OPEN ACCESS Freely available online

Journal of Nutrition & Food Sciences

Research Article

Effect of Processing Method on the Proximate Composition and ß-Carotene Contents of Yellow Fleshed Cassava and Orange Fleshed Sweet Potato

Ukozor Alphonsus U.C[1*], Okwulehie Felicia C[1], Mbah Cynthia A[1], Olubiyi Elizabeth O[1], Lemchi Stella N[1], Ohaka Regina A[1], IHEME Geraldine O[1]

[1]*Department of Home Economics, Alvan Ikoku Federal College of Education, P.M.B. 1033, Owerri, Imo State, Nigeria*

ABSTRACT

Introduction

Cassava (Manihot esculenta Crantz), a food security crop ,grown mainly by small scale farmers, thrives in marginally fertile soils and can tolerate wide range of rainfall. In Nigeria, the leading cassava production is estimated at 50 million tons (IFAD/FAO, 2000)

Nutritionally, the root is starchy, containing about 60-70% moisture and 32-35% total carbohydrate of which 80% is starch with greater proportion as amylopectin (Rawel and Kroll, 2003). It has varying amounts of crude fat (0.1-0.3 %), protein (1-3%) and fibre (1.5%) depending on the age and variety (Charles et al., 2005). The requirement for vitamin A can be satisfied either by animal food products containing preformed vitamin A or plant food products containing provitamin A carotenoid (Lintig and Vogt,2004)

Carotenoids are major sources of vitamin A in the diets of a large proportion of the world's population. Approximately 600 carotenoids are found in nature but only three are important precursors of vitamin A in humans: β-carotene, α-carotene, and β–cryptoxanthin. Of these, β-carotene is the major provitamin A component of most carotenoid-containing foods (Parker,1996)

Yellow cassava varieties that have recently been released in Nigeria (2011) contain ~6 μg/g (fresh weight) total β-carotene, while breeding is on-going to deliver varieties up to 15 μg/g (fresh weight) (Ruel,2001). The color of the crop ranges from deep yellow to slightly orange.

Studies showed that retention of carotenoids differs not only per processing and storage method for a certain variety,(Amaya, 1997); but also within a variety and this might be due to the variable distribution of dry weight matter within a root, (Amaya, 2001).

Cassava bio-fortified with micronutrients could be a sustainable approach to control micronutrient malnutrition and this could reach the public especially in the tropics through some of the key cassava-based food products such as fufu, gari, pupuru, abacha and lafun.

Sweet potato (Ipomoea batatas) plays a major role worldwide as a staple crop and is especially important in developing countries (Laurie et al., 2015). Sweet potato is thought to have originated in Latin America (Davidson,1999).

The orange flesh sweet potato (OFSP) has significant antioxidant activity, and can potentially improve vitamin A status in children (Laurie et al., 2015; Hotz et al., 2012; Li and Mu, 2012; Burri, 2011). It is reported that one medium sized OFSP can provide about twice the β-carotene needed for the recommended daily requirement of vitamin A. The roots are usually consumed after processing like boiling, baking or making fried chips.

The bioavailability of ß-carotene is affected by the method of processing of OFSP, "raw < baked < steamed/boiled < deep fried" (Buri,2011). Consumption of OFSP in conjunction with small amounts of fat can increase ß-carotene bioavailability by up to 20-fold. A 2006 study examined ß -carotene retention in boiled, mashed OFSP of the popular Resisto variety (Jaarsveld et al.2006). Results showed that the most successful way to retain ß-carotene (up to 92%) was by boiling for 20 minutes with the lid on. When boiled with the lid off, the potatoes took longer to cook through and lost slightly more ß-carotene (retention of 88%).

