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Postharvest Loss Reduction in Tropical Tuber Crops for Enhanced Food and Nutrition Security

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Abstract—*Tropical tuber crops have been found to constitute an important part of the regular diet providing valuable nutritional elements and dietary energy, and play an important role in enhancing food security and eradicating poverty in the tropical and subtropical countries. It is estimated that about 30-40% of the total horticultural produce including tropical tuber crops are lost after harvest. Postharvest losses occur at different stages such as harvesting, grading, packaging, transporting and storage, with storage being the stage of biggest loss. Loss occurs at every stage of the supply chain starting from harvesting to consumption. The causes of postharvest losses are multiple, however, the most significant losses are caused by physiological breakdown and microbial attack due to lack of appropriate storage facilities, inappropriate packaging and inadequate means of transportation. In developing countries, food losses mainly happen post-harvest while in the developed countries good food is wasted in retail stages of the supply chain and by consumers. Cassava, yam, sweet potato and taro representing important group of tropical tuber crops have found an important place in developing world's diet, and are considered as new world's food security crops. Postharvest handling of these crops is a challenge, given the uniform harvesting times and relative market glut that can occur. With the exception of flour and starch processing, root crop storage and processing represents a serious challenge to the industry. Significant losses occur during processing, where the numbers of factories are insufficient to meet demand, and most processing units are small and use outdated technologies. The highest rates of loss in these perishable commodities are mainly due to lack of proper storage facilities, absence of proper handling, transportation, pre- and postharvest treatment and processing. The farmers lack market linkages and usually sell their produce to a single buyer creating a monopoly. Linking farmers to market and optimizing logistics such as improvement in infrastructure including good roads and development of cold storage facilities are the key areas need to be improved. Improved utilisation of food, either as a food source or valorisation of waste streams contributes to sustainable use of the world's resources by decreasing losses. Strategies to minimize food losses and waste along the supply chain can contribute to reduce the amount of 'missing' food for increased food and nutrition security.*

Keywords*: Postharvest loss, tuber crops, food and nutrition security.*

1. INTRODUCTION

Tropical tuber crops, the most efficient converters of solar energy because of their higher biological efficiency are believed to produce the highest rate of dry matter per day per unit area, and are known to supply cheap source of energy. In addition to the supply of dietary energy, these crops provide considerable amount of protein, minerals and vitamins along with the appreciable amount of starch and sugars. The high beta carotene content of orange-fleshed sweet potato can help to prevent vitamin A deficiency in developing countries. Similarly, purple-fleshed sweet potatoes ad yams rich in anthocyanins are also gaining importance as antioxidant foods. Besides these components, tropical tubers contain phenolic compounds, which may act as antioxidants to safeguard the human body from certain chronic diseases. Similar to phenolic acids, anthocyanins have free radical scavenging property. Thus, the poor people having only limited access to the expensive protein, vitamin and antioxidant rich animal foods like meat, fish, egg, milk and butter, can meet the daily requirement of some essential nutrients through increased consumption of different tropical tuber crops. Tubers are used either as a staple or subsidiary food in several countries of South America, Africa and South East Asia, and form the means of sustenance for millions of people in the tropical and subtropical world.

In the era of extensive population growth and nutrition crisis, the cereals and grain legumes will not be able to bridge the food shortage gap. In spite of the increasing production, there will be huge shortage of food grains in future. In this context, tropical root and tubers like cassava, sweet potato, yam and edible aroids could be the right choice as alternate food source to bridge the food shortage gap. Emphasis should, therefore, be given to these less understood tropical tuber crops, well known since ancient times for saving mankind during food crisis due to their ability to withstand adverse biotic and abiotic stresses. Cassava, yam, sweet potato and taro representing important group of tropical tuber crops have found an important place in developing world's diet, and are considered as new world's food security crops.

