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SHORT COMMUNICATION

Retention of carotenoids in orange-fleshed sweet potato during processing

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Abstract The retention of carotenoids was studied in the storage roots of ten sweet potato clones possessing different intensities of dark orange-flesh colour in four different processing methods—oven drying, boiling, sun drying and frying. The results indicated that the extent of retention varied with the method of processing. The highest retention was observed in oven drying (total carotenoids 90%–91% and β-carotene 89%–96%) followed by boiling (total carotenoids 85%–90% and β-carotene 84%–90%) and frying (total carotenoids 77%–85% and β-carotene 72%–86%). The lowest retention of total carotenoids (63%–73%) and β-carotene (63%–73%) was recorded in the sun drying method.

Keywords Retention · Carotenoids · Orange-fleshed sweet potato · Processing

Introduction

Sweet potato (*Ipomoea batatas* (L) Lam) is an important tuber crop grown in the tropics, sub-tropics and warm temperate regions of the world for its edible storage roots. The roots are used as a source of carbohydrate and dietary fibre. Dietary fibre has the potential to reduce the incidence of a variety of diseases in man including colon cancer, diabetes, heart diseases and digestive disturbances (Palmer 1982). The flesh colour of the root varies from various shades of white, cream, yellow to dark-orange depending upon the carotenoid content. In the orange-fleshed sweet potato the major carotenoid present is β-carotene. Carotenoids have been linked with the enhancement of immune system and decreased risk of degenerative diseases such as cardiovascular problems, age-related macular degeneration and cataract formation (Byers and Perry 1992). Sweet potato is also a rich source of provitamin A, vitamin B1 (Thiamin) and vitamin C (Huang et al. 1999).

Vitamin A deficiency is considered a serious problem of public health significance in over 70 countries. It is an essential micronutrient for normal immune function of the body. Vitamin A is usually produced in animal body. In plants, it is present in the form of provitamin A. Of the approximately 600 carotenoids found in nature, only three are important precursors of vitamin A in humans beings *viz*, β-carotene, ά-carotene and β-cryptoxanthin (Jaarsveld et al. 2005) and β-carotene is the major provitamin A of most carotenoid containing food (Parker 1996). Recent studies associated with the consumption of carotenoid rich food showed the decrease of the incidence of certain cancers in human beings (Gester 1993). Food fortification, dietary diversification and vitamin A supplementation are the recommended strategies to control vitamin A deficiency. Orange-Fleshed Sweet Potato (OFSP) forms an important source of carotene rich food (Woolfe 1992). Jalal et al. (1998) suggested that a food based approach may be a successful way of reducing the prevalence of vitamin A deficiency. 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

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making fried chips. In order to alleviate the vitamin A deficiency, it is necessary to get information regarding the retention of the total carotenoids and β-carotene in the different processing methods. The true retention is an important component defining the ultimate importance of carotenoids in the consumed orange-fleshed sweet potato. Hence, the objective of the present study is to find out the variability of carotenoids between the clones and the retention of total carotenoids and β-carotene content arising from different processing methods.

The material for the study comprised of storage roots of ten orange-fleshed sweet potato from a poly cross breeding programe. Twenty clones possessing different intensities of orange flesh colour were selected from sweet potato germplasm maintained at Central Tuber Crops Research Institute (CTCRI). Hundred and fifty vine cuttings from each clone were planted in an isolation block in 3 replications. The vine cuttings of 20–30 cm length from the apical portion of the vines were selected for planting. The clones were randomly planted to get equal chances of intercrossing with each other. Seeds were collected, scarified and germinated to raise the progeny. Only orange-fleshed clones were selected and undesirable clones were rejected at each stage of evaluation. The clones for the present study were selected based on flesh colour, root shape and dry matter content. Each clone was planted in a plot size of 3.0×2.4 m in randomized block design with 3 replications. The distance between and within the ridges were 60 and 20 cm respectively accommodating 60 plants/clone/replication and the recommended package of practices of CTCRI (2004) was followed. Farmyard manure at the rate of 5 t/ha was broadcasted before preparing the ridges. Chemical fertilizers like urea (125 kg), rock phosphate (125 kg) and muriate of potash (85 kg)/ha were applied at the time of planting. Interculturing operations (earthing up and weeding) were carried one month after planting and 55 Kg urea, 125 kg ammonium sulphate /ha were applied along the sides of the ridges. After 2 months, earthing up was done again. The trial was harvested after 90 days.

