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RESEARCH ARTICLE

NUTRIENT PROFILING AND QUALITY MAINTENANCE OF SWEET POTATO (*Ipomoea batatas* L.) GENOTYPES DURING AMBIENT STORAGE

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ABSTRACT

Sweet potato (*Ipomoea batatas* L.) is considered as staple food in many developing countries. The major nutritional value in sweet potato tubers lies in its carbohydrates (starches and simple sugars), protein and fat. Sweet potato is a cheap calorie producer and is rich in vitamin A and C, and tubers have anti-diabetic, anti-oxidant and anti-proliferative properties due to the presence of valuable nutritional and mineral components *viz.,* phosphorus, calcium, magnesium and sodium with low glycemic index. As sweet potatoes face the problem due to weevils, shrinkage and loss of nutrients in storage, the present investigation on shelf-life and nutritional profiling in twelve different sweet potato genotypes were studied in order to determine the varieties for better storage. Among the sweet potato genotypes tried, the BSP_1 exhibited superior qualities like higher calcium and phosphorus content (50.47 and 153.20 mg/100g), dry matter (61.7%), high scores for skin and flesh color (4.93 and 5.00), low values for TSS (4.4 °Brix), reducing and non reducing sugars (0.67 and 0.21%), starch (0.60%), physiological loss in weight (13.5%) and weevil incidence (10%). The genotype also maintained all these characters throughout the storage period. The genotypes Sree Bhadra and BSP_{23} were the next best genotypes to maintain all the above mentioned characters.

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INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is the sixth most important crop grown worldwide after wheat, rice, maize, potato and cassava and is considered as staple food in many developing countries. The largest quantity of sweet potato production is noticed in Asia and the Pacific Islands (93% of global production). The major nutritional value in sweet potato tubers lies in its carbohydrates (starches and simple sugars), protein and fat (Allen *et al*., 2012). Sweet potato tubers have anti-diabetic, anti-oxidant and anti-proliferative properties due to the presence of valuable nutritional (low glycaemic index) and mineral components viz., phosphorus, calcium, magnesium and sodium (Aboubakar *et al*, 2010). Dietary fiber present sweet potato tuber 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).

MATERIALS AND METHODS

The present investigation was carried out during the period from 2016-17 in the laboratory Rashtriya Krishi Vikas Yojana (RKVY) research unit of the Department of Postharvest Technology, Kittur Rani Channamma College of Horticulture (University of Horticultural Sciences, Bagalkot), Arabhavi, Gokak Taluk and Belgaum district of Karnataka state which is situated in northern dry zone (Zone-3) of Karnataka state at 16°15' north latitude, 74°45' east longitudes and at an altitude of 612.05 m above the mean sea level. Representative even sized fresh sweet potatoes tuber of different varieties were procured from the research field of AICRP - Tuber crops, operating at Regional Horticulture Research and Extension Centre, Dharwad of Karnataka state. Tubers were well matured and free from damage of pest and disease infestation. Procured sweet potatoes were washed under running tap water to remove adhered soil; damaged and infected tubers were discarded and good tubers were dried under shade. All the chemicals used in this investigation were of analytical grade.

Physiological loss in weight (%)

The physiological loss in weight (PLW) was estimated at an interval of 15 days during storage. Initial tuber weight was recorded at the beginning of the storage period. The tubers were weighed and the weight was termed as final weight on the particular date of observation. The following formula was employed to calculate the PLW for each date of observation.

$$\text{Physiological loss in weight (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

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Volume (%)

The volumes of the tubers were calculated at 15 days intervals by randomly selecting and marking a tuber from replication. For this, two containers of different sizes were used. The smaller container was filled with water up to the brim such that, any further addition of water would spill it out of the container. Then the marked tuber was gently dipped in the water keeping the smaller container inside the bigger one, which led to displacement of water from the small container and it was equal to the volume of the tuber (based on Archimedes principle). The spilled out water from the larger container was then measured using a measuring cylinder and it was expressed as volume of the tuber.

$$\text{Loss in volume (\%)} = \frac{\text{Initial volume} - \text{Final volume}}{\text{Initial volume}} \times 100$$

Skin and Flesh color

The skin and flesh colors were noted on initial day, 15 and 30 days after storage. They were analyzed by giving them scores out of five by visual means.