In spite of having the greatest possibility for being adopted as a staple food in regular diet, the tropical tuber crops have not gained as much popularity as they deserve because of some anti-nutritional factors and problems in postharvest handling due to their large volume and low shelf-life. Due to high moisture content, large unit size, high respiration rate, soft texture, and prone to bruising, rotting and sprouting, tropical tuber crops are very perishable in nature posing a shelf life of only a few days to a few weeks. It is estimated that about 30-40% of the total horticultural produce including tropical tuber crops are lost after harvest. Postharvest losses occur at different stages such as harvesting, grading, packaging, transporting and storage, with storage being the stage of biggest loss. Loss occurs at every stage of the supply chain starting from harvesting to consumption. The causes of postharvest losses are multiple, however, the most significant losses are caused by physiological breakdown and microbial attack due to lack of appropriate storage facilities, inappropriate packaging and inadequate means of transportation. In developing countries, food losses mainly happen post-harvest while in the developed countries good food is wasted in retail stages of the supply chain and by consumers. With the exception of flour and starch processing, root crop storage and processing represents a serious challenge to the industry. Significant losses occur during processing, where the numbers of factories are insufficient to meet demand, and most processing units are small and use outdated technologies. The highest rates of loss in these perishable commodities are mainly due to lack of proper storage facilities, absence of proper handling, transportation, pre- and postharvest treatment and processing. The farmers lack market linkages and usually sell their produce to a single buyer creating a monopoly.

In this paper, nutritional facts, storage behaviour and the techniques for reducing postharvest loss of some important tropical tuber crops like sweet potato, cassava, yam, elephant foot yam and taro have been discussed to promote food and nutrition security.

2. MATERIALS AND METHODS

As a part of the evaluation of tropical tuber crops for identifying elite genotypes having better nutritional quality, longer storability and suitability for processing, different experiments were conducted under All India Coordinated Research Project on Tuber Crops at Kalyani Center, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India. Fresh tubers of some tropical tuber crops were used for estimating nutritional and anti-nutritional qualities. After washing, peeling and shredding, fresh tubers were dried at 65^0C till the tubers gained constant weight to determine the dry matter content (%). Starch (%), total sugar (%), vitamin C (mg/100g) and β-carotene (mg/100 g) content of the tubers were estimated following the standard procedures as described in A.O.A.C. (1990). Protein content of fresh tubers was estimated spectrophotometrically using Folin-Ciocalteau reagent by Lowry's method (1951). The readings were taken at 660 nm and calculated the amount of protein from standard curve. Folin-type assays (Folin-Denis and Folin-Ciocalteu reagents) were used following the spectrophotometric method as described by Swain and Hills (1959); Walter and Purcell (1979) for quantifying total phenolic compounds in the tubers of different tropical tuber crops. Total soluble oxalate (TSO), water soluble oxalate (WSO) and calcium oxalate were differentiated as described by Holloway *et al*. (1989). The subsequent analysis for oxalate content was made following the methods as described in AOAC (1990). Storability of the tubers were also studied. Sweet potato tubers were stored in three different storage conditions and their storage behavior was studied at weekly intervals. Physiological loss in weight (PLW %) and rotting percentage (RP %) of tubers during storage were calculated as mentioned below.

$$\text{PLW (\%)} = \frac{\text{Initial weight}(w_1) - \text{Final weight}(w_2)}{\text{Initial weight }(w_1)} \times 100$$

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

All the replicated data were statistically analyzed following the method CRD as described by Panse and Sukhatme (1985).

3. RESULTS AND DISCUSSION:

Some potential cultivars of different tropical tuber crops having higher yield, better nutritional quality and longer storability were identified for commercial cultivation. A few storage techniques and processing methods for preparing value added products have also been standardized to reduce the postharvest losses of these crops.

