Agraarteadus
2 • XXXII • 2021 214–224

Journal of Agricultural Science
2 • XXXII • 2021 214–224

STORABILITY OF SWEET POTATO GENOTYPES UNDER ORDINARY AMBIENT STORAGE CONDITIONS

Prakash Bhattarai[1], Kalyani Mishra Tripathi[2], Durga Mani Gautam[2], Arjun Kumar Shrestha[2]

[1]Nepal Agricultural Research Council, National Potato Research Programme, Khumaltar15, Lalitpur Metropolitan City, 44700, Nepal
[2]Agriculture and Forestry University, Rampur, Chitwan, Bharatpur 15, Bharatpur Metropolitan City, 44209, Nepal

Saabunud: Received: 26.04.2021

Aktsepteeritud: Accepted: 30.08.2021

Avaldatud veebis: Published online: 30.08.2021

Vastutav autor: Corresponding author: Prakash Bhattarai

E-mail:
prkash235@yahoo.com (PB)
kmishra@afu.edu.np (KMT)
durgagautam2013@gmail.com (DMG)
akshrestha@afu.edu.np (AKS)

ORCID:
0000-0002-7016-9472 (PB)
0000-0002-4434-9306 (KMT)
0000-0002-0730-5427 (DMG)
0000-0002-9253-2033 (AKS)

Keywords: ambient storage, biochemical changes, rotting, storage, sweet potato, weight loss.

DOI: 10.15159/jas.21.20

ABSTRACT. The study was carried out to evaluate the storage performance of sweet potatoes in different conditions under ordinary ambient temperature (10.11–17.49 °C) at Khumaltar, Lalitpur (1350 masl) district of Nepal from December, 20 to March, 13 during the years 2018/19 and 2019/20. The experiment was laid out in Factorial Completely Randomized Design with three replications. Tuberous roots of three sweet potato genotypes ('CIP 440015', 'CIP 440267', and 'Local White') harvested at 4-month maturity were stored inside an ordinary room in dry sand, sawdust, thin jute sack, natural mud pot, and open crates (control). Data were taken on the 2nd, 4th, 6th, 8th, 10th, and 12th weeks of storage. The pooled results showed a significant effect of storage conditions on physiological loss in weight and rotting (%) of sweet potato genotypes. With the progression of the storage period, physiological weight loss (PLW) and rotting (%) were significantly increased in all treatments. At the 12th week of storage, the highest PLW was recorded in the tubers stored in open crates (70.2%) followed by natural mud pot (65.2%) whereas the lowest PLW was observed in tubers stored inside the dry sand (50.2%). Genotype 'CIP 440015' showed good storability with minimum PLW. No weevil infestation and sprouting were observed during the experimental period. The lowest percentage of tuber rotting was recorded in the genotype 'CIP 440015' (55.3%) and inside dry sand (48.7%) at the 12th week of storage while it was the highest up to 85.9% in 'CIP 440267'. The highest rotting 76.7%) was recorded in thin jute bags which is statistically at par with natural mud pot (76.5%). The interaction effect of storage conditions and genotypes was found not significant. The results showed an increment in dry matter and reducing sugar content while the reduction in ß-carotene and starch content of tubers after 3 months of storage inside dry sand. There was positive and strong correlation of storage duration with dry matter (r = 0.750) and reducing sugar (r = 0.658) whereas, negative correlation with starch (r = –0.918) and ß-carotene (r = –0.352) content of sweet potato genotypes. The study concluded that sweet potato tuber can be kept for 8 to 10 weeks in dry sand with minimum postharvest loss in ordinary room condition and the genotype 'CIP 440015' has good storability among the tested genotypes in similar conditions.

Introduction

Sweet potato, *Ipomoea batatas* (L.) Lam., is one of the important tuber crops grown in the tropics. It belongs to the family *Convolvulaceae* (Tortoe, 2010). After wheat, rice, maize, potato, barley, and cassava, it is the world's seventh most important food crop (FAO, 2016). It is a tropical perennial crop but cultivated as an annual; grown in more than 100 countries. China alone produced 80 to 85% of sweet potato production in the world while the remaining countries in Asia have the next highest production and then, followed by Africa and Latin America (CIP, 2009). Sweet potato consumption is thought to be declining as income increases, a

trend that is often attributed to urbanization, partly because it is seen as a "poor man's food," but mainly due to a lack of post-harvest processing and storage (FAOSTAT, 2008; CIP, 2009).

In Nepal, most of the middle hill districts and terai are the main sweet potato growing areas (Lohani, 1981) and are mainly grown in the kitchen garden in small areas (Gautam, 1991). It is one of the neglected and underexploited food crops of Nepal but has religious and cultural values in some festivals. Sweet potato is a good source of vitamin-A, carbohydrates, dietary fibre, potassium, and iron. Vitamin A deficiency is common in developing countries, including Nepal, and has severe consequences for young children (Low *et al*., 2007). The orange and red-fleshed sweet potato are additionally enriched with beta-carotene, the precursor of Vitamin A. As a result of their high nutritional value, productivity, and low input requirements, sweet potatoes have become a valuable food in developing countries. Sweet potatoes are transformed into functional ingredients, foods, and industrial products using a variety of processing technologies. Orange and purple-fleshed sweet potatoes can be used to produce natural beta carotene and anthocyanin pigments used in beverages and other food products, as well as starch and sugar.

In Nepal, post-harvest losses of vegetables are 15–30% (Gautam, Bhattarai, 2012). Sweet potato post-harvest losses vary from 15–65% due to fresh weight loss during one to four months of storage (Coursey, 1984; Rashid, 1987; Kone, 1991; Ray, Balagopalan, 1997). Nepal still lacks reliable statistics on areas, production, and post-harvest losses of sweet potato tubers. But, high perishability and poor storage of sweet potato roots in ambient conditions remain a major constraint to the farmers. No systematic work on storage methods and losses has been done so far. Sweet potato utilization is mainly confined to the production sites because of the poor keeping quality of the tubers. Being perishable and poorly handled in developing countries; sweet potato roots may suffer higher post-harvest losses. About 45–54% of roots and tubers in Sub-Saharan Africa are spoiled after harvest (Gustavsson *et al*., 2011; FAO, 2003).

Sweet potato roots have a thin, delicate skin that is high in moisture (60–70%) and free sugar (4–15%) (Woolfe, 1992). They also have a high respiratory rate right after harvest, which causes the texture to soften as a result of the heat output and made sweet potato a perishable product. Once removed from the plant, sweet potatoes cannot be stored for long periods (Wagner *et al*., 1983; Mtunda *et al*., 2001; Rees *et al*., 2001). Sweet potato roots have a shelf life that varies from a few days to a few weeks depending on the varieties, harvest maturity, and storage conditions **(**Lewis, Morris, 1956; Wagner *et al*., 1983; Doku, 1989; Kurup, Balagopalan, 1991; Acedo *et al*., 1996; Cabanilla, 1996; Mtunda *et al*., 2001). Sweet potato storage is not practised in many parts of the world, including Nepal, due to its limited shelf life (Bourke, 1982; Doku, 1989; Jusuf *et al*., 1997; Rees *et al*., 2001; Rees *et al*., 1998). Larger roots are often removed from individual plants, allowing smaller roots to grow and be harvested as required (Karuri, Ojijo, 1994).

