CARIBBEAN TECHNOLOGICAL CONSULTANCY SERVICES NETWORK

CTCS

CARIBBEAN DEVELOPMENT BANK

TECHNICAL INFORMATION PACKAGE
ON POSTHARVEST HANDLING
OF PERISHABLES
VOLUME IV - ROOT CROPS

Prepared by:
Ena C. Harvey
For Technology and Energy Unit
P.O. Box 408, Wildey
St. Michael
BARBADOS

November, 1986

ACKNOWLEDGEMENT

Published with financial support from
INTERNATIONAL DEVELOPMENT RESEARCH CENTRE, CANADA

ACKNOWLEDGEMENTS

The Author gratefully acknowledges the kind assistance of:

1. Ministry of Agriculture, Lands and Fisheries, St. Lucia in general, and Mr. A. Satney in particular, for organizing a comprehensive tour of local postharvest handling operations.

2. The National FoodCrop Farmers' Association (NFFA) of Trinidad & Tobago, for providing useful information on local handling of specific vegetables.

This Technical Information Package on Postharvest Handling of Perishables consists of four (4) volumes:

VOLUME I - FRUITS

VOLUME II - FRUIT VEGETABLES

VOLUME III - LEAFY VEGETABLES

VOLUME IV - ROOT CROPS

ABSTRACT

High rates of moisture loss, susceptibility to damage and infection, sprouting and regrowth are identified as the major constraints to extended postharvest life of tropical root crops. Traditional and state-of-the-art methods for harvesting, curing, storage and disease control are reviewed, and recommendations are made on effective techniques for minimization of postharvest deterioration. Special emphasis is given to careful handling and temperature management since these play a major role in the extension of shelf life.

Recent developments in the mechanical harvesting of cassava, and treatments for the prevention of vascular deterioration in cassava roots are discussed.

Finally, investment opportunities in fresh produce handling, together with requirements for such investment are outlined. A list of suppliers for common types of equipment used for fresh produce handling is also compiled.

KEYWORDS: Root Crops, Postharvest Technology, Cassava, Tannia, Dasheen, Eddoe, Yam, Sweet Potato, Irish Potato, Harvesting, Storage, Curing, Packaging, Investment Opportunities.

SUMMARY

The Manual presents postharvest requirements for handling tropical root crops. General and specific recommendations are given on harvesting, field temperature management, curing, storage, pest and disease control, packaging and utilization. Crops discussed are aroids (dasheen, tannia, eddoe), cassava, potato (English and sweet), and yam.

Methods and techniques presented have been tested in the Caribbean Region, Latin America, Africa, South East Asia and Hawaii. Many of the methods are used commercially and are effective, as well as economical.

Possible investment opportunities in fresh produce handling, together with requirements for such investment are outlined. A list of suppliers for common types of equipment used in fresh produce handling is also compiled.

TABLE OF CONTENTS

1. INTRODUCTION

At the First International Symposium on Tropical Root Crops held in 1967, the role of root crops as important food and industrial materials, and their yield potential, in comparison to other crops were recognized. Up until then, many root crops were either regarded as inedible or poisonous foods, utilized by the tropical peoples of the world. Root crops play a major role in the nutrition of millions of people. Cassava provides a nourishing staple for 200 to 400 million inhabitants of countries including Africa, Brazil, India, Asia, Latin America and the Caribbean. Yams are major staples in Africa and the Caribbean and the aroids and sweet potato constitute important staples in Hawaii, South East Asia and the Caribbean.

Despite their importance, however, root crops have not yet been accorded the status which they deserve. In most of the producing countries, including the Caribbean, small farmers still use production methods which are laborious, tedious and time consuming. In addition, yields are often low and postharvest losses are high.

Poor methods of harvesting, handling and storage are the major cause of high postharvest losses. Significant reductions in these losses can be achieved by applying simple techniques which can be effectively and economically implemented by the farmer.

In this Manual, recommendations are made on the postharvest management of root crops in general, and detailed techniques are given for selected species. Emphasis is placed on methods and techniques which are effective and which can be easily implemented within existing root crop production and marketing systems in the Caribbean.

2. BACKGROUND

POSTHARVEST MANAGEMENT OF ROOT CROPS

Tropical root crops are highly perishable. Their bulkiness, high moisture content and thin skins predispose them to physical injury, moisture loss and easy attack by pests and diseases. In addition, root crops (except cassava) undergo cyclic growth involving dormancy, sprouting and regrowth. Sprouting marks the end of postharvest life of the tuber and is one of the major factors causing postharvest loss.

The quality of harvested tubers is affected by both pre- and post-harvest factors. Preharvest operations such as cultivar selection and crop management (fertilization, irrigation, pest and disease control, pruning) therefore need to be considered in the development of methods and techniques for extending the shelf life of harvested tubers.

2.1 Variety Selection

Most of the root crop varieties used have been developed by a process of selection for characteristics such as yield, seasonality, climatic adaptability, disease/pest resistance, storage and shelf life qualities. Size, shape, flesh colour , flavour and texture also play important roles in variety selection.

2.2 Harvesting and Field Handling

2.2.1 Maturity Indices

Common indices used to determine whether the crop can be harvested include the time from planting to harvesting, and field indices such as wilting and senescence of foliage. In most systems however, the crop is harvested over a long period of time depending on the market demand. Although this practice may tie up land unnecessarily, it provides the farmer with a convenient form of storage for the highly perishable roots. Tubers should not be left unharvested for prolonged periods, however, since they become woody and prone to attack by soil pests.

Manual harvesting methods predominate in the Region. Common implements used include wooden digging sticks, and garden tools such as forks and spades. Damage levels are usually high (25-30%) with manual harvesting.

Root crops grown in pure stand have been successfully harvested in Barbados since 1972 using the Barbados Root Crop Lifter (Harvey and Jeffers, 1973). More recently, another lifter, produced by Carib Agro-Industries Ltd has become commercially available and can be used for a variety of root crops. This machine has a higher draft requirement than the Barbados Root Crop Lifter and its depth of operation does not allow for lifting of the larger varieties of cassava. It is also more expensive. A number of aids for harvesting cassava have also been developed in Brazil and Colombia.

2.2.2 Field Handling

Root crops should be harvested in good weather since the presence of moisture on the surface of tubers encourages infection. If roots are harvested under wet conditions, they should be dried properly before being put into storage.

Careful handling is critical. Tubers are very susceptible to abrasion, compression and impact bruising. Care should therefore be exercised in the removal of the root from the soil and in the packing and stacking of field containers. It is not always advisable to remove adhering soil since the soil may act as a buffer against injury during transport and subsequent handling. Container surfaces (particularly wooden surfaces) should be inspected to determine the potential for injury to the produce.

Protection during transport out of the field can be improved by:

- grading access roads to eliminate ruts, potholes and bumps which cause vibration bruising,
- restriction of transport speeds to levels that will avoid free movement of individual units of produce,
- reduction of tyre pressure on vehicles to reduce shock transmission to produce,
- use of air suspension systems on transport vehicles.

2.3 Postharvest Treatments

2.3.1 Curing

Unlike other perishables which are precooled, root crops are usually subjected to a high temperature/high humidity treatment immediately after harvest. This treatment, termed curing, is necessary for the promotion of wound healing and the formation of a thick periderm which effectively retards moisture loss and protects the tuber from infection.

Curing takes place naturally when the harvested tubers are left in the field at ambient conditions. In the case of potatoes, vine killing before harvest encourages natural curing in the soil, before the tubers are lifted. In some areas of Latin America, China and South East Asia, the high temperature and high relative humidity required for curing are created by piling the tubers in specially built clamps containing alternating layers of tubers and soil and/or grass. A lamp is sometimes provided for added heat and also for smoke, which augments the curing effect. Ash is sometimes applied to cut surfaces of tubers to promote the formation of scar tissue.