5 = Highly acceptable
4 = Acceptable
3 = Fairly acceptable
2 = Poorly acceptable
1 = Not acceptable

Firmness (kg/cm2)

Firmness was assessed using the hand held penetrometer. The tubers from each sweet potato genotype were used and the pressure required to penetrate the tubers was recorded in terms of kg/cm^2. Higher the pressure required, firmer the tuber.

Weevil incidence (%)

The weevil incidence in tubers of all the sweet potato genotypes was recorded on number basis i.e. the total number of tubers attacked by weevils was counted by cutting them open and observing the flesh. The following formula was used for calculation.

$$\text{Weevil incidence (\%)} = \frac{\text{Number of tubers affected by weevils}}{\text{Total number of tubers}} \times 100$$

Rotting (%)

The percentage of rotting of tubers in all the sweet potato genotypes was recorded on number basis i.e. the total number rotten of tubers was counted by external appearance and also by cutting them open and observing rotting portion the flesh. The following formula was used for calculation.

$$\text{Rotting (\%)} = \frac{\text{Number of rotten tubers}}{\text{Total number of tubers}} \times 100$$

Ascorbic acid content (mg/100g)

Ascorbic acid content of sweet potato tubers was estimated by using the method given by AOAC (1990), which was based on the reduction of 2,6-dichlorophenol indophenols (2,6-DCPIP) by ascorbate.

Total titratable acidity (%)

The total titratable acidity of sweet potato was estimated by titrating the sample against strong base i.e. NaOH.

Reducing and Non-reducing sugars (%)

The reducing and non reducing sugars present in sweet potato tuber genotypes were estimated using 3, 5-Dinitro Salicylic Acid (DNSA) method (Miller, 1972).

Starch (%)

Starch content in sweet potato tubers was estimated by anthrone reagent method. The sample was treated with 80 per cent alcohol to remove sugars and then starch was extracted with perchloric acid (52%). In hot acidic medium starch was hydrolyzed to glucose and dehydrated to hydroxylmethyl furfural, this compound forms a green colored product with anthrone (Bates *et al.,* 1943).

Total soluble salts (°Brix)

The total soluble solids (TSS) of the sweet potato genotypes were estimated using the hand held refractometer on the different days of observation. A small amount of the flesh of tuber was crushed using mortar-pestle and its juice was obtained by filtering it using multiple layers of muslin cloth. The obtained clear juice was applied in drops on the prism of the calibrated refractometer and the values were read.

Beta-carotene content (mg/100g)

Beta-carotene present in sweet potato tubers was estimated by using petroleum ether method.

Dry matter content (%)

Dry matter content of sweet potato tubers was determined by drying the finely sliced piece of tuber in microwave oven (Onida Power Barbecue-28, MIRC Electronics ltd., Mumbai) at 40 and 60 power intensity until the constant weight was achieved. The dry weight was calculated using the following formula.

$$\text{Dry matter content (\%)} = \frac{W_2}{W_1} \times 100$$

Where,
W_1 = Fresh weight of the tubers
W_2 = Dry weight of the tubers

Moisture content (%)

Moisture present in sweet potato tubers was determined by using moisture balance (Model: P1019319, A & D Company Limited, Japan). Two gram of sample was placed in the sample dish and dried in the electric moisture balance until it automatically showed constant moisture in percentage. The instrument indicates the end point of measurement by a beep and gives the constant value for moisture.

Calcium and Phosphorus (mg/100g)

The mineral present in sweet potato tubers were estimated by using wet digestion method. The sweet potato samples were

dried by slicing into chips and were further ground into powder. 0.25 g of sample was taken in 100 ml conical flask and 5 ml of HNO_3 was added to it and kept for pre-digestion. Diacid mixture was prepared using HNO_3 and $HClO_4$ in the ratio 9:4. 15 ml of this diacid mixture was added to all the samples for digestion and they were heated on a hot plate until red fumes were observed and white curd-like precipitate is obtained. Then the flasks were cooled and the volume was made to 100 ml. This sample was further used for estimation of calcium and phosphor by EDTA (Ethylene Diamine Tetra Acetic acid) method and the quantity were expressed in mg/100g.

RESULTS AND DISCUSSION

The results obtained on different parameters of sweet potatoes stored in ambient condition are discussed below.

