Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2017; 6(6): 2313-2317
Received: 29-09-2017
Accepted: 30-10-2017

Performance of some purple-fleshed Sweet Potatoes (*Ipomoea batatas* L.) as influenced by different storage conditions

Rajani Maddipatla, Payel Panja, Pran Krishna Thakur, Reshmi Kumari, Venkata Satish Kuchi and Surajit Mitra

Rajani Maddipatla
Department of Post-Harvest Technology of Horticultural Crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

Payel Panja
Department of Post-Harvest Technology of Horticultural Crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

Pran Krishna Thakur
Department of Post-Harvest Technology of Horticultural Crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

Reshmi Kumari
Deputy Director of Horticulture, Satna, Madhya Pradesh, India

Venkata Satish Kuchi
Department of Post Harvest Technology, College of Horticulture, Dr. YSR Horticultural Universirty, Anantharajupeta, Andhra Pradesh, India

Surajit Mitra
Department of Post-Harvest Technology of Horticultural Crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

Correspondence
Payel Panja
Department of Post-Harvest Technology of Horticultural Crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

Abstract
Sweet potatoes are becoming a research focus in recent years due to their unique nutritional and functional properties. Purple sweet potato is a special type having high anthocyanin pigment and phenol content in the root. Sweet potato physiological parameters and biochemical constituents were evaluated to study the comparative performance in five cultivars (X-9, TSP-12-10, Cross 4, Sree Kanaka and Kishan) at harvest and after storage for 30 days under ambient, cool and refrigerated storage condition. All cultivars in different storage conditions exhibited steady weight loss and sprouting from the beginning and the tubers kept in refrigerated storage significantly least PLW%, followed by cool storage and ambient storage. Results of different storage conditions indicated that, there was a downward trend in starch, ascorbic acid and anthocyanin content with the increasing of storage time while total sugars and phenol contents gradually increased. Sugar content of the tubers tended to increase due to hydrolysis of starch which is responsible to enhance sprouting. Increase of total sugar content and retention of anthocyanin was highest in refrigerated storage followed by cool and ambient storage. After 4 weeks exposure to 5^0C, the rate of increase of phenolic content of sweet potato tubers was significantly higher whereas loss of ascorbic acid was minimum than tubers stored in cool (20^0C) and ambient condition (30-35^0C). The highest starch, ascorbic acid and antioxidant property *viz.*, anthocyanin and total phenol were obtained from Cross-4 which also attained a promising performance in morphological characteristics. So it is identified to be superior considering all qualitative aspects which can be selected for further improvement and can be promoted for cultivation.

Keywords: Sweet potato, Cultivars, Physical parameters, Biochemical constituents, Storage

Introduction
Sweet potato (*Ipomoea batatas* L.) is a dicotyledonous species belonging to the morning glory family, Convolvulaceae. It is considered as an easily cultivatable and manageable crop as it can be cultivated under less favorable conditions with minimum amount of agricultural inputs. Sweet potato is the seventh most important crop in terms of global production. In developing countries, it ranks third in value of production and fifth in caloric contribution to the human diet [1]. It is mainly consumed by low income people because it is one of the cheap substitutes for starchy staples such as rice, wheat, and potatoes and contains a considerable level of soluble sugars, vitamins, minerals, and other nutrients. Sweet potato root starch with unique physicochemical properties is particularly valued as a functional food ingredient [2]. In terms of total phenolic content on a fresh weight basis, sweet potato ranked eighth among 23 most commonly consumed vegetables in the world [3]. Purple fleshed sweet potato has high levels of acylated anthocyanins and other phenolics with antioxidant and anti-inflammatory activities [4]. Anthocyanins of purple sweet potatoes possess aromatic acylated glycosyl groups, and exhibit relatively high pH tolerance and thermostability [5]. Phenolic compounds may play an important role in preventing chronic illnesses such as cardiovascular diseases, certain type of cancers, neurodegenerative diseases, and diabetes [6]. Although vegetables are highly perishable, the time from harvest to consumption for sweet potato can range from weeks to months without damage. The phytochemical content can be affected in storage condition such as temperature, humidity and exposure to light due to tissue biochemical responses. Hence, there is a need to exploit the existing potential available in the nutritionally rich germplasm of sweet potato for improved nutritional implications. The aim of this study was to elucidate the changes in the profile and content of physicochemical content during different types of storage condition of five distinct sweet potato genotypes grown in West Bengal.

Materials and Methods

The experiment was conducted at AICRP Tuber Crops laboratory of Directorate of Research, Kalyani, West Bengal during the year of 2012-2014. Matured tubers of sweet potatoes namely, X-9, TSP-12-10, Cross 4, Sree Kanaka and Kishan were randomly collected from the research field of Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. Then stored at different condition for one month where observation of physical parameters and biochemical characteristics were recorded as weekly and 30 days interval respectively.