4. YIELD AND NUTRITIONAL QUALITIES:

Significant variations in yield and nutritional quality of the tubers were observed among different cultivars of sweet potato, elephant foot yam, yam, taro and cassava (Table 1 and 2). Tuber yield of sweet potato varied from 18.37 (t/ha) in 'BCSP-10' to 29.61 (t/ha) in 'Kamala Sundari'. The highest dry matter and starch content of 24.16 % and 22.17 % respectively were observed in 'BCSP-7'. Maximum protein content (2.65%) was found in the cultivar 86×17 followed by DOP MIX 93-13. Bradbury *et al.* (1985b) also reported great variation in protein content among different cultivars of sweet potato. The highest and lowest total sugar content of the tubers were recorded in 'Tripti' (2.74 %) and 'BCSP-5' (1.32 %) respectively. The tubers of 'Kamala Sundari', '90/101' and 'BCSP-7' recorded higher vitamin C content and ranged from

32.14 to 23.47 mg/100g. Two orange-fleshed cultivars ‘Kamala Sundari’and ST-14 recorded an appreciable amount of beta-carotene content ranging from 8.24 to 6.38 mg/100g. Marked variation in chemical constituents of the tubers of different cultivars of orange fleshed sweet potato was also observed by Mitra *et. al*. (2010). Purple-fleshed sweet potatoes were found to contain higher anthocyanin and phenolic compounds. The highest anthocyanin content (16.52 mg/100g) was recorded in the cultivar cross 4 followed by x-24, X-134 and X-140. Maximum total phenol content was also recorded in the tubers of purple-fleshed sweet potato cultivars. The cultivar X-140 had significantly higher amount of total phenols (54.64 mg/100gm) followed by DOP -92-120 (51.52 mg/100gm), 86×17 (49.32 mg/100gm). Guoquan and George (2000) also reported higher anthocyanin content in purple-fleshed sweet potatoes.

Table 1: Yield and nutritional quality of tropical tuber crops

Crops	Tuber yield (t/ha)		Dry matter (%)		Starch (%)		Protein (%)		Total Sugar (%)	
	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Sweet potato	17.23-28.61	23.41	19.47-25.68	23.26	14.61-21.56	19.37	0.69-1.61	1.23	1.23-2.67	1.78
Taro	11.27-16.46	13.57	23.16-27.64	24.31	12.48-16.63	14.48	0.73-1.12	0.94	0.69-1.21	0.93
Elephant foot yam	26.46-47.12	39.53	22.31-26.43	24.17	12.17-16.79	14.59	1.13-1.84	1.43	0.72-1.16	0.91
Yams	19.14-31.62	23.18	27.21-33.19	31.36	21.52-24.37	23.12	1.21-2.58	1.83	0.62-1.11	0.87
Cassava	18.57-27.29	21.27	34.72-37.66	36.19	23.76-26.41	24.58	0.79-1.11	0.86	1.02-1.31	1.14

Average dry matter, Starch and protein content of elephant foot yam corms among different cultivars were 24.17%, 14.59% and 1.57% respectively. Tuber yield of taro varied from 10.12 to 14.87 t/ha among the cultivars. The highest dry matter (29.18 %) and starch (16.62 %) content was recorded in ‘BCC-10’ whereas, the protein content was recorded highest (0.94 %) in BCC-32. Average dry matter, starch and protein content of cassava tubers were 36.19%, 24.58% and 0.86% respectively. Whereas, an average dry matter, Starch and protein content of yam tubers were 31.36%, 23.12% and 1.83% respectively.

The red skinned cultivars of sweet potato like BCSP-5, BCSP-7 and 90/101 with attractive colour and shape rated very high by the farmers which can reduce the health hazard caused by red dye used in colouring the white skinned cultivars. The cultivar BCSP-7 with high starch, protein, vitamin C and low sugars can be used as culinary purposes as a substitute for potato. Consumption of orange-fleshed cultivar like Kamala Sundari with high β-carotene content (8.24 mg/100g) would be helpful in combating night blindness of the children who are at high risk. Purple-fleshed sweet potatoes having high anthocyanin is also gaining importance as a functional food having free-radical scavenging and antioxidant capacities which are linked to a broad-based range of health benefits including improvement in visual acuity and liver function, and the prevention of obesity and diabetes. High yield potential in some cultivars of taro and cassava with good nutritional quality having high starch can find its use in baby foods and diet of people allergic to cereals.