In Nepal, the possible causes of post-harvest losses are mechanical damage during harvest, rough handling, and weevil, and other pest infestation, sprouting, and weight loss. A lack of an adequate, experimentally validated, and tested storage system is one of the most common causes of spoilage after harvest. During the long-term storage of sweet potato tubers, biochemical and physiological processes occur, resulting in qualitative and quantitative changes (Grace *et al.*, 2014; Abidin *et al*., 2016).

In Nepal, sweet potato is stored by leaving the root in the mounds even when matured, which ties the soils down to the crop and leads to fibrous roots and high weevil infestation. A few farmers stored in lined pits and on the floors of dark airy rooms where losses are very high. The roots are usually stored in clamps, in bamboo baskets (*Thunse, Dali*), and jute sacks in the shaded corner of the house. Some farmers store sweet potatoes in heaps on the earthen floor where sprouting and rooting is high particularly at a higher temperature.

Long-term storage of sweet potato gives rise to a major challenge to its food security in global marketing (Rees *et al*., 2001; van Oirschot *et al*., 2003). In the tropics, sweet potatoes can sprout in two to three weeks if stored at room temperature (Rees *et al.*, 2003). In ordinary conditions, sweet potato roots cannot be kept for more than one month (Gautam *et al*., 1993a). The cool chain is commonly used to store roots in advanced countries, with optimum storage conditions of 13.5 °C and relative humidity of 90–95%. This has been reported to extend the shelf-life up to a year (Picha, 1986). Sweet potatoes are stored in cold storage, ventilated storage, and tunnels in developed countries. Cold storage facilities, however, are not always accessible in developing countries like Nepal due to economic and technical constraints. Poor farmers cannot afford such sophisticated technology. Sweet potato farmers in developing countries lack adequate storage technology, which discourages large-scale investment in the crop and restricts its food security prospects. This has sparked a hunt for viable storage alternatives that small farmers in these areas can follow.

Sweet potato is largely eaten by poor village people and its storage in the sophisticated method involves high cost and at the same time, it is hardly affordable by the village people (Gautam *et al*., 1993b). The present research looked at the storage performance of sweet potatoes in different conditions. Improved storage methods can improve sweet potato tuber supply throughout the year at current production levels as well as add value to the crop, increasing returns to farmers and potentially improving their quality of living (Dukuh *et al*., 2015). The present study is important because it aims at determining genotypes that have greater storability. This study was carried out to evaluate the storage performance of sweet potato genotypes in different storage conditions at ambient temperature.

Materials and Methods

Storage experiment was conducted during the consecutive years 2018/19 and 2019/20 in mid-hill at National Potato Research Programme (NPRP), Khumaltar, Lalitpur (located at 27° 40' N, 85° 20' E, 1350 m asl) Nepal. The experiment was laid out using Factorial Completely Randomized Design with three replications in ambient room temperature. The experiment consisted of a total of fifteen treatment combinations of five different storage conditions *i.e.*, inside dry sand (S_1), inside sawdust (S_2), thin jute sack (S_3), natural mud pot (diameter 32 cm and length 43 cm) (S_4), and open plastic crates as control (S5) and three sweet potato genotypes ('CIP 440015', 'CIP 440267' and 'Local White') (Fig. 1). The general information of used genotypes is presented in Table 1. The selected two elite orange-fleshed sweet potatoes (OFSP) genotypes and a 'Local White' (Table 1) grown in respective sites were used for experimentation. Tuberous roots were harvested 4 months after planting. Roots more than 20-gram weight free from wounds, diseases were selected and cured by spreading in the floor for two days at ordinary room temperature with enough ventilation.

Table 1. Sweet potato genotypes were used as the treatments for the experiment

Genotypes (G)	Variety	Origin	Source and date
G1.'CIP 440015'	W-220	USA	CIP, Peru, Lima (2010)
G2.'CIP 440267'	Hung Loc 4	Vietnam	CIP, Peru, Lima (2010)
G3. 'Local White'	–	Lamjung, Nepal	Farmer, Nepal (2014)
Planting date	August 18, 2018, and August 19, 2019		
Harvesting date	December 18, 2018 and December 19, 2019		

Source: NPRP, 2018

Each treatment had 30 tuberous roots from each genotype and was kept in different storage conditions accordingly. In S1 and S2 treatments, sweet potatoes were placed in perforated plastic crates and covered by dry sand and sawdust leaving 2 cm from the top. The initial moisture content (%) of sweet potato roots were 75.27, 73.65, and 75.46 in the genotypes 'CIP 440015', 'CIP 440267', and 'Local White' respectively. The study was conducted from December to March (90 days) in both years.

The temperature and relative humidity of the storage room was recorded with the help of a digital Thermo-Hygrometer daily at 6.00 AM and 5.00 PM. Physiological weight loss (%) was recorded on the 2nd, 4th, 6th, 8th, 10th and 12th weeks of storage. Observations were also made on sprouting, rotting, and insect attack. Weight loss was determined by the difference between initial weight and final weight. The number of rotten roots was taken and recorded. The total per cent rotting was determined as the number of rotten roots divided by the total roots count and expressed as a percentage. Similarly, roots were examined for the presence of sweet potato weevil. The number of roots damaged was divided by the total number of roots count and expressed as a percentage to obtain per cent weevil damage.

Dry matter, starch, reducing sugar, and beta carotene content was analyzed by the AOAC method (AOAC, 2005). Dry matter content (%) was determined by chopping and mixing of tubers into small pieces and drying of 100 g sample in a hot air oven at 80 °C for the first six hours and then at 65 °C till constant weight was obtained (Kumar *et al.*, 2006).

Reducing sugar (%) was determined by the dinitrosalicyclic colourimetric method (Miller, 1959). Light absorbance was recorded in a spectrophotometer (Agilent Technologies, Cary 60 UV-VIS, USA) at 510 nm. To calculate the milligrams reducing sugars per 100 g fresh weight, a standard curve was plotted with different concentrations of glucose (100–600 µg glucose mL^{-1} water on the x-axis and absorbent reading on the y-axis. The absorbent reading of samples was recorded and calibrated based on a standard curve and presented as milligram reducing sugars per 100 gram fresh weight of sweet potato. The ß-carotene content of the sweet potato tuber samples was determined by the solvent partition method as described in Ranganna (2007). The starch content of sweet potato was determined by the Lane and Enyone method described by Ranganna (2007). The data were analyzed with GenStat version 18 software for windows (VSN International, 2016). Means were separated by Duncan's Multiple Range Test at a 5% level of significance. The correlation was calculated for different parameters. The Karl Pearson Correlation coefficient was introduced to measure the association which follows a parametric test.

Figure 1. Different storage conditions and sweet potato genotypes. A – inside dry sand; B – inside sawdust; C – thin jute sack; D – natural mud pot; E – open crates; F – 'CIP 440015'; G – 'CIP 440267' and H – 'Local White'

Results and Discussion

Storage environment

During the storage periods of 2018/19 and 2019/20, the average temperature ranged from 10.86 °C to 17.06 °C and 10.11 °C to 17.49 °C, respectively. In the same way, relative humidity ranged from 52.57 to 70.29%, which was consistently low (Table 2). The average temperature of the storage environment was increased slightly later in the storage period, which might be associated with temperature rises in the outer environment. The coefficient of variation clearly showed that the variability of temperature and humidity at the storage room (Table 2). According to Kushman and Deonier (1975), the best storage conditions are 15 °C and 85–90% relative humidity. Improving the storage environment can be able to extend the storage life (Samarasinghe, 1991; Ray, Balagopalan, 1997; Rees *et al*., 1998).

