PUBLICATION HQ/027/12

Techpacks for training in on-farm post-harvest, packing and grading systems of Root and Tuber Crops

TECHNICAL REPORT

By

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August 2013

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- *An output of the CFC/EU-financed project: "Increased Production of Root and Tuber Crops in the Caribbean through the Introduction of Improved Marketing and Production Technologies" being implemented by CARDI in Barbados, Dominica, Haiti, Jamaica, St. Vincent & the Grenadines and, Trinidad & Tobago.*

Introduction

Tropical root and tuber crops have been a part of the Caribbean diet from time immemorial. Over the last few decades there has been significant interest in them because of their potential to contribute to food security as well as their health benefit properties.

Apart from the obvious problems associated with production, marketing, etc., there is a plethora of poor postharvest handling practices associated with these crops resulting in high losses to the producer. They require proper handling from the time of harvest so as to significantly improve their shelf life. Adopting proper postharvest handling procedures is also important from a quality and food safety perspective for further processing of these crops.

These roots and tubers may be harvested and marketed at various stages of development.

Both mechanical and manual harvests can be used but, in the Caribbean, most are harvested manually and transported in bulk for sale to wholesalers. Significant packinghouse operations or processing are not common in the Caribbean Region.

Roots and Tubers have several common characteristics. Firstly, they are all storage organs, principally of carbohydrates; secondly, they generally have low respiration rates (depending on their stage of development) and, thirdly, they have a reasonable storage life especially if handled well to avoid growth after harvest by rooting and sprouting.

For the purposes of this study, sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*) and yam (*Dioscorea spp*.) will be used as typical examples of tropical root crops.

POSTHARVEST HANDLING OF SWEET POTATO (*Ipomoea batatas*)

1. **Harvesting**

In the case of sweet potato, harvesting is still done mostly by hand with the use of a garden fork to first loosen the soil and then lifting the vines with the tubers attached; the tubers are then removed from the vines and placed in harvesting crates. Vine-killing chemicals are occasionally used before mechanical harvesting. Caution must be exercised, however, as physical damage during the harvesting operations can be the major cause of postharvest losses.

As with cassava, the ridge and furrow method facilitates harvesting far better than flat beds.

Harvesting can also be done using mechanical harvesters but one needs to pay attention to the depth of the harvesting blade, the speed of the tractor and soil conditions, in an effort to reduce the amount of physical damage to the tuber.

2. Curing

One of the simplest and most effective ways to reduce water loss and decay during postharvest storage of root and tubers is curing after harvest. Curing facilitates healing of minor wounds in certain root crops resulting in substantial improvement in shelf life. It is achieved under specific conditions of temperature and relative humidity over a period of time. Under such conditions, there is the formation of the periderm around the damaged area of the tuber as suberisation of new epidermal tissue takes place forming scar tissue and healing minor bruises on the tubers. The type of wound also affects periderm formation. Abrasions result in the formation of deep, irregular periderm, cuts result in a thin periderm and, compressions and impacts may entirely prevent periderm formation. Careful handling will result in uniform periderm formation and extended storage life.

Curing will not benefit severely damaged tubers. Prior to curing there are several operations including cleaning, grading, sizing, and packing which must be carefully done to maximize the benefits from the process. For the curing process, sweet potatoes are placed in sanitised harvesting trays lined with low density polyethylene liner and placed in a well-ventilated clean sanitized room at a temperature ranging between 32 and 34^{O}C (90 and 93^{O}F) and 90-95% relative humidity for 4-7 days. The tubers are checked periodically for completion of curing.

The process flow chart is shown in Figure 1.

Figure 1: Postharvest handling steps for curing sweet potatoes

Careful harvesting to prevent bruising/damage

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Removal of excess soil

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Nesting crates to pack and transport

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Initial Sorting to remove diseased or severely-damaged tubers and washing
(Dry brush or wash and partially dry, removing excess dirt or moisture)

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Final sorting, sizing and grading

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Chlorinated rinse

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Fungicidal dip

↓

Air drying

↓

Curing

↓

Transport in a timely manner to packinghouse/packing shed

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Store in a cool area

3. **Storage**

When the cycle is well managed, tubers may be stored from 3 to 10 months in mechanically-refrigerated or ventilated storage areas.

4. **Preparation for market**

(i) **Packing -** The tubers are packaged into consumer units (bags, trays) and then placed into master containers or bulk shipping containers (bags, boxes, and bins).