Table 1. Post harvest behavior of different sweet potato genotypes in maintaining calcium, phosphorus and beta-carotene content

Genotypes	Calcium (mg/100g)			Phosphorus (mg/100g)			Beta-carotene (mg/100g)		
	DAS								
	0	15	30	0	15	30	0	15	30
BSP_1	50.47	48.30	40.27	155.20	144.43	127.43	1.24	0.93	0.74
BSP_2	48.67	45.43	32.50	142.53	132.17	125.87	1.65	1.34	1.19
BSP_3	45.50	40.67	30.50	140.33	128.73	115.00	0.79	0.68	0.63
BSP_4	41.80	35.97	28.50	143.63	132.50	115.50	0.25	0.21	0.16
BSP_5	41.33	35.70	28.53	145.50	134.07	118.77	0.61	0.43	0.41
BSP_6	48.33	42.70	31.43	148.43	135.57	117.30	0.31	0.30	0.25
BSP_7	46.73	44.07	31.60	144.97	129.23	111.27	0.97	0.69	0.56
BSP_8	49.43	44.83	36.70	146.87	127.80	113.50	1.49	1.14	1.09
BSP_9	45.63	39.63	34.40	148.27	132.70	116.87	0.32	0.15	0.09
BSP_{10}	42.47	34.67	28.10	141.47	131.67	119.00	0.32	0.22	0.09
BSP_{23}	49.07	45.63	40.10	154.23	143.73	126.20	13.64	13.00	12.46
Sree Bhadra	49.63	46.03	41.13	153.03	144.63	126.83	2.95	2.61	2.40
Mean	46.59	41.97	33.23	146.87	134.77	119.46	2.05	1.81	1.67
S.Em±	0.18	0.22	0.15	0.20	0.22	0.44	0.03	0.04	0.05
C. D. @ 1%	0.72	0.87	0.59	0.81	0.88	1.76	0.11	0.14	0.20

DAS: Days after storage

Table 2. Post harvest behavior of different sweet potato genotypes in maintaining Ascorbic acid (mg/100g), Total titratable acidity (%) and Dry matter content (%)

Genotypes	Ascorbic acid (mg/100g)			Total titratable acidity (%)			Dry matter content (%)		
	DAS								
	0	15	30	0	15	30	0	15	30
BSP_1	16.30	10.87	5.43	0.19	0.27	0.15	38.3	41.5	43.3
BSP_2	14.49	10.87	5.43	0.31	0.35	0.27	33.4	38.1	41.7
BSP_3	21.74	16.30	10.87	0.27	0.35	0.19	31.6	33.6	39.5
BSP_4	25.36	19.93	12.68	0.31	0.39	0.27	29.6	35.7	40.2
BSP_5	23.55	18.12	12.68	0.27	0.31	0.23	36.5	40.7	46.8
BSP_6	12.68	10.87	5.43	0.31	0.31	0.27	26.8	34.4	40.2
BSP_7	14.49	9.06	5.43	0.23	0.31	0.19	32.1	32.5	39.1
BSP_8	21.74	14.49	5.43	0.31	0.35	0.23	38.2	40.3	42.8
BSP_9	18.12	9.06	5.43	0.35	0.39	0.23	33.5	39.4	39.2
BSP_{10}	18.12	12.68	7.25	0.31	0.31	0.23	37.0	40.3	40.1
BSP_{23}	21.74	14.49	9.06	0.39	0.46	0.31	44.0	46.2	48.1
Sree Bhadra	18.12	12.68	7.25	0.35	0.39	0.31	32.1	34.1	37.9
Mean	18.87	13.28	7.70	0.30	0.35	0.24	34.4	38.1	41.6
S.Em±	1.73	1.48	1.17	0.06	0.06	0.05	0.40	0.33	0.17
C. D. @ 1%	6.86	5.85	4.63	NS	NS	NS	1.57	1.30	0.69

DAS: Days after storage

Calcium and Phosphorus (mg/100g)

Presence of minerals like calcium and phosphorus are genotype dependent characters (Agbemafle *et al.,* 2014). In the present investigation, the amount of calcium in the tubers decreased irrespective of the genotypes as the storage period progressed. However, the genotype with BSP_1 recorded maximum amount of calcium on initial day (50.47 mg/100g) and on 15th day (48.30 mg/100g) among all the genotypes. And the genotype Sree Bhadra recorded higher quantity of calcium (41.13 mg/100g) on 30 DAS, followed by BSP_1 and BSP_{23} (40.27 and 40.10 mg/100g respectively). There is consistent decrease in the mineral content during storage as these are utilized for metabolic activities such as respiration and continuous chemical changes occurring in tubers such as degradation of minerals during rotting (Sungthongwesis, *et al.* 2016). The amount of phosphorus decreased in all the genotype as the storage period progressed irrespective of the genotypes. Initially the genotype BSP_{23} had the maximum value (154.23 mg/100g) of phosphorus which was on par with BSP_1 (153.20 mg/100g) whereas, Sree Bhadra recorded the maximum amount of phosphorus (144.63 mg/100g) after 15 days of storage which was on par with BSP_1 (144.43 mg/100g). Further, BSP_1 recorded the maximum amount of phosphorus (127.43 mg/100g) which was on par with Sree