Table 2. Weekly average temperature (Temp) and relative humidity (RH) of the experimental site

Week	December 2018 to March 2019				December 2019 to March 2020			
	Temp, °C		RH, %		Temp, °C		RH, %	
	6:00 AM	5:00 PM	6:00 AM	5:00 PM	6:00 AM	5:00 PM	6:00 AM	5:00 PM
1	12.49	13.97	65.14	63.14	11.06	12.0	62.0	60.13
2	11.04	12.40	59.00	56.14	11.03	12.02	68.14	65.14
3	10.86	12.21	59.86	57.00	11.07	12.61	70.29	70.14
4	11.30	12.66	62.71	61.86	11.57	13.04	59.43	66.43
5	11.86	13.16	64.71	62.43	10.11	12.07	52.86	61.00
6	11.79	12.93	67.00	64.29	11.23	12.89	63.57	63.43
7	12.06	13.79	63.57	61.29	11.06	13.19	59.86	58.29
8	12.89	13.56	68.43	65.71	13.07	14.97	66.57	67.29
9	13.31	14.86	69.29	67.00	14.56	16.30	68.29	67.71
10	14.49	16.03	61.14	58.71	14.10	15.79	66.43	66.71
11	13.36	14.79	60.71	60.29	14.73	16.91	65.29	59.71
12	14.89	17.06	60.00	54.71	15.59	17.49	61.57	58.57
Mean	12.52	13.95	63.46	61.04	12.43	14.10	63.69	63.71
SD	1.29	1.49	3.48	3.83	1.86	2.05	4.86	4.05
CV, %	10.37	10.69	5.49	6.27	14.97	14.54	7.63	6.36

Physiological loss in weight

The combined results revealed a significant impact of storage conditions on physiological loss in weight (PLW) of sweet potato genotypes. Cumulative PLW was significantly increased in all the treatments with the progression of the storage period (Table 3). At the end of the storage period (12th week), the highest PLW was recorded in the tubers stored in open crates (70.2%) followed by natural mud pot (65.2%) whereas the lowest PLW was observed in tubers stored inside the dry sand (50.2%). Reduction in the cumulative weight loss was observed in the tubers stored in dry sand, sawdust, and thin jute sack with significant variations. Regarding genotype, 'CIP 440015' showed good storability with minimum PLW (55.4%) as compared to other genotypes. The data showed that the maximum weight loss (70.0%) was observed in genotype 'CIP 440267'. Data reveals that the interaction effect of storage conditions and genotype was non-significant on PLW of sweet potato (Table 4). Sweet potato weight loss is aided by respiration (Kushman, Pope, 1972; Winarno, 1982; Picha, 1986). Respiration rate has an inverse relationship with storage life. Picha (1986) also stated that respiration rates were the highest on harvest day, decreased during curing, and continued to decrease at a slower rate during the first few months of storage. Sweet potatoes stored in sand lost less weight than those held at room temperature. Similar results were reported by Smamarasinghe (1991); Karuri, Ojijo (1994); Ray *et al*. (1994) and Hoa (1997). Sand storage altered the atmosphere by limiting oxygen supply and maintaining a low temperature, as well as serving as a barrier to sweet potato weevil entry (Ray, Balagopalan, 1997). Barabara *et al*. (2020) reported that the genetic features of the cultivars had significant influences on the number of losses during storage.

Table 3. Effect of storage conditions and genotype on the weight loss and sprouting of sweet potato stored at ambient room temperature during the storage period (December–March) of 2018/19–2019/20

Treatments	Cumulative PLW (%)						Sprouting (%)
	Weeks after storage						
	2nd	4th	6th	8th	10th	12th	2nd–12th
A. Storage conditions (S)							
S1 (Inside dry sand)	3.59^{c}	10.52^{c}	18.2^{b}	27.4^{b}	40.2^{b}	50.2^{b}	0.0
S2 (Inside saw dust)	9.22^{b}	20.73^{ab}	30.8^{a}	39.6^{a}	51.8^{a}	62.9^{a}	0.0
S3 (Thin jute sack)	9.12^{b}	19.05^{ab}	29.5^{a}	40.2^{a}	53.7^{a}	63.4^{a}	0.0
S4 (Natural mud pot)	7.94^{b}	16.98^{b}	27.6^{a}	40.0^{a}	53.5^{a}	65.2^{a}	0.0
S5 (Open crates, control)	13.40^{a}	22.33^{a}	31.7^{a}	45.0^{a}	59.9^{a}	70.2^{a}	0.0
P-value	<0.001	<0.001	<0.001	0.002	0.008	0.017	–
LSD (0.05)	2.462	3.594	6.70	8.57	10.53	11.59	–
B. Genotypes (G)							
G1 ('CIP 440015')	7.73	14.61^{b}	22.3^{b}	30.4^{c}	43.7^{b}	55.4^{b}	0.0
G2 ('CIP 440267')	9.33	20.75^{a}	34.0^{a}	47.4^{a}	60.3^{a}	70.0^{a}	0.0
G3 ('Local White')	8.90	18.40^{a}	26.4^{b}	37.5^{b}	51.4^{b}	61.7^{ab}	0.0
P-value	0.232	<0.001	<0.001	<0.001	<0.001	0.007	–
LSD (0.05)	1.907	2.784	5.19	6.64	8.16	8.98	–
CV, %	42.9	30.2	36.6	33.6	30.6	28.0	–
S	***	***	***	**	**	*	–
G	NS	***	***	***	***	**	–

NS – not significant, * – significant at P < 0.05, ** – significant at P < 0.01, *** – significant at P < 0.001
The same lowercase letters in the column are not significantly different by DMRT at a 0.05 level of significance

Table 4. Interaction effect of storage conditions and genotype on the PLW and sprouting of sweet potato stored at ambient room temperature during the storage period (December–March) of 2018/19–2019/20

Treatments	Weight loss, %						Sprouting, %
	Weeks after storage						
	2nd	4th	6th	8th	10th	12th	2nd–12th
S1G1	2.56	6.40	15.58	23.50	34.00	43.63	0.0
S1G2	4.03	14.71	24.09	36.00	48.89	58.47	0.0
S1G3	4.18	10.46	14.94	22.62	37.57	48.53	0.0
S2G1	8.82	17.41	24.03	31.98	45.47	54.75	0.0
S2G2	10.94	23.95	40.13	50.43	63.90	75.21	0.0
S2G3	7.90	20.85	28.10	36.39	46.05	58.77	0.0
S3G1	7.28	15.78	22.19	30.10	45.59	55.78	0.0
S3G2	8.64	20.37	35.66	47.79	60.91	71.40	0.0
S3G3	11.42	20.98	30.79	42.71	54.58	62.93	0.0
S4G1	8.02	13.86	22.64	32.00	43.05	58.80	0.0
S4G2	8.57	19.40	32.39	46.80	61.30	70.50	0.0
S4G3	7.24	17.69	27.73	41.18	56.16	66.39	0.0
S5G1	11.96	19.62	27.15	34.30	50.63	64.21	0.0
S5G2	14.46	25.33	37.63	56.19	66.39	74.30	0.0
S5G3	13.75	22.03	30.26	44.40	62.60	72.10	0.0
P-value	0.697	0.986	0.965	0.938	0.977	0.995	–
S × G	NS	NS	NS	NS	NS	NS	–
LSD (0.05)	4.265	6.224	11.61	14.85	18.24	20.08	–
CV, %	42.9	30.2	36.6	33.6	30.6	28.0	–