5. STORAGE BEHAVIOUR:

Physiological weight loss (%) in sweet potato:

Significant variation in physiological loss in weight (PLW) was observed among the tubers stored in different storage conditions. In refrigerated storage ($4-5^{0}$C), the tubers exhibited significantly least PLW followed by the tubers stored in cold temperature ($18-20^{0}$C) and ambient ($32-35^{0}$C) storage at 90-95% relative humidity. All the cultivars in different storage conditions exhibited steady weight loss from the beginning of storage, and increased linearly over time. It was observed that different textural changes like shrinkage of skin, change of skin colour due to enzymatic degradation also occurred in the tubers causing postharvest deterioration in quality of tubers. Storage temperature and relative humidity were found to play important roles in the physiological changes of fresh tubers including physiological weight loss. Water loss was rapid at low relative humidity due to the vapour pressure difference between the tubers and surrounding air which is a driving force for moisture transfer from the wet product to the air. The turgidity and freshness of the tubers could be maintained over a longer period at the relative humidity higher than the 90% by checking moisture loss from the tubers.

Rotting (%):

Rotting started in the tubers stored in zero energy cool chamber from the 14^{th} day of storage in all the cultivars of sweet potato irrespective of flesh colour followed by ambient condition from the 21^{st} day of storage. No rotting was observed in the tubers stored in cool room and refrigerator up to 28^{th} days of storage.

6. POSTHARVEST LOSS REDUCTION:

Improvements in the post-harvest handling and processing of tropical tuber crops are necessary to derive maximum benefits from crop production outputs by reducing losses and maintaining product quality and nutritional value. As the tubers are susceptible to physical injury during harvesting and postharvest handling, extra care should be taken to avoid damage to the corms since this may lead to rapid deterioration during subsequent handling and storage. Tubers harvested for fresh marketing need to be washed, sorted, graded and packed in crates for transportation in order to reduce the incidence of mechanical damage to tubers. Tubers destined for storage should be carefully cleaned without washing, and cured properly to enhance healing of any physical injury persisted during harvesting. Some value added products like chips, noodles and alcohol from sweet potato; pickle and dried cubes from elephant foot yam; flakes, pickle and flour from yams; chips and flour from taro, and chips and starch from cassava tubers can be prepared to reduce the postharvest loss of tropical tuber crops.

Though cassava is a good source of energy, its use for food and other industrial products is greatly hampered by its short shelf life and presence of cyanogenic glycosides. Processing plays an important role in the reduction of cyanogens and their derivatives. In order to attain levels within the recommended safe limits set by WHO, initial cyanide content of the tubers should not exceed 250ug/g for efficient processing.

7. CONCLUSION

The orange fleshed sweet potato cultivars like ST-14 and Kamala Sundari having low dry matter can be used as table purpose, and due to their high β-carotene content can be considered ideal for alleviation of Vitamin A malnutrition and thereby combating night blindness in poorer section of people. Purple-fleshed tubers containing higher anthocyanin and total phenol than white fleshed cultivars exert several health-promoting functions in humans. So their consumption should be encouraged. Cultivars with high starch content can be recommended for preparation of value-added food products like alcohol, flour, snacks, noodle *etc.* The cultivars with high protein content can be promoted in the malnourished areas.

Owing to the poor resource base of the farmers, tuber crops based farming system with low input driven production technologies can make a dent in the cultivation scenario of tropical tuber crops. Thus, along with the improved cultivation techniques, proper postharvest handling and processing of the tropical tuber crops can play an important role in upliftment of socio-economic condition of the small and marginal farmers by providing food and nutritional security.