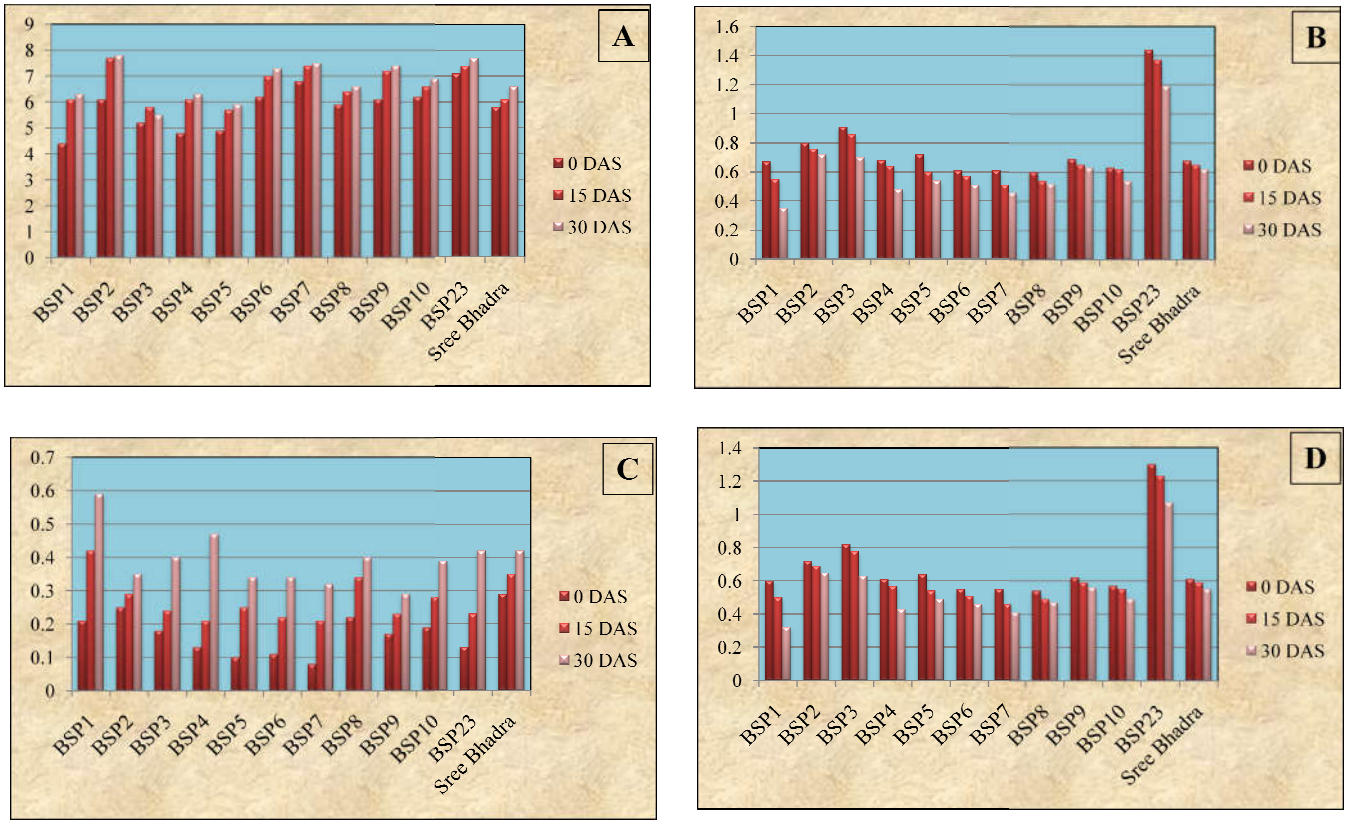

Fig. 1. Post harvest behavior of different sweet potato genotypes in maintaining TSS (A), reducing sugars (B). non-reducing sugars (C) and starch content (D)

