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TECHNICAL INFORMATION PACKAGE
ON POSTHARVEST HANDLING
OF PERISHABLES
VOLUME II - FRUIT VEGETABLES

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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

A high metabolic rate, combined with susceptibility to moisture loss, physiological and physical injury, and infection, are identified as the major hazards to extended postharvest life in vegetables. Methods and techniques for harvesting, cooling, pest and disease control, storage, and packaging are reviewed. Emphasis is given to integration of careful handling and temperature management techniques since these play a major role in reducing the rate of postharvest deterioration. They also have the advantage of being easy and economical to implement, particularly in the context of postharvest systems in the Caribbean and other tropical regions of the world.

Recent developments in the use of surface coatings, dips, and plastic films for delaying ripening and senescence are highlighted.

Finally, 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 for fresh produce handling is also compiled.

KEYWORDS: Fruit vegetables, beans, carrot, cauliflower, corn, christophene, cucumber, melongene, ochro, pepper, pumpkin, tomato, tropical, Caribbean, postharvest, storage, packaging.

SUMMARY

The Manual presents postharvest requirements for handling tropical fruit vegetables. General recommendations are given on the postharvest management of vegetables. Specific recommendations are then presented on methods and techniques for harvesting, field temperature management, washing, pest and disease control, storage and packaging of beans, carrot, cauliflower, corn, christophene, cucumber, melongene, ochro, pepper, pumpkin and tomato. Methods and techniques presented are applicable to current systems for production , handling and marketing of vegetables in the Caribbean Region.

Emphasis is given to the use of integrated methods of quality control involving careful handling, temperature management, preventive strategies for control of pests and diseases and protective packaging.

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.

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1. INTRODUCTION

Most vegetables are utilized at an immature stage of development. At this stage, they have a characteristically high metabolic rate and lack many of the protective structures, such as wax and thickened cuticle or periderm, which protect against physical injury, moisture loss and invasion by pests and diseases. They are also very susceptible to physiological injury caused by extremes of temperature, imbalances in atmospheric composition and gaseous contaminants such as ethylene gas.

Temperature management is the most important factor in postharvest management of fresh produce. Cooling harvested vegetables to safe low temperatures reduces respiration rate and moisture loss. Careful handling preserves the integrity of the vegetable and minimizes the risk of infection and ripening which lead to losses in quality. Treatments such as the application of chemicals and protective packaging materials are generally used to supplement the beneficial effects of careful handling and good temperature management.

2. BACKGROUND

POSTHARVEST MANAGEMENT OF VEGETABLES

Vegetables can be divided into the following categories, based on the part of the plant from which they are derived:

- Seeds and pods (beans, peas)
- Bulbs, roots and tubers (onion, carrot, beet, potato, yam, dasheen, cassava)
- Flowers, buds, stems and leaves (cauliflower, celery, herbs, spinach, lettuce, cabbage, parsley, patchoi)

Except for some of the roots and tubers, most vegetables are utilized as immature organs. At this stage of maturity, they have a characteristically high metabolic rate and lack many of the protective structures such as wax and thickened cuticle or periderm which protect against physical injury, moisture loss and invasion by pests and diseases. They are also very susceptible to physiological injury caused by extremes of temperature, imbalances in atmospheric composition and gaseous contaminants such as ethylene gas.

The quality of harvested vegetables is affected by both pre- and post-harvest factors. Preharvest operations such as cultivar selection and crop management (fertilization, irrigation, pest and disease control) affect the inherent storage characteristics of the vegetable. Good postharvest practices, on the other hand, are aimed at maximizing the

storage potential through reduction of the high metabolic rate of the harvested product; control of moisture loss and its effects; and minimization of physical and physiological injury.

2.1 Variety Selection

Since crop varieties perform differently under different production systems, varieties that have been tested under local conditions should be used.

Particular attention should be given to characteristics such as yield, seasonality, climatic adaptability and disease/pest resistance. Shipping, storage and shelf life characteristics, and market qualities such as size, shape, colour and flavour, also play an essential role in cultivar selection.

2.2 Harvesting and Field Handling

2.2.1 Maturity Indices

The maturity of the harvested vegetable is directly related to its transit and marketing life and quality. Immature vegetables do not develop good quality after harvest and overmature vegetables deteriorate quickly during storage and marketing. Harvesting at the correct stage of maturity ensures:-

- fitness for consumption
- suitability for storage and transport
- ability to ripen normally (in the case of tomatoes)

For vegetables, maturity indices are based on the expected time from planting to harvesting, field indices such as wilting and senescence of foliage (onions), or on the shape (tomato) size, gloss (eggplant, christophene), tenderness (snap beans, peas) or firmness/compactness (cabbage, lettuce, cauliflower) of the produce itself. Frequent harvesting is necessary for crops like okra, beans and cucumber which maturequickly.

Manual harvesting methods predominate in Caribbean vegetable production systems. They have the advantages of accurate maturity selection, multiple harvests, and careful handling. Common tools include knives, secateurs and digging spades.