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Table 2: Anti-oxidant and anti-nutritional quality of tropical tuber crops

Crops	Beta-carotene (mg/100g)		Anthocyanin (mg/100g)		Vitamin C (mg/100g)		Phenol (mg/100g)		Anti-nutrients (mg/100g)	
	Range	Ave-rage	Range	Ave-rage	Range	Ave-rage	Range	Ave-rage	Range	Ave-rage
Sweet potato	2.34-9.68[1]	5.82	3.21-17.69[2]	8.47	5.31-23.53	13.76	19.23-53.47	33.29	2.34-11.43[a(d)]	6.72
Taro	0.20-0.32	0.27	-	-	3.21-5.46	4.17	14.21-37.34	21.47	7.23-13.49[b]	8.16
Elephant foot yam	0.21-0.34	0.28	-	-	2.19-4.77	3.74	31.26-55.23	42.18	6.12-14.68[b]	9.27
Yams	0.19-0.31	0.26	5.32-23.41[2]	12.84	4.38-15.13	9.29	21.37-57.86	43.41	9.23-17.61[b]	11.73
Cassava	1.73-2.61	2.19	-	-	4.36-14.27	8.61	27.34-51.21	37.56	0.41-0.47[c]	0.43

[1]orange-fleshed sweet potato; [2]purple-fleshed sweet potato; [a(d)] trypsin inhibitor (mg/g, dry weight basis); [b]calcium oxalate; [c]cyanogenic glycoside

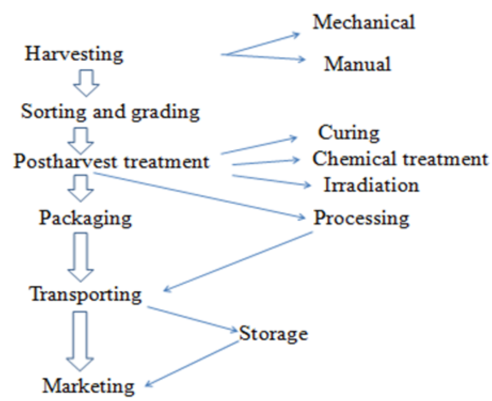

Fig-1. Important steps in post harvest

Table 3: Ideal conditions for storage ofmanagement of tuber crops tuber crops

Commodity	Tempera-ture (^{o} C)	Relative Humidity (%)	Approxima-te storage life
Cassava	0–2	85–90	5–6 months
Sweet potato	13-14	85-90%	4-5 months
Yams	14-15	80-85%	5-6 months
Elephant Foot yam	9-10	85-90%	4-5 months
Taro	9-10	85%	4-5 months

Table 4: Value added products from different tuber crops

Products	Preparation
Sweet potato chips	Tubers were peeled, sliced, blanched and dried in dehydrator.
Elephant foot yam pickle	Corms were peeled, grated, slightly fried with spices, packed in glass jar, kept in Sun for a few days for fermentation. Consumed as a side dish.
Elephant foot yam dried cubes	Corms were peeled, cut into small cubes, soaked in water containing salt, dehydrated in mechanical dryer.
Yam flakes	Tubers were peeled, boiled, mashed, mixed with salt and spices, then thin flakes are dehydrated and packed in polyethylene bags. Consumed either by frying in oil or by making paste with hot water like pounded yam.
Yam pickles	Tubers were peeled, grated, slightly fried with spices, packed in glass jar. Consumed as a side dish.
Yam flour	Tubers were peeled, sliced into thin pieces, dried, ground into powder, sieved and packed in polyethylene lined sacks. Consumed like wheat flour.
Cassava chips	Tubers were peeled, sliced, soaked in water and dried in the Sun.

Table 5. Postharvest behaviour of sweet potato tubers during storage

Cultivar	Nature of deterioration	Storage condition	Duration of storage			
			7 days	14 days	21 days	28 days
Kamala Sundari [1](OFSP)	PLW (%)	Refrigerated storage	1.35	2.46	3.55	4.46
		Cool storage	2.62	4.28	7.24	9.71
		[4]ZECC	3.90	5.70	9.23	13.62
		Ambient storage	5.82	9.76	13.59	17.98
		C.D. (0.05)	1.27	2.41	3.29	3.96
	Rotting (%)	Refrigerated storage	0	0	0	0
		Cool storage	0	0	0	0
		ZECC	0	6.41	11.27	21.12
		Ambient storage	0	0	7.24	15.31