Unsurprisingly, the type of processing influences the level of provitamin A retention in OSP. Different drying techniques produce varying levels of retention; it was reported that solar oven drying retained more provitamin A carotenoids than open-sun drying (Mulokozi and Svanberg,2003) (24% compared to

Correspondence to: Ukozor Alphonsus U.C, Department of Home Economics, Alvan Ikoku Federal College of Education, P.M.B. 1033, Owerri, Imo State, Nigeria, Tel: 08037760255; E-mail: aucukozor@gmail.com

Received: July 29, 2021; **Accepted:** August 24, 2021; **Published:** September 03, 2021

Citation: Alphonsus UUC, (2021) Effect of Processing Method on the Proximate Composition and ß-Carotene Contents of Yellow Fleshed Cassava and Orange Fleshed Sweet Potato. J Nutr Food Sci. 11:p547.

47% losses). Limiting the exposure to damaging ultraviolet radiation may explain these results.

Globally, the processing methods that result in the highest levels of retention are: boiling/steaming (80-90%)(Bengtsson et al., 2008; Hegenimana et al.,1999), roasting, frying (70-80% (Vimala et al.,2011) and sun/solar drying (60-80%) (Bengtsson et al., 2008;Bechoff et al.,2010; , Bechoff et al.,2011; Mulokozi and Svanberg,2003, Vimala et al.,2011, Bechoff et al.,2009).

MATERIALS AND METHODS

Source of Materials and Treatment

A low cyanide bio-fortified yellow cassava variety (Tropical Mosaic Series; (TMS 01/1368) and orange flesh sweet potato (OFSP) were obtained from the Forward Africa, Okigwe Road, Owerri, Imo State.

Production of Cassava-Based Traditional Foods

The freshly harvested cassava tubers were divided into four (4) portions and then subjected to the different traditional processing methods commonly used in the production of the various products namely, fufu,gari,abacha and flour (control).

Production process of cassava flour

Some quantities (500g fresh weight) of the cassava tubers were washed, peeled and sliced to 5 mm thickness before sun-drying for 5 days to obtain cassava chips, which were milled, sieved and packaged, to obtain cassava flour (CFL).

Production process of fufu: A portion (500g) of the cassava tubers was peeled, cut into small sizes, steeped in water to ferment for three days (72h). The fermented mass was mashed manually and sieved by adding water to the retted mass to remove the fibres using cheese cloth. After 24 h, the water (liquor) on top of the sediment was decanted and the remaining mass (mainly starch) was dewatered using hydraulic press and the cake was oven-dried at 60°Cfor 24h. Traditional method of preparation of fufu (thick paste) was adopted for the processing of the dried yellow cassava cake samples into thick pastes. This was accomplished by continuous mixing of the cassava cake in boiled water (1:4 w/v) until a thick paste is obtained. It was further pouded in a wooden mortar using a pestle, resulting in a thick paste, fufu (CFF), which was left to cool for 10 min prior to analysis.

Production process of gari: Another portion (500g) was washed, peeled and grated into mash. The mash was packed into sacks and left for 2 days in a fermentation trough to ferment. The fermented mash was dewatered by placing under hydraulic press. The dewatered cakes were pulverized and sieved to separate the fibrous materials. The sieved flour was then toasted in a large, shallow stainless steel pan with constant stirring until creamy, free-flowing granules were obtained (CML).

Production process of abacha: The fourth portion (500g) was washed, peeled, cut into chunks and boiled in water until cooked (softened). It was steeped in fresh potable water (25±3°C) for 24h, thoroughly washed in fresh water and sliced into 2mm thick, cylindrical flakes (CFK). It was then oven-dried at 60 °C for 24h prior to analysis.

Production of Sweet Potato-Based Traditional Foods

The freshly harvested tubers of OFSP were similarly divided into four (4) portions (500g each) and then subjected to the different traditional processing methods commonly used in the production of the various products namely, boiling, frying, roasting and sun-drying

Production process of boiled OFSP

The tubers were washed, peeled and cut into chunks. They were boiled in water at 100°C for 30 min until softened; allowed to cool and oven-dried at 60°C for 24h, prior to analysis (PBL).

Production process of fried OFSP

The tubers were washed, peeled and sliced into 2mm thick chips. They were deep- fried in one liter of boiling refined vegetable oil bath at 150°C for 5 min The fried sweet potatoes were drained on absorbent paper and cooled for 20 min in desiccators, prior to analysis (PFR).