Artificial curing is usually done in environmentally controlled rooms which maintain a fixed temperature and relative humidity for a specified period of time. Curing rooms are often used for subsequent storage.

2.3.2 Washing

Adhering soil on harvested tubers harbours soil pathogens and also iterferes with cooling and respiration. Tubers intended for storage should therefore be washed. If the soil has hardened onto the surface, it is advisable to soak the roots before brushing off the loosened soil. Tubers should be dried properly before they are put into storage. This can be done by circulating warm air over them for a few minutes.

2.3.3 Grading/Sorting

Manual grading or sizing may be done. Training of workers in grading techniques and careful handling is important.

2.3.4 Storage

Once the tuber is well cured, it should be cooled to a low safe temperature in order to retard respiration rate, sprouting and rooting. Retardation of respiration is necessary for control of the conversion of starch into sugar, which has deleterious effects on texture, flavour and taste of the tuber and its processed products. Tropical root crops are susceptible to chilling injury and maintenance of recommended temperature and relative humidity levels is critical.

The maintenance of adequate air circulation in the storage room is also critical since the buildup of carbon dioxide causes physiological injury. Stacking methods should therefore allow for adequate air exchange for respiration. It is also important to use bags with a wide mesh so as to facilitate air penetration. When root crops are stored in bulk, the height of the pile is the major factor affecting air circulation.

Storage with ethylene-producing commodities such as fruits and fruit vegetables should be avoided since ethylene encourages sprouting.

2.3.5 Pest and Disease Control

Root crops are commonly attacked by wound-invading fungi and bacteria which enter via cuts, wounds and bruises. They may also be infested with soil pests such as nematodes and weevils, especially if they are 'stored' in the soil for a long period of time.

An integrated preventive approach should be employed in the strategy for control of postharvest pests and diseases. This includes the use of resistant varieties; field control of pathogens and their vectors, especially those which give rise to latent infections; careful harvesting and handling; reduction of inoculum levels by strict attention to sanitation of harvesting tools, field containers, packinghouse equipment, water for soaking and washing; prompt separation of decayed and sound produce; and good control of temperature and humidity levels in storage.

The physiological and physical condition of the produce and the type of postharvest handling it receives also have a great effect on the losses incurred. Tubers with high vitality exhibit considerable resistance to bacterial and fungal attack compared to stressed or senescent produce which is often disease-prone. Handling procedures should therefore emphasize methods which maintain product quality and which, directly or indirectly limit the potential for invasion and development of pathogens.

Where chemical control is necessary, storage diseases can be controlled with the application of benzimidazole fungicides.

2.3.6 Sprout Inhibition

The length of the dormancy period varies with variety, conditions during growth, date of harvesting and the storage temperature.

Sprouting may be suppressed by the pre- or post-harvest application of sprouting inhibitors. These include chemicals such as maleic hydrazide (pre-harvest), CIPC (iso-propyl-(chloro)phenyl carbamate) and gibberelic acid (GA_3). Sprout suppressants can be applied as dusts, dips or vapourized liquids.

2.3.7 Other Treatments

Protective packaging such as plastic films, bags and liners, and surface coatings such as waxes are very effective in restricting moisture loss and they have been used with varying degrees of success on tropical root crops. Most plastics are impermeable to gases and ventilation holes must be provided to allow for the necessary exchange of oxygen and carbon dioxide. High humidity within the package can result in condensation of moisture which encourages the development of decay-causing organisms. Wax coatings must also be very thin so as not to interfere with gas exchange.

2.3.8 Packaging

Root crops may be field-packed into woven polypropylene sacks, wooden crates or woven baskets. These containers are also used for wholesale marketing. While they have advantages of high capacity and economy, these containers have poor compression characteristics and frequent recycling often exposes produce to the risks of injury and infection.

Ventilated bags, plastic crates and fibreboard cartons offer advantages over these traditional types of containers with respect to the degree of protection offered, ease of cleaning and utilization of space.

2.4 Transport

Recommended methods and techniques for proper handling of vegetables during transit deal mainly with the choice of carrier, the use of efficient loading patterns and management of temperature, relative humidity and levels of gases such as CO_2, O_2, ethylene and other volatiles in the product environment.

2.4.1 Choice of Carrier

Air freight and refrigerated transport are the two modes of transport available for the export of perishables. The small schooners used in the intra-egional trade are highly unsuitable, in terms of the poor handling of the produce and the lack of proper controls for maintaining the recommended levels of temperature and relative humidity. The high cost and limited capacity of air shipment, on the other hand, often outweigh the advantages of the relatively shorter transit time.

2.4.2 Loading and Environmental Control

Uniform temperature control and maximum utilization of available refrigeration are highly dependent on the loading pattern and on good air circulation throughout the load.

A good loading pattern should:

- provide a network of channels to allow uniform air circulation throughout the load such that produce temperatures are maintained at optimum levels.
- be sufficiently stable to remain intact during transit, to help prevent container failure and/or commodity damage.
- utilize the inherent strength of the package.

3. TECHNOLOGY

3.1 AROIDS

3.1.1 Botanical Name: Colocasia spp.; Xanthosoma spp.

3.1.2 Descriptors: **Colocasia esculenta var antiquorum** (L) Schott - eddoe
Colocasia esculenta var esculenta (L) Schott - dasheen, taro:
Xanthosoma spp - tannia, new cocoyam, yautia, tanier.

3.1.3 Importance

Nutritional. Aroids are major carbohydrate sources for millions of people in the Pacific Islands, Africa, South East Asia, the Far East and the Caribbean. The protein content of dasheen and tannia is slightly higher than that of yam, cassava or sweet potato. The tubers also contain appreciable amounts of vitamin C, thiamin, riboflavin, niacin, calcium, phosphorus, iron and potassium. Dasheen and tannia leaves are rich in protein (23%), minerals (calcium, iron and phosphorus) and vitamins (C and B complex).

Economic. World production of aroids has increased only slightly within the last few years. The crop suffers severe competition, in producing countries, from yam and cassava. Some of the difficulties associated with the crop include problems of breeding, storage, pests and diseases control and laborious methods of production.

Taro starch has great potential in both food and manufacturing industries. The Hawaiian food poi, made from taro starch is hypoallergenic and is well adapted for specialty diets. The extremely fine texture of taro starch makes it superior to other starches such as corn, tapioca and potato as a basic ingredient in the manufacture of biodegradable plastics.

3.1.4 Variety Selection

Cultivars are distinguished on the basis of corm size, shape, flesh colour, colour of lamina, veins and petioles, acridity of tuber and leaves, and starch properties. Table 1 outlines the regional distribution of aroid cultivars.

Table 1. Regional distribution of aroid cultivars

Country	Tannia	Dasheen	Eddoe
DOMINICA	Rabess Jamaic Smooth white Chou Bouton Toby	Common Soufe Noir Blanc	Dasheen Chou
ST. VINCENT	Barbados Red Seed John Short South River Grand Bay	Common	Black White
ST. LUCIA	White Yellow Jamaique	White Common	
TRINIDAD & TOBAGO	White Blue		

Source: Adams, H. CARDI Annual Report, 1984

In St. Vincent, tannia cv. Barbados White is grown for export due to its early maturity. The Trinidad Blue cultivar is favoured for its yield and taste.