Ambient storage : Temperature 30-35ºC, RH 60-65%
Cool storage : Temperature 20ºC, RH 85-90%
Refrigerated storage : Temperature 4-5ºC, RH 95-100%

Physiological loss in weight and sprouting were computed based on the initial tuber weight and on the total number of tubers respectively and both are expressed as percentage. Total sugar and ascorbic acid were estimated according to Ranganna [7]. The starch content was determined by the anthrone method [8]. Anthocyanin was estimated according to Srivastava and Kumar [9]. Total phenols were calculated by spectrophotometer using Folin-Ciocalteu reagent [10]. The experiment was laid out for analysis of variance by using factorial completely randomized design (FCRD) with 3 replications.

Results and Discussion

Significant variation was observed among different storage conditions on physiological loss in weight (PLW) during 30 day of storage. All cultivars in different storage conditions exhibited steady weight loss from the beginning of storage, increasing fairly linearly over time. Cross 4 was significantly lowest throughout the period of ambient storage *i.e.* at 1st week (2.85%), 2nd week (5.42%), 3rd week (7.63%) and 4th week (9.13%), which was statistically different from all the other cultivars in storage period. The maximum amount was obtained with Kishan (3.76-11.98%) throughout the period of storage and it was statistically *at par* with Sree Kanaka at 1st to 3rd week, whereas, at 4th week statistically different from all the other cultivars. PLW (%) of Cross 4 remained significantly low throughout the cool storage period *i.e.* at 1st to 4th week with value ranging from 1.47 to 4.89%, was statistically different from all the other cultivars at1st, 3rd and 4th week, whereas at 2nd week was *at par* with X-9. Kishan (1.94-6.34%) was found significantly higher in cool storage which was *at par* with Sree Kanaka at 1st and 2nd week of storage but statistically different from the other cultivars at rest of the storage time. In case of refrigerated storage, at 3rd and 4th week of storage minimum PLW% was noticed in cv. X-9 (2.14% and 2.75%) which was statistically similar with Cross-4, whereas at 1st and 2nd week cv. Cross-4 was recorded with lowest content. The cv. Kishan was recorded with highest content in refrigerated storage condition from 1.24-4.42%, which was statistically different from other cultivars. The tubers kept in refrigerated storage exhibited significantly least PLW%, followed by cool storage and ambient storage.

It was evident that the cultivars varied significantly with respect to sprouting behavior and from 1st week there was an increasing trend during ambient storage. It was revealed that at 4th week the significantly lower sprouting (47.33%) of sweet potato was obtained in cv. Cross-4, which was statistically different from other cultivars, whereas, cv. Kishan (82.23%) secured highest amount. In case of cool and refrigerated storage there was no sprouting of tubers. The cultivars with high sprouting (%) recorded maximum physiological weight loss.

Storage temperature and relative humidity play an important role in the physiological changes of fresh produce including physiological weight loss [11]. Water loss was rapid at low relative humidity, since the vapour pressure difference between the commodities and surrounding air was driving force for moisture transferred from wet product to the air. It was also observed that different textural changes also occurred in tubers like shrinkage, change of skin colour for enzymatic degradation, attack of insect weevil etc. Shrinkage is related to water loss due to transpiration. This was similar to the findings of Berg and Lentz [12].

The significant increase in the total sugar content was observed in all the cultivars and the trend continued during the different storage condition. It was highest in case of refrigerated condition than that of cool and ambient storage. Varieties also produced significant effect on total sugar at 5% level of critical difference. The content of Sree Kanaka was high at harvest (2.30%) and reached a maximum in the ambient (3.25%) and refrigerated (5.45%) storage condition, which was statistically similar with Cross-4 and Kishan. Cross-4 was recorded with highest content (4.19%) in cool storage and was *at par* with Sree Kanaka and Kishan. Regarding varieties, the minimum amount was obtained with X-9 at harvest to 30 DAS throughout the different storage condition. However, it was *at par* with TSP-12-10 at harvest and ambient storage whereas, in cool and refrigerated condition, statistically different from all the other cultivars. The most striking chemical changes, which occur during storage of tubers are hydrolyses of starch and accumulation of sugars in sweet potato [13]. The breakdown of starch is essential to enhance sprouting in order to utilize and translocate the food reserves from tuber.