Production process of roasted OFSP

The tubers were washed and simply roasted on a grill above heated charcoal. The temperature around the charcoal was about 200°C and the distance between grill and charcoal was 5 cm. During roasting, sample was turned regularly, to ensure an even heating and also avoid charring. The roasting time was 30 min. After roasting, sample was wrapped with absorbent paper and air-cooled 20 min.

They were peeled and cut into sizeable chunks; oven-dried at 60°C for 24h, prior to analysis. (Vimala et al.,2011).

Production process of OFSP flour

The tubers were washed, peeled and sliced into 2mm thick chips. They were sun-dried in a stainless steel tray for 3 days (72h), milled and sieved for analysis (PFL).

Determination of Proximate Composition

The proximate composition (moisture, protein, ash, fat, crude fibre and carbohydrate content) were determined by AOAC (2005).

Beta-Carotene Determination

Beta-carotene content of the cassava products was determined spectrophotometrically using the low volume hexane extraction method performed by Fish et al., (2002). Approximately 0.6g (determined to the nearest 0.001g) duplicate samples were weighed from each sample into 2 forty ml amber screw-top vials that contained 5ml of 0.05%(w/v) BHT acetone,5ml of 95% ethanol, and 10ml of hexane. Samples were stirred on a magnetic stirring plate during sampling.

Samples were extracted on an orbital shaker at 180 rpm for 15 min on ice. After shaking, 3ml of deionized water was added to each vial and the samples were shaken for an additional 5 min on ice. The vials were left at room temperature for 5min to allow for phase separation. The absorbance of the upper, hexane layer was measured in a 1cm path length quartz

cuvette at 479 nm blanked with hexane. The beta-carotene content was then estimated using absorbance at 479nm.

Statistical Analysis

All determinations were carried out in triplicate and error reported as standard deviation from the mean. All data were subjected to a one-way analysis of variance (ANOVA) and significance accepted at p≤ 0.05. The means were separated using Duncan Multiple Range Test (DMRT) with SPSS package (version 17.0).

Results and Discussion

TREATMENTS	MC(g)	CF(g)	FAT(g)	ASH (g)	PROTEIN(g)	CHO(g)	β-carotene(µg)
CFK	73.08±0.12b	3.11±0.29b	1.61±0.04b	1.56±0.04b	7.47±0.26a	86.25±0.57b	2710±11.53a
CFL(control)	9.12±0.10d	2.07±0.01d	1.31±0.04c	0.99±0.06c	2.81±0.04c	92.83±0.06a	748.33±8.51d
CFF	86.60±0.24a	4.53±0.23a	3.04±0.27a	2.21±0.14a	5.18±0.41b	85.05±0.71c	1143±14.00c
CML	11.62±0.06c	2.33±0.05c	1.50±0.02bc	0.95±0.02c	2.43±0.06c	92.78±0.08a	1461.67±8.39b
LSD(0.05)	0.28	0.35	0.26	0.15	0.46	0.86	20.44

Table 1: Proximate composition and beta carotene contents of yellow fleshed cassava products per 100g (dmb).

Each result is the mean of a triplicate determination. Means with different superscripts differs along each row

Key: CFK= cassava flake (abacha), CFL= cassava flour (control), CFF= cassava fufu (akpu), CML=cassava meal (gari); MC=moisture content, CF-crude fibre, CHO= total carbohydrate

TREATMENTS	MC(g)	CF(g)	FAT(g)	ASH (g)	PROTEIN(g)	CHO(g)	β-carotene(µg)
PRS	69.00±0.14b	2.66±0.04a	5.58±0.12a	3.43±0.18ab	13.33±0.17b	75.00±0.42b	890±13.08b
PBL	74.34±0.41a	2.16±0.13c	3.30±0.02b	3.69±0.03a	15.36±0.18a	75.50±0.24b	949.33±7.37a
PFR	65.44±0.21c	2.02±0.13c	5.67±0.07a	3.32±0.18b	12.00±0.41c	76.99±0.35a	523.33±13.58c
PFL	17.46±0.19d	2.36±0.04b	3.46±0.15b	2.87±0.11c	5.79±0.21d	85.51±0.23a	453.33±43.29d
LSD(0.05)	0.48	0.18	0.21	0.26	0.49	0.61	44.99

Table 2: Proximate composition and beta-carotene contents of orange fleshed potato (dmb).