About 5 kg of randomly selected tubers were divided into five portions to perform different types of processing *viz.* fresh, boiling, frying, oven-drying and sun-drying. Roots were peeled, cut into small pieces and 100 g were used for processing. The root samples were analyzed (triplicate) for dry matter, total carotenoids and β-carotene content. The same experiment was repeated for three seasons (summer, kharif and rabi) during the year 2008 and the data statistically analyzed. The statistical analysis of variance and comparison of mean values with least significance difference were carried out with the package Genstat DE (Genstat 2008).

Fresh: The total carotenoids and β-carotene of each clone was determined on fresh raw unprocessed samples immediately after harvest.

Boiling: Unpeeled samples of root size of 100 g were boiled in distilled water for 30 min at 100°C. Two grams of this material after cooling was used for further analysis.

Frying: Roots were peeled made into thin slices and blanched for 1 min in boiling water. The samples were dried in oven at 36°C overnight. These were fried in vegetable oil until crispy and the carotenoids were estimated.

Oven-drying: The roots were peeled and sliced into single layer circular pieces of 2 mm thickness, spread in a tray and oven dried at 50–60°C for 24–48 h.

Sun-drying: Similar pieces to above were placed under sun for 48 h.

About 2 g of tissue was randomly selected (in triplicate) from the different processing methods to estimate the total carotenoids and β-carotene based on the procedure described in AOAC (2000). Briefly, root samples were extracted with hexane-acetone mixture (60+40) till colourless. The extract was washed with distilled water to remove acetone and dried using anhydrous sodium sulphate. The optical density was measured at 450 nm. β-carotene was separated from the extract by column chromatography using aluminium oxide and eluted using hexane + acetone (96+4). The concentration of total carotenoids and β-carotene was calculated using a calibration curve with β-carotene as standard.

The sweet potato clones included in the study showed different intensities of dark orange-flesh colour. The flesh colour of the root was directly associated with the β-carotene content. Similar results were reported by Simonne et al. 1993; Kidmose et al. 2007. The anova table and data on total carotenoids, β-carotene and dry matter content are given in

Table 1 Analyses of 10 orange-fleshed sweet potato clones

Source	Variate	d.f.	s.s.	m.s.	v.r.	F.pr.
Method × variety	Total carotenoids	36	133131	3698	1.00	0.466
	Retention total	36	1042.0776	28.9466	220.80	<.001
	β-carotene	36	4.638E+01	1.288E+00	912.58	<.001
	Retention β	36	1448.4131	40.2337	348.98	<.001

Table 2 Effect of different processing methods on total carotenoids and β-carotene