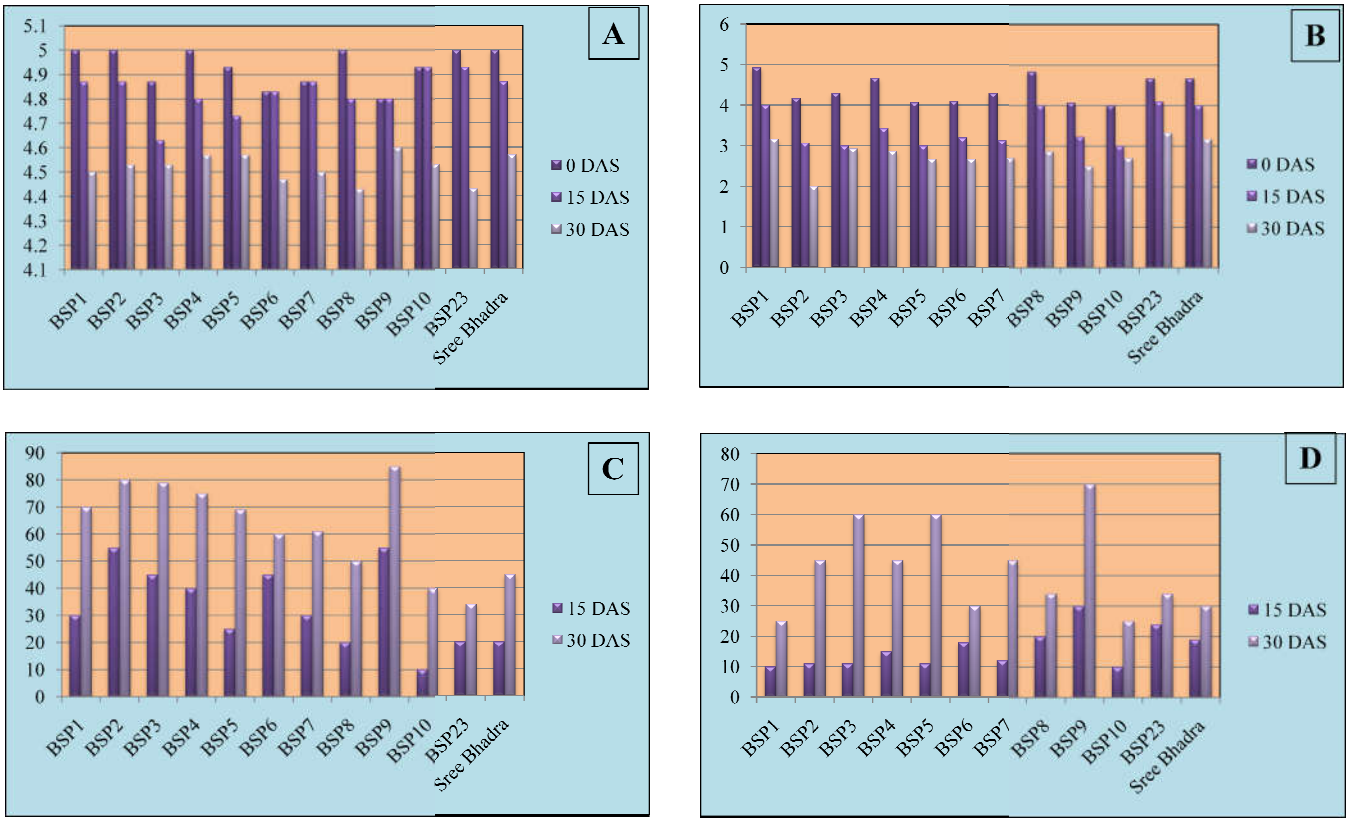

Fig. 2. Post harvest behavior of different sweet potato genotypes in maintaining flesh color (A), skin color (B), occurrence of rotting (C) and weevil incidence (D)