3.1.5 Harvesting and Field Handling

The time from planting to harvesting varies with cultivar and method of cultivation. Dasheen is ready for harvest 6-18 months after planting while tannia and eddoe require 9-12 and 5-8 months, respectively. Common field indices include yellowing and withering of the leaves, decrease in growth, reduction in leaf number and leaf area, shortening of the leaf petiole and decrease in height of plants in the field.

No serious deterioration occurs if the crop is left in the ground for a few weeks after maturity and, to some extent, harvesting is normally done at the farmer's convenience. However, if rains occur after maturity, or harvesting is delayed too long, growth may resume, resulting in the production of new roots which makes harvesting difficult.

Tubers are harvested manually with the aid of tools such as cutlasses, forks and digging sticks. Care should be taken to avoid injury since heavy losses are easily incurred. In upland culture, pulling of withered aerial portions of the plant is sometimes enough to lift corms and cormels. In flooded systems, the root system is severed with a rod measuring 1-2 m, before the tuber is prised from the soil. Mechanical harvesting, using yam and root diggers, often results in high levels of damage (4-6% higher than manual methods).

Tuber damage can be reduced in wetland cultivation by draining fields 3-4 weeks before harvest. This reduces root volume and facilitates easier removal. In cases where *Phytophthora colocasia* leaf blight is a problem, removal of infected leaves before harvest could prevent contamination of corms by spores washed from leaf lesions. In Fiji, petioles are cut to 30 cm and left intact to prolong storage life of tubers.

3.1.6 Postharvest Treatments

3.1.6.1 Curing

Curing at 25-30°C and 95-100% relative humidity is recommended for the promotion of wound healing and periderm formation. The application of ash to cut surfaces and curing with smoke appear to aid the healing process.

3.1.6.2 Pest and Disease Control

Ashing of baskets used to store dasheen is reported to be effective in reducing termite damage. Dasheen, unlike tannia and eddoe, rots within a week of harvest. Corm rot may be caused by a number of organisms which include *Phytophthora*, *Pythium* , *Fusarium*, *Sclerotium* and *Botrydiplodia spp.*. Broad-spectrum fungicides are often used: dipping dasheen corms in Benomyl solution (500 ppm) reduced the incidence of corm rot in Jamaica (Been *et al.* 1975). Treatments with 250 ppm Ridomil (MX 58: 10%

metalaxyl and 48% mancozeb) mixed with 500 ppm benomyl effectively prevented dasheen corm rot up to 22 days. Corm treated immediately after harvest with both mixtures, stored well for up to 4 weeks and corm quality was satisfactory at 6 weeks. The use of benomyl or sodium hypochlorite dips, combined with storage in polyethylene bags, prolonged storage life of dasheen in the Solomon Islands to one month. Sodium hypochlorite has the advantages of economy, safety and no harmful chemical residues.

3.1.6.3 Storage

Varietal differences in storage exist among tannia, dasheen and eddoe cultivars and several storage techniques are reported. Traditional techniques include storage in pits, ashed baskets, raised rafters and ventilated huts. These methods are practical, low cost and effective.

In Trinidad, tannia was stored for 8 weeks and dasheen, for 2 weeks, at ambient conditions, without appreciable loss in eating quality. Underground storage in pits is common in Egypt and Samoa for dasheen and for tannia in the Cameroun. Storage of dasheen in pits extends storage life to 4 weeks and corms can last up to 2 months when stored in straw impregnated with boric acid. In the Cameroun, pit storage of tannia was more satisfactory than storage in trays in well-ventilated huts (Adams, 1984).

Low temperature storage, (7-10^{o}C) often augmented with chemical treatments for prevention of infection and sprouting, can extend the storage life of dasheen by 3 to 6 months. Storage at temperatures less than 7^{o}C results, however, in death of buds and corm decay.

3.1.6.4 Packaging

Corms may be packaged in polyethylene and woven polypropylene bags, fibreboard cartons or Bruce boxes. Moistened and/or fungicide-impregnated packing materials may be incorporated in cartons and wooden boxes. For export, individual corms should be wrapped in plain white paper or coir powder.

3.1.7 Utilization

Tubers can be processed into a wide variety of products such as canned, frozen and dehydrated foods. Flours and starches can be used in a number of extruded snack food items, instant juice mixes and bakery items. The leaves of the plants can be used as a vegetable.

3.2 CASSAVA

3.2.1 Botanical Name: Manihot esculenta (Crantz)

3.2.2 Descriptors: Cassava, manioc, yuca, aipim, cassada

3.2.3 Importance

Nutritional. Cassava is primarily a source of carbohydrate. Its food composition is similar to that of other starchy roots but its protein content is somewhat lower. It is relatively rich in calcium and ascorbic acid, with nutritionally significant amounts of thiamin, riboflavin and nicain. All varieties of cassava contain prussic acid (hydrogen cyanide) in amounts which vary from harmless to lethal. The compound is removed by normal processing of the raw tubers and therefore presents no hindrance to their food value. Cassava is one of the most economical sources of calories, providing some 200-1000 calories per day to 700 million people.

Economic. The cassava plant has a high biological efficiency which is attributable to its drought resistance, unique ability to grow in poor soils, tolerance to poor husbandry and relative resistance to weeds and pests. It is one of the highest yielding plants in the vegetable kingdom and may well be the largest single cultivated crop in the tropics.

The importance of cassava as an industrial material is rapidly increasing. Cassava starch is used in the manufacture of sandpaper, cardboard, charcoal briquettes, dolls, flashlight batteries, moulded plastic toys, antihalation powders, photographic film and adhesives. As a food processing ingredient, cassava starch is superior to corn, wheat or potato starch becase of its bland flavour and excellent freeze-thaw stability. It is used as a diluent in chemical and drug manufacturing industries and as a carrier in cosmetics, pills and capsules. It is also used in drilling muds and in the manufacture of explosives.

Cassava also provides the raw material for the production of industrial alcohol, a renewable energy resource which has the potential for replacing a significant percentage of petroleum.

3.2.4 Variety Selection

Cassava varieties are broadly classified into two main classes, based on their HCN content:

- Bitter poisonous species (*Manihot esculenta* Crantz; *M. ultissima* Pohl.
- Sweet non-poisonous species (*M. dulcis* Baill.; *M. palmatta* Muell.; *M. aipa* Pohl.

No clear distinction exists between these two varieties, however, since environmental and soil conditions may affect HCN content.

Recommendations on variety selection are generally based on local programmes of breeding and selection. Common selection criteria include characteristics such as high yield; high dry-matter or starch content; resistance to prevailing pests, weeds and diseases; or adaptability to mechanization. The actual names of varieties differ among countries; in Trinidad & Tobago, for example, Maracas Black Stick, Red Stick and White Stick are used. MCOL, MMEX, CMC varieties are three common Colombian varieties.

3.2.5 Harvesting and Field Handling

Harvesting begins 6 to 12 months after planting, depending on variety. In the Caribbean, roots are harvested manually with the aid of a hoe or other traditional digging tools. These methods predominate, partly because cassava is grown by peasant farmers in multi-cropping systems, often on hilly terrain. The crop is normally harvested over a period of time as the roots are required. Manual harvesting leads to substantial losses due to damage (cuts and bruises) and breakage of the roots.

The increasing utilization of cassava as an industrial crop has led to increased emphasis on mechanization of production. For harvesting, various root lifters have been designed and tested with different varieties. A 2-row semi-automatic mechanical planter and a mechanical cassava lifter (available as a 1- or 2- row machine) have been designed and successfully tested at U.W.I., Trinidad. The planter is capable of a planting rate 6-10 times that normally achieved manually, while the lifter has successfully harvested MCOL, Red Stick, White Stick and Maracas Black Stick several times faster than can be done manually, with levels of damage ranging from 3% for MCOL to 12% for Maracas Black

Stick (Harvey, 1986).

