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EFFECT OF COOKING METHODS ON β CAROTENE, ANTHOCYANIN, VITAMIN C AND ANTIOXIDANT CONTENT OF SWEET POTATO

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ABSTRACT

Two cultivars of sweet potatoes ST-14 Orange Flesh Sweet Potato (OFSP) and ST-13 Purple flesh sweet potato (PFSP) were studied which were found to be significant source of antioxidants like anthocyanin, β carotene and ascorbic acid. Effect of cooking methods viz steaming, frying and dehydration on β carotene, anthocyanin, vitamin C and antioxidant activity (AOA) were studied in OFSP (ST14) and PFSP (ST-13) in raw and cooked samples. Retention of β carotene content in OFSP was 85% by steaming followed by drying 79% and frying 78% whereas anthocyanin showed increase of 174.10% by steaming but decrease by 71.71% and 78.53% by dehydration and frying respectively. Vitamin C content measured in fresh ST-14 was 19%. Steaming showed 17.9% followed by 15.13% and 15.26% in frying and dehydration. Ascorbic acid content found in ST-13 was 21.23% in fresh followed by 15.85%, 20.05% and 18% in steamed, fried and dehydrated samples. AOA measured in fresh samples of ST-14 and ST-13 showed 61.48% and73.09 % inhibition. Steaming showed highest inhibition i.e. 69.28% and 82.56 % whereas dehydration showed lowest as 43.93% and 50.25% in OFSP and PFSP respectively. Fried samples of ST-14 and in ST-13 showed 44.69% and 52.11% inhibition. Study revealed that steaming of sweet potatoes was the most effective cooking method. High retention of carotene, anthocyanin and vitamin C in colored sweet potatoes showed that these bioactive compounds have good antioxidant activity to contribute to health benefits.

Key Words: Orange fleshed sweet potato, Purple fleshed sweet potato, β Carotene, Anthocyanin, Vitamin C, Antioxidant

INTRODUCTION

Most of the antioxidant compounds in a typical diet are derived from plant sources and belong to various classes of compounds with a wide variety of physical and chemical properties. Fruits and vegetables contribute to the prevention of several diseases including cancer and cardiovascular diseases (Nakamura *et al* 2008, Dauchet *et al* 2006). The free radicals are generated in the human body through aerobic respiration and exist in different forms, including superoxide, hydroxyl, hydroperoxyl, peroxyl and alkoxyl radicals. Generally, natural antioxidant enzymes in healthy individuals remove these free radicals. However, dietary antioxidants are helpful in assisting the body to neutralize free radicals. These antioxidant compounds including carotenoids and phenolics reduce the oxidative stress produced by free radicals and thus protect cells and body tissues (Mujić *et al* 2011). Therefore, it is important to consume diet high in antioxidants, such as fruits and vegetables, to reduce the harmful effects of oxidative stress. Sweet potatoes (*Ipomoea batatas* L.) are rich in dietary fibre, minerals, vitamins, and antioxidants, such as phenolic acids, anthocyanins, tocopherol and β-carotene. In recent years, several reports have indicated that the phytochemical in sweet potatoes displayed antioxidative or radical-scavenging activity and exerted several health-promoting functions in humans.

Orange flesh sweet potato is a rich source of β-carotene (provitamin A), a very good source of vitamin C and a good source of copper, dietary fibre, vitamin B_6, manganese, potassium and iron, while purple-fleshed varieties are rich source of anthocyanins (Teow *et al* 2007). The purple and orange fleshed sweet potatoes contain large amounts of anthocyanin and β-carotene, respectively. Color and variety can influence levels and profiles of phenolics as well as of anthocyanins and carotenoids (Van den Berg *et al*, 2000; Steed and Truong, 2008)). It has been reported a high content of anthocyanin pigments in the tuber of purple sweet potato are more stable than those of other plants which are purple-red color (Bolívar and Louis, 2004).