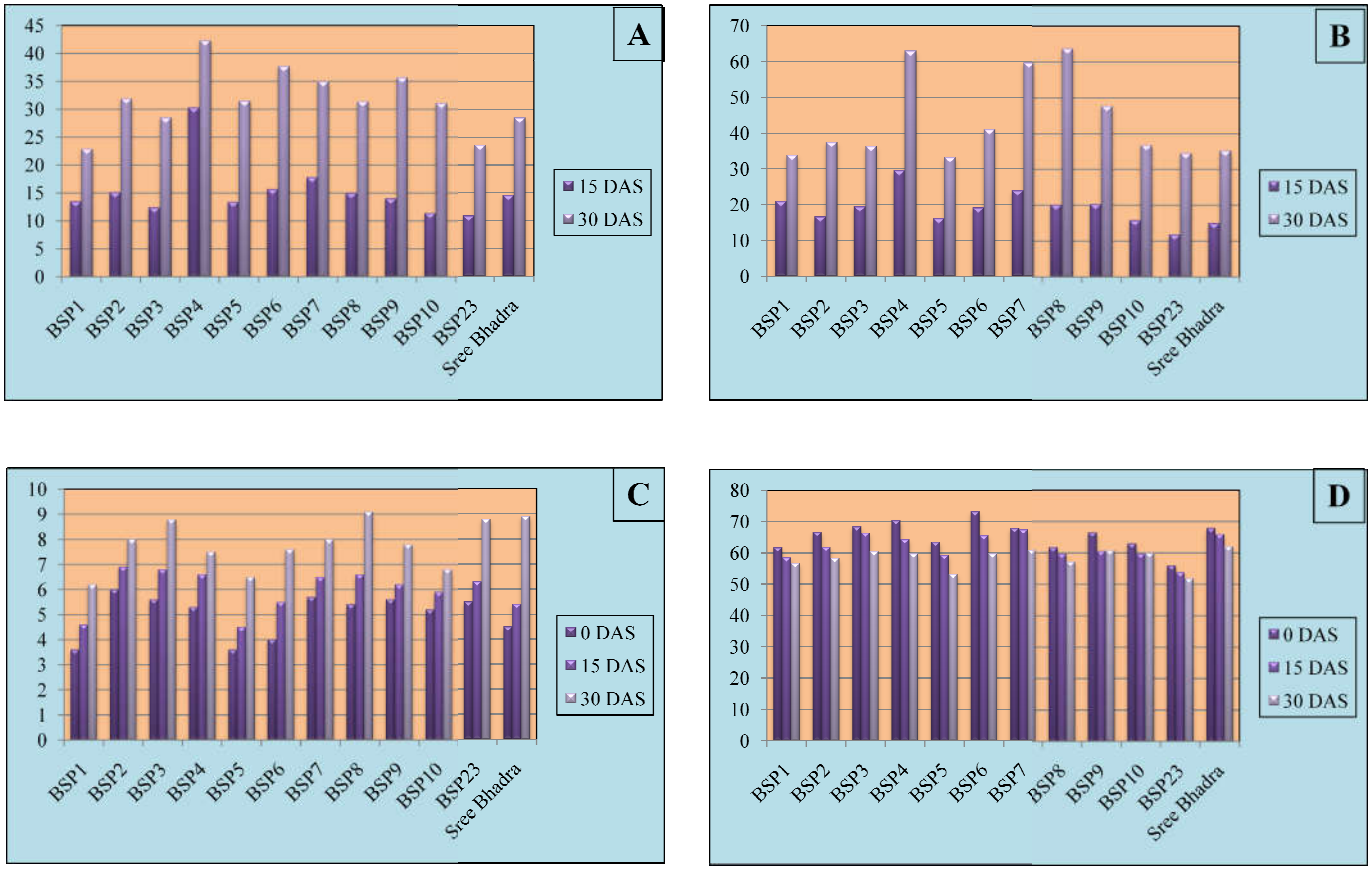

Fig. 2. Post harvest behavior of different sweet potato genotypes in sustaining physiological loss in weight (A), loss in volume (B), maintaining firmness (C) and moisture content (D)

Bhadra and BSP_{23} (126.83 and 126.20 mg/ 100g respectively) after 30 days of storage. The decrease in amount of these minerals can be attributed to the presence of anti-nutritional factors such as oxalate and phytate which react with them and make them unavailable as reported by Akpan and Umoh (2004).

Beta-carotene (mg/100g)

Beta-carotene is sensitive to heat and oxygen as opined by Emmanuel *et al.* (2010). Oxidation of carotenoids results in the loss of beta-carotene in the fruits and vegetables as reported by Shekhar *et al.* (2015). In the present investigation, the highest beta-carotene was recorded in the orange fleshed genotype BSP_{23} throughout the storage on initial day, 15 DAS and 30 DAS (13.64, 13.00 and 12.46 mg/100g respectively). Sree Bhadra was found to be next to BSP_{23} by maintaining second highest content of beta-carotene. This variation occurred due to the difference in flesh colors which is a genotype dependent factor (Blessington *et al.* 2010, Desai *et al.,* 2013).