2.2.2 Field Handling

Vegetables may suffer many types of handling abuse at harvest. These include abrasion, compression, and impact bruising, cuts, breakage and heat stress. Methods and techniques available for minimizing these injuries include:
(i) Careful field supervision - This is the most critical factor in protecting vegetables from injury. Physical injuries can result from improper picking procedures, excessive dropping of vegetables into containers, overfilling, and careless transfer into larger containers.
(ii) Use of appropriate field containers - In the Caribbean, woven baskets, polypropylene sacks, and wooden crates are commonly used in domestic marketing and in intra-regional trade. These containers have the advantages of high capacity

and economy: - baskets hold 25 - 50 kg and cost EC$10 - $15.00; sacks have a capacity of 12 - 30 kg and cost between EC$1.00 and $1.50; and wooden crates made from broken pallets and costing EC$10 - $15, have a capacity of 150 - 325 kg. They however have poor compression- and wet-strength characteristics and frequent recycling often exposes produce to the risk of spoilage and infection. Possible improvements can be achieved by using supplemental packaging materials such as liners, wraps, trays, shims and pads; by stacking containers within their design limits; and by proper venting of containers.

Moulded, vented, stackable plastic crates and corrugated cartons offer advantages over these traditional types of containers with respect to the degree of protection offered, ease of cleaning, and utilization of space.

(iii)Use of harvesting aids - Picking bags and aprons facilitate more careful harvesting of vegetables. One such apron, recently developed at CARDI, has two compartments which allow for in-field grading. Zippers at the base facilitate emptying and minimize bruising.

(iv) Protection during field transport - Several simple yet effective techniques are available for reduction of injuries incurred during transport from the field. Some of these are:

- Grading of 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 pressures on vehicles to reduce shock transmission to produce.
- Use of air suspension systems on transport vehicles
- Inspection of container surfaces to determine the potential for injury to produce.

2.2.3 Field Temperature Management

The rapid removal of field heat (precooling) and the retardation of moisture loss are the most important postharvest treatments for vegetables. Several cooling methods are available and the choice of a method depends on product adaptability, rate of cooling desired, potential for re-warming, type of packaging and package handling system and cost.

Given the climatic conditions, available infrastructure and level of quality control prevailing in the Region, hydrocooling, evaporative cooling and forced-air cooling are best suited to the postharvest handling systems currently in use. Top-icing, using crushed or flaked ice, is appropriate for leafy vegetables such as lettuce, green onions and watercress. Most fruit vegetables cannot, however, tolerate ice contact.

Spray hydrocooling is often preferred over immersion

methods since the latter may lead to water absorption and splitting, as is the case with tomatoes. With tomatoes and sweet peppers, imbibition of water tends to occur via the small pore at the stylar end of the vegetables. If inoculum levels of pathogenic organisms in the cooling water are high, the vegetables can decay internally before external symptoms become apparent.

Evaporative cooling techniques are very energy efficient and economical and they offer significant benefits for precooling in the less humid islands such as Barbados and Antigua where low wet-bulb temperatures would facilitate cooling to low temperatures.

Temperature management does not automatically imply the need for refrigeration. In cases where precooling facilities may be inaccessible, the following practices are recommended:-

- Harvesting in the early morning when crop moisture content is highest and moisture stress on the product is lowest. This reduces the field heat load and also cuts down on subsequent cooling costs.
- Shading of harvested vegetables under natural shade such as trees or vines or artificial ,fixed or portable shade such as sheds or tarpaulin.
- Covering of transported loads with light-coloured (silver or white) tarpaulin. The tarpaulin should be supported so as to maintain an air space over

the load. Wetting of the tarpaulin will increase the cooling effect further by providing an evaporative cooling surface.

2.3 Product Preparation

Harvested vegetables undergo a number of treatments prior to distribution. These may include washing; grading; sorting; application of chemical and surface treatments to control moisture loss, sprouting, rooting, pests, diseases, ripening and senescence; packaging and storage.

2.3.1 Washing

Washing is often combined with precooling and fungicide applications for disease control. Vegetables such as melongene and ochro are susceptible to water spotting and should not be washed unless heavily soiled with dirt or chemical spray residues.

2.3.2 Grading/Sorting

Manual sizing is commonly practised for most vegetables. Training of workers in grading techniques and careful handling is important. In mechanized sorting systems, the delivery system, the sorting belt and distribution system should be designed to avoid injuries. Produce should flow along belts one layer deep, the height and number of drops should be minimized, corners should be smooth and well-rounded and produce flow rates should be controlled to avoid unnecessary accumulation on the line.

2.3.3 Control of Disease

Vegetables are commonly attacked by bacteria which are responsible for most of the soft rots that occur during storage. The major types of soft-rotting bacteria, the Erwinia and Pseudomonads, gain entry into the plant tissue via wounds and natural openings such as stomata and lenticels.

An integrated preventive approach should be employed in the strategy for postharvest control of diseases. This involves 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 precooling and dumping; 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. Vegetables 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.