(ii) **Loading into transit vehicles -** Bulk transport can be used for movement to markets or processing plants but, for fresh market, most products are loaded in shipping type containers (pallets for boxes; manually stacked for bags). Room cooling before shipment to market is advised. This should be between 13° to 16°C (55° to 60°F) before shipment after harvesting and, packing.

(iii) **Special treatments -** For storage, sweet potatoes can be sprayed with maleic hydrazide (MH) a few weeks before harvest to inhibit sprouting during storage. Aerosol applications of CIPC (3-chloro-isopropyl-N-phenyl carbamate) can be circulated around stored potatoes to further inhibit sprouting. Rodent control is also necessary in large storage areas.

(iv) **Non-refrigerated storage methods -** Ground storage can be used for several of the tropical and subtropical roots, including cassava. Pits, trenches, and clamps can also be used for storage of harvested tropical roots and tubers. Pits are occasionally used in some areas for short-term, small-scale storage of sweet potatoes while ventilated storage in cellars and warehouses is also used.
Facilities with temperature and relative humidity controls provide forced-air circulation through bulk piles of potatoes or onions, or through and around stacks of bulk bins: these are only justified when volumes of production are significant.

(v) **Recommended storage conditions -** The general storage recommendations are based on the fact that most roots and tubers are chill-sensitive. While some can be successfully field-stored e.g. cassava, others will deteriorate rapidly if harvested and not treated.

5. **Postharvest losses**

The major causes of postharvest losses are:

- Mechanical damage due to poor handling.
- Pest damage due to sweet potato borer.

- Rotting due to fungal and bacterial infection.

6. **Quality requirement for sweet potato for proper curing**

- Red skinned and of full maturity.
- The skin must be intact with all bruised properly cured.
- Free from pests and postharvest rots.
- Free from chemical residues.

These quality requirements can be easily met if the appropriate postharvest handling steps are followed.

7. **Maturity indices**

Several key indicators can be used to determine maturity, namely:

- Latex exudation: If the tubers are immature then the latex turns black almost immediately after snapping the vine from the tubers.
- Dryness of tissue after cutting: samples of tubers can also be cut into small pieces and observed. Cut pieces from mature tubers tend to dry out very rapidly after cutting. Immature tubers remain moist on the cut surface.
- Leaf yellowing: As the tuber matures the leaves on the vine tend to yellow.

8. **Field grading, field storage and transportation**

Tubers should be graded in the field. Tubers which show visible symptoms of rotting or damage due to sweet potato borer should not be taken to the packinghouse. Selected tubers should be placed in harvesting crates and kept in a cool area before transportation as soon as possible to the packinghouse.

Tubers should be transported out of the field during the cooler part of the day. Transportation in vehicles with covered trays is preferred.

9. **Packinghouse operations**

a. **Whole tubers**

On arrival at the packinghouse the operations are similar to the steps prior to curing as described earlier. Tubers which show visible symptoms of microbial or other damage are removed and immediately destroyed. Following air drying, the tubers can be offered for immediate sale.

b. **Damaged tubers**

Tubers which have been severely bruised and will not benefit from curing should be washed, peeled, cut into pieces and placed in clean potable water. They are given a final rinse followed by air drying and freezing.

Citric acid can be used as a final dip to prevent browning which is a far more serious problem if the tubers brought to the packinghouse are immature.

10. **Postharvest storage rots**

Poor postharvest handling practices starting in the field can lead to storage rots of sweet potato. Some of the important postharvest rots are black rot, Java black rot, rhizopus soft rot and bacterial soft rot.

11. Pest problems affecting postharvest quality

The sweet potato borer is a field problem which can cause major postharvest losses. Holes on the surface of the tubers together with the presence of rots may indicate its presence. If the tubers are cut then tunneling becomes apparent and larvae of the borer are often present inside the tunnels. Field inspection and borer control should be conducted.

12. Conclusion

Appropriate technology is available and should be used during postharvest handling operations for sweet potato. If these practices as outlined above are followed, then benefits will accrue through shelf life extension, maintenance of good quality and, consumer confidence in the products. On the other hand, failure to adopt good postharvest practices will result in high losses.

POSTHARVEST HANDLING OF CASSAVA (*Manihot esculenta*)

Cassava roots are primarily organs which store starch. The harvested roots are generally swollen adventitious roots. If the plant originated from seeds the tap root also becomes swollen and stores starch. Cassava is a highly perishable tuber crop. Extreme care must be taken along the entire chain of operations from harvesting to marketing if the integrity of the tubers are to be maintained.