3.2.6 Postharvest Treatments

Two independent types of deterioration, physiological and microbiological, account for the extremely high perishability of cassava. Physiological deterioration, also known as vascular disolouration, appears within 24-48 hours after harvesting. The starchy root tissues turn blue-black, especially near the xylem and they remain hard and taste bitter after cooking. The rate and extent of physiological deterioration depend on variety and growing conditions and are closely correlated with wounding. Microbiological deterioration, induced by several pathogens, generally begins 5-7 days after harvest.

Several procedures have been established for reducing the rate of cassava deterioration and extending the storage life of the roots. These include:

- Pruning plants prior to harvest. All the branches and leaves are removed from the aerial part of the plant by cutting the stem to 15-30 cm above the ground. The pruned plants are left in the ground and harvested 3 weeks after pruning.
- Reduction in mechanical damage. Both discolouration and rotting originate at sites of damage, especially in the neck of the root. Deterioration is reduced if the individual roots are left attached to the plant stem during storage.
- Reduction of water loss during storage. This can be

achieved by waxing, storage in field clamps, packing into boxes containing moistened packing materials such as sawdust or coconut straw (coir), or by storage in polyethylene bags.

- Storage in interlayered cassava leaves. This procedure involves stacking high-quality roots between layers of cassava leaves in a volume ratio of 1:3.6. The resulting temperature and relative humidity created in the stack promotes curing. In addition, the high level of HCN liberated slowly from the leaves during the first 7-8 days is thought to inhibit pathogenic infection. The technique is also effective in reducing the breakdown of starch to sugar.
- Use of thiabendazole fungicides. Both types of deterioration can be effectively controlled by a technique developed at CIAT and used commercially in Colombia. The roots (30-40 kg) are packed in a sisal bag which is immersed for 5 minutes in a drum containing 0.04% thiabendazole fungicide solution. The roots are then spread out to dry in the shade for approximately 30 minutes before packing and sealing in polyethylene bags. The bags may be stored at room temperature indoors or in a shaded area outdoors. The fungicide prevents microbial growth and the bags provide the temperature and relative humidity (30-40^{o}C; 85% RH) necessary for curing to take place.

Treatment and packaging of the roots must be done within 4 hours after harvest. Maximum recommended storage time is 2 weeks. Roots kept for longer than this period develop an undesirable sweet flavour when cooked.

3.2.7 Utilization

Cassava roots are utilized in a variety of ways. Fresh roots may be cooked as vegetables or processed further into a range of fermented and dried products including bammie, gari, casareep, chips, farina, flour, and starch. Processed chips or flour may also be used as the major carbohydrate source in the feed ration of both ruminant and non-ruminant farm animals.

3.3 POTATO AND SWEET POTATO

3.3.1 Botanical Name - Descriptors: *Ipomoea batatas* (L) Lam. - sweet potato, Louisianna yam
Solanum tuberosum - English potato, Irish potato

3.3.2 Importance

Nutritional. Potatoes are valued for their high nutritive value, flavour and digestibility. They are important carbohydrate staples in many tropical countries, including the U.S.A., the U.K., Europe, South East Asia, Africa, India, Brazil and the Caribbean. In addition to carbohydrates, potatoes furnish reasonable amounts of high quality protein, vitamins and minerals. Predominant minerals include potassium, sodium, phosphorus and calcium. Yellow and orange-fleshed sweet potato varieties are rich in beta carotene, ascorbic acid and vitamins of the B complex. The leaves and tender shoots of are also highly nutritious and are richer than the tubers in protein, vitamin and mineral content.

Economic. Potatoes outrank all other vegetable crops in economic importance (Salunkhe and Desai, 1982). World production of potatoes ranks with that of the world's leading staples, rice and wheat.

English (white) potatoes are exported by most of the major producing countries in both fresh and processed forms. In the case of sweet potatoes, most of the world production is consumed locally, with little produce entering international trade. It is predicted, however, that the importance of sweet potato will increase in the future due to its favourable agronomic characteristics and its versatility in both the food- and non-food processing industries.

3.3.3 Variety Selection

3.3.3.1 Potato

In Jamaica, the Russet Burbank is the major processing variety grown. Varieties grown for fresh consumption include Spunta, Centennial and a number of European selections. The Patrones variety has been found to give high consistent yields in Barbados.

3.3.3.2 Sweet Potato

Varieties are classified on the basis of the texture of the cooked tuber:

Firm, dry, mealy - Namagold, Onokeo, WI cultivars

Moist, soft, gelatinous - Centennial, Goldrush, Kandee

Some selected West Indian varieties include A26/7, C104, 02/59/94, C26/6, C26/100, K4, T25, 049 (Grenada, Trinidad & Tobago); Clipper Martha, Flagall, and Prison Farm (Jamaica); Cricket Gill, Aubry, Six Weeks (Grenada).

3.3.4 Harvesting and Field Handling

3.3.4.1 English Potato

The timely killing of potato vines, 2-3 weeks prior to harvest, effectively stops tuber growth and allows the periderm (skin) to thicken and toughen. This 'skin setting' results in a more attractive potato that has better resistance to postharvest water loss and decay than tubers harvested from green vines. In Jamaica, tubers grown on red bauxite soils are normally dried for 2 weeks before harvest to prevent skin stripping.

Tubers are harvested about 3 months after planting when approximately of the plants have senesced. Harvesting is normally done with the aid of common garden tools. In Barbados, Irish potatoes have been harvested successfully using a modified Ransomes digger elevator.

Harvesting should be done in fair weather since the presence of surface moisture tends to encourage the development of rots. . Grading and bagging is often done in the field. In hilly areas, potatoes are packed into baskets lined with burlap, which are then carried as hampers by donkey.

Rough handling in the field increases the incidence of moisture loss and infection.

3.3.4.2 Sweet Potato

Tubers are ready for harvest within 3- 8 months after planting. The duration of the crop varies with cultivar and environment, but, in general, the crop requires 5-6 months to mature. If harvesting is done too early, yields will be low; on the other hand, if the crop is left too long in the ground, tubers become fibrous and unpalatable and prone to weevil attack. It is often advisable to sample the field for maturity. One index which can be used is that sap exuded from mature tubers dries rapidly without discolouration (Onwueme, 1978).

In small-farmer production systems, roots are dug manually using common garden tools, or lifted with the aid of a tractor-drawn plough. On sloping terrain, vines are sometimes turned back to allow for further tuberization. Sweet potatoes grown in pure stand can be harvested mechanically using a rotary- or flail-type mower to remove the vines, followed by a digger such as the Barbados or the Carib Rootcrop lifter. Small varieties have been successfully lifted in Barbados using a modified conventional elevator digger designed originally for lifting English potatoes (Harvey and Jeffers, 1973).

Physical damage during harvesting and subsequent handling is a major cause of storage losses since it predisposes the tubers to fungal infection, internal breakdown, and loss of moisture. The harvested tubers should be protected from sunscald, and excessive handling should be avoided by field packing directly into storage crates which can hold 10-15kg. Baskets should not be used.

3.3.5 Postharvest Treatments

3.3.5.1 Curing

Curing promotes rapid healing of wounds and increases the toughness of the periderm so rendering the tuber more resistant to handling damage. In the case of white potatoes, curing should be done at 15-18^{o}C and 90-95% RH for 1-2 weeks. Care should be taken to minimize the risk of infection with *Phytophthora* and *Erwinia* which tend to develop easily under these conditions. Potatoes should therefore be first dried before curing. If bulk-ventilation systems are used, the presence of soil, unevenly distributed within the heap, may obstruct air flow, preventing cooling and drying in localized spots. Care should be taken to maintain curing temperatures at recommended values. Temperatures above 25^{o}C result in high respiration rates and the development of black heart.