2.3.4 Treatments for retarding moisture loss and senescence

Moisture loss in vegetables can be reduced by (1) maintaining a high moisture content in the air surrounding the vegetable, (2) precooling, (3) reduction of air movement especially in low temperature storage, (4) protective packaging, (5) application of surface coatings and (6) trimming.

Protective packaging such as plastic films, bags and liners, and surface coatings such as waxes are very effective in restricting moisture loss. Most plastics are, however, 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.

Trimming can reduce moisture loss in certain crops, such as carrot and corn. Carrots should be topped and shanks and flag leaves should be trimmed from ears of sweet corn prior to packing.

Many growth regulators are used to control sprouting, rooting and senescence in vegetables. Maleic hydrazide is commonly used as a pre-harvest sprout inhibitor in onions and potatoes.

2.3.5 Storage

Most leafy and fruit vegetables are not adapted to prolonged storage. Where storage is necessary, recommended

conditions should be used. Ethylene has serious detrimental effects, especially on leafy and root vegetables. It causes yellowing and senescence in leafy vegetables, russet spotting in lettuce, bitterness in carrots and a tough texture in beans. It also encourages sprouting and ripening. Sources of ethylene include ripening fruits and vegetables, decayed and injured produce, diesel engine exhaust, cigarette smoke and some rubber materials.

Susceptible vegetables should be isolated from sources of ethylene. In addition, ethylene should be eliminated from storage and handling areas by removal of the above sources and by installing ethylene scrubbers containing potassium permanganate.

2.3.6 Packaging and Packing

Packages for vegetables should provide:-

- Protection against handling abuse in marketing and distribution channels.
- Accomodation for temperature management during pre-cooling, storage and ripening.
- Wet-strength and compressive-strength characteristics compatible with in-package cooling operations, high volume packaging systems and handling methods in distribution channels.
- Consumer appeal, if used for display and promotion.

The handling of vegetables in a wide assortment of package sizes may lead to marketing problems particularly in

the case of exports to overseas markets. Recommendations made by the Organization for Economic Cooperation and Development (OECD) and the Unitization Committee of the United Fresh Fruit and Vegetable Association (UCUFFVA) on the metrication and standardization of package sizes should be noted by Caribbean exporters. Metric size packages that should be considered for use in the export trade are :- 400 x 300 mm, 500 x 300 mm, 500 x 400 mm, 600 x 400 mm and 600 x 500 mm (outside base dimensions). These package sizes are compatible with the metric pallet which is 1000 x 1200 mm.

2.4 Transport

The choice of carrier, use of efficient loading patterns, and management of environmental conditions (temperature, relative humidity, gaseous composition, levels of harmful volatiles) in transit, must be taken into account in the transportation of vegetables.

2.4.1 Choice of Carrier

In the export trade, air freight and refrigerated marine transport are the two modes of transport available. The small schooners used in the intra-regional 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 of produce.

A good loading pattern should:

- provide a network of channels to allow uniform air circulation throughout the load such that vegetable 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.

Compatibility tables compiled by Lipton and Harvey, (1977) separate the fruit and leafy vegetables discussed, into the following three groups:

Group 1. Recommended transit conditions: 4.5-7.5°C, 95% RH, Ice never in contact with commodity.

Snap beans, ochro, green peppers (not with ochro), red peppers, pink tomatoes.

Group 2. Recommended transit conditions: 4.5-13°C, 85-90% RH, Ice never in contact with commodity.

Cucumbers, eggplant, potatoes, pumpkin and squashes.

Group 3. Recommended transit conditions: 0-1.5°C, 95-100% RH.

Carrots, greens, lettuce, parsley, peas, spinach, sweet corn.

3. TECHNOLOGY

3.1 BEANS

3.1.1 Botanical Name - Descriptor:

Phaseolus vulgaris - Salad beans, snap beans, green beans, string beans
Vigna sinensis - bodie bean

3.1.2 Importance

Nutritional. The pods and immature seeds provide protein, appreciable amounts of vitamins, and minerals.

Economic. The demand for tropical snap beans on European markets is increasing.

3.1.3 Variety Selection

Common string bean varieties used in the Region include Provider, Top Crop, Contender, Prince, Canadian Wonder, Gallatin 50, Green Crop and Green Genes. Most of the varieties have an early concentrated pod set with pod length varying from 10-15 cm. Two bodie varieties, a long, vining type (one-yard and half-yard) and a short bush variety (Los Banos Bush Sitao are grown in Trinidad. The bush variety produces firm fleshy light green pods (25 cm long), borne on long erect peduncles. California 5 blackeye bean is also used as bodie.

3.1.4 Harvesting and Field Handling

The stage of maturity at which beans are harvested is critical. If harvested too early, the beans will wither quickly and yields will be poor. Overmature pods tend to be discoloured, fibrous and distended. Pod length varies widely with variety and growing conditions and is generally not a

Bodie beans should be harvested after they have attained maximum length but before indentations on the pods become pronounced.

Manual harvesting methods produce the best quality beans. Pods should be picked every 2-3 days but not less than twice weekly. Beans can be field packed directly into marketing containers.

