

Potential of sweetpotato in reducing vitamin A deficiency in Africa

By:

Hagenimana^{**}, V., K'osambo^{*}, L.M., and Carey^{**}, E.E.

ABSTRACT

Dietary vitamin A deficiency causes debilitating health problems such as xerophthalmia, corneal lesions, keratomalacia, and, in many instances death. Frequent reports about these problems affecting young children from developing countries, continue. To maximize the availability of pro-vitamin A carotenoids, we surveyed main carotenoids in different sweetpotato cultivars in fresh or processed forms. Orange-fleshed roots contained higher total carotenoid and β -carotene content than white- and cream- fleshed lines, and all *trans*- β -carotene predominated for more than 80%. Carotenoids from orange-fleshed sweetpotato are highly vitamin A active and their consumption in Africa where vitamin A deficiency is prevalent should be encouraged. Twelve weeks after planting, the yield and amount of pro-vitamin A present in roots of orange-fleshed cultivars evaluated were high enough to provide adequate dietary pro-vitamin A and suggest the start of piecemeal harvesting. Incorporation of flour made from orange-fleshed sweetpotato roots into buns, chapatis, and mandazis significantly enriched the products in pro-vitamin A. Results of this study suggest that increased consumption of orange-fleshed sweetpotatoes in either fresh or processed form can contribute in alleviating dietary deficiency of vitamin A.

* University of Nairobi, Dept. of Botany, P.O. Box 30197, Nairobi, Kenya.

** International Potato Center (CIP), Sub-Saharan Africa Region, P.O. Box 25171, Nairobi, Kenya.
Phone: 254-2-632054, Fax: 254-2-630005, E-mail: v.hagenimana@cgiar.org

INTRODUCTION

Recent studies associating consumption of foods rich in carotenoids with a decreased incidence of certain cancers in humans, and the possible role of carotenoids in immunity, fertility, and early prophylaxis of cardiovascular diseases in livestock have generated interest in these compounds (Pfander, 1992). Carotenoids represent the most widespread group of naturally-occurring pigments in nature. They are primarily of plant origin and β -carotene, with few exceptions, predominates. β -Carotene serves as an important nutritional component in foods, as a major precursor of vitamin A, and it provides pleasant yellow-orange colors to foods (Simon, 1997).

Dietary vitamin A deficiency causes debilitating health problems such as xerophthalmia, corneal lesions, keratomalace, and, in many instances death. Frequent reports about these problems affecting young children from Africa continue (WHO, 1995).

Since the early 1990s, the main strategy for combating vitamin A deficiency has been to distribute massive dose capsules. However, the same effect could be achieved by consuming sufficient quantities of β -carotene- and vitamin A-rich foodstuffs. This is the safest approach to controlling vitamin A deficiency, and also the most sustainable in many rural areas of Africa where chronic deficiencies are still common (Jalal et al., 1998; Roels et al. 1958). Foods such as dairy and meat products containing pre-formed vitamin A are often too expensive for most people in African countries. Therefore, it is important to make more potent and sustainable food sources of pro-vitamin A carotenoids available and improve their production, shelf life, and consumer acceptance. This could make a tremendous contribution to improving human nutrition and health.

Sweetpotato has been receiving increasing attention from agriculturalists and ecologists interested in developing sustainable food production systems in the tropics, in part because it

can grow on soils with limited fertility, is relatively drought tolerant, provides good ground cover, and is usually cultivated without fertilizer or pesticide (Ewell, 1990). Also, it has remarkable pro-vitamin A quantities (Woolfe, 1992). In parts of West, Central, and East Africa, sweetpotato is an important staple food source of calories and is consumed by all age-groups, but is particularly liked by children, who also are at most risk of vitamin A deficiency (Low et al., 1997). Widely consumed varieties, however, are white or pale yellow in flesh color and contain very little β -carotene (Ameny and Wilson, 1997). Orange-fleshed sweetpotato storage roots high in carotenoids and vitamin A active, β -carotene, are less eaten. Consumption of orange-fleshed sweetpotato roots and sweetpotato-based processed foods would provide sustainable, cost-effective, and necessary vitamin A. Therefore, the use of orange-fleshed sweetpotatoes as a food source of pro-vitamin A merits further attention.