Storage conditions: S1 – inside dry sand, S2 – inside saw dust, S3 – thin jute sack, S4 – natural mud pot, S5 – open crates, control. Genotypes: G1 – 'CIP 440015', G2 – 'CIP 440267', G3 – 'Local White'. NS – not significant

Sprouting

Sprouting is one of the reasons for the post-harvest deterioration of sweet potatoes (Ravi, Aked, 1996). No sprouting was observed on the stored tuber during the experimental period. No sprouting could be due to prevailing lower temperatures (13±3 °C) during the storage period at ambient room conditions (Table 2). Sprouting can be inhibited by storing roots at a lower temperature (14 °C), according to Ray and Ravi (2005). After harvest, sweet potato roots sprout if environmental conditions are favourable (Afek, Kays, 2004). Sprouting is favoured by high temperature coupled with humidity during storage (Bourke, 1982; Jana, 1982; Winarno, 1982). In the present experiment, the temperature of the storage room was low and not favourable for sprouting.

Rotting and insect attack

The rotting of the tubers was very much affected by different storage conditions (Table 5). Tuber rotting caused the most storage waste during the 12th week of storage. The pooled data showed that the rotting of sweet potato genotypes was significantly differed by different storage conditions at the 8th, 10th, and 12th weeks of storage. The rotting (%) was found significant among the genotypes. The lowest percentage of rotting was recorded in the genotype 'CIP 440015' (55.3%) and inside dry sand (48.7%) at the 12th week of storage while it was the highest up to 85.9% in 'CIP 440267' genotype. The highest rooting (76.7%) was noticed in thin jute sack which was statistically at par with natural mud pot (76.5%). The interaction effect of storage conditions and genotypes on rotting was found insignificant (Table 6).

Table 5. Effect of storage conditions and genotype on the rotting, weevil infestation and dry matter content of sweet potato stored at ambient room temperature during the storage period (December–March) of 2018/19–2019/20

Treatments	Weeks after storage					
	6th	8th	10th	12th	6th–12th	8th
	rotting, %				insect attack, %	dry matter, %
	A. Storage conditions (S)					
S1 (Inside dry sand)	13.0^{b}	25.4^{c}	35.9^{b}	48.7^{b}	0.0	31.30
S2 (Inside saw dust)	19.3^{ab}	32.6^{bc}	51.3^{a}	69.0^{a}	0.0	33.69
S3 (Thin jute sack)	17.6^{ab}	40.9^{ab}	58.7^{a}	76.7^{a}	0.0	34.12
S4 (Natural mud pot)	24.4^{a}	48.1^{a}	61.3^{a}	76.5^{a}	0.0	35.13
S5 (Open crates, control)	18.7^{ab}	38.2^{abc}	54.0^{a}	71.0^{a}	0.0	34.44
P value	0.222	0.008	0.006	<0.001	–	0.659
LSD (0.05)	–	12.5	14.0	12.0	–	–
	B. Genotypes (G)					
G1 ('CIP 440015')	6.2^{c}	21.1^{b}	33.6^{c}	55.3^{b}	0.0	32.14^{b}
G2 ('CIP 440267')	33.7^{a}	59.4^{a}	77.8^{a}	85.9^{a}	0.0	38.44^{a}
G3 ('Local White')	15.9^{b}	30.7^{b}	45.3^{b}	63.9^{b}	0.0	30.63^{b}
P-value	<0.001	<0.001	<0.001	<0.001	–	0.001
LSD (0.05)	7.4	9.7	10.8	9.3	–	4.1
CV, %	77.5	50.9	40.5	26.4	–	16.6
S	NS	**	**	***		NS
G	***	***	***	***		**

NS – not significant, * – significant at P < 0.05, ** – significant at P < 0.01, *** – significant at P < 0.001
The same lowercase letters in the column are not significantly different by DMRT at a 0.05 level of significance

Minimum tuber rotting in the sand and sawdust could be due to the stability of uniform temperature. Fluctuating ambient temperature during day and night might have accelerated the rotting of tubers kept exposed to the open environment. The temperature record showed the range from 10.11 to 17.49 °C ambient temperature (Table 2). Chilling injury at low temperatures can cause tuber decay, and sweet potato roots are particularly susceptible to chilling injury at temperatures of 12.5 °C (55 °F) or lower because they are native to the tropics. Symptoms of chilling injury include fungal decay, internal pulp browning, and root shriveling. Sweet potato roots should not be stored at a temperature below 12 °C as they are susceptible to chilling injury. Ray and Ravi (2005) reported that optimal storage temperatures in sweet potatoes range from 13 to 15 °C with 85 to 95% RH. Reese*t al*. (2001) and Mtunda *et al.* (2001) observed that postharvest physiological deterioration

(PPD) in sweet potatoes was caused by postharvest injury, increased respiration, rooting, and microbial damage, which accounted for 41 to 93% of root damage.

Table 6. Interaction effect of storage conditions and genotype on the rotting and weevil infestation of sweet potato stored at ambient room temperature during the storage period (December–March) of 2018/19–2019/20)

Treatments	Weeks after storage					
	6th	8th	10th	12th	6th–12th	8th
	rotting, %				insect attack, %	dry matter, %
S1G1	3.9	13.9	23.3	30.0	0.0	30.41
S1G2	25.6	43.3	55.0	77.2	0.0	35.08
S1G3	9.4	18.9	29.4	38.9	0.0	28.41
S2G1	7.8	17.2	30.6	57.2	0.0	29.74
S2G2	38.9	62.8	85.6	88.1	0.0	41.44
S2G3	11.1	17.8	37.8	61.7	0.0	29.88
S3G1	7.2	21.1	32.8	62.8	0.0	33.37
S3G2	30.0	67.2	93.3	95.6	0.0	34.84
S3G3	15.6	34.4	50.0	71.7	0.0	34.17
S4G1	8.9	30.0	42.2	64.5	0.0	33.31
S4G2	41.1	70.0	85.6	86.4	0.0	40.79
S4G3	23.3	44.4	56.1	78.7	0.0	31.29
S5G1	3.3	23.1	39.2	62.2	0.0	33.87
S5G2	32.8	53.4	69.8	82.2	0.0	40.06
S5G3	20.0	38.1	53.2	68.7	0.0	29.39
P-value	0.893	0.740	0.581	0.574	–	0.769
S × G	NS	NS	NS	NS	–	NS
LSD (0.05)	–	–	–	–	–	–
CV, %	77.5	50.9	40.5	26.4	–	16.6

Storage conditions: S1 – inside dry sand, S2 – inside saw dust, S3 – thin jute sack, S4 – natural mud pot, S5 – open crates, control. Genotypes: G1 – 'CIP 440015', G2 – 'CIP 440267', G3 – 'Local White'. NS – Not significant

No weevil infestation was noticed in all the treatments during the experimental period (Table 5). Prevailing low temperatures during the study period could be unfavourable for weevil infestation. The infestation has a strong relationship with location, altitude, and planting season. Several studies have concluded that higher temperatures may increase the growth rate of the insect's population as well as the risk and severity of the outbreaks (Ladányi, Hufnagel, 2006; Gomi *et al*., 2007). Ladányi and Hufnagel (2006) also reported that the increase in temperature, the higher the rate of the population of insect growth. At a lower elevation of fewer than 2000 m above sea level damage, the crop tends to be more (Okonya, Kroschel, 2013; Lutulele, 2001). In the drier period, the higher the temperature, the higher the frequency, which may be the possible influence on sweet potato weevils (Okonya, Kroschel, 2013). As shown by previous findings, the conditions in this experiment were not conducive to weevil infestation.