Sweet potato can be used to substitute part of the various flour and starchy vegetables such as potato to make *chapathis*, snacks and other baked goods. In addition to serving as a source of energy and nutrients like, sweet potato flour can add natural sweetness, color and flavor to the processed food products. Recipies can be made with higher proportions (10-100%) of sweet potato by various cooking methods. It can be used as a substitute for wheat flour to lower (bakery) costs and as such decrease imports of wheat flour, and as an alternative market outlet for those selling the roots as raw material as well as add to the nutrient content. Each cooking methods lead to different changes in the quality attributes of sweet potato (Takenaka,2006).Therefore, the objective of this study was to determine the individual composition of the β carotene , anthocyanin and antioxidant capacity of two cultivars of sweet potato i.e. orange fleshed sweet potato (OFSP) ST-14 and purple fleshed sweet potato (PFSP) ST-13 and to investigate the effect of heat-processing methods that are commonly used with sweet potatoes.

MATERIALS AND METHODS

Sweet potato tubers were procured from Department of Vegetable Science, Punjab Agricultural University, Ludhiana. Both sweet potatoes were subjected to several pre-treatment operations such as sorting and grading, washing and cutting .The samples of sweet potato tubers were cooked by steaming, frying and dehydration. Preparation of sweet potato flour was made ready to eat (RTE) by steaming and then dehydrated to flour. The tubers size approximate 30g were steamed in Pressure cooker at 15 psi for 2-3 minutes then dried using a convection drying oven at temperatures 60^0 C for 12 hour till the weight became constant. The flour (moisture content 6–7%) was obtained by grinding the dried pieces using a grinder. For frying, tubers were cut in to 2-3 mm slices and deep fried in refined oil for 3-4 minutes. Analysis of samples were done by using standard methods from AOAC for ascorbic acid and β carotene (Rangana, 1995) in Food and Nutrition lab, PAU Ludhiana. Total phenolic content was measured using the modified Folin–Ciocalteu method and antioxidants by DPPH method.

RESULTS AND DISCUSSION

β-CAROTENE

Burgos *et al* (2001) opined that the β-carotene content varied in the intensity of coloration of the sweet potatoes. They further indicated that the β-carotene content ranged from 0.0 to 0.4 mg/100g in cream colored sweet potatoes and 4.29 mg / 100g and 18.55mg/ 100g in deep orange colored sweet potatoes. The results of the present study Table 1 on ST-14 revealed 8.83, 8.14 and 8.27 mg /100g β carotene in steamed, fried and dehydrated flour as compared to 10.38mg/100g in fresh tubers, which falls in the range of β-carotene content of the tubers varied from 2.58 to 9.74 mg/100 g among the cultivars and higher values were recorded in ST-14, 362- 7, Kamala Sundari, CIP SWA-2, 440038 and S-1281(Mitra ,2012). Study done by Emmanuel *et al* http://www.asareca.org also showed that boiling and steaming of roots seemed to result in better retention of all-trans-β-carotene than roasting and dehydration. Their study revealed that β-carotene content in fresh OFSP was 8.75 mg/100g and dried sweet potato chips had 8.04mg/100 g and this remained the same after flour processing. Results of the present study revealed that different methods of cooking like steaming, frying and dehydration to flour that retention of β carotene content in OFSP var. ST-14 was maximum 85% by steaming followed by drying 79.67% and frying 78.42% , which follow almost similar results indicated by Vimala *et al* (2011) that the OFSP varieties varied significantly in their carotenoids content and retention capabilities. Highest retention of total β-carotene (89%–96%) was observed in the oven drying method followed by boiling 84%–90%. In the frying method, the retention of β-carotene was 72%–86%. 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 (Vimala *et al, 2011*). 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, according to Carlos *et al* (2012) among the heat-processing methods, flour presented the greatest losses of major carotenoids, likely because of the longer exposure to heat and to air circulation, which promote the degradation and oxidation of carotenoids. Bengtssona *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. Recipies developed by CTCRI, Bhubaneswar with OFSP showed that high amount of β-carotene (92%) is retained in the processed product compared to the fresh tubers (Attaluri, 2010).