In the case of sweet potato, natural curing takes place if roots are left in the field at ambient tropical conditions (27-29^{o}C; 5-90 RH) for 4-7 days. Extension of the curing period beyond 7 days may lead to the development of pithiness. Curing may also be done in artificially heated, well-ventilated rooms or chambers.

3.3.5.2 Sprout Inhibition

Potatoes often sprout during prolonged storage. For sweet potatoes, sprouting can be effectively reduced with pre-harvest sprays of maleic hydrazide (3000 ppm, 3 weeks before harvest). or by treating tubers with the methyl ester of naphthalene acetic acid (MENA) in acetone. Treatment with 0.5-4 thiourea for 2-12 hours is also effective but it increases the respiration rate of the tubers (Schlimme, 1966).

CIPC (iso- propyl-(chloro)phenyl carbamate), applied as an aerosol spray (25-30% active ingredient) provides a cheap and effective means of sprout suppression in white potatoes. Best results are obtained when the potatoes are dry and the skin is sufficiently suberized.

3.3.5.3 Storage

3.3.5.3a Potato

Cooling is started after curing. In commercial cool storage, the storage temperature should be lowered gradually by 1-2°C per day. Recommended storage temperature is 3-5°C. If potatoes are intended for the production of chips, temperatures should be maintained between 6-8°C.

Potatoes may be stored either in packaged form using mesh bags, crates or boxes or in bulk, at heights no greater than 4 m. Potatoes in sacks should be stacked in blocks 3 x 3m, with a free space of about 30-40 cm between the blocks for air circulation.

3.3.5.3b Sweet Potato

Traditional methods include leaving the crop unharvested until needed and storage in a number of structures which include underground pits covered with grass, platforms and baskets. In general, losses due to sprouting and spoilage are high with these methods and tubers do not store satisfactorily for more than 6- 8 weeks (Onwueme, 1978).

Tubers can be stored for 13-20 weeks at 13-16°C and 85-95% relative humidity (Pantastico *et al*, 1975). At temperatures lower than 10-13°C, chilling injury results. Symptoms include internal breakdown, blackening, increased decay, high acidity and the development of 'hardcore' (hardened areas in the centre of the roots) after cooking. At temperatures higher than 16°C, respiration rate increases, leading to the production of heat, loss in dry matter, dehydration, sprout development and pithiness. The incidence of infection by Rhizopus and Fusarium also tends to increase at temperatures above 16°C.

3.3.5.4 Pest and Disease Control

3.3.5.4a Sweet Potato

Pests

Sweet potato weevils (*Cylas* and *Eusepes*) cause extensive tuber damage, especially in the dry season. Control measures include the implementation of quarantine measures; the use of insecticides such as Fenthion (0.01%), Fenitrothion or Carbaryl, applied three times every three weeks starting at tuber formation; crop rotation; the use of resistant cultivars, and prompt and early harvesting.

In general, nematodes are not very serious pests of sweet potato. *Meloidogyne spp* is the most widespread. Control measures include immersion of planting material in hot water (47°C for 65 minutes) (Salunkhe and Desai, 1984) the use of nematicides and planting of nematode-resistant varieties.

Diseases

Soft rots, caused by *Rhizopus spp*, are common postharvest infections in sweet potatoes. They can be controlled by:

- the use of resistant varieties
- crop rotation every 3-4 years
- careful harvesting under dry conditions
- prompt transfer of crop from field to storage area
- careful management of temperature and relative humidity during curing and storage

Fungicides which have been found to be effective include 2,6-dichloro-4-nitroaniline (3-4 ppm), 0.75% Dichloran or 0.5-1% sodium ortho-phenyl-phenate (SOPP).

3.3.5.4b English Potato

The main storage diseases of white potatoes ae caused by *Rhizopus nigricans*, *Pseudomonas spp.*, *Erwinia carotovora*, and *Fusarium spp*. Control measures include the use of disease resistant planting material, crop rotation, careful handling, sanitation, drying and cooling and the use of fungicides. Sanitation measures involve cleaning and disinfecting contact surfaces with 0.01% formaldehyde solution, removal of culled and decayed potatoes, and washing of tubers with water containing 50 ppm free chlorine.

Benzimidazoles (thiabendazole, carbendazim, Benomyl and thiofanate-methyl) are effective in the control of some potato storage diseases such as dry rot and black rot.

3.3.5.5 Packaging

In the Caribbean, potatoes are handled in fabric mesh sacks with a capacity of 30-40 kg. For retail marketing, tubers may be sold in loose form or prepackaged in smaller units held in perforated polyethylene bags.

Fibreboard cartons and wire-bound wooden crates (Bruce boxes) are used for packaging sweet potatoes for export. The 2-piece, double walled, full-telescopic cartons measure 40 x 30 x 20cm (depth), and have a capacity of 10 kg. Boxes should be rated at 2413 kPa bursting strength and have ventilation slots on all sides. Coir or other cushioning materials can be used to protect tubers within the container, particularly if the transit time is long. Consumer packaging in plastic-wrapped trays or bags often leads to increased incidence of rotting induced by the high humidity created by the plastic.

3.3.6 Utilization

Both English and sweet potatoes may be consumed boiled, fried or baked. Roots can be processed into canned, frozen and dehydrated products which can be used in the preparation of a range of consumer foods. Sweet potato flour acts as a dough conditioner in bread manufacture and functions as a stabilizing agent in ice cream.

Sweet potato leaves and tender shoots are eaten as vegetables. Low-grade, coarse-textured varieties can be used for feeding cattle, sheep, poultry or swine. Leaves are also fed to livestock either in the fresh form or as silage.

Tubers are utilized in the industrial production of edible and fermented syrups, industrial alcohol, lactic acid, acetone, butanol, vinegar and yeast. Waste from sweet potato processing provides a good source of raw material for the manufacture of pectin.

Sweet potato starch does not compete favourably with other starches and its use in industry is limited. However, it is used in the manufacture of sizing paper and textiles and in laundries. In India, it is also used in the manufacture of adhesives, dextrins, compositions for insulating fabrics, coating formulations for dry cells and in cosmetics.

3.4 YAM

3.4.1 Botanical Name: Dioscorea spp

3.4.2 Descriptors:

D. **alata** - Lisbon yam
D. **rotundata** - Negro yam
D. **cayenensis** - Yellow yam
D. **esculenta** - Chinese yam
D. **trifida** - Cush cush, yampie

3.4.3 Importance

Nutritional. Yams are essentially carbohydrate foods with the main component of the tuber being starch. Protein content (1-2%) is similar to potato and superior to cassava. They are fairly good sources of vitamin C (6-10mg/100g) and have trace quantities of other vitamins and minerals.

Economic. The Caribbean is the second most important yam-producing region in the world (Onwueme, 1978). The economic importance of yam lies mainly in its utility as a carbohydrate food for the producing region, and to a very small extent, in its ability to earn foreign exchange on fresh produce markets. Wide commercialization of yams has, until recently, been limited by the need to retain a portion of the harvest as planting material; laborious production systems; long growing seasons; low yields and storage problems. Most of these limitations have now been overcome through the commercial production of yam plants using tissue culture techniques

Most yam starches have high gel strengths compared with other tropical starch crops, and their rheological properties should be exploited for the processed food industry. With respect to non-food uses, many species of yam contain small amounts of sapogenins which are used in pharmaceutical manufacture of several corticosteroid drugs. The alkaloids present in some species (D. hispida and D. dumetorum) are used in the manufacture of poisons and pharmaceuticals. The use of yam starch as an industrial material is not widespread.

