

Evaluation of the Potential of Freshly Bred Orange-Fleshed Sweet Potato Varieties in Combating Vitamin A Deficiency

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Abstract

Orange-fleshed sweet potato (OFSP) is advocated as a rich and readily accessible source of vitamin A. This study was done to evaluate the potential of the newly bred OFSP varieties in combating vitamin A deficiency. OFSP varieties and white fleshed sweet potato (WFSP) varieties were used for the study. β -carotene was extracted with acetone and its spectrophotometric reading at 450 nm used to calculate its concentration. The optimum amount of OFSP required to meet vitamin A needs for children of different age groups were established. Results indicate that β -carotene was below detection levels in WFSP varieties but was detectable in OFSP varieties regardless of the processing treatment. The concentration varied significantly ($P < 0.05$) between OFSP varieties and between processing treatments. The reduction rate of β -carotene varied with processing treatments and was much higher in fried potatoes (3.2 –37.1%) than boiled potatoes (19.6 – 21%). This implies a higher retention rate of β -carotene (78.97% – 80.44%) in boiled than fried OFSP varieties (62.88% – 67.83%). The optimum amount of OFSP (g/day) required to meet +vitamin A requirements for 7–12 months to 10–13 years varied from 98.91 and 144.27 g/day to 148.36 and 216.41 g/day for Kiegea and Mataya cultivars (OFP varieties), respectively. The results provide an insight of the richness of OFSP varieties in β -carotene and its great potential in preventing vitamin A deficiency.

Keywords: Children; Age groups; β -carotene; Vitamin A requirements; Processing treatments

Introduction

Vitamin A deficiency (VAD) is a serious prevalent public health problem in many developing countries (WHO 1995). It mainly affects the poor, young children under five years, pregnant and lactating women (Low et al. 1997). In children, VAD causes millions of deaths, poor growth and development, increased risks of infections and severity of infections, and blindness. About 140 millions children are affected from VAD globally; 100 millions live in sub-Saharan Africa (Mason et al. 2001). More findings (WHO 2009) indicate that low serum retinol concentration ($< 0.70 \mu\text{mol/l}$) affects an estimated 190 million pre-school age children and 19.1

million pregnant women worldwide. This corresponds to 33.3% of the preschool-age population and 15.3% of pregnant women in populations at risk of VAD, worldwide. VAD also enhances several risks to pregnant women including; death during pregnancy, miscarriage, night blindness, pre-mature baby, giving birth to low weight children and also it may increase the risk of spread of HIV/AIDS virus infections (Tumwegamire et al. 2004). In Tanzania, VAD is categorized as a 'problem of public-health significance'. Likewise, the health agencies worldwide in order to reduce the effects of VAD, they promote the usage of vitamin A capsules, supplements, fortifying processed and

packaged foods to children, pregnant and lactating women especially in hospitals and health centers. These efforts have proven to reduce cases of the deficiency. For example, the vitamin A supplements delivered twice a year to children less than 5 years have been shown to reduce child mortality by 24% (Imdad et al. 2010). Also, children blindness cases related to VAD have significantly been reduced.

Currently, the cheapest and cost-effective method for combating VAD is through food-based strategies by promoting consumption of locally available vitamin A-rich foods that can be grown in home gardens. Orange-fleshed sweet potatoes (OFSP) can be a very suitable crop for food-based strategy (Low et al. 2007). OFSP are high in carotenoids and β -carotene (Takahata et al. 1993). Consumption of OFSP can provide sustainable vitamin A, which plays crucial role in preventing night blindness (Ndirigue 2004). Research findings (Low et al. 2007) have established that a small amount of 100 –150 grams of OFSP varieties can supply daily recommended allowance for children under 5 years of age. Farmers in Tanzania have been growing white fleshed sweet potatoes (WFSP) varieties for many years due to their high yielding capacity, high dry matter and acceptability by consumers though they have low beta-carotene levels. Two varieties of OFSP (Mataya and Kiegea) were released in 2010 for use by Tanzanian farmers (MAFC 2010). These varieties have moderate yields (12 –15 t/ha), are tolerant to Sweet Potato Virus Disease (SPVD), and have moderate dry matter content. However, limited information is available regarding their nutritional potential in addressing nutritional deficiencies, particularly vitamin A. Therefore, the aim of this study was to evaluate the potential of the released OFSP varieties, in combating vitamin A deficiency.