ANTHOCYANIN

The composition of anthocyanins and total phenolics is dependent on various factors such as, cultivar, climatic conditions and altitude, as well as the storage conditions of the tubers (Lachman *et al* , 2012).The purple color of the sweet potatoes varied with different PSP cultivars. Steed and Truong (2008) found total anthocyanin content in *var '*Stokes Purple' varied from 57.5mg /100g in puree to 174.4 mg /100g fw in raw potato peel. Anthocyanin level of sweet potato cultivar Hatay Kirmizi indicated a mean around 120 mg/g. Anthocyanins were detected 13767 ± 8.94 mg/100g; 38734 ± 6.70 mg/100g; 6755 ± 10.22 mg/100g in boiled, steamed and fried sweet potatoes, respectively as studied by Tokusoglu and Yildirimz (2012*).* In the current study the total anthocyanin content in fresh sample was 106.03mg/100g fw (Table 1). Anthocyanin showed increase of 174 10% (2.74 folds) by steaming but decrease by 78.53% (1.39 folds) and 71.71% (1.20 folds) by dehydration and frying respectively (Table 2) which follow the same trend to studied by Tokusoglu and Yildirimz *(*2012*)*. They studied that total anthocyanins increased to 1.14 fold after boiling process and 3.22 fold after steaming process and decreased 1.78 fold after frying process ($p \leq 0.05$). It was determined that steaming was the most effective among the heat-treated sweet potatoes (HTSPs). Yang and Gadi (2008) studied that PFSP powder processed by hot air-drying without steaming lost 65% of anthocyanin content, 35% of antioxidant activity and 40% of total phenols where as steaming of PFSP roots at atmosphere pressure for 0.5 h increased 40% of anthocyanin content and enhanced the purple color of PFSP. Dehydration at 60°C for 24 hours retained anthocyanin content and purple color of steamed PFSP.

Both steaming and dehydration increased the percentage of polymeric anthocyanins in PFSP. In a study done by Lemos *et al* (2013), the cooking techniques (boiling, steaming and microwave) were responsible for a statistically significant ($p<0.05$) increase in the amount of anthocyanins when compared with the raw potatoes. Leong and Oey (2012) found effects of processing on anthocyanin, carotenoids and vitamin C in summer fruits and vegetables that the heated fruits contained more anthocyanins than the fresh fruits. Heating results in enzyme inactivation, texture changes of fruits and vegetables and unavoidable leaching of water-soluble compounds which could alter the entire phytochemical profile and content of fruit and vegetables. The findings were reported by Nazni and Dharmalingam, 2014.

VITAMIN C

Each cooking methods lead to different changes in the quality attributes of sweet potato (Wang and Kays, 2001). According to study done by Takenaka (2006) Vitamin C content in raw sweet potato slices was 63.38 mg /100g. Vitamin C content in fried sweet potato chips ranged between 9.23 to 44.93 mg /100 g. Generally, ascorbic acid content decreased gradually with the increase in pre-drying time. The results obtained in this study (Table 1) showed that the ascorbic acid content found in ST-13 was 21.23% in fresh, followed by 15.85%, 20.05% and 18% in steamed, fried and dehydrated samples. Vitamin C content in fresh ST-14 was 19%. Steaming showed 17.9% followed by 15.13% and15.26% in frying and dehydration which approximately meet the values with different OFSP observed by Mitra (2012) that the tubers of SV-98, Kamala Sundari, 90/101 and ST-14 recorded higher values of vitamin C content ranging from 18.66 to 26.82 mg/100 g. Babalola (2010) studied the effect of some processing methods (cooking, frying and baking) on the Vitamin C content of sweet and Irish potatoes that raw sweet and Irish potatoes contained 160 and 79.3 mg/ 100 g of Vitamin C, respectively. The highest loss of 71.25% was observed in cooking followed by frying 61.93 while baking produced a loss of 51.50%. The treatment by blanching resulted in a decrease in the levels of vitamin C by as much as 85% Begum *et al* (2009).The reasons for losses in the content of the vitamin C are the solubility in water, thermic destruction and enzymatic oxidation during the technological process Selman (1994). However, Chukuwu *et al* (2012) found that Vitamin A and C retained more in cooked than in fried sweet potato. Study by Leong and Oey, 2012 revealed an interesting discovery that heating increased the content of the total vitamin C content, due to protection from enzymatic oxidation . The findings were reported by Nazni and Mythili, 2014.