3.4.4 Variety Selection

Recommendations on variety selection are generally based on ethnocultural considerations and on local programmes of breeding and selection. Varieties are selected based on criteria such as quality of planting setts, early maturity, organoleptic acceptability, or adaptability to peculiar local ecological conditions.

Lisbon yams are common to Barbados (White Lisbon), Trinidad and Jamaica, the Leewards and the Windwards, while the Negro and Yellow cultivars are more popular in Jamaica and Puerto Rico. Some elite cultivars of D. alata selected in Puerto Rico for good shape and flavour include Florido, Forastero, Smooth Statia and White Lisbon.

3.4.5 Harvesting and Field Handling

Harvesting may be done at any time after large-scale leaf yellowing has set in. Generally, most of the crop is harvested at the end of the rainy season or during the early part of the dry season. Little tuber material is added during the last month before vine death, and the time of harvesting is therefore not very critical. Harvesting can be done up to two months after leaf senescence (Onwueme, 1978).

Manual harvesting methods predominate in subsistence production systems. A simple wooden or iron-shod digging stick and a machete are the most common tools. Yams (D. alata) grown in pure stand have been mechanically harvested successfully in Barbados since 1972 using a harvester known as the Barbados Root Crop Lifter (Harvey and Jeffers, 1973). More recently, a second root crop lifter has been developed by a Barbados-based firm, Carib Agro-Industries Ltd. and is commercially available. Levels of damage reported for both machines range from 4-10%, whereas with manual harvesting, damage levels are as high as 20-30%. Damage is usually most severe with large tubered cultivars.

3.4.6 Postharvest Treatments

3.4.6.1 Curing

Curing of yams is essential in order to promote hardening and healing of wounds through suberization and periderm formation. To some extent, natural curing takes place when yams are left in the field after harvesting. However, prolonged exposure to the sun results in reduced storage life and should be avoided. Artificial curing conditions reported as satisfactory for D. rotundata and D. alata are 29-32^{o}C and 90-95% RH for 4 days (Gonzalez and Collazo de Rivera, 1972) 30^{o}C and 91% RH for 7 days or 40^{o}C and 98% RH for only 24 hours (Been et al., 1977). Curing heals only clean-cut wounds : bruised areas do not heal and should be exised.

3.4.6.2 Sprout Inhibition

Most of the sprout inhibitors used for enhancing storage life of potatoes have little or no effects on yams since the bud primordia on which they act are not formed in yam tubers until well after harvest. Gibberelic acid (GA_3) at a concentration of 100 ppm delayed sprouting in *D. alata* yams by 10 weeks (Clarke and Ferguson, 1985). However, commercial application appears to be uneconomic.

3.4.6.3 Pest and Disease Control

Dry rot, caused by nematodes (*Pratylenchus coffeae* and *Scutellonema bradys*) can result in serious losses in stored yams. Hot water treatments (51°C for 30 minutes) or treatment with a nematicide (Vydate at 1200 ppm) has been recommended. Fungal rots caused by *Penicillium, Fusarium* and *Botrydiplodia spp* account for the greatest losses on stored tubers. Control measures include the use of thiabendazole fungicides (250ppm Benlate) and alkaline treatments such as lime and ash on exposed wounds or cut surfaces. White Lisbon yams are less susceptible to fungal rots than Cush cush.

Internal Brown Spot virus disease is widespread in the Caribbean region. Whole affected tubers are indistinguishable from healthy ones. However, when cut, affected tubers show internal browning. The only effective methods of control are the use of virus-free material and roguing of diseased plants from the field.

3.4.6.4 Storage

Storage methods for yams range from simple, low-cost traditional methods to low temperature storage with chemical treatments for control of pests, diseases and sprouting. Individual tubers can be stored for up to four months. *D. alata* and *D. rotundata* have the longest dormancy periods. *D. cayenensis*, *D. esculenta* and *D. trifida* do not store well. Traditional stroage methods include:

- Storage in the ground until required.
- Stacking in heaps that may consist of only a few dozen tubers or several tonnes. The heaps are normally shaded or covered with straw or leafy branches.
- Pit or clamp storage. This has been shown to be unsuccessful and is not commonly used.
- Storage in or under unused houses, sheds or huts.
- Barn storage. This is the common method used in West Africa. Oilpalm leaf ribs or unbarked timber, spaced about 50 cm apart, are held together by more rigid horizontal sticks to form a vertical framework. Individual tubers are then fastened to this framework, with their long axis horizontal, using string or raffia. Barns are usually built in dense shaded areas or covered with thatched roofs and raised off the ground.

Galvanized steel sheets are sometimes placed around the base as a rodent barrier.
This method of storage is cheap and relatively effective. However, up to 40-50% of tubers may be lost due to moisture loss and sprouting.

Low temperature storage (12-15°C) reportedly extends the storage life of yams to 6 months. However, above the chilling limit of 12°C, attack by psychrophilic pathogens, to which yams have little natural resistance, can result in storage losses (Noon, 1978).

3.4.6.5 Packaging

Yam tubers may be packed in fibreboard cartons or Bruce boxes containing cushioning materials. Large yams can be junked and treated with fungicide on their cut surfaces.

3.4.7 Utilization

By far, the greater proportion of yams is consumed in the fresh state. The processing of yams into canned slices and dehydrated products (flour, flakes, extruded foods) has been investigated but has not yet been shown to be commercially successful.

WHERE TO TURN FOR FURTHER ASSISTANCE

1. Ministries of Agriculture throughout the Region.
2. Department of Agricultural Extension, Faculty of Agriculture, University of the West Indies.
3. Department of Crop Science, Faculty of Crop Science, University of the West Indies, St. Augustine, Trinidad & Tobago.
4. Agro-Technology Products and Services Division, Caribbean Industrial Research Institute (CARIRI), UWI Campus, St. Augustine.
5. Caribbean Food Corporation, Queens Park West, Port of Spain, Trinidad.
6. The InterAmerican Institute for Cooperation on Agriculture (IICA).
7. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.
8. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.
9. Tropical Development and Research Institute, (formerly TPI), London, U.K.
10. Caribbean Agricultural Research and Development Institute, Regional Offices.
11. The Technology and Energy Unit, Caribbean Development Bank, Barbados.

NEEDS FOR FURTHER RESEARCH

1. Refinement and commercialization of traditional methods of postharvest handling and processing root crops.
2. Quantification of the mechanical, rheological and other engineering properties of root crops.
3. Research on maximization of the industrial potential of tropical root crops.
6. Development of appropriate packaging materials and containers for marketing and distribution.

4. BIBLIOGRAPHY

Adams, H. (1983) Aroids for Food, Feed and Fuel - An Overview of the Aroid Industry in The Eastern Caribbean Islands of Dominica, St. Lucia, St. Vincent and Grenada. Paper presented at CATIE, Costa Rica, February, 1983.

Been, B. O., Perkins, C., and Thompson, A. K. (1977). Yam curing for storage. Acta Hortic. 62: 311-316.

Brathwaite, C.W.D. (1985) An Introduction to Diseases of Tropical Crops. Inter-American Institute for Cooperation on Agriculture (IICA), Trinidad, WI.

CARDI/EDF Aroid/Arrowroot Sub Project No. 5100.33.94.041 - Aroid Cultivation in Dominica. CARDI, Dominica, WI.

CARDI/EDF Project - Semi-Annual Report, Oct 1984-Mar 1985. The Increased Production of Aroids (Tannia, Dasheen and Eddoes) and Arrowroot in the Eastern Caribbean, CARDI, Dominica, WI.