Good field temperature management practices include harvesting in the cool hours of the day and shading or rapid cooling of the beans.

3.1.5 Postharvest Treatments

3.1.5.1 Cooling

The high rate of respiration of the immature pods, combined with the rapid rate of moisture loss, lead to wilting and deterioration, especially if the beans are packed in large containers where the heat is not easily dissipated. Hydrocooling (sprinkling with cool, clean water) or evaporative cooling are effective in retarding wilting.

3.1.5.2 Disease Control

Beans stored for too long or at unfavourable storage temperatures are subject to various decays including watery soft rot, slimy soft rot and Rhizopus rot. Removal of visibly infected beans at harvest and prompt cooling retard the development of the disease.

3.1.5.3 Storage

Recommended storage conditions are 7°C and 95-100% relative humidity. Storage at or below 4°C for three days or longer results in chilling injury evidenced by the development of surface pits and russet discolourations.

3.1.5.4 Packaging

Beans can be field-packed directly into well-ventilated wholesale crates or waxed cartons with a 10-15kg capacity (Figure 1). Wilting can be retarded by using perforated 150-250 gauge polyethylene liners. For retail marketing, beans can be packaged in pulp or polystyrene trays, with a capacity of 0.5kg, and overwrapped with perforated film (25, 0.6-cm perforations/kg of beans).

3.1.6 Utilization

Beans can be eaten fresh or processed by canning, freezing, or dehydration.

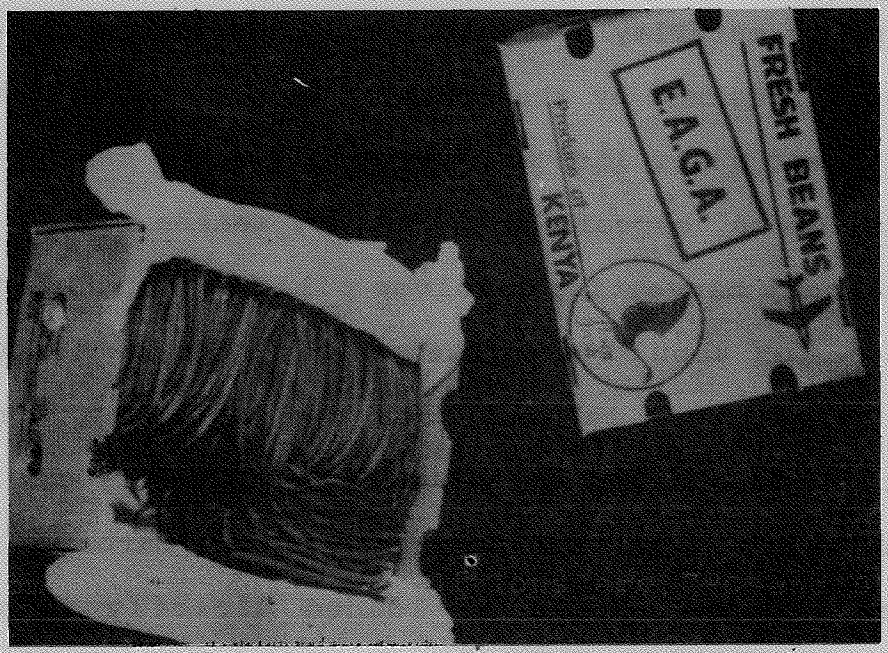

Figure 1. Packaged snap beans

3.2 CARROT

3.2.1 Botanical Name: Daucus carota

3.2.2 Descriptors: carrot

3.2.3 Importance

Nutritional. Carrots have a high nutritive value. They are rich in beta-carotene and contain appreciable amounts of thiamine and riboflavin.

Economic. The carrot is an important vegetable crop in Barbados and St. Vincent.

3.2.4 Variety Selection

Varieties recommended for the Caribbean include Chantenay Royal, Chantenay Red Core, Danvers Half Long Red Cored, and Hybrid F1 Early Cross.

3.2.5 Harvesting and Field Handling

The duration of the crop is usually 14-16 weeks from seeding to maturity. Carrots can, however, be harvested at any size required by the market. Fully mature carrots have the longest shelf life and can be harvested over a period of several weeks, especially in the dry season.

Manual harvesting involves pulling the roots out by the tops, which should be subsequently removed since a great deal of moisture is lost from the roots via the leaves, resulting in wilting and weight loss. Carrots can be lifted mechanically using machinery such as the Barbados Root Crop Lifter. Roots should be loaded directly into storage

crates, or bulk bins and shaded to restrict moisture loss.

3.2.6 Postharvest Treatments

3.2.6.1 Cooling and Washing

Carrots packaged in field crates can be hydrocooled by overhead sprays. In bulk handling systems, the roots can be flumed out of the trailer with jets of water which clean and cool them simultaneously. If roots are heavily soiled, the dirt can be removed by first soaking in a soak tank and then gentle brushing using a rotary washer.