Materials and Methods

Description of study area

The study was carried out in Kibaha district, one of the six districts of the Coast

region, Tanzania. Other districts are Rufiji, Mafia, Mkuranga, Bagamoyo, and Kisarawe. The district is bordered in the North by Bagamoyo district, in the East by Dar es Salaam Region, to the South by the Kisarawe district and to the west by Morogoro region. Kibaha district covers an area of about 1,812 total km². According to the 2012 census, the district has a population of 198,697 people. It is located within the latitude -6.7813° S and longitude 38.9929° E. The district experiences a typical tropical climate with an average temperature of 28 °C, with rainfall ranging from 800 mm to 1000 mm per annum. It has a bimodal rainfall pattern, a short rainy season from October to December and long rainy season between March and June. Typical of coastal areas, the district has hot and humid conditions, with an average day temperature of 30 °C.

Experimental design and field layout

This trial study was experimented using a randomized block design at the National Root Crops Research Institute (NRCRI). The vine cuttings of OFSP varieties (Kiegea and Mataya) and WFSP varieties (Sinia and Vumilia) for the trial were propagated in a field multiplication block. Each clone was planted in an experimental plot size of 6.0 × 4.0 m in randomized block design with 3 replications. The distance between and within the ridges were 100 and 30 cm, respectively. No fertilizers were used in any of the trial field and weeding and cultivation were done as per the institute advice. All of the four varieties were harvested from the same experimental field, the usual cultural practices such as early planting and delaying harvest hold were observed.

Pre-preparation of potato root samples

Four sweet potato cultivars, namely Kiegea, Matai (which are OFSP varieties) and Sinia and Vumilia (WFSP varieties) were used in this study. These cultivars were planted in early March 2018 and the consignments of the roots were harvested in

Mid-June 2018. Only sound potato roots free of diseases or physical damage were chosen for data collection. The roots were thoroughly washed with tap water and dried with paper toweling. The roots were then transported immediately to the International Institute of Tropical Agriculture (IITA) for laboratory analysis.

Sample preparation and cooking processes

Two cooking processes were considered, that is, boiling and frying. Raw samples were used as control.

Raw samples: Sampled roots were peeled, cut into equal parts, thoroughly mixed and 3 g of each variety was measured using an analytical balance scale (Mettler, Switzerland) and transferred into a mortar. The samples were ground with 50 ml of cold acetone (acetone refrigerated at 4 °C for 2 h prior to use) being added slowly and then filtered using a glass microbore filter disk (GF/A, What man, England) Filter (porosity 3; pore size 20-30 µm) with suction through a sintered glass funnel in a fume chamber. The mortar, pestle, funnel, and residue were washed with small amounts of acetone (which was used as an extraction medium), receiving the washings in the suction flask through the funnel. The extraction was repeated until the sample from the mortar was devoid of colour. About 40 ml of petroleum ether was put in a 500 ml separating funnel containing the filtrate with teflon stop-cock and 1-2 ml of acetone was added. Distilled water (300 ml) was added slowly along the neck without shaking to avoid emulsion formation. The two phases were then left to separate and the lower aqueous layer discarded. The sample was washed 3–4 times with distilled water (approx. 200 ml) each time to remove residual acetone. In the last phase, washing was done in such a way that the upper phase was not discarded. The upper layer was then collected into a 50 ml flask through a filter containing anhydrous sodium sulphate to remove residual water.