Table 1: Physiological loss in weight (PLW %) of sweet potato cultivars during different storage condition

Cultivar	Ambient Storage				Cool Storage				Refrigerated Storage			
	1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week
X-9	3.14	6.26	8.31	10.15	1.65	2.84	4.42	5.46	0.73	1.32	2.14	2.75
TSP-12-10	3.38	6.63	8.89	10.84	1.80	3.08	4.47	5.69	0.82	1.63	2.48	3.16
Cross 4	2.85	5.42	7.63	9.13	1.47	2.72	3.50	4.89	0.68	1.38	2.15	2.84
Sree Kanaka	3.58	6.80	9.24	11.37	1.85	3.30	4.52	5.37	0.95	1.61	2.82	3.45
Kishan	3.76	7.07	9.87	11.98	1.98	3.29	4.98	6.38	1.18	2.06	3.38	4.26
S. Em.(±)	0.07	0.09	0.11	0.12	0.05	0.08	0.08	0.10	0.03	0.05	0.06	0.08
C.D (0.05)	0.22	0.30	0.35	0.40	0.16	0.24	0.27	0.34	0.10	0.17	0.20	0.27

Table 2: Sprouting (%) of sweet potato cultivars at ambient storage condition

Cultivar	Sprouting (Ambient Storage)			
	1st week	2nd week	3rd week	4th week
X-9	-	-	34.72	60.22
TSP-12-10	-	28.12	38.64	64.24
Cross 4	-	-	25.56	47.33
Sree Kanaka	25.02	36.35	56.21	76.60
Kishan	27.52	45.62	68.18	82.23
S. Em.(±)	0.76	0.92	1.23	1.38
C.D (0.05)	2.36	2.89	3.78	4.25

Starch content of tuber was significantly influenced by cultivars and showed a declining trend with the advancement of storage stages. The starch content of Cross-4 was significantly superior at harvest (15.56%) and then showed a declining trend at 30 days of ambient, cool and refrigerated storage was recorded as 14.49%, 11.43% and 8.74% respectively, which was statistically different from all the other cultivars. On the other hand, the lowest content was recorded in cv. X-9 which was *at par* with Sree Kanaka at harvest. However, it was statistically different from the other cultivars at storage period. Sugar content of the tubers tended to increase due to hydrolysis of starch by amylases into dextrin and maltose [14]. Cottrell *et al.* [15] reported that amylolytic activity was found to be greater in tubers stored at low rather than high temperatures.

Anthocyanin content of tubers decreased during storage and varieties also produced significant effect at 5% level of critical difference. At harvest, it revealed that cv. Cross-4 being significantly superior in terms of anthocyanin content which was reduced from 16.43 mg/100g to 9.51 mg/100g in ambient storage, 11.78 mg/100g in cool and 14.08 mg/100g in refrigerated storage, whereas, they were statistically different with all the other varieties. Lowest content was recorded in Sree Kanaka at harvest (1.57 mg/100g) and also in different storage condition *viz.*, ambient (0.92 mg/100g), cool (1.10 mg/100g) and refrigerated (1.34 mg/100g). However, it was statistically not similar with other varieties. The loss was more in ambient condition and retention of anthocyanin was more in refrigerated storage followed by cool storage.

Table 3: Changes in total sugar (%) and starch (%) in sweet potato cultivars during different storage condition

Cultivar	Total Sugar				Starch			
	At Harvest	30 DAS			At Harvest	30 DAS		
		Ambient	Cool	Refrigerated		Ambient	Cool	Refrigerated
X-9	1.79	2.50	3.19	4.20	9.98	9.36	7.53	5.66
TSP-12-10	1.91	2.62	3.53	4.58	10.77	10.04	8.10	6.11
Cross 4	2.26	3.22	4.19	5.39	15.56	14.49	11.43	8.74
Sree Kanaka	2.30	3.25	4.17	5.45	10.28	9.62	7.82	5.93
Kishan	2.23	3.14	4.09	5.40	11.30	10.55	8.39	6.32
S. Em.(±)	0.06	0.08	0.08	0.10	0.09	0.07	0.06	0.05
C.D (0.05)	0.19	0.25	0.28	0.36	0.37	0.25	0.23	0.18

Table 4: Changes in anthocyanin (mg/100g) and total phenol content (mg/100g) in sweet potato cultivars during different storage condition

Cultivar	Anthocyanin				Total Phenol			
	At Harvest	30 DAS			At Harvest	30 DAS		
		Ambient	Cool	Refrigerated		Ambient	Cool	Refrigerated
X-9	9.50	5.61	6.71	8.06	42.37	53.50	64.77	94.28
TSP-12-10	8.30	4.73	5.88	7.05	39.07	50.11	60.19	88.85
Cross 4	16.43	9.51	11.78	14.08	51.76	64.63	78.92	117.20
Sree Kanaka	1.57	0.92	1.10	1.34	28.55	38.34	45.68	64.22
Kishan	8.10	4.72	5.82	6.96	44.27	59.02	65.61	104.38
S. Em.(±)	0.20	0.10	0.12	0.18	0.88	1.01	1.19	1.33
C.D (0.05)	0.68	0.36	0.41	0.58	2.70	3.12	3.62	4.18