3.2.6.2 Disease Control

Soft rots, caused by *Erwinia carotovora* and *Sclerotinia sp* are common postharvest diseases in the Caribbean. Control measures include:

- Crop rotation
- Control of the maggot fly where this insect is responsible for the spread of the disease
- Careful handling to minimize bruising at harvest
- Precise control of temperature and humidity during storage
- Dipping in 0.1% sodium orthophenyl phenate solution. (The concentration of the solution must be carefully monitored since a 1% solution damages the roots).

3.2.6.3 Storage

Carrots can be stored at $0^{o}C$ and 93-95% relative humidity for 4-6 months. Mixed storage with ethylene-producing commodites results in the development of

bitterness in the roots.

3.2.6.4 Packaging

Plastic net bags or polypropylene sacks (25kg capacity) are suitable for packaging carrots. Lining net bags with perforated polyethylene reduces both wilting and mechanical damage to roots. For storage at 0-1°C, bags and liners should be perforated with two 0.6cm diameter holes per kg of carrots. The area of the ventilation holes should be doubled for every 10°C rise in storage temperature since the incidence of decay is higher at higher temperatures.

3.2.7 Utilization

Carrots are consumed mainly as fresh vegetables in the Caribbean. They can be frozen, canned or dehydrated. The most suitable cultivars for processing are Red Cored Chantenay, Danvers Half Long and Nantes.

3.3 CAULIFLOWER

3.3.1 Botanical Name: Brassica oleracea

3.3.2 Descriptors: cauliflower

3.3.3 Importance

Nutritional. Cauliflower is a rich source of protein and is low in calories, fat and carbohydrates. It contains all the essential amino acids, particularly the sulphur containing amino acids. Like other crucifers, cauliflower is an excellent source of minerals such as calcium, iron, magnesium, sodium, potassium and phosphorus. It also contains substantial amounts of beta-carotene, ascorbic acid, riboflavin, niacin and thiamine.

Economic. Cauliflower is produced on a limited scale in the Caribbean. The major producing countries are China, India, Italy and France.

3.3.4 Variety Selection

Recommended varietes for the Caribbean include Fengshan Extra Early, Farmers Early #3, Snow Queen, Early Patna, and Snow Prince.

3.3.5 Harvesting and Field Handling

The crop is usually ready for harvest within 3 months after planting. After the curds have been formed, they should be protected from exposure to sun and rain which cause discolouration. Leaves may be broken over the curds for protection. Well-formed heads are harvested by cutting

the plants well below the heads with a sharp knife or sickle. The heads are then trimmed by cutting squarely across the leaves, leaving about 3 cm protecting the head. The remaining stubs protect the head from abrasion injury in containers. Harvested heads are packed in crates and wire-bound boxes.

3.3.6 Postharvest Treatments

3.3.6.1 Cooling and Storage

Hydrocooling can be used for precooling of cauliflower. The heads are not usually stored for long periods. If storage is necessary, however, temperatures should be maintained as close to 0°C as possible.

3.3.6.2 Disease Control

Soft rot, caused by *Erwinia carotovora* is commonly found on cauliflower. It is initiated in wounds or in tissue injured during harvest or subsequent handling. Recommended control measures include:

- Adequate spraying during the last weeks of the growing period, to protect the heads from *Alternaria* Leaf Spot and Downy Mildew, the lesions of which provide openings for soft rot bacteria.
- Careful harvesting and handling
- Storage at low temperatures (4-10°C)
- Control of the maggot fly which can spread the bacterial inoculum.

3.3.6.3 Packaging

Crates, fibreboard cartons, or wire-bound crates can be used for marketing cauliflowers. For retail marketing, individual heads may be wrapped in transparent film and packed in various types of trays, or sealed in high density polyethylene (10 m) film.

3.3.7 Utilization

Cauliflower is eaten as a fresh vegetable and is often used as a component of mixed pickles and relishes.

3.4 CHRISTOPHENE

3.4.1 Botanical Name: Sechium edule (Jacq.) Swartz

3.4.2 Descriptors: Choyote, chayote, cho-cho, choko

3.4.3 Importance

Nutritional. The christophene is indigenous to Southern Mexico and Central America. It is a common vegetable throughout the Caribbean Region. The edible portion of the vegetable contains mainly water and carbohydrate. There are also small amounts of Vitamin A, protein and fat. The tuberous roots, young leaves, and seeds are all edible.

The christophene contains a proteinase which makes it useful for tenderizing meat.

Economic. Christophene is grown on a small scale in the Caribbean for domestic consumption. There is some trade from St. Vincent to Trinidad.

3.4.4 Variety Selection

Two varieties, a white and a green are common in the Caribbean. Local seed material is usually used.

3.4.5 Harvesting and Field Handling

Christophene is usually picked at an immature stage of development. Harvesting generally begins 3-5 months after planting and may continue for several weeks. Indices used include the size (0.25-0.5 kg), and roundness or smoothness of the surface. Colour is not a good index of readiness for harvest. The overmature vegetable tends to be very

fibrous and unpalatable.

The christophene has a waxy skin which provides a natural barrier to moisture loss. Nevertheless, harvesting should be done in the cool hours of the day and the fruits should be kept in a shaded area. Care should be taken not to damage the fruit.