Each result is the mean of a triplicate determination. Means with different superscripts differs along each row

Key: PRS=roasted potato, PBL= boiled potato, PFR=boiled potato, PFL= potato flour (control)MC=moisture content, CF-crude fibre, CHO= total carbohydrate

Treatment	β-carotene (µg100g-1) fwb	% Retention
CFL (control)	680.08	~100
CML (gari)	1291.82	189.95
CFK (abacha)	729.52	107.28
CFF(fufu)	153.16	22.52

Table 3: Percentage apparent retention of β-carotene in processed yellow flesh cassava (YFC).

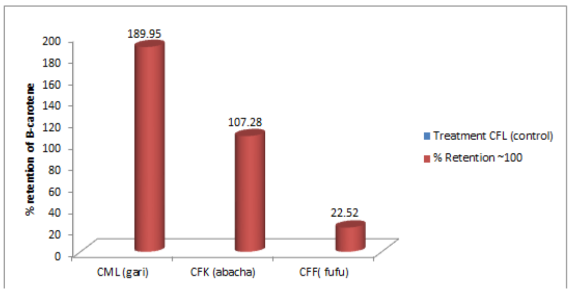

Figure 1: Percentage apparent retention of ß-carotene in processed yellow flesh cassava.

Treatment	β-carotene (µg100g-1) fwb	% Retention
PFL (control)	374.18	~100
PRS (roasted)	275.90	73.73
PBL (boiled)	243.60	65.10
PFR(fried)	181.39	48.48

Table 4: Percentage apparent retention of β-carotene in processed orange flesh sweet potato (OFSP).

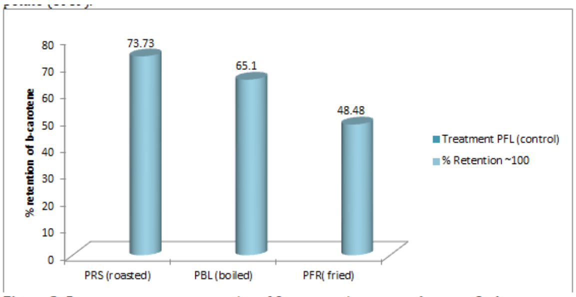

Figure 2: Percentage apparent retention of ß-carotene in processed orange flesh sweet potato.

RESULTS AND DISCUSSION

Proximate composite: Cassava

As shown in Table 1, there were significant increases in all the parameters except carbohydrate. Crude fibre significantly increased from 2.07g100-1 in the flour (CFL) to 4.53g100g-1 in the fufu (CFF), the highest value. This increase could be attributed to minimal loss of fibre during fermentation. Similarly, fat increased from 1.31 g100-1 in the control (CFL), to 3.04 g100-1 in CFF (fufu). Ash, in the same vein, significantly increased ($P<0.05$) from 0.99 g100-1 in CFL to 2.21 g100-1 in CFF. This obviously was due to the metabolites of microbial fermentation of cassava to fufu.

The highest value of 7.47 g100-1g in protein was observed in CFK (abacha) while the least was found in gari (CML). This result could be explained based on the fact that abacha, is boiled and steeped overnight, leading to hydrolysis of protein unlike gari, which undergoes grating, fermentation, de-watering and roasting (high heat, which leads to denaturation of protein).