Biochemical changes

Dry matter (DM) content of tuber was not influenced significantly by storage conditions after eight weeks of storage whereas, the highest DM (35.13%) content was in a natural mud pot and lowest in dry sand (31.13%) (Table 5). Interaction effect of storage conditions and genotypes was not significant on dry matter content, while genotypes significantly differed with the highest (38.44%) in 'CIP 440267' and the lowest 30.63% in 'Local White'. The value of this characteristics may be influenced by the genetic features of genotypes and similar results were reported by Barabara *et al*. (2020) in sweet potatoes.

Selected chemical constituents were analyzed twice in this study, once at the time of harvest and again after three months of storage, to determine their level of change after three months of storage from the best storage method (inside dry sand) found (Tables 7, 8). The results showed an increase in dry matter and reducing sugar content, as well as a decrease in beta carotene and total starch content after 3 months of storage inside dry sand. Table 8 shows the correlation matrix for the simple correlation coefficient for the association between parameter values of the variable. There was a positive and strong correlation of storage duration with dry matter (r = 0.750) and reducing sugar (r = 0.658) whereas, a negative correlation with starch (r = –0.918) and ß-carotene (r = –0.352) content of sweet potato genotypes (Figs. 2–5). It is well known that physiological and biochemical changes in tubers after storage cause this, but it is also influenced by endogenous factors.

Table 7. Dry matter, starch, reducing sugar and Beta-carotene content after 3 months (12 weeks) storage of sweet potato genotypes inside dry sand during 2018/19

Quality parameters	Storage Duration					
	0 month (at harvest)			3 months (after storage)		
	genotypes			genotypes		
	'CIP 440015'	'CIP 440267'	'Local White'	'CIP 440015'	'CIP 440267'	'Local White'
Dry matter, %	24.73	26.35	24.54	25.96	29.12	27.92
Starch content FWB, %	22.73	25.51	24.19	15.12	19.53	16.48
Reducing sugar FWB, %	4.21	3.16	4.66	9.79	4.72	5.89
ß-carotene content DWB, mg 100 g^{-1}	124.71	161.48	6.64	56.87	106.16	5.87

FWB – fresh weight basis, DWB – dry weight basis

Table 8. Correlation matrix for the association between dry matter, starch, reducing sugar and Beta-carotene content of sweet potato genotypes

Quality parameters	Dry matter, %	Starch content FWB, %	Reducing sugar FWB, %
Starch content FWB, %	–0.453		
Reducing sugar FWB, %	0.021	–0.845*	
Beta-carotene content DWB mg 100 g^{-1}	0.047	0.467	–0.451

* – significant at P < 0.05; FWB – fresh weight basis, DWB – dry weight basis

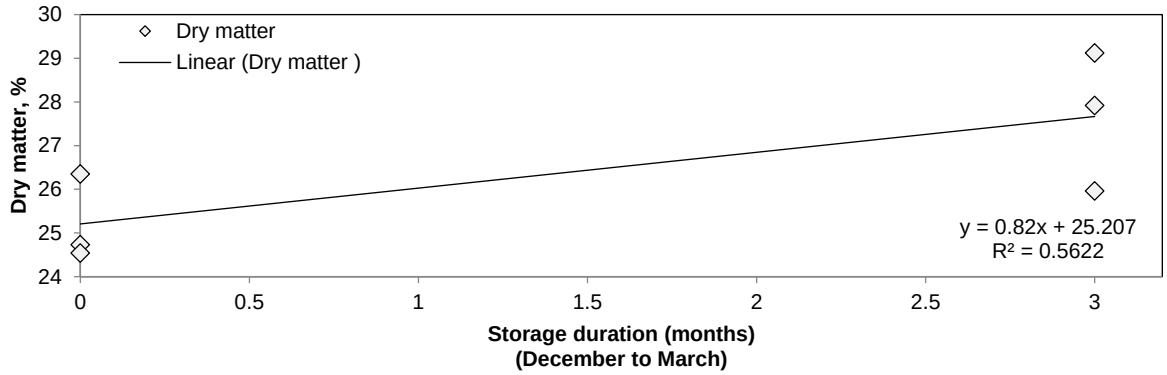

Figure 2. Correlation between storage duration and dry matter in G1 ('CIP 440015'), G2 ('CIP 440267') and G3 ('Local White')

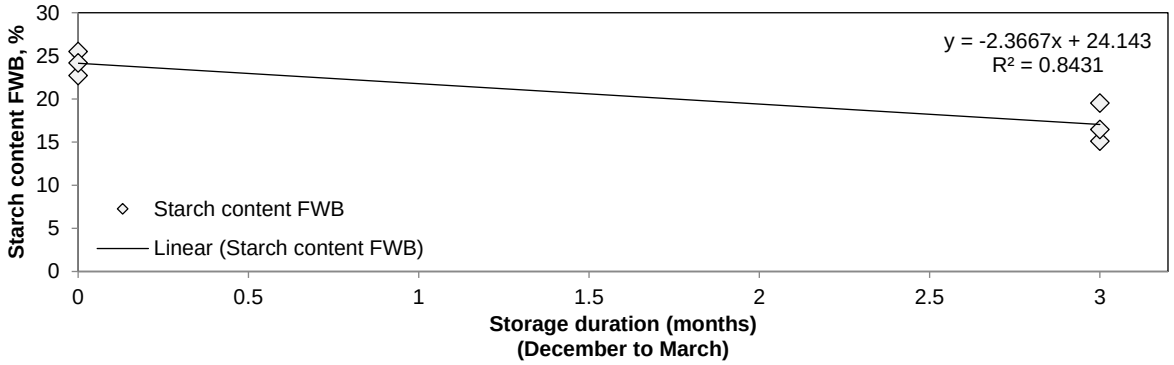

Figure 3. Correlation between storage duration and starch content in G1 ('CIP 440015'), G2 ('CIP 440267') and G3 ('Local White') (FWB – fresh weight basis)

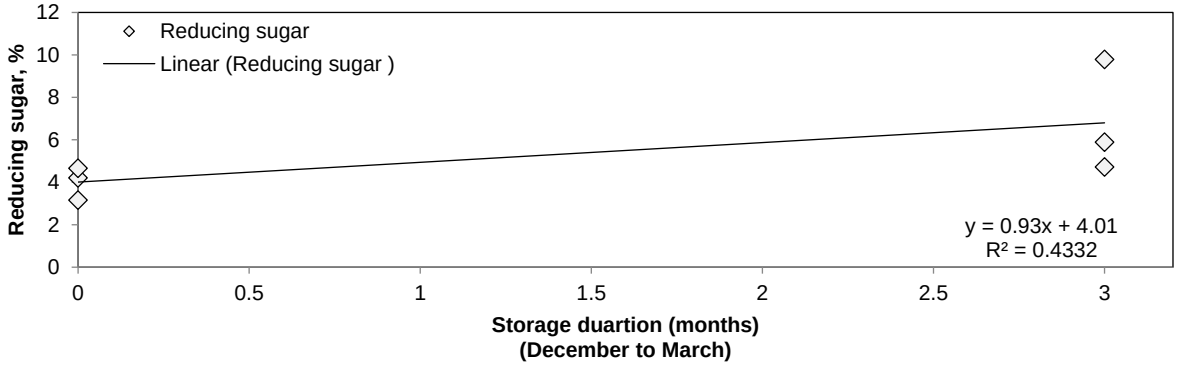

Figure 4. Correlation between storage duration and reducing sugar content in G1 ('CIP 440015'), G2 ('CIP 440267') and G3 ('Local White')