Fresh sweetpotato roots are bulky and highly perishable, and in Africa, they are commonly consumed fresh, usually boiled. They are generally not harvested and stored for extended periods. Instead, farmers piecemeal harvest the crop. The only kind of storage regularly practiced in Africa is in-ground storage, by which farmers keep unharvested mature sweetpotatoes in the field until they are needed for consumption or sale (Smit, 1997). Some inconclusive reports say that carotenoid content changes during sweetpotato storage root growth and development (Data *et al.*, 1987). Studying variation in carotenoid content, especially pro-vitamin A carotenoid content, during storage root development is relevant in the process of maximizing the availability of that nutrient. Proper recommendations could then be made to farmers to start practicing piecemeal harvesting.

In semi-arid areas with a long dry season, in-ground storage is limited by attacks from sweetpotato weevils (*Cylas spp.*). Farmers have traditionally chipped or crushed sweetpotato roots, sun-dried, and stored them for year-round use. The International Potato Center (CIP) has been working to make more nutritious sweetpotato varieties available to African

countries (Gichuki et al., 1997). Chipping, drying and storing orange-fleshed sweetpotato can overcome the seasonal shortages of pro-vitamin A, a micronutrient short in the diets of many low-income African households during the dry season when there are no fresh, green vegetables. However, little is known about the effect of drying and processing into flour and flour related products on the carotenoid contents.

MATERIALS AND METHODS

Plant material. Sweetpotato cultivars from Kenya, Uganda, and from CIP's pathogen-tested collection (CIP, 1998) with storage root flesh colors ranging from white to orange were selected, grown in Kabete, Kenya, and used in this study.

The effect of root age on carotenoid content was assessed by sampling sweetpotato roots grown at 12, 16, 20, and 24 weeks after planting. At each stage, three plants were randomly selected and the largest storage roots piecemeal harvested from each randomly selected plant. Different plants were sampled at each harvest.

Chipping and drying. Sweetpotato chips were dried at 65°C in a forced-air oven to a moisture content of 6-8%. The process of producing dried sweetpotato chips used, was that described by Hagenimana et al. (1998b). To check for changes in total carotenoid contents during storage, dried chips from each cultivar were stored in opaque paper bag and sampled for flour processing after 3, 6, and 11 months of storage under ambient air conditions.

Preparation of buns, chapatis and mandazis. Buns, chapatis (flat unleavened bread), and mandazis (doughnuts) were prepared as described by Hagenimana et al. (1998).

Carotenoid extraction. Extraction procedure from Khachik et al. (1992) was used.

Spectrophotometric determination of total carotenoid and β -carotene contents. Total carotenoids and β -carotene were determined spectrophotometrically as described by Imungi and Wabule (1990).

HPLC carotenoid analysis. One ml of total carotenoid extract from 2 g of grated sweetpotato sample was freeze-dried and reconstituted in HPLC mobile phase of 90% Methanol:10% Tetrahydrofuran. The reconstituted samples were ultra-filtered through 0.5 μ m microfilters before injection into the HPLC system. HPLC analyses were done as described by Ruddat and Will III (1985) at the laboratory of the International Livestock Research Institute (ILRI), Nairobi, Kenya.

Standards used to identify different HPLC carotenoid chromatographic peaks were: β -carotene, α -carotene, lycopene from Sigma, St-Louis, ζ -carotene, β -cryptoxanthin were kindly donated by Drs. W. Schuep and J. Schierle from Hoffmann La Roche, Switzerland, β -carotene-5,6-monoepoxide and β -carotene-5,6,5',6'-diepoxide were kindly donated by Dr. Peter Molnar from the University of Pecs, Hungary. Identification of the various HPLC carotenoid peaks was based on consistent retention times and co-chromatography.

RESULTS and DISCUSSION

Carotenoids and vitamin A values of sweetpotato roots

HPLC results indicated that a good number of carotenoids occur in sweetpotato root extracts. Six of these were present in significant amounts with the predominance for more than 80% of all-*trans*- β -carotene in most orange-fleshed sweetpotato roots analysed (Figure 1). All-*trans*- β -carotene, β -carotene-5,6-monoepoxide, β -carotene-5,6,5',6'-diepoxide and unidentified carotenoid, denoted P1, were present in all cultivars analysed. The amount was, however,