3.4.6 Postharvest Treatments

3.4.6.1 Storage

Fruits can be stored for several weeks at 7-10°C and 90-95% relative humidity.

3.4.6.2 Disease Control

No serious postharvest diseases are reported for christophene. However, preventive measures such as careful handling and good temperature management should be emphasized in disease control in the vegetable.

3.4.6.3 Packaging

Christophene can be marketed in ventilated fibreboard cartons or packaged in perforated polyethylene bags.

3.4.7 Utilization

The young leaves, fruits, seeds and tuberous roots of the christophene plant are consumed as cooked vegetables. Christophene is also used extensively in the production of pepper sauces and pickles in the Caribbean.

3.5 CORN

3.5.1 Botanical Name: Zea Mays

3.5.2 Descriptors: Corn, maize

3.5.3 Importance

Nutritional. Corn is a major carbohydrate food for millions of people. It provides energy, protein and fat, as well as vitamins and minerals.

Economic. Corn ranks third in world production of food grains, surpassed only by wheat and rice. It forms 50% of the total world coarse grains output and is projected to achieve expansion in volume and fastest rate of growth (Salunkhe and Desai, 1984).

3.5.4 Variety Selection

In the Caribbean, both field (grain) types and sweet types are grown. Pioneer Hybrids (X304A and B; X306B) and a number of local varieties, such as Chaguaramas Local and Chaguaramas Hybrid (Trinidad), are grown for grain.

Sweet corn cultivars are generally classed according to the time of their edible maturity (early, medium or late), and according to colour (yellow and white flint). In general, yellow-flint varieties are superior in eating quality. Many of the Top-Cross hybrids are popular.

3.5.5 Harvesting and Field Handling

In the case of field corn, harvesting is normally delayed for as long as possible to allow for natural drying

of the grain in the field. In unfavourable weather, or where birds and pests can cause damage to ripening corn, the crop may be harvested earlier and dried artificially to 10-12% moisture.

Maturity is the single most important factor in controlling the quality of sweet corn. Three distinct stages have been identified in the maturation of sweet corn kernels: pre-milk, milk and dough. The pre-milk stage is characterized by a sweet taste, lean, immature and small kernels and a clear watery juice. At the milk stage, the taste is also sweet, but the kernels are larger and the juice is milky in appearance. In the dough stage, rapid conversion of sugars to carbohydrate occurs and quality is poor.

Sweet corn is harvested at the milk stage. Maturity indices include browning of the silks, and the exudation of the 'milk' when the kernel is pierced with the thumbnail.

Quality deteriorates rapidly once the ears are harvested. At tropical ambient conditions, the conversion of sugar to starch is accelerated causing a drastic reduction in eating quality. The crop must therefore be harvested under cool conditions and delivered to a suitable cooling facility without delay. Ears may be packed in wire-bound crates containing at least 54 ears. Sweet corn should not be handled in bulk unless copiously iced throughout the pile.

3.5.6 Postharvest Treatments

3.5.6.1 Cooling

Hydrocooling with drenches at 0°C is effective in reducing the field and respiration heat of the ears. Icing, either in the field or at the cooling station, is also effective in maintaining high quality.

3.5.6.2 Storage

Sweet corn is seldom stored. If storage is necessary, ears should be held at 0°C and 90-95% relative humidity. Under these conditions, the corn can only be held for only a few days.

3.5.6.3 Packaging

Sweet corn can be packaged in wire-bound crates and wet-strength paper bags for wholesale marketing. For retail markets, ears can be husked and packed in trays overwrapped with transparent film or left unhusked and shrink-wrapped in polyethylene. Polyethylene films and the presence of the husk increase the freshness of the corn by maintaining high humidity.

3.5.7 Utilization

Corn can be utilized for the production of a number of commercial food ingredients which include corn meal, corn flour, corn starch, high fructose corn syrup, liquid glucose, dextrose, monohydrate glucose powder, corn dextrin, starch and oil. The stalks, cobs and grain are also used to produce ethanol.

3.6 CUCUMBER

3.6.1 Botanical Name: Cucumis sativa

3.6.2 Descriptors: cucumber

3.6.3 Importance

Nutritional. Cucumbers provide carbohydrates, vitamin C and minerals.

Economic. The cucumber is an important commercial crop in China, the U.S.S.R., Japan, the U.S. and Turkey. In the Caribbean, cucumbers are consumed mainly as fresh vegetables. Existing export markets are highly competitive.

3.6.4 Variety Selection

Recommended varieties for use in the Caribbean include, Gemini, Triumph, Challenger, Saticoy, Baton Vert, Southern Delight and Daser. In Trinidad, common varieties grown include Explorer, Multipix, Chipper, Calypso and Green Slicer.

3.6.5 Harvesting and Field Handling

Cucumbers are harvested when they are smooth, shiny, dark green and tender. Size tends to be variety dependent and is generally not a good index of readiness for harvest. Harvesting should be carried out 2-4 times per week to secure maximum yields and high grade fruit. Overmaturity is evidenced by yellowing and shrivelling of the skin, and the development of bitter off-flavours in some varieties.