Boiled samples: Raw samples of each variety (300 g) were cleaned using portable water; 500 ml water was added and then boiled unpeeled in stainless steel saucepans with the lid on to boiling point (100 °C). Keeping the skin on helps retain the nutrients and enhances the nutritional quality (Rodriguez-Amaya and Kimura 2004). The potatoes were cooked until soft for approximately 40 minutes, when the core temperature reached approximately 100 °C. Samples were then cooled to room temperature and peeled (skin was easily peeled off from cooked potato samples). The flesh (peeled potato) was mashed with a spoon, thoroughly mixed and weighed to 1 kg sample which was packed in plastic bags and sealed. Samples were coded and stored at –20 °C until analysis. Three grams (3 g) of the sample was used for extraction of beta carotene as was for raw samples.

Fried samples: Peeled and sliced raw samples of each potato variety (300 g) were dried shortly for 5 minutes in open air and then immersed in 300 ml of preheated oil for 10 min at 170 °C. Samples were then cooled to room temperature. The fried samples were then mashed in a clean plastic container with a fork, thoroughly mixed and weighed samples (1 kg) were packed in plastic bags and sealed for analysis of β-carotene. Samples were coded and stored after in the analytical laboratory at –20 °C. Three grams (3 g) of the samples were used for extraction of beta carotene as was for raw samples. Each individual cooking experiment (boiling and frying) and control experiment (raw samples) was conducted in triplicate.

Determination of β-carotene contents

The absorbance of the extract (1.5 ml) of the four potato cultivars was determined at 450 nm using UV-visible spectrophotometer model BioMate-6 (Sigma Adrich). The concentration of beta carotene was calculated using the equation below as described in Rodriguez-Amaya and Kimura (2004).

$$\text{Carotene content (mg/100g)} = \frac{A \times \text{volume (mL)} \times 10^3}{A_c \times \text{Sample weight (g)}}$$

Where: A = Absorbance; Volume = Total volume of extract = 50 ml; A_c = Absorption coefficient of carotene in petroleum ether = 2592.

$$\text{Grams per day OFSP} = \frac{(\mu\text{g RE/day})}{(\mu\text{g bioaccessible beta carotene / gram sweet potato} \times 12)}$$

Where: $\mu\text{g RE}$ represents microgram retinol equivalents and 12 represents a conversion ratio for marginal vitamin A deficiency, i.e., 12- μg beta-carotene: 1- μg retinol for well-nourished individual.

The optimum amount of OFSP was computed based on the concentrations of bio-accessible beta-carotene and the weight of 1 cup of sweet potato (US Department of Agriculture 2015). The saving cup that was used to measure the amount (in grams/day) of OFSP needed to supply VA requirements of a person at different life stages weighed 255 g when full. Therefore, to calculate the number of cups/day of OFSP that would supply 100% of the requirement for VA, the amount of OFSP in gram/day was divided by 255 g/cup. This amount corresponded to the amount of OFSP needed by an individual with marginal VA status. A child who is 5 years-old or younger needs to consume only 100 g OFSP/day (almost half a cup) of OFSP roots in order to receive the recommended daily amount of vitamin A (Tsou and Hong 1992).

Statistical analysis of data

Statistical Analysis of the data was done by using SPSS (version 12.0 SPSS Inc, IL, USA). Descriptive statistics were performed and values expressed as mean, standard deviation and percentage. ANOVA was done at the 5% level of significance to determine differences in the mean values among different sweet potato cultivars and the specific differences between pairs of means were separated by using Duncan's Multiple Range Test.

Determination of the optimum amount of OFSP needed to supply recommended vitamin A to a child

The amount in grams/day of OFSP needed to meet the requirements of a child with marginal vitamin A status at different life stages was calculated following the formula deduced by Low et al. (1997).