Potato

Crude fibre was highest in the roasted sample, PRS-2.66 g100-1, but least in the fried sample (PFR), 2.02 g100-1. It actually significantly increased ($P<0.05$) in roasting but decreased ($P>0.05$) in frying. These were both high temperature processes. This could be attributed to the variation in the other parameters. Frying expectedly increased fat content in PFR (5.67 g100-1); during frying, water loss is compensated for, by the uptake of fat, resulting in the increase. Good quality potato chips should be less than 35% (Tchango and Ngalani, 1998).

Boiling increased ($P<0.05$) ash from 2.87 g100-1 in the control – PFL (flour) to 3.69 g100-1. Similarly, the boiled sample (PBL) had the highest protein; moist heat could have led to some hydrolysis of crude protein in the potato. Carbohydrate decreased ($P>0.05$) significantly in both roasted (PRS) and boiled samples (PBL). These losses could be as a result of conversion of sugar to caramel and dextrin by the high temperature of roasting; and diffusion (leaching) of free sugar during boiling.

Apparent Retention of ß-Carotene

Cassava

As shown in Table 3, the highest percentage retention was found in gari (CML), 189.95% while the least was observed in fufu (CFF) -22.52%; hence the range was 22.52-189.98%. The highest retention observed in gari corroborates the report of Rodriguez-Amaya (2002), who reported a significant increase ($P<0.05$) in mean total carotenoid concentration, from 4.9 g100-1 in the raw roots to 10.6 g100-1 in gari sample. The author reported a mean percentage true retention of 44.9% for total carotenoid (80% being ß-carotene) with a range of 38.1 to 49.8%. The least value (substantial losses) (22.52%) observed in processed fufu could be due to decreases associated with a longer proceeding time and after a higher processing temperature, and also when food is cut or pureed (Rodriguez-Amaya, 2002). This is scientifically explained by the fact that carotenoids (mostly ß-carotene) are destroyed by heat, and oxidize and isomerize when exposed to heat and light.

The observed increases in ß-carotene apparent retention in gari (CML) and abacha (CFF), much higher than in the control sample (CFL) may be due to a greater extractability of carotenoid from processed samples. unaccounted loss of moisture, and leaching of soluble solids during processing (Rodriguez-Amaya, 2002). The author further stated that chemical transformations that occur in heat treatment involve isomenization and expoxidation of carotenoids and not their formation. Iglesias et al (1997) reported that the stability of carotenes in response to different processing methods was genotype-dependent. The authors reported that boiled cassava retained (true retention) the highest amount of total carotene (73.5%) followed by gari (44.9%) raw fufu (40.8%) and cooked fufu (21.5%).

Cassava processing involves a combination of activities which are performed in stages. Such activities are (i) peeling, (ii) chipping, crushing, milling, slicing or grating, (iii) dehydration by pressing, decanting, or drying in the sun, (iv) fermenting by soaking in water, heaping or stacking, (v) sedimentation (vi) sieving, and (vii) cooking, boiling, toasting or steaming. This sequence of activities varies with product desire, and may result in losses of total carotenoid through enzymatic and non-enzymatic oxidation at each stage of processing and may be responsible for the observed differences in ß-carotene retention of different cassava products. (Rodriguez-Amaya,1997; Smotlin and Grasvenor, 2003; Simpson, 1986; Rodriguez-Amaya et al., 2006).

Charez et al., (2000) reported than even drying shadow-drying, and boiling resulted in the highest levels of retention of ß-carotene; gari had the lowest. Iglesia et al., (1994) reported that boiling resulted in 34% reduction (66% retention) in carotene content.

Sweet Potato

The result on the apparent retention of ß-carotene in OFSP is shown in Table 4. It ranged from 48.48% in PFR (fried) to 100% in the control sample (PFL). This result indicated varying degrees of reduction, and hence, retention of ß-carotene according to the processing method. The least retention was observed in PFR whereas the highest retention was found in PRS (roasted). The work of Boy and Millof (2009), revealed that ß-carotene retention ranges were 50-130%; 40-110% and 67-95% respectively for boiled, roasted and fried sweet potato.