Chandler, F. L. (1985) Towards an Efficient System of Cassava Production. Paper presented at Joint Meeting of The Caribbean Food Crops Society and The American Society for Horticultural Science - Tropical Region, Technology for Agricultural Development, Sept 8-13, 1985, PoS, Trinidad, WI.

Clarke, A. and Ferguson, T. U. (1985) The Role of Gibberellic Acid in Yam Production in Trinidad. Paper presented at The Joint Meeting of Caribbean Food Crops Society and American Society for Horticultural Science - Tropical Region, Technology for Agricultural Development, Sept 8-13, 1985, PoS, Trinidad, WI.

Coursey, D. G. (1967) Yams. Longmans, London.

Coursey, D. G. (1983) Yams. In Handbook of Tropical Foods (ed. Chan, H. T. Jr.) Marcel Dekker, Inc. NY, USA, pp 555-601.

Edmond, J. B., and Ammerman, G. R. (1971) Sweet potatoes: Poduction, Processing, Marketing,AVI Publ. Co. Inc, Westport, Conn, USA, 334 pp.

Gonzalez, M. A., and Collazo de RIvera, A. (1972). Storage of fresh yam (Dioscorea alata L.) under controlled conditions. J. Agric. Univ. P. Rico. **56**: 46-6.

A Guide to Production and PostHarvest Requirements - Detailed Crop Recommendations. Design of an Integrated Agricultural Production and Marketing System, Vol.3C, A Report prepared for the Caribbean Food Corporation, Pos, Trinidad, Haskins-Sells & Tasi-Deloitte Consultants.

Harvey, E. C. (1985) Recent Developments in Postharvest Handling, Storage and Transport of Fruits, Vegetables and Ornamentals. Paper presented at The Joint Meeting of Caribbean Food Crops Society and American Society for Horticultural Science - Tropical Region, Technology for Agricultural Development, Sept 8-13, 1985, PoS, Trinidad, WI.

Harvey, W. O'N. (1986) Personal communication.

Harvey, W. O'N. (1985) A Two-Machine System for Mechanical Preparation and Planting of Cassava Stem Cuttings. Paper presented at Joint Meeting of the Caribbean Food Crops Society and the American Society for Horticultural Science - Tropical Region, Technology for Agricultural Development, Sept 8-13, 1985, Pos, Trinidad, WI.

Harvey, W. O'N. and Jeffers, J.P.W. (1973) Attempts at Mechanical harvesting of Root Crops in Barbados. Proc 11th Annual Meeting of the Caribbean Food Crops Society held in Barbados, pp. 259-264.

Hesen, Ir. J.C. (1982) Storage and Quality of Potatoes. Publikatie 345, Instuut Voor Bewaring en Verwerking van Landbouwprodukten Wageningen.

Kasmire, R. F. (1984) Effects of brief, intermittent exposures of sweet potatoes to chilling temperatures during storage. Perishables Handling No. 55, p 6, Univ. of Calif., Davis, CA

Lutz, J. M. and Hardenburg, R. E. (1977) The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. USDA Handbook No. 66. US Govt. Printing Office, Wash., DC., USA.

Meijers, Ing. C.P. (1980) Directives for potato storage. Publikatie 234 II, Instituut Voor Bewaring en Verwerking van Landbouwprodukten Wageningen, Holland.

Meijers, Ing, C. P. and Rastovski, Ir. A. (1986) Potato Storage in Warm Countries. Dutch Information Centre for Potatoes. The Hague, Holland.

Meyer, N. L. and Simpson, W. R. (1981) Methods of reducing Storage Losses of Potatoes and Onions. A Report for the Instituto de Estabilizacion de Precios and the USAID, Santo Domingo, DR.

Morris, S. C. (1981) Postharvest storage and handling of sweet potatoes. CSIRO Fd. Res. Q. 41, pp 63-67.

Nicholas, (1985). Export Handbook for U.S. Agricultural Products USDA Agriculture Handbook No. 593. U.S. Govt. Printing Office, Wash. D.C., USA

Noon, R. A. (1978) Storage and market diseases of yams Trop. Sci. 20: pp. 177-178.

Nutritive Value of Fruits, Nuts and Vegetables. Agricultural Handbook No. 8, US Govt. Printing Office, Wash. DC, USA.

Odigboh, E. U. (1983) Cassava: Production, Processing, and Utilization. In Handbook of Tropical Foods (ed. Chan, H. T. Jr.) Marcel Dekker, Inc. NY, USA. pp. 145-200.

Onwueme, I.C. (1978). The Tropical Tuber Crops. John Wiley & Sons Ltd., USA.

Pantastico, ER.B. (1975) Postharvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables, AVI Publ. Co. Inc., Westport, Conn, USA.

Plucknett, D. L. (ed.) (1979) Small-scale Processing and Storage of Tropical Root Crops. Westview Tropical Agriculture Series, No. 1, Westview Press, Inc. CO. USA.

Plumbley, R. A. (1979) Report on an Assignment to Trinidad and St. Vincent - Transport and Handling of Sweet Potatoes. Tropical Products Institute R864, TPI, London, UK.

Rickard, J.E. (1984) Postharvest Deterioration of Cassava Roots. Cassava Newsletter. 8, No.2, Dec 1984.

Salunkhe, D. K. and Desai, B. B. (1984) Postharvest Biotechnology of Vegetables, Vol II, CRC Press Inc. USA

Schlimme, D. V. (1966) Anatomical and physiological aspects of sprout initiation and development in sweet potato storage roots, Diss. Abstracts, 26(9), p 4947.

Thompson, A. K. (1972) Report on an Assignment on Secondment to the Jamaican Government as Food Storage Advisor. Tropical Products Institute, R 278, TPI, London, UK.

Vegetable Crop Recommendations (1980) Ministry of Agriculture, Barbados, WI.

Weber, E. J., Cock, J.H. and Chouinard, A. (1978). Cassava Harvesting and Processing. Proc. workshop held at CIAT, Cali, Colombia, 24-28 April, 1978

7. INVESTMENT OPPORTUNITIES AND TECHNICAL REQUIREMENTS

A range of investment opportunities exists within the production-distribution system for perishable produce (fruits, vegetables and root crops). They include:

1. Contract production of produce of defined specification for markets (exporters, packers, hotels, or supermarkets).

   The producer should be experienced in the production of the particular crop. In addition, he must be able to meet the conditions of the contract with respect to volume, quality and scheduling of delivery. The location and layout of the production area should facilitate good control over harvesting areas and supervision of harvesting crews. Shaded areas should be located at strategic points in the field for temporary storage of harvested produce.

   Provision should be made in the contract for the handling of waste and culls. The quantity of product harvested can be measured by weighing and/or counting container units.

2. Contract harvesting of produce for packer or exporter and/or harvesting machinery rental.

   The contractor should have access to experienced harvesting crews, well-trained in selection and handling of the product. It is also advisable for the contractor to have additional labour ready, should the rate of harvesting need to be increased. Appropriate and adequate numbers of field containers, harvesting tools and aids, protective clothing, and transport units should be supplied in advance.

In cases where the crop is harvested mechanically, the operator should be competent in the proper operation of the machine and should be able to carry out on-the-spot adjustments and service and maintenance operations in the field.

Where in-field operations such as precooling, trimming or grading have to be done, the contractor should ensure that the necessary utilities (water, power) are available. Conditions of contract with the producer should include provision for use of the farmer's utility supplies.

The rental of machinery and equipment for harvesting involves the establishment of a rated charge based on the service rendered or on the number of time units taken to complete the service.