Results and Discussion

β - carotene content of unprocessed and processed OFSP and WFSP

Table 1 indicates that β -carotene was below detection level in WFSP varieties (Sinia and Vumilia) but was detectable in OFSP varieties (Kiegea and Mataya) regardless of the treatments. The β -carotene contents varied significantly ($P < 0.05$) between the OFSP varieties and between processing treatments. The processing treatments (boiling and frying) had significant ($P < 0.05$) negative effects on β -carotene contents which varied significantly between OFSP varieties. The reduction rate of β -carotene varied with processing treatments. It was much higher in fried potatoes than in boiled potatoes (Table 1). These results generally imply that the retention rate of β -carotene (78.97%–80.44%) was higher in boiled OFSP potatoes than in fried OFSP potatoes (62.88%–67.83%). The variation could be due to heating intensity and shielding effect of the heating media. β -carotene is fat soluble but water insoluble. Furthermore, the variation in β -carotene retention could also be due to the difference in the enzymatic oxidation during processing (Ameny and Wilson 1997). Other researchers (Demasse et al. 2007) indicated that variations during processing could also be attributed to the temperature, duration of frying, and stage of maturity. Previous findings (Mudambi and

Rajagopal 1977) also observed a decrease in β -carotene content of palm oil samples heated between 138 °C and 258 °C with an interval of 12 °C. The amount of β -carotene declined with a rise in temperature. The damage of β -carotene was highest when the oil was heated constantly for 30 min at various selected temperatures. Other researchers (Ishiwu et al. 2014) also recorded a significant decrease in beta-carotene content as boiling or frying period increased between 2 and 30 minutes. In their study, the beta-carotene content decreased by 61.4% while it decreased by 63.6% when the tomato pulp was fried for 30 minutes. In the present study, boiling was done for 40 minutes, whereas frying was for 10 minutes. Another study by Gurmu and Mekonen (2019) also indicated variations in β -carotene retention due to treatment, e.g., sun drying retained 63–73%, oven drying 89–96%, boiling 84–90% and frying 72–86% β -carotene among the OFSP varieties. The results of the

present study compare well with the previous findings (Gurmu and Mekonen 2019) in terms of β -carotene retention rate due to heat treatments (frying and boiling) implying a much higher destructive effect of frying. The variations in β -carotene contents between cultivars in the present study could also be attributed to other factors such as genetic variations (Demasse et al. 2007). Nonetheless, the β -carotene contents recorded in the present study fall within the range of earlier reported results (Takahata et al. 1993) which varied between 0.01 and 26.6 mg/100g on fresh weight basis (fwb). A study by Gurmu and Mekonen (2019) quantified β -carotene content of four genotypes which ranged from 2.4 to 12.4 mg/100 g with an average β -carotene content that was greater than 10 mg/100 g. This is lower than the β -carotene content quantified in the present study.

Table 1: β - carotene contents of differently treated OFSP and WFSP varieties

Variety/ Cultivar		Processing Treatments			% reduction	
		Fresh	Boiled	Fried	in boiled samples	in Fried samples
OFSP	Kiegea	21.57 ± 0.45 ^a	17.35 ± 0.20 ^a	14.63 ± 0.30 ^a	19.6%	32.2%
	Mataya	14.79 ± 0.19 ^b	11.68 ± 0.45 ^b	9.30 ± 0.16 ^b	21%	37.1%
WFS	Sinia	ND	ND	ND		
	Vumilia	ND	ND	ND		

Values are means of triplicate experiments and values for the same treatment within the same column with different superscript letters are significantly different at $P < 0.05$. ND = Not Detected.

Optimum amount of OFSP needed to supply the required amount of vitamin A for the different age groups

The availability and amount of β -carotene in OFSP are influenced by several factors including genetic variability and soil composition. In this regard, although dietary reference intakes for VA are available, however owing to inherent variations among

cultivars, it was deemed important to establish the optimum amount needed to meet individuals demands based on the richness of vitamin A in OFSP cultivars (Kiegea and Mataya). VA determination was done for the various age groups as presented in Table 2 (from 7–12 months to 10–13 years of age) as age is among the determining factors.