Table 5: Changes in Ascorbic acid content (mg/100g) in sweet potato cultivars during different storage condition

Cultivar	Ascorbic acid			
	At Harvest	30 DAS		
		Ambient	Cool	Refrigerated
X-9	12.78	6.43	7.50	10.64
TSP-12-10	9.40	4.70	5.48	7.66
Cross 4	14.11	7.05	8.32	11.69
Sree Kanaka	11.46	5.71	6.70	9.44
Kishan	10.83	5.42	6.29	8.93
S. Em.(±)	0.33	0.18	0.24	0.28
C.D (0.05)	1.02	0.68	0.89	0.98

Data in the Table 4 shows that there was a significant variation during different storage condition on the total phenol content. A steady and gradually increase was exhibited where highest was in refrigerated storage followed by cool and ambient storage. The results were consistent with Picha [16], who reported darkening of the cambium and vascular bundles in non-cured 'Whitestar' and 'Rojo Blanco' sweet potato roots exposed to 7 °C for 3 weeks. Long-term exposure to low temperature results in internal tissue darkening of sweet potato roots, which has been attributed to an increased content of phenolic compounds [17]. Maximum amount was obtained from Cross-4 (51.76 mg/100g) at harvest and it was continued throughout the period of storage *i.e.*, ambient (64.63 mg/100g), cool (78.92 mg/100g) and refrigerated (117.20 mg/100g) storage. They were statistically different from all the other cultivars. Significantly lowest content was recorded in Sree Kanaka at harvest and also after 30 days of storage which was statistically different with other cultivars. Ishiguru *et al.* [18] reported that polyphenolic content increased during storage more at 5^0C than at 15^0C. The changes in phenolic compound metabolism in response to low temperature depend on the tissue sensitivity. Yamaki and Uritani [19] reported vacuolar membrane degradation in some regions of the sweet potato root tissue. This may have resulted in a greater influx of phenolic compounds into the cytosol from their vacuolar storage location. Phenolic compounds build up gradually as a result of chilling and are oxidized in presence of air to form dark pigments [20].

Drastic reduction was noticed in ascorbic acid content and it was rapid in ambient storage than that in cool and refrigerated storage. In all cultivars loss was minimum in refrigerated storage than that of cool and ambient storage and thus retention of ascorbic acid content was more in refrigerated storage followed by cool and ambient storage. Significantly highest amount was obtained from Cross-4 at harvest (14.11 mg/100g) and 30 DAS which was statistically different from the other cultivars at harvest and refrigerated storage but similar with X-9 in ambient and cool storage. TSP-12-10 exhibited significantly lowest values for ascorbic acid content at harvest and also in storage period. It was statistically *at par* with Kishan in cool storage whereas, statistically different at harvest and other storage condition from all the other cultivars. Higher ascorbic acid content at initial stage of harvest might be attributed to adequate supply of hexose sugar via photosynthetic activity and reduction in ascorbic acid at later stages might be related to enzymatic loss of ascorbic acid through oxidation [21]. Ascorbic acid found to be decreased with increase in the storage period, which was observed as a common phenomenon during storage [22]. The result also corroborates the findings of Ray and Ravi [23] in sweet potato.

Conclusion

A limited time exposure to low temperature may enhance the nutraceutical value of sweet potatoes without any loss of marketable quality. Sweet potatoes exposed to low temperature stress for extended periods may be targeted by the functional food industry as a concentrated source of anthocyanin and phenolic antioxidants. Purple-fleshed sweet potato cultivars have a potential for long-term storage without causing highly significant changes in comparison with other tropical fresh produce whereas refrigerated storage can be performed better as maximum retention of nutritional quality than that of cool and ambient storage. The significant increase in the PLW% and sprouting were more pronounced from the starting and the trend continued up to 30 days of storage whereas, the tubers kept in refrigerated storage exhibited least amount, followed by cool storage and ambient storage. It can be observed that significant reduction in starch, ascorbic acid and anthocyanin content were occurred, whereas, the total sugar and phenol content of the tubers increased under the storage period. Increase of total sugar content and retention of anthocyanin was highest in refrigerated storage followed by cool and ambient storage. After 4 weeks exposure to refrigerated condition, the rate of increase of phenolic content of sweet potato tubers was significantly higher whereas loss of ascorbic acid was minimum than tubers stored in cool and ambient condition. From the above results, it can be concluded that Cross-4 attained a promising performance in morphological characteristics and also obtained the highest amount of starch, ascorbic acid, anthocyanin and total phenol which was significantly superior over rest of the varieties.

Acknowledgement

I extend my deep sense of reverence and gratitude to the AICRP Tuber Crops laboratory and Department of Post-Harvest Technology of Horticultural Crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India for providing the infrastructure and all necessary facilities to conduct this study.

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