Cassava contains compounds, namely, cyanogenic glucosoides. It also contains cyanohydrins and hydrocyanic acid (HCN) which are formed as a result of the metabolism of cyanogenic glucosides. Accumulation of cyanogenic glucosides is depenedent upon many factors. From a postharvest quality and food safety perspective, varietal differences are known to occur. There are some varieties which should be harvested early (6-7 months) after planting since leaving them in the field for a longer period, increases the accumulation of cyanogenic glucosides.

1. Postharvest losses

The primary cause of spoilage in cassava is a phenomenon referred to as cassava root deterioration. Two types of deterioration occur, namely, a primary physiological deterioration and, a secondary deterioration due to microbial spoilage.

The initial physiological response is brought about due to damage of the roots during postharvest operations. Once the roots are damaged, phenolic compounds present in the tissue are converted to coloured compounds called quinines. The process is catalysed by an enzyme, polyphenol oxidase, acting on the phenolic compounds in the presence of oxygen; moisture loss further exacerbates the conditions.

This primary response expresses itself as a blue-black discolouration of the internal tissue in the roots and is often referred to as vascular streaking. Initially the streaking is observed along the vascular bundles but eventually the entire starchy flesh parenchyma becomes discoloured. Even small damage to the peel is sufficient to cause vascular streaking.

Following this primary response, microorganisms enter in parts of the roots that have been damaged resulting in the secondary deterioration (Figure 2a and 2b):

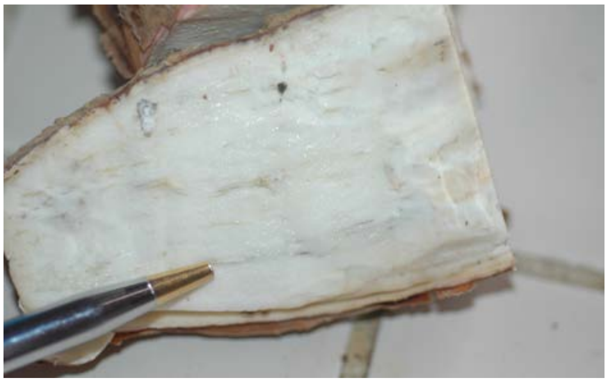
Figure 2a. Vascular streaking of cassava roots.


Figure 2b. Secondary infection of roots.

2. Key steps in the postharvest handling of cassava roots.

Quality requirement

Harvested cassava roots should be:

- Free from soil and other organic matter.
- Free from mechanical bruising.
- Free from pests.
- Free from rotting.
- Free from vascular streaking.

Under conditions typical of the Caribbean Region, there are several reasons for rapid quality loss in harvested cassava roots, including:

- Poor harvesting technique.
- Poor choice of field packaging material.
- Poor field storage practices.
- Rough handling during postharvest operations.
- Poor transportation.
- Inappropriate packinghouse handling and retail display of roots.

A flow chart (Figure 3) of the postharvest unit operation for cassava is given below. Each step, from the point of harvest to final consumption must be carefully done if quality is to be maintained.

Figure 3. Postharvest handling steps for Cassava roots.

Harvesting and field sorting

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Temporary field storage

↓

Transportation to packinghouse

↓

Initial sorting and washing

↓

Final sorting

↓

Chlorinated rinse

↙ ↘

Postharvest treatment of whole roots | Further processing of broken roots

3. Maturity indices

Knowing when the roots are ready for harvest is a key first step in ensuring roots with good eating quality. Generally, if harvesting is delayed, the roots will become "brittle" when cooked and be of poor eating quality, a condition often described by consumers as "past'. While there is still debate as to what actually happens, it is believed that after the accumulation of maximum starch in the roots, the plant tends to remobilise the starch to sugars to facilitate new shoot growth and, therefore, the roots lose their "mealiness" when cooked.

Generally, leaf yellowing is a good indicator of root maturity. The time from planting, eating quality and, the special requirement of some varieties due to high cyanogenic glucoside accumulation, are also important considerations in the determination of time of harvest.

4. Harvesting, field handling and field grading.

Under ideal conditions, the stems are cut leaving about 40-50 cm (18-24 inches) above the ground. The roots are left for a further 2 weeks in the soil before harvesting. This technique is believed to facilitate filling out of the roots with starch resulting in a superior product. In areas subject to a praedial larceny problem, this practice will be difficult to implement.

Once the roots are ready for harvesting, they should be carefully removed from the soil. Ridges facilitate the easiest harvesting of roots when compared to the other systems of bed formation. Since the roots are generally confined to the ridges, the edges of the ridges are loosened with a garden fork and the cluster of roots removed from the soil. When grown on flat beds and or cambered beds, it is difficult to know exactly where the roots are and, therefore, a greater likelihood that they will be punctured during harvesting operations.

