetable was estimated at 4 µg β-carotene to be 1 µg retinol. This VEB of 6: 1 for a mixed diet is referred to as the retinol equivalence and is used in many food consumption tables. A recommended safe intake for female and male adults is 600 µg and 500 µg retinol daily respectively [39]. When comparing the extruded products, there were some reductions during processing. A study in Colombia showed that a value of 2.80 µg to 1 µg VEB was obtained for β-carotene and retinol in biofortified cassava porridge [23]. An equivalent study with biofortified cassava porridge carried out in the USA determined a VEB of 4: 5: 1 when provided without added oil and a VEB of 4: 2: 1 when provided with added oil [41]. Considering the VEB of 2.80 µg β-carotene, (calculated as the percentage of the PVAC content of 18.17 µg divided by 2.80 µg) of the extruded products, it can contribute 10% solution to the problem of vitamin A deficiency (VAD) in adult. This means that in practicality, a child who is subjected to the consumption of 100 g of Orange-fleshed sweet potato baked product on a daily bases would have 70% vitamin A daily nutritional requirement met (calculation was based on total β-carotene) than samples K_{es} and M_{es} (17.10 µg/g and 11.87 µg/g). In other to encourage the consumption of snacks made from biofortified cassava, there is the need for breeders to develop varieties of biofortified cassava with low cyanide contents to reduce the risk of toxicity. Also, farmers should be trained to reduce cyanide content through proper boiling methods [42].

The highest 13-Cis β-carotene occurred in sample L_{es} (5.19 µg/g) followed by P_{es} (3.39 µg/g) and K_{es} (3.22 µg/g) respectively. There was no significant difference ($p > 0.05$) among samples I_{es} (2.17 µg/g), J_{es} (2.39 µg/g), M_{es} (2.76 µg/g), N_{es} (2.04 µg/g) and O_{es} (2.48 µg/g) which were similar to dehydrated cassava chips (0.68 - 3.25 µg/g) reported by Luciana et al. [43]. A work done by Wasiu et al. [44] on processing step of yellow-fleshed high quality cassava and its use in composite bread had values of 0.13 µg/g and 0.53 µg/g which were a bit higher than the results obtained in this research. This could be attributed to varietal effects on the yellow-fleshed high quality cassava used for processing.

In fresh roots, carotenoids occur predominantly in all trans configuration. However, cis-isomers with different biological properties ranging from bioavailability to decreased provitamin-A and antioxidant capacity may be formed from this process [45]. Comparing the trans-β-carotene of this study as seen in sample Q on the fresh basis had 2.15 µg/g (Table 4) which was higher than the value reported by Bechoff et al. [46] for fresh weight basis of garri produced from yellow biofortified cassava. The highest total β-carotene value was observed in sample S (6.57 µg/g), followed by sample Q (YRC 4.21 µg/g) and sample R (Plantain 2.54 µg/g). These values were lower than the findings by Maziya-Dixon et al. [47] and Onadipe [48] which indicated a total carotene content of 16 and 20 µg/g respectively on a fresh weight basis. The result from fresh root of four cassava genotypes harvested at 12-months after planting reported by Luciana et al. [48] had a value of 4.98 µg/g for hybrid 2003 14/11 cassava which had no significant difference ($p > 0.05$) from the result obtained from this research work (Sample Q). A work by Carvalho et al. [33] evaluated hybrid 2003 14/11 and BRS Dourada variety with β-carotene concentrations (5.37 µg/g) comparatively higher than the β-carotene content of sample Q, value (3.32 µg/g) obtained for fresh root cassava genotype harvested at 12 months after planting and 1.79 µg/g content of fresh peeled cassava on a fresh weight basis reported by Victor et al. [49].

5. Conclusion and Recommendation

Generally, this research study revealed differences among the fresh roots, composite flour blends and extruded baked snacks with respect to total carotene. However, no different experiment provided a higher retention of total carotenoids in all the samples. The composite flour blends showed the best β-carotene retention. Unfortunately, the best processing method for Yellow root cassava, Orange-fleshed-sweet potato and Plantain was not possibly indicated. However, the observable differences may be due to the behavioural patterns evident in the different cultivars and should be further investigated.

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