Manual harvesting allows for more harvests and careful

handling of both the fruits and vines, thereb promoting multiple harvests. It is often advisable to cut or clip the fruit rather than to pluck or twist them off. Multiple handling can be avoided by field packing directly into storage crates.

3.6.6 Postharvest Treatments

3.6.6.1 Cooling and Storage

Cucumbers can be hydrocooled from 24°C to 13°C in 4°C water in about 15 minutes. The optimum storage conditions are 10-12°C and 95-100% relative humidity. Below 10°C, chilling injury symptoms (surface pitting, discolouration) develop rapidly. At storage temperatures above 16°C, cucumbers tend to yellow rapidly. This colour change is accelerated by mixed storage with tomatoes, fruits and other ethylene-producing commodities.

3.6.6.2 Disease Control

Soft rot, caused by *Erwinia sp* and cottony leak (resulting from infection by *Pythium spp*) are common in the Caribbean. Careful handling of the fruits to minimize bruising, and the use of crop rotation are control measures which can be used.

3.6.6.3 Packaging

Cucumbers can be packed into crates with a capacity of 20-25kg. Smaller containers reduce injury and extend shelf life but may not be justified in terms of extra handling, packaging and transportation costs. Individual fruits may

be wrapped in high density polyethylene having a thickness of 10 m.

3.6.7 Utilization

Apart from their use as fresh vegetables, cucumbers of the pickling type are used extensively for the commercial preparation of fermented and acid-pack pickles.

3.7 EGGPLANT

3.7.1 Botanical Name: *Solanum melongena*

3.7.2 Descriptors: Eggplant, melongene, aubergine, bedengram, baigan, bungan, brinjal, Guinea squash, garden egg.

3.7.3 Importance

Nutritional. Eggplant is one of the staple vegetables of India, China, South U.S.A. and the Caribbean. It is rich in water soluble carbohydrates, minerals and vitamins.

Economic. World production of eggplants is in the region of 4.5 MMT (Salunkhe and Desai, 1984). There is good potential for export of Caribbean eggplants to European markets.

3.7.4 Variety Selection

Varieties exist in a range of shapes and colours, ranging from white, yellow and green to striped , and dark purple cultivars. Important cultivars for the Caribbean include Black Beauty, Long Purple, Hybrid Blackpride, Vaughan's Hybrid, Hybrid F1 Early Prolific and Florida Market. All of these produce dark purple fruit and the latter two varieties are resistant to **Phomopsis** rot.

3.7.5 Harvesting and Field Handling

Fruits can be harvested any time after they have attained sufficient size: usually when they are half-grown and not beyond a diameter of 10 cm. The skin should be firm and glossy, the stem and calyx green, and the flesh white

and tender, with no trace of bitterness. Overmature fruits tend to be dull, seedy and fibrous.

The eggplants should be cut or clipped neatly from the plant leaving the calyx intact and about 1-2 cm of stem attached to prevent excessive water loss and infection. Fruits should be harvested in the cool hours of the day and kept shaded to minimize peel damage. They may be packed directly into market boxes if they do not require washing. Excessive handling should be avoided.

3.7.6 Postharvest Treatments

The quality of eggplants is largely indicated by the condition of the peel. When water loss exceeds 5%, the peel becomes dull and shrivelled.

3.7.6.1 Cooling

Fruits cool slowly and are not well adapted to hydrocooling or icing. In addition, hydrocooling causes water spotting and icing leaves fruits spongy and wrinkled. Good field temperature management and cool storage should therefore be practised.

3.7.6.2 Disease Control

Fruit rots, caused by *Alternaria, Phomopsis, Erwinia carotovora*, cottony leak (*Pythium sp*) and anthracnose are prevalent postharvest diseases of eggplant. *E. carotovora* and *Phytophthora* may be transmitted to the pepper by insects or via contact with contaminated implements, contaners, fruits, washwater or rain splash. Infection can be

minimized by sanitation (removal of ashering debris, soil and infected fruits; washing with 1-2% chlorine solution), and drying before packing. Anthracnose and Phomopsis fruit rots occur as latent infections. Pre-harvest spraying with Dithane M45 or 4:4:50 Bordeaux mixture should be carried out since postharvest chemical treatment is usually ineffective. The incidence of Rhizopus and Fusarium rots can be minimized by avoiding fruit injury and keeping the fruit surface dry. Alternaria infection invariably occurs in response to chilling injury and may be controlled by holding the fruits at recommended storage temperatures. Prompt cooling reduces the incidence of the other infections.

3.7.6.3 Storage

Eggplants are not adapted to long term storage. They cannot be kept satisfactorily even at the recommended storage conditions of 10-13^{o}C and 92% relative humidity, for more than 1-2 weeks. At temperatures below 7^{o}C, chilling injury symptoms (surface scald, bronzing, surface pitting, discolouration and death of the calyx) occur.