The root clusters are separated into individual roots by cutting above the swollen storage roots leaving a piece of woody tissue attached to each root.

Harvested roots should be placed in harvesting crates and kept in a cool part of the field. The practice of placing roots in bags or sacks has the distinct disadvantage of increasing the chances of damaging them, especially during transportation, resulting in a greater incidence of spoilage. When harvesting crates are used, less damage is likely to occur.

5. Field grading

Another good practice is to sort roots in the field. Because of the very nature of the crop, some amount of damage is expected during harvesting operations. It is a very good practice to separate damaged roots from whole undamaged ones. Roots that show visible symptoms of rotting should be removed at this stage and not transported to the packinghouse.

6. Packinghouse operations

On arrival at the packinghouse, roots should be treated and prepared for market as soon as possible. Failure to do so will result in greater postharvest losses. Wetting the roots will reduce moisture loss and will help to reduce vascular streaking. Damaged roots should be treated first since they are the most perishable.

7. Handling damaged cassava roots

Damaged roots are best utilised in processing into value-added products since they will deteriorate rapidly if sold fresh. Broken wholesome pieces may be processed into cassava flour, frozen cassava chunks or frozen grated cassava. The important unit operations involved are shown in Figure 4.

Figure 4: Steps in handling damaged cassava roots for further processing

Washing

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Chlorinated rinse

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Peeling

↓

Further processing

8. Treating and handling whole roots

Even whole roots will deteriorate rapidly if they are not treated and stored properly in a timely manner. Operations that should be carried out are as shown in Figure 5.

Fig 5: Postharvest treatment steps for whole cassava

Preliminary sorting

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Wash to remove soil

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Final sorting

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Rinse in chlorinated dip at 100 ppm chlorine

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Rinse in potable water/ fungicidal dip

9. Storage

Place in sanitised crates between layers of sanitised wet jute sacks for immediate sale. The sacks are wetted periodically to maintain quality.

Moisture barriers may also be used. Roots can be stored after postharvest treatment in sealed low density or high density polyethylene bags. They can also be waxed with food grade paraffin wax.

10. Variety and maturity indices for some cassava varieties (Table 1)

Table 1. Variety and maturity indices for some cassava varieties.

Variety	Time from planting to harvesting (months)
Maracas black stick	9-10
White stick	9-11
M. Mex 59	7-11
Butter stick	9-10
CMC 40	9-11
M Col 22	5-7

Note: Varieties CMC 40 and M.Col 22 accumulate high levels of HCN in the flesh and should be harvested at the stipulated time.

POSTHARVEST HANDLING OF YAM (*Dioscorea spp.*)

1. Pre-harvest operations

Maturity assessment is critical to achieving good quality yam. In the field, the mature crop is generally distinguishable by cessation of vegetative growth and yellowing of leaves.
The period from planting or field emergence to maturity is variable depending on the species and hence there is no standard reliable and objective index of yam tuber maturity. The most frequently reported measure is the period from planting to harvest (growing period), but it has been suggested that the time from emergence to maturity provides a better measure of growing period since planted tubers can remain dormant for some time.
Most edible yams, however, reach maturity 8-11 months after planting. Techniques such as using physiologically-aged planting material, pre-sprouting of sets, application of sprout-promoting substances (e.g. ethephon and 2-chloroethanol) and harvesting before complete shoot senescence can decrease field dormancy and thereby reduce the length of the period from emergence to maturity.

2. Harvesting

Harvesting is generally done by hand using spades or diggers. Spades made of wood are preferred to metallic tools as they are less likely to damage the fragile tubers; however, this type of tool needs regular replacement. Yam harvesting is a labour-intensive operation that involves standing, bending, squatting, and sometimes sitting on the ground depending on the size of mound, size of tuber or depth of tuber penetration.
In forested areas where yams are “dug”, tubers growing into areas where there are roots of trees can pose a problem during harvesting and often receive considerable physical damage. Many also get deformed during growth as a result of the obstacles they encounter. These tubers are usually downgraded.
Current crop production practices and species used pose considerable hurdles to successful mechanisation of yam production, particularly for small-scale rural farmers. Extensive changes

in current traditional cultivation practices, including staking and mixed cropping, and possibly tuber architecture and physical properties, will be required to allow mechanization; however, yams can be harvested during the cropping cycle to obtain a first (early) and second (late) harvest. The first harvest has been referred to by the terms ”topping‟, “beheading‟, and “milking‟.