Variety	Method	Total carotene (mg/100 g.f.w)	Percentage of retention (%)	β-carotene (μg/g.f.w.)	Percentage of retention (%)	Dry matter (%)
KS-7	Fresh	7.5±0.23	100	5.9±0.33	100	25±0.17
	Boiling	6.3±0.01	85	5.0±0.10	85	
	Frying	5.8±0.14	77	4.8±0.13	82	
	Oven drying	6.7±0.02	90	5.5±0.20	94	
	Sun drying	5.2±0.01	70	4.2±0.20	72	
ST-14-1	Fresh	14.1±0.06	100	12.8±0.33	100	21±0.17
	Boiling	12.8±0.20	91	10.7±0.43	84	
	Frying	12.1±0.02	86	09.5±0.33	74	
	Oven drying	13.5±0.06	96	11.4±0.16	89	
	Sun drying	10.2±0.33	73	09.3±0.20	73	
ST-14-16	Fresh	12.8±0.42	100	11.2±0.36	100	22±0.17
	Boiling	11.1±0.32	87	10.0±0.01	89	
	Frying	10.3±0.23	80	09.7±0.06	86	
	Oven drying	11.6±0.25	91	10.1±0.13	90	
	Sun drying	08.7±0.27	68	08.2±0.13	73	
ST-14-34	Fresh	11.6±0.32	100	09.6±0.42	100	23±0.26
	Boiling	10.5±0.33	91	08.0±0.33	83	
	Frying	09.7±0.41	84	07.8±0.13	81	
	Oven drying	10.6±0.10	91	08.7±0.06	90	
	Sun drying	07.3±0.12	63	06.6±0.36	68	
ST-14-49	Fresh	8.9±0.38	100	07.5±0.30	100	24±0.17
	Boiling	8.1±0.33	90	06.9±0.26	91	
	Frying	7.6±0.22	85	06.4±0.06	85	
	Oven drying	8.5±0.16	95	07.0±0.06	93	
	Sun drying	6.2±0.05	69	05.1±0.23	68	
ST-14-53	Fresh	13.7±0.38	100	12.1±0.33	100	21±0.17
	Boiling	11.8±0.36	86	10.3±0.40	85	
	Frying	10.9±0.36	80	09.6±0.30	79	
	Oven drying	12.4±0.32	91	11.0±0.33	91	
	Sun drying	08.9±0.47	65	07.6±0.46	63	
ST-14-6	Fresh	13.1±0.38	100	11.5±0.30	100	24±0.17
	Boiling	11.8±0.38	91	10.0±0.40	87	
	Frying	10.8±0.46	82	08.8±0.23	77	
	Oven drying	12.2±0.40	93	10.6±0.40	92	
	Sun drying	09.2±0.56	70	08.1±0.23	70	
ST-14-9	Fresh	11.2±0.32	100	09.8±0.36	100	22±0.26
	Boiling	10.1±0.33	89	08.8±0.01	89	
	Frying	09.6±0.27	85	08.1±0.06	82	
	Oven drying	10.6±0.17	94	09.4±0.10	96	
	Sun drying	08.1±0.15	72	06.9±0.10	71	
SV-3-17	Fresh	15.5±0.15	100	13.6±0.12	100	20±0.17
	Boiling	13.7±0.28	89	12.2±0.30	89	
	Frying	12.7±0.38	82	11.2±0.26	82	
	Oven drying	14.7±0.17	95	12.7±0.26	93	
	Sun drying	10.8±0.29	70	09.0±0.26	66	
SV-3-22	Fresh	10.9±0.38	100	09.2±0.13	100	23±0.17
	Boiling	09.8±0.32	90	07.8±0.23	85	
	Frying	09.0±0.32	83	06.6±0.20	72	
	Oven drying	10.3±0.12	95	08.6±0.30	93	
	Sun drying	07.9±0.20	73	06.2±0.20	67	
LSD (5%) Variety × Method	0.062	0.34	0.034	0.31	–	

The values for Total carotene and β-carotene is the mean±SD of 9 (n=9) replicates experiments

Tables 1 and 2. The storage roots of all the orange-fleshed clones possessed low dry matter content which varied between 20% and 25%. The data showed that only one clone KS-7 had 25% dry matter however, the total carotenoids (7.47 mg/100 g.f.w.) and β-carotene (5.85 mg/100 g.f.w.) in this clone was low compared to other clones. Negative associations of flesh colour and dry matter was observed in the present study. Similar results were reported by Jones et al. (1976), Jones (1977), Zhang and Xie (1988).

The results indicated that the total carotenoids in the fresh root samples ranged from 7.47 to 15.47 mg/100 g.f.w. and β-carotene varied from 5.85 to 13.63 mg/100 g.f.w. (KS-7 and SV3-17). In all the clones more than 80% of total carotenoids was β-carotene. According to Takahata et al. (1993), β-carotene of sweet potato ranged from 10 to 26,000 μg/100 g or 0.01 to 26.6 mg/100 g.f.w. Hagenimana et al. (1999) reported β-carotene level of 11.8 mg/100 g in the variety Xushu 18. However in the present study majority of the clones possessed >10 mg/100 g.f.w. total carotenoids and >9 mg/100 g.f.w. β-carotene. The highest total carotenoids (15.47 mg/100 g.f.w.) and β-carotene (13.63 mg/100 g.f.w.) in the fresh and processed sample was observed in the clone SV3-17.