dependent on the cultivar. Comparisons of chromatographic profiles of the sweetpotato extracts from different cultivars and the co-chromatography with carotenoid identified the presence of all-*trans*- β -carotene, β -carotene-5,6-monoepoxide, and β -carotene-5,6,5',6'-diepoxide (Table 1). P1 predominated in white- or cream-fleshed cultivars like KSP 20, Naveto (CIP440131), and KEMB 10 where it formed a significant proportion of total carotenoids. The possible identity of this carotenoid was able to be postulated on basis of its elution pattern. Early elution of P1, as well as that of P2, strongly suggests that it is a xanthophyll, possibly lutein, and P2, zeaxanthin. Large variation was observed in carotenoid content among the cultivars studied. This was a reflection of the wide spectrum of the root flesh color of sweetpotato. White-flesh roots like those from cultivars Mugande, TIS 2534 (CIP440062), LM88.014 (CIP188001.2), and KSP 20 had the lowest total carotenoid, while orange-fleshed cultivars like Camote amarillo (CIP400014), Japon Tresimesino Selecto (CIP420009), Kakamega 4 (SPK004), Zapallo (CIP420027) had the highest (Figure 2). Our results agree with the conclusion that carotenoids, especially β -carotene, are largely responsible for the orange flesh color in sweetpotato storage roots (Almeida-Muradian et al., 1992; Takahata *et al.*, 1993). The depth of orange flesh color was mainly a function of the concentration of all *trans* β -carotene, as was similarly reported by Simonne et al. (1993). These results indicate that carotenoids from orange-fleshed sweetpotato are highly vitamin A active and are consistent with Jalal et al. (1998) who recently showed that consumption of β -carotene-rich foods mainly in the form of orange-fleshed sweetpotato increased serum retinol levels in Indonesian children and alleviate signs of vitamin A.

Low et al. (1997) suggested that cultivars having more than 100 μ g retinol equivalent per 100 g fresh roots were good sources of vitamin A. Table 2 shows the vitamin A values of some 17 cultivars. Cultivars like TIB 11 (CIP440057), W-220 (CIP440015), Unknown, Japon Tresimesino Selecto (CIP420009), Zapallo (CIP420027), and Kakamega 4 (SPK004) have sufficient levels of retinol equivalents to meet this criteria. Their cultivation, consumption,

and utilization in different dishes should be encouraged in combating nutritional vitamin A deficiency in Africa.

Effect of root age

Sixteen to twenty week old roots contained higher carotenoid concentrations than younger roots (Figure 3). These differences in total carotenoid content between young and older roots depended on the cultivar. Sixteen-week old roots from Kakamega 4 (SPK004) were two-fold higher in total carotenoid content than 12-week old roots. Orange-fleshed cultivar Japon Tresimesino Selecto (CIP420009) had two-thirds of its total carotenoid content available after just 12 weeks. Concentration of total carotenoid continued to increase up to the 24th week in low-carotenoid-content cultivars TIS 2534 (CIP440062) and Kemb 10 (Figure 3). Therefore, to receive the maximum pro-vitamin A benefits from the sweetpotato, piecemeal harvesting and consumption of roots from Japon Tresimesino Selecto (CIP420009) could begin after 12 weeks, after 16 weeks from Kakamega 4 (SPK004), and after 20 to 24 weeks from the lower carotenoid content cultivars.

Effect of drying and storage of sweetpotato chips on total carotenoid contents

Drying sweetpotato storage roots at 65°C for 12 hours reduced the total carotenoid contents by 30%, while storage of dried chips for 11 months reduced the total carotenoid contents from 70 to 59% (Figure 4, and more details from Hagenimana et al., 1998b).

Total carotenoids in processed sweetpotato products

Figure 5 (from Hagenimana et al., 1998b) shows that the incorporation of orange-fleshed sweetpotato roots significantly increased the total carotenoid contents of the products over those containing no sweetpotato, and improve the color of the products, giving them an attractive egg-like appearance.

CONCLUSION

- Orange-fleshed roots contained higher total carotenoid and β -carotene content than white- and cream- fleshed lines, and all *trans*- β -carotene predominated for more than 80%. Carotenoids from orange-fleshed sweetpotato are highly vitamin A active and their consumption in Africa where vitamin A deficiency is prevalent should be encouraged.
- Twelve weeks after planting, the yield and amount of pro-vitamin A present in roots of orange-fleshed cultivars evaluated were high enough to provide adequate dietary pro-vitamin A and suggest the start of piecemeal harvesting.
- Incorporation of flour made from orange-fleshed sweetpotato roots into buns, chapatis, and mandazis significantly enriched the products in pro-vitamin A.
- Results of this study suggest that increased consumption of orange-fleshed sweetpotatoes in either fresh or processed form can contribute in alleviating dietary deficiency of vitamin A.