Total soluble solids (°Brix)

In present investigation, the total sugars of sweet potato tubers increased continuously up to the end of the experiment. Accumulation of total sugars could be attributed to the dormancy release and onset of sprouting as thereafter the cultivars showed sprouting, which continued to increase up to the end of experiment (Abdullah and Safraiy, 2015). Initially the maximum value for TSS (7.1°Brix) was recorded genotype BSP_{23}. On 15 DAS, the genotype BSP_3 had maximum value (7.7°Brix) for TSS and on 30 DAS, maximum amount for TSS (7.8°Brix) was recorded in the genotype BSP_2. The change in sugar content during storage consequently increased the ratio of reducing sugars to non-reducing sugar. Observations made in this experiment are similar to the findings of Huang *et al.* (2014).

Reducing and non-reducing sugars (%)

In an investigation by Kumar *et al.* (2002) opined that the reducing sugars is a variety dependent factor. In the present study, the genotype BSP_{23} exhibited the maximum amount of reducing sugars (1.44, 1.37, 1.19% respectively) on first, 15^{th} and 30^{th} day. The minimum value for reducing sugars (0.35%) was recorded in BSP_1 at the end of experiment. It also recorded the maximum content of non-reducing sugars (0.42 and 0.59%) on 15 and 30 DAS. Decrease in reducing sugars and increase in non-reducing was due to utilization of reducing sugars for the metabolic processes in the tubers during storage and accumulation of non-reducing sugars due to sprouting (Ingabire and Hilda, 2011). Pressey and Shaw (1996) also observed a decline in reducing sugars during storage at higher temperature.

Starch (%)

Amount of starch in different varieties is a character which varies with genotype and different chemical constituents in the tubers as quoted by Zhang *et al.* (2002). In the present investigation, the maximum amount of starch was recorded in BSP_{23} (1.30%) initially and same genotype had maximum of 1.23 and 1.07 per cent starch respectively after 15 and 30 days of storage. Starch content of sweet potato tubers, which is

indeed a varietal trait, slightly decreased during storage. The decline in starch content was correlated with α-amylase activity in storage. There was a stronger positive and significant correlation between starch and reducing sugar content. The reduction in starch was due to the catabolic reactions in storage leading to conversion of complex starch molecules into simpler sugars. Similar reports have also been made by Khayatnezhad *et al*. (2011).

Ascorbic acid (mg/100g) and total titeratable acidity (%)

The genotypes differ in the amount of ascorbic acid content as stated by Singh *et al.* (2005) and it decrease on storage in ambient condition. However in the present investigation, the ascorbic acid content in the tubers decreased in all the genotypes as the storage time progressed. The maximum amount of ascorbic acid was recorded in BSP_4 on initial and 15 DAS respectively (25.36 and 19.93 mg/100g). Further on 30 DAS, two genotypes BSP_4 and BSP_5 recorded maximum amount of ascorbic acid (12.68 mg/100g each). A significant decrease in ascorbic acid noticed, could be due to enzymatic loss of L-ascorbic acid where it is converted to 2-3-dioxy-L-gluconic acid (Mapson, 1970). These results were found to be in line with the investigations of Cruz-rus *et al.* (2011) in strawberry and Brar *et al.*, (2013) in potato. The total titeratable was found to vary non-significantly.

Dry matter content (%)

The dry matter in the tubers increases during storage. However the amount of increase varies between genotypes (Ezekiel and Rani, 2006, Nabubuya *et al.,* 2012 and Ellong *et al.,* 2014). In the present investigation, the highest dry matter was observed in the genotype BSP_{23} on all the days of storage i.e. initially, 15 and 30 DAS (44.0, 46.2 and 48.1% respectively). These results are in conformity with study undertaken by Mehta and Kaul (1990), Serge and Tom (1996).

Skin and flesh color (Visible appearance)

The skin and flesh color is a genotype dependent factor as reported by Ellong *et al.* (2014). In the present study, the genotype BSP_{23} maintained its light orange color throughout the storage due to presence of high amount of beta-carotene and the genotypes BSP_6, BSP_9 and BSP_{10} had the lowest beta-carotene hence having white flesh. The skin of different genotypes exhibited different colors like pale yellow, pale brown, brown, light pink and light red. These results were in agreement with the result of Ali *et al.* (2015). There was no difference in flesh color throughout the storage, but the skin color of all the genotypes turned to brown and brownish due to loss of moisture at the end. Similar results were obtained by Ji *et al*. (2015) in potato.