Results indicated that the orange fleshed varieties varied significantly in their carotenoid content and retention capabilities. Highest retention of total carotenoids (90%–91%) β-carotene (89%–96%) was observed in the oven drying method followed by boiling (85%–90% and 84%–90%) in all the clones. In the frying method, the retention of total carotenoid was 77%–85% and β-carotene was 72%–86%. Least retention of total carotenoids (63%–73%) β-carotene (63%–73%) was recorded in the sun-drying process. Variation in retention of carotenoids may be due to the difference in the enzymatic oxidation during processing. This was also in agreement with the study by Ameny and Wilson (1997). The influence of different processing procedures on the carotene content of orange-fleshed roots have been reported in sweet potato (Huang et al. 1999), carrots (Debjani et al. 2005), and cassava (Chavez et al. 2007). More than 100% retention of carotenoids was reported in Spinach and Winged Bean through steam and water blanching (Dietz et al. 1988). No loss of β-carotene in chopped or grated raw sweet potato was observed by Jaarsveld et al. (2006). This showed that there was no or little enzymatic oxidation in cut fresh samples which accounted for the 100% retention. In all the other procedures, occurrence of less retention values could be due to leaching of vitamin A precursor as in sun drying or thermo chemical reaction occurring during cooking times (Chandler and Schwartz 1988). Moreover, variation in processing is also affected by slice thickness of pieces, temperature, duration of frying, and stage of maturity (Adelaide et al. 2007). The softness of steamed food is generally influenced by the cooking time. According to Bradbury and Holloway (1988) different varieties have different cooking time due to inherent variations in starch content, composition as well as the level of soluble fibres. High retention of ά and β-carotene during processing and storage could be attributed to the facts that cooking makes it easy for the complete elution of β-carotene in processed foods than in fresh. In methods like boiling and frying, the comparatively low retention in these processed samples may be due to the dripping off of the pigment. However, in oven-drying and sun-drying, it can be due to the thermo chemical reaction and leaching up of the pigments.

In the present study highest retention of total carotenoids and β-carotene was found in the oven-drying process, though it is not a common method of processing for human consumption. But, the high carotenoid retention may be beneficial for the production of value added sweet potato products. The present study showed that SV-3-17, ST-14-1 and ST-14-53 clones possessed high total and β-carotene content in the fresh as well as in the different processing methods. Chandler and Schwartz (1988) had reported that carotene deficient varieties are more susceptible to degradation than carotene rich ones. This observation was contradictory to the present study, in relation to the variety KS-7 where the carotenoid retention was more in than 80% (Table 2). Effects of various traditional processing methods on carotene content of sweet potato have been reported by Bengtsson et al. (2008), K'osambo et al. (1998), Hagenimana et al. (1999) etc. Bengtsson et al. (2008) had observed low retention values to the fresh unprocessed samples while K'osambo et al. (1998) could find decreased carotene content in boiled samples. A loss of 20%–30% was observed by Hagenimana et al. (1999) in CIP cultivars subjected to boiling as well as drying into chips compared to initial carotenoid amount in fresh storage roots. Retention of carotenoids after boiling is more important since majority of common people consume sweet potato roots after boiling. Products like sweet potato juice or salads could be recommended for maximum absorbance of carotene content in diet. The people who were traditionally dependent on the consumption of white-fleshed local cultivars are unaware of the nutritive value of orange-fleshed sweet potato as most of the varieties selected by the consumers are based on the best taste, flavour and texture rather than those having a better nutrient profile (Chattopadhyay et al. 2006). The reduction of carotenoids in the sun-drying process may be due to the detrimental effect of the sun-light on the stability of carotenoid pigment. However moderate amount of β-carotene (63%–73%) present in the sun-drying process may be useful for the production of sweet potato flour and orange coloured crispy chips.

The high carotenoid retention in different processing methods indicates the possibility of significantly improving the nutritive value by making more acceptable products to the consumers. The retention of carotenoids in different processing methods helps to validate the techniques for obtaining food products of higher nutritional quality.

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