Table 2: Amount of OFSP needed to supply optimum quantity of VA among children of different age groups

OFSP Cultivars	Estimated β -carotene contents *	Recommended VA intake for different age groups		Computed Optimum amount of OFSP (g/day) required to supply the recommended amount of VA	P-value
		Age groups (months/years)**	Recommended VA intake (μ g RE/day)**		
Kiegea	17.35	7– 12 Months	400	98.91	0.001
Mataya	11.68			144.27	
Kiegea	17.35	1–3 years	400	98.91	0.001
Mataya	11.68			144.27	
Kiegea	17.35	4–6 years	450	111.27	0.001
Mataya	11.68			162.31	
Kiegea	17.35	7–8 years	500	123.63	0.001
Mataya	11.68			180.34	
Kiegea	17.35	9 years	500	123.63	0.001
Mataya	11.68			180.34	
Kiegea	17.35	10-13 years	600	148.36	0.001
Mataya	11.68			216.41	

**These were obtained from Booth et al. (1992).

The estimated beta carotene contents of Kiegea and Mataya cultivars of OFSP variety were 17.35 and 11.68, respectively. The optimum amount of OFSP (g/day) required to meet VA requirements for different age groups (7–12 months to 10–13 years) varied from 98.91 and 144.27 g/day to 148.36 and 216.41g/day for Kiegea and Mataya cultivars, respectively (Table 2). This implies that Kiegea cultivar is a richer source of β -carotene than Mataya cultivar, suggesting that it has more potential in combating VAD. The variation in the amounts of OFSP (grams/day) needed to meet VA requirements are attributable to both age and concentrations of β -carotene in the OFSP cultivars. The results (Table 2) generally indicate that a much higher amount of Mataya cultivar is needed to supply the required optimum amount of vitamin A among different children age groups compared to Kiegea cultivar. According to earlier findings (Tsou and Hong 1992), a child who is 5 year old or younger needs to consume only 100 g OFSP/day (half-cup) of OFSP roots per day in order to receive the recommended daily amount of vitamin A. This amount corresponds well with the optimum amount established for

Kiegea variety that is required to supply the needed VA at 7–12 month, 1–3 years and 4–6 years.

The study by Burri (2011) showed that the amounts of OFSP needed to be consumed ranged from 31 to 176 g/d for a 10–13 year old child with good vitamin A status. The estimated optimum amounts for children aged 10–13 years in the present study are 148.36 and 216.41 g/d for kiegea and mataya cultivars, respectively which compare well with the ranges established earlier (Burri 2011) for the respective ages. Any recorded difference in the estimated amounts of the OFSP needed to meet VA requirements could be due to the concentrations of β -carotene in the current OFSP cultivars. The results generally indicate significant differences between OFSP cultivars (Kiegea and mataya) in meeting VA requirements for the different age groups. Linus (1999) revealed evident effects of boiling, cultivar, farming site and root age on β -carotene contents. He further indicated that the time taken to reach maximum carotenoid content varied with cultivars. Cultivar and root age could also be

the contributing factors to the differences in β -carotene content observed in the present study.

Conclusions

This study aimed at evaluating the potential of orange fleshed sweet potato varieties in combating vitamin A deficiency. The β -carotene contents were high and varied significantly ($P < 0.05$) between OFSP varieties but were below detection levels in WFSP varieties. This further confirms the superiority of OFSP varieties in β -carotene contents. It was demonstrated that both boiling and frying have significant adverse effects on beta-carotene concentrations. The deleterious effects of heat processing (boiling and frying) on β -carotene in OFSP varieties could be attributed to oxidation of the carotenoids by heat, air and light during processing. The findings further indicated that OFSP sweet potatoes varieties (kiegea and mataya) are richer sources of β -carotene and have the potential of meeting VA requirements for different age groups and address the problem of vitamin-A deficiency. The optimum amounts of OFSP (g/day) required to meet VA requirements for different age groups (7–12 months to 10–13 years) varied from 98.91 and 144.27 g/day to 148.36 and 216.41 g/day for kiegea and mataya cultivars, respectively. It is thus important to advocate and capture the attention of the general public on the richness of β -carotene in OFSP varieties and its potential in alleviating VA deficiencies.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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