ANTIOXIDANT

The main characteristic of an antioxidant is its ability to trap free radicals. Antioxidant compounds like phenolic acids, polyphenols and flavonoids scavenge free radicals. Especially anthocyanin phenolics and carotenoids provide sweet potatoes with their distinctive flesh colours containing cream, deep yellow, orange and purple and they act as antioxidants (Bengtssona *et al*, 2008; Van Jaarsveld *et al*, 2006). Results showed by Hwang *et al (*2012) that the proximate composition, ascorbic acid content, total carotenoids content, total polyphenol and antioxidant activities were significantly affected by the cooking procedures. Phenolic contents, including free and bound, and antioxidant activity during processing also depend on the type of crop. In general, antioxidant contents were preserved fairly well during most types of processing. Interestingly, the antioxidant content increased in products such as carrots, spinach, mushrooms, asparagus, broccoli, cabbage, red cabbage, green and red peppers, potatoes, and tomatoes during microwave cooking, steaming, or boiling (Bente *et al* 2006). Whereas Truong and Avula (2010) found processing such as peeling, boiling, roasting and steaming can also reduce the antioxidant capacity by the polyphenol oxidase enzyme that catalyzes the oxidative polymerization of phenolic acids during peeling and size reduction of sweet potatoes and promotes discoloration of the peeled and cooked sweet potatoes. Study done by Carlos *et al* (2012) on the heat-processing methods also revealed decreased carotenoids, total phenolic compounds content and antioxidant activity. The production of flour resulted in the greatest loss of phytochemicals evaluated. According to Teow *et al* (2007), total phenolic components can be used as an indicator in assessing the antioxidant activity of fruits and vegetables, including sweet potatoes.

Results of the current study showed that antioxidant activity measured (Table 2) in fresh samples of ST-14 and ST-13 showed 61.48% and 73.09% DPPH inhibition. Steaming showed highest inhibition i.e. 69.28% and 82.67% whereas, dehydration showed lowest viz 43.93% and 50.25 % in OFSP and PFSP respectively. Fried samples of ST-14 and in ST-13 showed 44.69% and 52.11% inhibition, which follow the high content of anthocyanin and β carotene content with antioxidant activity as shown in Figure 3 and 4. Retention of β carotene content inST-14 was 85% by steaming followed by drying 79% and frying 78% whereas anthocyanin in ST-13 showed increase of 2.74 folds by steaming but decrease by 1.39 folds and 1.20 folds by dehydration and frying respectively with increase in antioxidant activity as in Figure 1 and 2. There were good and positive correlations (Table 2) between the β carotene($R^2 = 0.97$ - 0.99, p level≤0.01) and anthocyanin with DPPH capacity ($r = 0.99$, p level≤0.01) indicating that this may be used as an indicator for the antioxidant activity of sweet potato roots which showed maximum increase by steaming process. Lachman and Hamouz (2005) found that total antioxidant activity depends on the amount of phenolic acid, carotenoids and anthocyanins in the tuber. The antioxidant capacity may be associated with the ability of carotenoids to quench oxygen. According to Bellail *et al* (2012), thermal processing significantly ($P \leq 0.05$) increased the total phenolic content, as well as individual phenolic acids and antioxidant capacity. However, he found that deep-frying exhibited the highest increment. Study done by Teow *et al* (2007) on different cultivars of sweet potato Hernandez and clone 11-20, which are both dark orange-colored, had the highest β carotene content, with 167 and 226 µg/g fw, respectively and concluded that high antioxidant activities of clone 11-20 can be attributed to its phenolic and β-carotene contents.