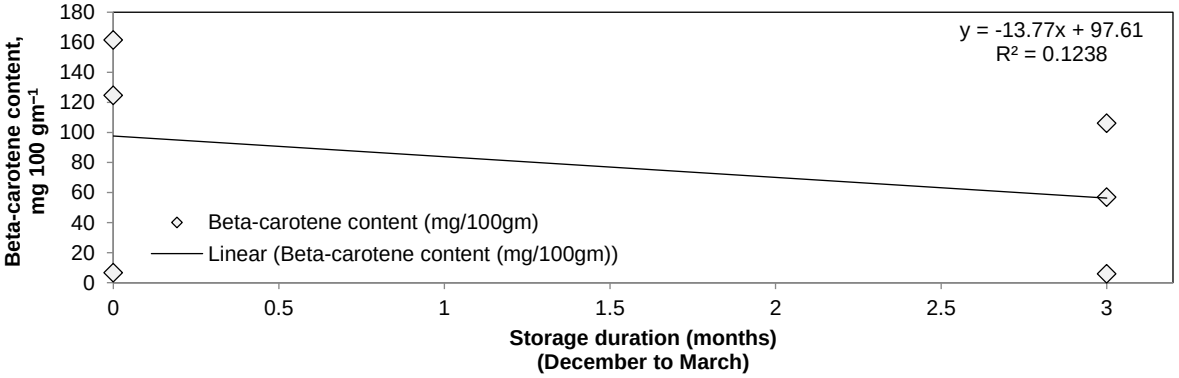

Figure 5. Correlation between storage duration and beta carotene content in G1 ('CIP 440015'), G2 ('CIP 440267') and G3 ('Local White')

The chemical composition of tubers analyzed after storage was affected by all experimental factors. According to Shuzbusha *et al.* (2010) and Grace *et al.* (2014), the higher the storage temperature, the more intense the transpiration, which results in higher tuber dry matter content. The physiological processes (transpiration and respiration) and the progress of temperature and humidity in storage are the indicators to monitor dry matter content changes during storage (Dandago, Gungula, 2011).

After 6 months of storage at 5 °C and 15 °C, there was a change in the content of starch, which is the main carbohydrate in sweet potato tubers (Barabara *et al*., 2020). Its composition is closely related to dry matter content, according to several authors (Njiti *et al.*, 2014; Kitahara *et al*., 2017; Krochmal-Marczak *et al*., 2018; Niu *et al*., 2019). The starch content of sweet potato tubers decreases over time during storage (Dandago, Gungula, 2011). Zhang *et al.* (2002) also observed a decrease in starch content during tuber storage, but it varied depending on genotype. According to Nabubuya *et al*. (2012), enzyme activity, especially amylase activity, causes starch content to decrease in sweet potato tubers during storage. Their activity increases in sweet potato tubers during storage, and they play a key role in reducing starch content during storage. To better understand the production of cold-induced sweetening (CIS), Yamdeu *et al.* (2015) analyzed carbohydrate metabolic changes in potato tubers stored at 15 °C and 4 °C for 150 days. They discovered that low-temperature storage had a negligible effect on the tubers' starch or maltose content, but did cause a significant increase in reducing sugars and total soluble sugars. Namutebi *et al.* (2004) reported that ß-carotene is generally decreased with the storage period for sweet potatoes.

Conclusion

The findings showed a significant effect of storage conditions on physiological loss in weight and rotting (%) of sweet potato genotypes. Despite the significant weight loss, the healthy tubers appeared to be edible and in good condition for up to 8–10 weeks. The comparative study showed sweet potatoes can be kept in better condition in dry sand and sawdust with minimum post-harvest losses. Genotype 'CIP 440015' had good storability at ambient conditions. In terms of quality, the results showed an increase in dry matter and reducing sugar content while decrease in beta carotene and total starch content after 3 months of storage. The findings of the experiment could be worth beneficial for the poor farmers of underdeveloped and developing countries like Nepal to prolong the shelf-life of sweet potatoes at ambient conditions.

Acknowledgement

The financial support for this research was supported by Nepal Agricultural Research Council (NARC), Nepal. The authors were thankful to National Potato Research Programme, Khumaltar, Lalitpur for providing the appropriate facilities to conduct the research activities. The authors sincerely acknowledge Mr Jiban Shrestha (Scientist, NARC, Nepal) for critical feedback on the manuscript.

Conflict of interest

The author declares that there is no conflict of interest regarding the publication of this paper.

Author contributions

PB – the lead investigator and also responsible for data collection from the field, literature search, and write-up.
KMT, DMG, and AKS – responsible for guidance and monitoring research activities.
All the authors read and approved the final manuscript.

References

Abidin, P.E., Kazembe, J., Atuna, R.A., Amagloh, F.K., Asare, K., Dery, E.K., Carey, E.E. 2016. Sand storage, extending the shelf-life of fresh sweet potato roots for home consumption and market sales. – Journal of Food Science and Engineering, 6:227–236. DOI: 10.17265/2159-5828/2016.04.005

Acedo, A.L. Jr., Data, E.S., Quevedo, M.A. 1996. Genotypic variations in quality and shelf life of fresh roots of Philippines sweet potato grown in two planting seasons. – Journal of the Science of Food and Agriculture, 72(2):209. DOI: 10.1002/(SICI) 1097-0010(199610)72:2<209:AID-JSFA640>3.0. CO;2-N

Afek, U., Kays, S. 2004. Postharvest physiology and storage of widely used root and tuber crops. – Horticultural Reviews, 30:253–316. DOI: 10.1002/ 9780470650837.ch7

AOAC, 2005. Official Method of Analysis (18th Ed). W. Horwitz, G.W. Latimer (Eds.). – USA: AOAC International.

Barabara, K.M., Barabara, S., Barabara, K., Honorata, D., Elvyra, J. 2020. The effects of temperature on the quality and storage stability of sweet potato (*Ipomoea batatas* L.) grown in central Europe. – Agronomy, 10:1665. DOI: 10.3390/agronomy10111665

Bourke, R.M. 1982. Sweet potato in Papua New Guinea. – 45. International: Review. Sweet Potato. Villareal, L., Griggs, T.D. (Eds.). – Proceedings of 1st International Symposium. Asian Vegetable Research Developmental Centre (AVRDC), Shanhua, Tainan, Taiwan, pp. 45–57.

Cabanilla, L.S. 1996. Sweet Potato in the Philippines: Production, Processing and Future Prospects. – International Potato Center (CIP), Lima, Peru, 100 p.

CIP, 2009. Sweet potato. – http://www.cipotato.org/ sweet potato/ Accessed on 06/10/12.

Coursey, D.G. 1984. Potential utilization of major root crops, with special emphasis on human, animal and industrial uses. – In Tropical root crops: Production and utilization in Africa. – Proceedings of the 2nd Triennial Symposium International Society for Tropical Root Crops. E.R. Terry, E.V. Doku, O.B.