Since one variety of OFSP was used in this work, the relatively low retention could be attributed to the difference in duration and temperature of processing (Kidmose et al, 2007). The authors explained that during heat treatment, the oxidative degradation and trans-cis isomerization of all trans ß-carotene occur with the intensity which depends on the extent of the heat. The least retention observed in the PFR (fried sample) is attributed to the presene of oil which increases the trans-cis isomerization during a short time treatme3nt of foids (Muyar-Mhiebach et al, 2005). Furthermore, diffusion of free sugar from food to oil during frying and boiling probably explain these losses.

CONCLUSION

Processing methods resulted in significant improvements in the proximate composition of yellow fleshed cassava except carbohydrate and orange fleshed sweet potato. ß-carotene was most retained in gari (CML) for cassava, whereas it was most retained in roasted potato (PRS)

REFERENCES

1. IFAD/FAO. (2000).The World Cassava economy facts and outlook. International Fund for Agricultural Development (IFAD) and Food and Agriculture Organization of the United Nations (FAO)., Rome, Italy.
2. Amaya, R. The retention of provitamin A carotenoids in prepared, processed, and stored foods. J Biol Sci. (1997);3:345- 444.
3. Amaya, R. The effect of processing and storage on carotenoids content of vegetables. J. Food Sci. (2001);7:2005-5802.
4. Anyanwu C.N, Ibeto C.N, Ezeoha S.L, Ogbuagu J.N. Sustainability of cassava (Manihot esculenta Crantz) as industrial feedstock, energy and food crop in Nigeria. Renewable Energy (2015);81:745-752.
5. AOAC. (2005) Association of Official Analytical Chemists. 17th edn, AOAC. Inc Arlington VA USA.
6. Bechoff, A., Dufour, D., Dhuique-Mayer, C., Marouzé, C., Reynes, M. and Westby,A.(2009) Effect of hot air, solar and sun drying treatments on provitamin A retention of orange-fleshed sweet potato. J. Food Eng. 92(2): 164-171.
7. Bechoff, A., Westby, A., Owori, C., Menya, G., Dhuique-Mayer, C., Dufour, D. and Tomlins, K.(2010). Effect of drying and storage on the degradation of total carotenoids in orange-fleshed sweetpotato cultivars. J. Sci. Food Agr. 90: 622-629.
8. Bechoff A, Tomlins K.I, Dhuique-Mayer C. Dove R, Westby A. On-farm evaluation of the impact of drying and subsequent storage on the carotenoid content of orange-fleshed sweet potato. Int J Food Sci Tech. (2011);46: 52-60.
9. Bengtsson A, Namutebi A, Alminger M.L, Svanberg U. Effects of various traditional processing methods on the all-trans-β-carotene content of orange-fleshed sweet potato. J Food Compos Anal. (2008);21(2):134-143.
10. Boy, E.and Miloff, A.(2009) Provitamin A carotenoid retention in orange sweet potato—A review of the literature. Sight and Life Mag. 3:27–33.
11. Burri B.J. Evaluating sweet potato as an intervention food to prevent vitamin A deficiency. Comp. Rev. Food Sci Food Safe. (2011);10:118-130.
12. Charles, A.L., Sriroth K, and Huang T.C. (2005). Proximate composition, mineral contents, hydrogen
13. Chavez, A.L., Sanchez, T., Ceballos H., Rodriguez-Amaya, D.B., Nestel, P., Tohme, J., and Ishitani, M.(2007). Retention of carotenoids in cassava roots submitted to different processing methods. J Sci Food Agric. 87:388–393.
14. Chavez A.L, Bedoya J.M, Sanchez T, Iglesias C, Ceballos H, Roca W. Iron, carotene, and ascorbic acid in cassava roots and leaves. Food and Nutrition Bulletin. (2000);21(4), 410-413.
15. Davidson A (1999). Oxford companion to food, New York: Oxford University Press. 912p.