Table-1- Effect of different cooking methods on anthocyanin, β carotene, vitamin c and antioxidant activity

	Fresh	Steamed	Fried	Dehydrated
ST 13				
Anthocyanine (mg/100g)	106.03 ± 4.92	290.63 ± 3.35	76.03 ± 0.41	83.27 ± 0.79
Vit C (mg/100g)	21.23 ± 1.22	15.85 ±0.35	20.05 ±0.22	18.30 ±0.16
DPPH (%inhibition)	73.09 ± 0.70	82.56 ±1.99	52.11 ±0.23	52.25 ±0.67
ST 14				
β Carotene (mg/100g)	10.38 ± 1.39	8.83 ± 0.39	8.14 ± 0.71	8.27 ± 0.40
Vit C (mg/100g)	19 ± 1.21	17.91 ± 1.36	15.13 ± 0.06	15.26 ± 0.23
DPPH (%inhibition)	61.48 ± 0.50	69.28 ± 4.08	44.69 ± 0.53	43.93 ± 0.44

Values represent n=3, mean ±SD

Table-2 - Retention in (%) of Anthocyanin and β Carotene and corelation with antioxidant activity

Cultivar	**Method of cooking**	**β Carotene**	**DPPH % inhibition**	**r**
ST 14	Fresh	100	61.48	0.97**
	Steamed	85.06	69.28	0.99**
	Fried	78.42	44.69	0.98
	Dehydrated	79.67	43.93	0.99
ST 13		Anthocyanin		
	Fresh	100	73.09	0.98**
	Steamed	174.10	82.56	0.998**
	Fried	71.71	52.11	0.99**
	Dehydrated	78.53	52.25	0.99**

** Significant at 1% level of significance (p level≤0.01)

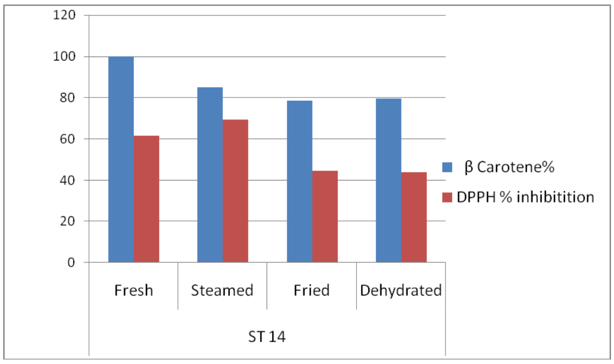

Figure 1- Retention in % of β Carotene (*ST14*)

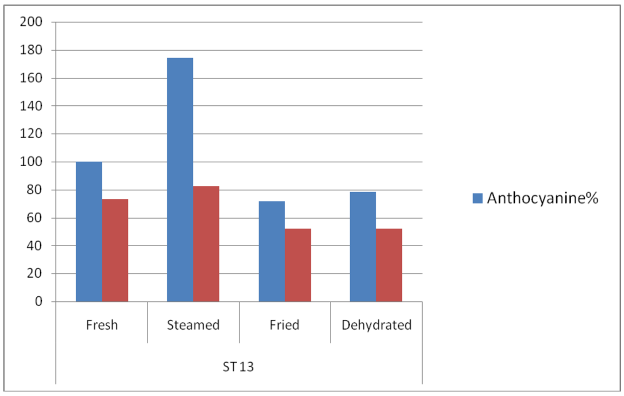

Figure 2 - Retention in % of Anthocyanin (*ST13*)

CONCLUSION

The desirable nutritional value of *Ipomoea batatas* is gaining recognition as the understanding between diet and health increases. Study revealed that steaming of sweet potatoes was the most effective cooking method. The processing may increase the chemical extractability of carotenoids and this may be a factor that increases the bioavailability of carotenoids for humans. It was found that the antioxidant properties of SPF were enhanced under gastrointestinal pH conditions, suggesting that it might possess a considerable amount of bound phenolic and other antioxidative compounds. (Chan *et al* 2012). High retention of carotene, anthocyanin and vitamin C in colored sweet potatoes showed that these bioactive compounds have good antioxidant activity. Thus, adequate implementation of cooking method can be effective in controlling oxidative stress and for the improvement of health. The processing of sweet potatoes into ready-to-eat products maximizes the uses of sweet potatoes and creates nutritional benefits as well as new economical and employment opportunities for farmers and health food industry.

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