Rotting (%)

Initially the tubers were found to be free from rotting. However, the rotting percentage increased during storage irrespective of the genotypes. Microbial spoilage together with water loss and biochemical changes is responsible for the deterioration of freshly harvested produce during storage (Dennis, 1977). The rotting percentage differs along with the genotypes (Naidu and Nandekar, 2005). In the present investigation, on 15^{th} day of storage, the genotype BSP_{10} showed the lowest rotting (10%) which was followed by BSP_8, BSP_{23} and Sree Bhadra (20% each). Further on 30 DAS, the genotype BSP_{23} showed the lowest value for rotting (34%) followed by BSP_{10} (40%). The rotting might be due to vulnerable nature of sweet potato tubers to different disease causing organisms and the attack of pests during storage or carried over from the field, which got sufficient time to multiply and grew with increasing storage period (Brar *et al*, 2013).

Weevil incidence (%)

The different genotypes of sweet potato differ in their resistance to the weevil damage (Saleem *et al*., 2004). In the present study, there was no visible damage to the tubers by weevils initially. However after 15 days of storage, the genotype BSP_1 showed the lowest incidence of weevils (10%) which was on par with the genotypes BSP_2, BSP_3, BSP_5 (11% each) and BSP_7 (12%) whereas the weevil incidence was highest in the genotype BSP_7 (30%). Similarly on 30^{th} day, the weevil incidence observed was lowest (25%) in the genotypes BSP_1 and BSP_{10} (Table 1). The incidence of weevils increased during storage and its severity varied from genotype to genotype. This might be due to the presence of inoculums in the tubers prior to storage (Desai *et al.,* 2013). Similar results were quoted in another study by Allolli *et al.* (2012) in sweet potato genotypes.

Tuber firmness (kg/cm^2)

Firmness is a character judged by the concentration of various biochemical substances (Tijskens *et al.*, 2001). In the present investigation, firmness of the tubers of all the genotypes increased as the storage period prolonged. Initially BSP_1 and BSP_5 recorded minimum value (3.6 kg/cm^2) with regard to firmness and were found superior over all other genotypes and they were on par with BSP_6 (4 kg/cm^2). After 15 days of storage, the tubers with minimum hardness (4.5 kg/cm^2) was recorded in genotype BSP_5, which were on par with BSP_1 (4.6 kg/cm^2) and Sree Bhadra (5.4 kg/cm^2). While on 30^{th} day, the tubers of BSP_1 showed the minimum value for firmness (6.2 kg/cm^2) and they were on par with BSP_5 (6.5 kg/cm^2). The maximum value (9.1 kg/cm^2) was recorded in BSP_8 (Table 3) which was the hardest and literally not acceptable. The firmness of tubers increased because of excessive loss of moisture from flesh and also from the periderm and increase in dry matter. These results were found to be in line with the results of Brar *et al.*, (2013) in potato.

Physiological loss in weight and loss in volume (%)

The PLW increases with progress in storage period however the values of PLW are a genotype dependent factor (Amoah *et al.,* 2011). In the present study, minimum PLW (10.9%) was recorded in BSP_{23} on 15^{th} day while on 30^{th} day, minimum PLW among all genotypes was recorded in BSP_1 (22.9%). It was directly correlated with volume loss. Minimum loss in volume (11.8%) was recorded in BSP_{23} on 15^{th} day whereas on 30 days of storage, the minimum volume loss (33.3%) was noticed in BSP_5 which was on par with BSP_1 (33.9%). This difference in PLW and volume loss might be due to the difference in respiration and transpiration rates in different genotypes and also increase in respiration rate as the storage prolonged (Mehta and Singh, 2002). These reports were found to be in line with the study by and Mehta and Ezekiel (2010) in potato and Huang *et al*. (2014) in sweet potato.

Moisture content (%)

The moisture content is oppositely correlated with dry matter, and was found to decrease as the storage period progressed. However the amount of decrease varied from genotype to genotype (Desai *et al.,* 2013). Lowest moisture content was maintained in BSP_{23} throughout the study (56.0, 53.8 and 51.9% on 1st, 15th and 30th day respectively). These results are in conformity with study undertaken by Omodamiro *et al*, (2013) and Agbemafle *et al.* (2014).

Conclusion

As evident from the overall assessment on the results obtained, the genotype BSP_1 was found to perform best among all the genotypes in ambient storage condition with its desirable characters like low weevil incidence, low amount of reducing sugars, low moisture content, high amount of minerals i.e. calcium and phosphorus, high dry matter and so on. It was also able to retain its qualities throughout the storage period.

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