16. Fish W. W, Perkins-Veazie P, Collins J. K. A quantitative assay for lycopene that utilizes reduced volumes of organic solvents. Journal of Food Composition and Analysis. (2002);5:309-317.
17. Hagenimana V, Carey E, Gichuki S.T, Oyunga M.A, Imungi J.K. Carotenoid contents in fresh, dried and processed sweetpotato products. Ecol. Food Nutr. (1999);37:455-473.
18. Hotz, C.C., Loechl, A., de Brauw, P., Eozenou, D., Gilligan, M., Moursi, B., Munhaua, P., van Jaarsveld, A., Carriquiry, J.V., Meenakshi (2012). A large-scale intervention to introduce orange sweet potato in rural Mozambique increases vitamin A intakes among children and women. British J. Nutr. 108:163-176.
19. Jaarsveld J, Marais, D., Harmse, E., Nestel, P., Rodriguez-Amaya, D. Retention of b-carotene in boiled, mashed orange-fleshed sweet potato. J Food Compost Anal. (2006);19(4):321-329.
20. Laurie S, Faber, M., Adebola, P., and Belete, A. Biofortification of sweet potato for food and nutrition security in South Africa. Food Res. Int. (2015);76:962-970
21. Li PG, TH Mu. Sweet potato: health benefits, production and utilization in China. In Potatoes: Production, Consumption and Health Benefits. C. Caprara (ed.). Nova Science Publishers. (2012);127-172.
22. Mulokozi G, U Svanberg U. Effect of traditional open sun-drying and solar cabinet drying on carotene content and vitamin A activity of green leafy vegetables. Plant Food Hum Nutr. (2003); 58(3):1-15.
23. Iglesias, C., Mayer, J. Chavez, L. and Calle, F. Genetic potential and stability of carotene content in cassava roots. Euphytica, 1997; 94,
24. Kidmose U, Christensen L.P, Agili,S.M, Thilsted S.H. Effect of home preparation practices on the content of provitamin A carotenoids in coloured sweet potato varieties (Ipomoea batatas Lam.) from Kenya. Innovative Food Sci Emerg Technol. (2007);8:399-406.
25. Makanjuola, O. M., Ogunmodede, A. S., Makanjuola, J. O., & Awonorin, S. O. (2012). Comparative Study on QualityAttributes of Gari Obtained from Some Processing Centres in South West, Nigeria. Advance Journal of Food Science and Technology, 4(3), 135-140.
26. Mayer-Miebach, E., D. Behsnilian, M. Regier and H.P. Schuchmann, (2005). Thermal processing of carrots, lycopene stability and isomerisation with regard to antioxidant potential. Food Res. Int., 38: 1103-1108.
27. Parker, R.S. (1996). Absorption, metabolism and transport of carotenoid. FASEB Journal, 1996; 10, 542-551.
28. Rawel HM, and Kroll J. (2003). Die Bedeutung von Cassava (Manihot esculenta, Crantz) als Hauptnahrungsmittel in tropischen L¨andern. Deutsche Lebensmittel-Rundschau 99:102–10.
29. Rodriguez-Amaya, D.B. Effects of processing and storage on food carotenoid. Sight and Life Newsletter, 2002; 3, 25-35.
30.

31. Rodriguez-Amaya, D.B., Rodriguez, E.B., and Amaya-Farfan, J. (2006) Advances in food carotenoid research: chemical and technological aspects, implications in human health. Malaysia Journal of Nutrition, 2006; 12(1), 101-121.
32. Ruel, M.T. Can food-based strategies help reduce vitamin A and iron deficiencies? A review of recent evidence. International Food Policy Research Institute, Washington, DC, USA, 2001
33. Tchango J, J.A. Ngalani. The banana production: Major economical stakes for food security. Proceedings of the International Symposium. (1998);729-740.
34. Vimala B, Nambisan B, Hariprakash B. Retention of carotenoids in orange-fleshed sweet potato during processing. J Food Sci Technol. (2011);48(4): 520-524.
35. von Lintig J, Vogt K. Vitamin A formation in animals: molecular identification and functional characterization of carotene cleaving enzymes. Journal of Nutrition. (2004);134:251S-256S