Successful operation of a machinery contracting enterprise requires the following:

- ability to select and procure appropriate machinery and suitable machine operators
- ability to attract clients, process applications efficiently and establish work priority
- timely execution of the work and proper record keeping
- establishment of an efficient system of collecting payment.

3. Operation of a packing plant.

This can be run as a private concern, or on a cooperative or joint ownership basis. Produce can belong to the owner(s) or it can be contracted from grower.

The packing plant should be strategically located within the production area. It should have good access to communications and basic utilities (water, electricity), and there should be facilities for disposal of waste water and culled produce. Adequate floorspace is required for:

- loading and unloading of produce
- installation of equipment for dumping, washing, sorting/grading, application of surface treatments, and packaging
- worker positions on the line
- movement of materials handling equipment
- storage of packaging materials and packages
- restroom facilities
- cold storage rooms
- offices
- storage of dry goods required for the operation.
- future expansion.

The layout of the packing area should facilitate the efficient flow of material and minimize the risk of cross contamination between dirty, incoming and clean, packed produce. The packing area should be well-lit, well-ventilated and easy to clean.

The operator of the packing station should be experienced and well informed on the process flow and storage requirements for the produce being handled. He must also be 'au courant' with developments in postharvest technology, particularly with respect to the use of approved chemicals and acceptable chemical residue levels.

Workers should be trained, as part of a ongoing quality assurance programme, in handling, sorting, grading, and packing techniques. On automated packing lines, equipment operators should be skilled in the proper operation of the machines and in making necessary adjustments or repairs.

4. Operation of a cold storage facility as a produce terminal.

Clients may be importers, exporters and packers of fresh produce. Again, this could be operated on an individual, cooperative or joint-ownership basis.

The facility should be strategically located near to marketing or shipping points. Cold storage operators should be experienced in the management of storage rooms and in maintaining recommended storage conditions (temperature, relative humidity, stacking requirements, air circulation rate, gaseous composition) for the particular products being handled. Servicing and maintenance of the refrigeration equipment can be undertaken by the suppliers of the system.

5. Operation of a ripening facility for fruits and fruit vegetables.

Considerable skill and experience are required for successful operation of a ripening facility. Fruit ripening conditions and ripening schedules need to be controlled precisely in order to obtain high quality, ripened products. The room should be designed and built with adequate insulation, thermostatically controlled refrigerating and heating units, and an appropriate system for introduction of the ethylene gas. In general, for large operations, it is advisable to have at least three rooms for efficient and flexible operation. Accessory equipment includes materials handling supplies (forklifts, handpallet trucks, pallets, racks, crates). Useful accessories include pulp and air thermometers, and smoke candles.

A regular programme of room maintenance and sanitation should be followed, particularly if more than one type of product is ripened.

6. Distributorship or Agency for packinghouse machinery, accessories for storage and ripening rooms, materials handling equipment.

In both cases, the agency or distributorship may be operated by an individual or by a group of entrepreneurs in the form of a registered Commercial compamy or Partnership.

The successful establishment of this enterprise requires the following:

- A knowledge of the sources of appropriate machinery
- A good understanding of import/export and customs procedures
- Reliable financial backing and the ability to obtain letters of credit for purchase from foreign sources
- Some skill at inventory management and control
- Technical capability to assemble, adjust and test equipment and supplies prior to delivery
- Authority to extend the manufacturer's warranty to local clients.
- Technical capability to effectively demonstrate the proper use and adjustment of equipment to end users and operators.
- The capacity to stock a comprehensive range of spare parts for the machinery, and to obtain an out-of-stock part for a client within a reasonable period of time.

7. Design, Fabrication and Manufacture of Equipment and Accessories for Postharvest Handling.

Existing workshops which have the capability for welding (both gas and arc), cutting and fitting can work in conjunction with private or governmental agencies to manufacture items such as:

- harvesting aids (finger knife attachments, bottom-dump or clip-release bags and aprons, ladders, picking poles and picking platforms),

- Small-scale batch and continuous hydrocoolers and evaporative coolers (fixed or portable).
- Packing line machinery.
- Portable, collapsible vendors' booths
- Batch and continuous hot water treatment systems for fruits and fruit vegetables.

8. NON-COMPREHENSIVE LIST OF CARIBBEAN, LATIN AMERICAN, U.S., U.K. AND EUROPEAN SUPPLIERS OF POSTHARVEST EQUIPMENT AND ACCESSORIES

(a) HARVESTING

YAM DIGGER

Carib Agro Industries Ltd.
Edgehill, St. Thomas, Barbados

CASSAVA HARVESTER

Richter Machinery (Aust) Pty. Ltd.,
P.O. Box 14, Boonah 4310, Queensland, Australia

Dr. W. O'N. Harvey
Faculty of Agriculture
University of the West Indies, St. Augustine Campus
Trinidad

ROOTCROP LIFTER (YAM, SWEET POTATO, CASSAVA, CARROT, ONION)

Dr. W. O'N. Harvey
Faculty of Agriculture
University of the West Indies
St. Augustine Campus, Trinidad

HARVESTING APRON

CARDI,
Graeme Hall, ChristChurch, Barbados

(b) POSTHARVEST OPERATIONS

GRADING/SORTING

Barbados Marketing Corporation,
Ministry of Agriculture, Food and Consumer Affairs,
Barbados

PACKINGLINE (WASHING, CLEANING, CONVEYING)

Greefa Machinebouw B.V.
Postbus 24, 4190 CA Geldermalsen, Holland

Pennwalt
Decco Tiltbelt Division
1713 South Carolina Avenue
Monrovia, CA 91016, USA

TEW Manufacturing Corporation, P. O. Box 87
Penfield, NY 14526, USA

P. J. Edmonds Ltd., Itchen Abbas, Winchester, Hants
S021 1BG, U.K.

Agri-Packaging & Supply Co.,
20720 E. Dinuba Ave., Reedley, CA 93654

FMC Corp., Citrus Machinery Div.,
Lakeland, FL 33802

PACKAGING

Machinery

ABC packaging Machine Corp
81 Live Oak Street., Tarpon Springs , FL 33589

Latin American Basin Import Export Inc. (LABINCO)
St. Suite 105-106, Miami, FL 33166

Rotex Packaging Systems
6901 N W 51 st., Miami FL 33166

Suis American Inc - Packaging Cente Inc
7321-23 N W 79 Terrace, Miami, FL 33166

Packages and Packaging Materials

Windward Is. Packaging Co. Ltd. (WINERA)
Box 248, Vieux Fort, St. Lucia

Polymer (Caribbean) Ltd
227 Western Main Road, Cocorite, Trinidad

Thermoplastics (Jamaica) Ltd
P.O. Box 680, Spanish Town, St. Catherine, Jamaica

Jamaica Packaging Industries Ltd
214 Marcus Garvey Drive, P.O. Box 10, KGN 10, Jamaica

Caribbean Packaging Materials Ltd.
Coolidge Industrial Estate, Box 210, Antigua

Barbados Packaging Industries Ltd., Applewhaites, St. Thomas, Barbados

Seals and Packaging Industries Limited, Farm East Bank, Demerara, Guyana.

Coates Bros (Jamaica) Ltd., Lot 9, Nanse Pen Close, Box 317, KGN 11, Jamaica

Caribbean Packaging Industries Ltd, Box 278, Port of Spain, Trinidad

COLD STORAGE EQUIPMENT AND SUPPLIES

Climate Control Ltd., 90 Edward St., Port of Spain Trinidad

Mecalfab Ltd., Corner Queen & Richmond Sts., Port of Spain, Trinidad

Electric Sales & Service Ltd., St. George St., Bridgetown, Barbados.