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Table 1. Retention Times of Carotenoid Standards and Sweetpotato Extract during HPLC Cochromatography

Peak identity	Carotenoid standards, Retention time, min ^a	Sweetpotato extract (Cultivar SPK 004), Retention time, min ^a	Sweetpotato extract + carotenoid standard, Retention time, min ^a
P1 (Unidentified)	–	2.69 ± 0.10	2.89 ± 0.09
P2 (Unidentified)	–	3.75 ± 0.15	4.05 ± 0.07
P3 (β-carotene-5,6,5',6'-diepoxide)	5.28 ± 0.5	5.36 ± 0.22	5.83 ± 0.21
P4 (β-cryptoxanthin)	6.30 ± 0.14	–	6.30 ± 0.14
P5 (Unidentified)	6.50 ± 0.05	–	6.50 ± 0.05
P6 (β-carotene-5,6-monoepoxide)	9.19 ± 0.08	8.61 ± 0.40	9.00 ± 0.05
P7 (ζ-carotene)	12.42 ± 0.18	–	12.57 ± 0.20
P8 (Lycopene)	13.89 ± 0.20	–	13.68 ± 0.14
P9 (α-carotene)	14.36 ± 0.06	–	14.43 ± 0.07
P10 (All-trans-β-carotene)	15.72 ± 0.49	14.60 ± 0.87	15.21 ± 0.08
P11 (Unidentified)	–	15.44 ± 0.33	15.70 ± 0.19

^a mean ± SD

Table 2. Carotenoids and Vitamin A Values of 17 Sweetpotato Cultivars Evaluated in Kenya, in 1996.

Cultivar	Flesh color	Total carotenoid content* (mg/100g fresh root \pm SD)	β -Carotene content* (mg/100g fresh root \pm SD)	β -Carotene-5,6- monoepoxide content (μ g/100g fresh root \pm SD)	β -Carotene to Total carotenoids % \pm SD
Naveto (CIP440131)	White	< 0.1	< 0.1	1.5 \pm 0.3	0.1
LM88.002 (CIP188001.1)	White	0.1 \pm 0.0	< 0.1	0.1 \pm 0.0	4.5
KSP 11	White	0.2 \pm 0.0	< 0.1	< 0.1	12.5
TIS 2534 (CIP440062)	White	0.1 \pm 0.0	< 0.1	0.1 \pm 0.0	12.1
Ex-Diani	White	0.2 \pm 0.0	< 0.1	0.1 \pm 0.1	10.1
Phillippine (CIP440160)	Dark cream	0.2 \pm 0.0	< 0.1	0.3 \pm 0.2	3.2
TIS 70357 (CIP440078)	Cream	0.2 \pm 0.0	< 0.1	0.2 \pm 0.0	15.8
NG 7570 (CIP440377)	White	0.2 \pm 0.0	< 0.1	0.1 \pm 0.0	9.9
Capadito (CIP420053)	Pigmented	0.2 \pm 0.0	< 0.1	ND	15.0
KEMB 10	Cream	0.4 \pm 0.0	0.1 \pm 0.0	2.3 \pm 0.2	39.6
Maria Angola (CIP420008)	Pale orange	0.4 \pm 0.0	0.1 \pm 0.0	0.5 \pm 0.1	28.4
Kakamega 4 (SPK 004)	Orange	2.6 \pm 0.2	1.5 \pm 0.1	68.0 \pm 0.0	59.0
Zapallo (CIP420027)	Pale orange	4.3 \pm 0.0	2.9 \pm 0.5	111 \pm 19.3	67.7
Japon Tresmesino Selecto (CIP420009)	Intermediate orange	5.5 \pm 0.3	4.6 \pm 1.4	90.2 \pm 2.7	82.7
Unknown	Pale orange	7.5 \pm 0.7	6.2 \pm 0.0	98.5 \pm 5.8	83.1
W-220 (CIP440015)	Intermediate orange	8.4 \pm 0.4	6.0 \pm 0.5	208.9 \pm 56.9	71.7
TIB 11 (CIP440057)	Orange	8.8 \pm 0.7	8.0 \pm 0.3	91.0 \pm 4.7	90.8

* Values less than 0.05 mg/100 g fresh root are indicated as 0.0