Arene, N.B. Mahungu (Eds.). Africa Branch, Ibadan, Nigeria, pp. 25–36.

Dandago, M.A., Gungula, D.T. 2011. Effects of various storage methods on the quality and nutritional composition of sweet potato (*Ipomoea balatas* L.) in Yola Nigeria. – International Food Research Journal, 18:271–278.

Doku, E.V. 1989. Root crops in Ethiopia. – In Root crops and low input agriculture: Helping to meet food self-sufficiency goals in Eastern and Southern Africa. – Proceedings of the 3rd Eastern and Sothern Africa regional Workshop on root and tuber crops, Mzunza, Malawi, 7–11 Dec. 1987. M.N. Alvares, S.K. Hahn (Eds.). International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, pp. 101–106.

Dukuh, I.G., Okyere, J., Braimah, M.M. 2015. Developing technology to improve the shelf life of sweet potato tubers. – International Journal of Pure and Applied Bioscience, 3(4):65–71.

FAO, 2003. Food loss, and waste facts. – http://www.fao.org/save-food/resources/infographic/en Accessed on 29/12/2016.

FAO, 2016. Crop production Data. – http://www.fao.org/faostat/en/#data/QC Accessed on 29/12/2016.

FAOSTAT, 2008. Production and area harvested statistics for sweet potato for 2007. – http://www.faostat.fao.org/site/567/default.aspx?PageID=567#ancor Accessed on 29/12/2016.

Gautam, D., Sharfuddin, A.F.M., Hussain, M., Siddique, M.A. 1993b. Underground storage method in sweet potato. – Bangladesh Horticulture, 21(2):33–42.

Gautam, D.M., Bhattarai, D.R. 2012. Postharvest horticulture. – Bhawani Printers. Chabahil, Kathmandu, Nepal.

Gautam, D.M. 1991. Production, post-harvest handling, and utilization of sweet potato in Nepal. – In Sweetpotato in South Asia: Postharvest handling, storage, processing, and uses. Dayal, T.R., Scott, G., Kurup, G.T., Balalagopalan, C. (Eds.). – Proceedings of a workshop held at CTCRI, Skeerariyam, Trivandrum, India, 9-13 September 1991, pp. 23–28.

Gautam, D.M., Sharfuddin, A.F.M., Siddique, M.A., Hussain, M. 1993a. Storage of sweet potatoes by various methods at ambient temperature. – Bangladesh Horticulture, 21(2):17–24.

Gomi, T., Nagasak, M., Fukuda, T., Hagihara, H. 2007. Shifting of the life cycle and life-history traits of the fall webworm in relation to climate change. – Entomologia Experimentalis et Applicata, 125(2): 179–184. DOI: 10.1111/j.1570-7458.2007.00616.x

Grace, M.H., Yousef, G.G., Gustafson, S.J., Truong, V.D., Yencho, G.C., Lila, M.A. 2014. Phytochemical changes in phenolics, anthocyanins, ascorbic acid, and carotenoids associated with sweet potato storage and impacts on bioactive properties. – Food Chemistry, 145:717–724. DOI: 10.1016/j.foodchem.2013.08.107

Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., Meybeck, A. 2011. Global food losses and food waste: Extent, causes, and prevention. – FAO, Rome, Italy, 29 p.

Hoa, V.D. 1997. Sweet potato production and research in Vietnam. – Proceedings of the International Workshop on Sweet Potato Production System Toward the 21st Century, Dec. 9–10. Miyazaki, Japan, p. 109.

Jana, R.K. 1982. Status of sweet potato cultivation in East Africa and its future. – Proceedings of 1st International Sweet Potato Symposium (Eds. R.L. Villareal, T.D. Griggs). Asian Vegetable Research Development Center (AVRDC), Shanhua, Tainan, Taiwan, p. 63.

Jusuf, M., Widodo, Y., Antarlina, S.S. 1997. Problems and subject of sweet potato production and utilization in Indonesia, – Proceedings of International Workshop on Sweet Potato Production System toward the 21st Century. Miyakonjo, Miyazaki, Japan, p. 83.

Karuri, E.G., Ojijo, N.K.O. 1994. Storage studies on sweet potato roots: Experience with KSP20 cultivar. – International Symposium Post-Harvest Treatment of Horticulture Crops. – Acta Horticulturae, 368:441–478. DOI: 10.17660/ActaHortic.1994.368.54

Kitahara, K., Nakamura, Y., Otani, M., Hamada, T., Nakayachi, O., Takahata, Y. 2017. Carbohydrate components in sweet potato storage roots: Their diversities and genetic improvement. – Breeding Science, 1:62–72. DOI: 10.1270/jsbbs.16135

Kone, S. 1991. Traditional methods for prolonged storage of sweet potatoes in Mali. – German Appropriate Technology Exchange (GATE), Eschborn, German, 2:14.

Krochmal-Marczak, B., Sawicka, B., Tobiasz-Salach, R. 2018. Impact of cultivations technology on the yield of sweet potato (*Ipomoea batatas* (L.) tubers. – Emirates Journal of Food and Agriculture, 30(11): 978–983. DOI: 10.9755/ejfa.2018.v30.i11.1863

Kumar, D., Singh, B.P., Paul Khurana, S.M. 2006. Processing quality of potato hybrid Ht/92-621 during storage at intermediate temperature along with sprout suppressant treatment. – Potato Journal, 33(1–2):90–93.

Kurup, G.T., Balagopalan, C. 1991. Sweet potato production, post-harvest handling and utilization in India. – In Sweetpotato in South Asia: Postharvest handling, storage, processing, and uses. Dayal, T.R., Scott, G., Kurup, G.T., Balalagopalan, C. (Eds.). – Proceedings of a workshop held at CTCRI, Skeerariyam, Trivandrum, India, 9-13 September 1991, pp. 33–39.

Kushman, L.J., Deonier, M.T. 1975. Effects of Storage temperature on Porto Rico and Goldrush sweet potatoes. – U.S. Department of Agriculture, Meridian, MS, USA.

Kushman, L.J., Pope, D.T. 1972. Causes of pithiness in sweetpotatoes. – N. Carolina Agric. Exp. Stn. Tech. Bull., 207.

Ladányi, M., Hufnagel, L. 2006. The effect of climate change on the population of Sycamore lace bug (*Corythuca ciliata*, Say, *Tingidae Heteroptera*) based on a simulation model with phenological response. –

Applied Ecology and Environmental Research, 4:85–112. DOI: 10.15666/aeer/0402_085112

Lewis, D.A., Morris, L.L. 1956. Effects of chilling storage on respiration and deterioration of several sweet potato varieties. – Proceeding of the American Society for Horticultural Sciences, 68:421–428.

Lohani, S.N. 1981. Sharkharkanda. – In: Nepal Ko Krishi Bali. Pub. D. Lohani, Kathmandu, pp. 366–370.

Low, J.W., Arimond, M., Osman, N., Cunguara, B., Zano, F., Tschirley, D. 2007. A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique. – Journal of Nutrition, 137:1320–1327. DOI: 10.1093/jn/137.5.1320

Lutulele, R.P. 2001. Sweet potato variety developments in the PNG highlands: Implications for future research and extension focus. – Proceedings of the Papua New Guinea Food Nutrition, pp. 683–688.