In single harvesting, each plant is harvested once and this occurs at the end of the cropping cycle when the crop is mature. The harvesting process involves digging around the tuber to loosen it from the soil, lifting it, and cutting from the vine with the corm attached to the tuber. The time of harvest is critical in terms of tuber maturity, yield and postharvest quality. Depending on the cultivar, the period from planting or emergence to maturity varies from about 6 to 7 months to as long as 10 months. The first harvest is carried out by removing the soil around the tuber carefully and cutting the lower portion, leaving the upper part of the tuber or the “head” to heal and continue to grow. The soil is returned and the plant is left to grow until the second harvest. Some yam cultivars produce several small tubers in the second growth following the early harvest.

3. **Transport and packaging**

Packaging tubers in full telescopic fibreboard cartons with paper wrapping or excelsior reduces bruising and enables large quantities of tubers to be transported over long distances. Tubers can be placed in loose packs, or units of 11 kg and 23 kg. The cartons are hand-loaded or unitised on pallets. Storing yams in modified atmosphere packaging (MAP) has beneficial effects, particularly if using appropriate packaging material with suitable size and number of holes for gas permeation. Sealing yam tubers in polyethylene bags reduces storage losses due to weight loss and development of necrotic tissue.

Coating tubers with Epolene E10 (a commercial vegetable wax) improves their appearance but there is no effect on levels of fungal infection.

4. **Curing of yam tubers**

Curing of root crops allows suberisation of surface injuries and reduces subsequent weight loss and rotting. Curing of yams is recommended before storage so as to “heal” any physical injury, which may have occurred during harvesting and handling. This can be accomplished under tropical ambient conditions or in a controlled environment. Traditionally, yams are cured by drying the tubers in the sun for a few days. The optimum conditions for curing are 29°-32°C (85°-90°F) at 90-96% relative humidity (RH) for 4-8 days. It has been found that tubers cured at higher temperatures (>40°C, 104°F) for 24 hours or treated with gamma radiation at 12.5 krads were free of mold and had least losses during subsequent storage. Storing at 15°C (59°F) with prompt removal of sprouts has been found to improve the eating quality of tubers, presumably due to the water loss associated with curing and the inhibition of the biochemical synthesis that accompanies sprouting.

5. **Cleaning**

Prior to long-term storage and marketing, yams are cleaned (without water) by scraping off soil and other debris on the surface. A knife or piece of stick is usually used. The root hairs are also removed so that the tuber has a smooth surface. Water must not be used to clean tubers before storage because of increased susceptibility to microbial infection and growth under the ambient humid storage conditions.

6. Storage

Three main conditions are necessary for successful yam storage, namely: aeration, reduction of temperature and, regular inspection of produce. Ventilation prevents moisture condensation on the tuber surface and assists in removing heat of respiration. Low temperature is necessary to reduce losses from respiration, sprouting and rotting; however, cold storage must be maintained around 12°-15°C (55°-60°F) as below this temperature physiological deterioration such as chilling injury occurs. A relative humidity (RH) of 70-80% is required. Regular inspection of tubers is important to remove sprouts, rotted tubers, and to monitor the presence of rodents and other pests.

In general, tubers should be protected from high temperatures and provided with good ventilation during storage. The storage environment must also inhibit the onset of sprouting (breakage of dormancy) which increases the rate of loss of dry matter and subsequent shrivelling and rotting of tubers. Notwithstanding cultivar differences, fresh yam tubers can be successfully stored in ambient and refrigerated conditions. Optimum conditions of 15°C or 16°C or 70% RH have been recommended for cureransit and storage life of 6-7 months can be achieved under these conditions.

Yam tuber decay occurs at higher humidity, and like most tropical crops, they are susceptible to chilling injury at low storage temperatures.

There are several traditional conditions used for yam storage, including: (a) leaving the tubers in the ground until required, (b) the yam barn, and (c) underground structures. Leaving the tubers in the ground until required is the simplest storage technique practiced by rural small-scale farmers. When carried out on-farm, this type of storage prevents the use of the farmland for further cropping. Harvested yams can also be put in ashes and covered with soil, with or without grass mulch until required. The yam barn is the principal traditional yam storage structures in the major producing areas.

7. Post-harvest losses

Post-harvest losses occur at various stages from production, postharvest handling, marketing, distribution and processing. These include losses in quantity and tuber quality, arising from physical damage, rodent attack, fungal and bacterial diseases, and physiological processes such as sprouting, dehydration, and respiration. Weight loss during storage in traditional or improved barns, or clamp storage can reach 10-12% in the first 3 months and 30-60% after 6 months.