Miller, G.L. 1959. Use of dinitrosalicyclic acid reagent for determination of reducing sugar. – Analytical Chemistry, 31:426–428. DOI: 10.1021/ac60147a030

Mtunda, K., Chilosa, D., Rwiza, E., Kilima M., Kiozya, H., Munisi, R.,Kapinga, R., Rees, D. 2001. Damage reduced shelf life of sweet potato during marketing. – Fifth Trennial Congress of the African potato Association, 28 May–2 June, 2000, Kampla, Uganda. African Crop Science Journal, 9(1):301–308. DOI: 10.4314/acsj.v9i1.27652

Nabubuya, A., Namutebi, A., Byaruhanga, Y.B., Narvhus, J., Stenstrøm, Y., Wicklund, T. 2012. Amylolytic activity in selected sweet potato (*Ipomoea batatas* Lam.) varieties during development and in storage. – Food Nutrition Science, 3(5):660–668. DOI: 10.4236/fns.2012.35090

Namutebi, A., Natabirwa, H., Lemaga, B., Kapinga, R., Matovu, M., Tumwegamire, S., Nsumba, J., Ocom, J. 2004. Long-term storage of sweet potato by small scale farmers through improved post-harvest technologies. – Uganda Journal of Agriculture Science, 9(1):914–922.

Niu, S., Li, X.-Q., Tang, R., Zhang, G., Li, X., Cui, B., Mikitzel, L., Haroon, M. 2019. Starch granule sizes and degradation in sweet potatoes during storage. – Postharvest Bioogy and Technology, 150:137–147. DOI: 10.1016/j.postharvbio.2019.01.004

Njiti, V., Xia, C.Q., Zhang, Y., Meng, A., Nanjundaswamy, A., Madlock, D. 2014. Inheritance of amylase activity and dry matter in the sweet potato storage root. – Proceedings of the ASA, CSSA and SSSA International Annual Meeting, Long Beach, CA, USA, 2–5 November, 2014.

NPRP, 2018. Annual Report of the fiscal year 2016/2017. – National Potato Research Programme, Khumaltar, Lalitpur, Nepal.

Okonya, J.S., Kroschel, J. 2013. Incidence, abundance and damage by the sweet potato butterfly (*Acraea acerata* Hew.) and the African sweet potato weevils (Cylasspp.) across an altitude gradient in Kabale district, Uganda. – International Journal of Agriculture Science, 3(11):814–824.

Picha, D.H. 1986. Weight loss in sweet potatoes during curing and storage: contribution of transpiration and respiration. – Journal of the American Society for Horticultural Science, 111:889–892.

Ranganna, S. 2007. Handbook of Analysis and Quality control for fruits and vegetable products (2nd Ed.). – Tata McGraw-Hill Publishing Company Ltd. New Delhi, India, 1112 p.

Rashid, M.M. 1987. Indigenous technologies and recent advances in sweet potato production, processing, utilization, and marketing in Bangaladesh. – Paper presented at an International Sweet Potato Symposium, 20–26th May. VISCA, Baybay, Leyte, Phillippines.

Ravi, V., Aked, J. 1996. Review on tropical root and tuber crops. II. Physiological disorders in freshly stored roots and tubers. – Critical Reviews in Food Science and Nutrition, 36:711–731.

Ray, R.C., Balagopalan, C. 1997. Post-Harvest Spoilage of Sweet Potato. – Technical Bulletin Series 23 Central Tuber Crops Research Institute (CTCRI), Trivandrum, India.

Ray, R.C., Ravi, V. 2005. Post-harvest spoilage of sweet potato in tropics and control measures. – Critical Reviews in Food Science and Nutrition, 45(7–8):623–644. DOI: 10.1080/10408390500455516

Ray, R.C., Chowdhury, S.R., Balagopalan, C. 1994. Minimizing weight loss and microbial rotting of sweet potato (Ipomoea batatas) in storage under tropical ambient conditions. – Advances in Horticultural Science, 8(3):159–163.

Rees, D., Kapinga, R., Mtunda, K., Chilosa, D., Kiozya, H., Rwiza, E., Kilma, M., Munisi, R. 2001. Effect of damage on market value and shelf life of sweet potato in urban markets of Tanzania. – Tropical Science, 41(3):142–150.

Rees, D., Kapinga, R., Rwiza, E. 1998. The potential for extending the shelf-life of sweet potato in East Africa through cultivar selection, in Tropical Root crops: staples for Sustainable Food security into the next Millennium. – Proceedings of the 11th International Society of Tropical Root Crops Symposium, St. Augustine, Trinidad, 20–28 Oct, 1997. – Tropical Agriculture, 75:208.

Rees, D., van Oirschot, Q.E.A, Amour, R., Rwiza, E., Kapinga, R., Carey, T. 2003. Cultivar variation in keeping quality of sweet potatoes. – Postharvest Biology and Technology, 28(2):313–325. DOI: 10.1016/S0925-5214(02)00180-1

Samarasinghe, S.H.M.C. 1991. Production postharvest handling, and utilization of sweet potato in Sri Lanka. – In Sweetpotato in South Asia: Postharvest handling, storage, processing, and uses. Dayal, T.R., Scott, G., Kurup, G.T., Balalagopalan, C. (Eds.). – Proceedings of a workshop held at CTCRI, Skeerariyam, Trivandrum, India, 9-13 September 1991, pp. 29–32.

Shuzbusha, D., Tusiime, G. Edema, R., Gibson, P., Mwanga, R.O.M. 2010. Diallel analysis of root dry

matter content in sweet potato. – Proceedings of the 2nd RUFORUM Biennial Meeting, Entebbe, Uganda, 20–24 September, 2010. p. 1013–1017.

Tortoe, C., Obodai, M., Amoa-Awua, W. 2010. Microbial deterioration of white variety sweet potato (*Ipomoea batatas*) under different storage structures. – International Journal of Plant Biology, 1:10–15. DOI: 10.4081/pb.2010.e10

van Oirschot, Q.E.A., Rees, D., Aked, J. 2003. Sensory characteristics of five sweet potato cultivars and their changes during storage under tropical conditions. – Food Quality and Preference, 14:673–680. DOI: 10.1016/S0950-3293(02)00209-4

VSN International. 2016. GenStat for Windows 18th Edition. – VSN International, Hemel Hempstead, UK.

Wagner, A.B., Burns, E.E., Paterson, D.R. 1983. The effect of storage systems on sweet potato quality [Ipomoea batatas]. – Horticulture Science, 18:336–338.

Winarno, F.G. 1982. Sweet potato processing and by-product utilization in the tropics. – Sweet potato: Proceedings of the First International Symposium Shanhua (Taiwan). L. Villareal, T.D. Griggs (Eds.). Asian Vegetable Research Developmental Centre (AVRDC), Shanhua, Tainan, Taiwan, pp. 373–384.

Woolfe, J.A. 1992. Sweet potato an untapped food resource. – Cambridge University Press, Cambridge, UK, 660 p.

Yamdeu, J.H.G., Gupta, P.H., Patel, N.J., Shah, A.K., Talati, J.G. 2015. Effect of storage temperature on carbohydrate metabolism and development of cold-induced sweetening in Indian potato (*Solanum Tuberosum* L.) varieties. – Journal of Food Biochemistry, 40:71–83. DOI: 10.1111/ jfbc.12190

Zhang, Z., Wheatley, C.C., Corke, H. 2002. Biochemical changes during storage of sweet potato roots differing in dry matter content. – Postharvest Biology and Technology, 24(3):317–325. DOI: 10.1016/S0925-5214(01)00149-1