3.7.6.4 Packaging

Fruits for export can be either jumble packed or placed in rows in fibreboard cartons with a net capacity of 5-7 kg. Cartons are usually divided into two layers, separated by a sheet of single wall corrugated paper (Figure 2). Ventilated bags (six to ten 6-mm holes per kg of eggplants), or

individual sealing in 10 m high density polyethylene or 20-30 m polyethylene may be used for retail packaging. Fibreboard cartons with ventilation holes and plastic liners may also be used for larger lots.

3.7.7 Utilization

Eggplants are generally consumed as fresh vegetables. They can, however be dehydrated to produce powder which is used in the preparation of soups and other foods.

Figure 2. Eggplants packaged in fibreboard carton

3.8 PEPPERS

3.8.1 Botanical Name: - Capsicum sp.

3.8.2 Descriptors: Capsicum anuum - Sweet pepper, green pepper, bell pepper
Capsicum frutescens - Hot pepper

3.8.3 Importance

Nutritional. Sweet peppers are a rich source of water-soluble carbohydrates, and vitamins A, B and C. Hot peppers are similar in nutritional content but cannot be consumed in large quantities because of the presence of the pungent and irritating flavouring agent, capsaicin, which is responsible for their sharp taste.

Economic. There is good potential for the export of both sweet and hot peppers from the Caribbean to North American and European markets: Volumes of peppers exported from the Caribbean (Trinidad & Tobago, Barbados and St. Lucia) are on the increase. Hot peppers are valued for their flavouring properties in many food items, particularly pickles and sauces. They therefore generate considerable foreign exchange for producing countries which export either the dried peppers or oleoresin extracts.

3.8.4 Variety Selection

Recommended sweet pepper varieties include Hybrid F, Wonder Giant, Resistant Giant, California Wonder 300, and Emerald Giant, all of which are resistant to Tobacco Mosaic Virus. Other varieties are Bullnose, Yolo Wonder and Florida Giant.

Hot varieties include Hontaka (Takii), Yatsufusa, Cayenne, and Hungarian Yellow Wax. A number of local red and yellow hot pepper varieties are planted throughout the Caribbean.

3.8.5 Harvesting and Field Handling

The stage of maturity at which sweet peppers are harvested depends, to some extent, on the market requirements for size and colour. In general, however, harvested fruits should be firm, waxy and glossy and should separate easily from the plant. Fruits can be removed by snapping the stem at the natural abscission point followed by trimming or by clipping the stem at a length of 1-2 cm. The attached stalk aids in reducing water loss and spoilage. Care should be taken not to damage the plants during harvest. Hot peppers are usually picked when they begin to turn colour. At this stage, the stem can be easily detached from the plant.

The length of the harvest may extend up to 8 weeks though beyond 4 weeks, the quality of the fruits tends to deteriorate. Frequent picking is necessary to obtain fruit of optimum maturity and to minimize losses of overripe fruit. Harvested fruits should be kept cool and shaded since they are highly susceptible to dehydration and insolation damage which cause dulling and shrivelling of the skin. Heavy-duty ventilated plastic field crates can be used.

3.8.6 Postharvest Treatments

3.8.6.1 Cooling and Washing

Harvested peppers should be precooled as soon as possible after harvest to reduce field heat. Spray hydrocooling is preferred over immersion methods since in the latter, temperature differences between the pepper and the water may result in imbibition of water through the style, causing the pepper to decay internally (Henry, 1986). If immersion methods must be used, the temperature difference between the pepper and the water should be minimized as far possible and free chlorine levels should be maintained at 70 ppm.

Cooling and washing are carried out simultaneously. Washing is necessary to remove visible fungicide residues and any adhering soil or debris. Peppers should be thoroughly dried before they are packed.

Peppers are waxed before shipment to reduce moisture loss and scuffing. The cost of application of the wax should, however, be consistent with the market value of the product.

3.8.6.2 Grading

Primary considerations in the grading of sweet peppers are size, stage of maturity, colour and wholesomeness. Grading should be done on a table with a smooth surface or on trays built with canvas bottoms to prevent bruising.

3.8.6.3 Storage

At temperatures of 7-10°C and 90-95% relative humidity, both hot and sweet peppers keep satisfactorily for 2-3 weeks. They are subject to chilling injury at temperatures below 7°C, while temperatures above 10°C encourage ripening and bacterial soft rot. Prepackaged and/or waxed peppers last up to a week longer than untreated peppers (Lutz and Hardenburg, 1977).

3.8.6.4 Disease Control

Stored peppers are subject to a number of rots caused by Alternaria, Anthracnose, Erwinia, Rhizopus and Botrytis spp. Alternaria develops when the fruit is subjected to too much sun or chilling temperatures. Infection can be retarded by holding peppers at recommended temperatures. Hot water treatment (30 sec dip in 50°C water) is recommended for control of bacterial soft rot. Careful handling and rapid cooling retard the development of Rhizopus and bacterial soft rot. Cultural controls for control of anthracnose infection include crop rotation; removal and destruction of all crop remnants and diseased fruits, destruction of seeds from infected areas, and treatment of infected seed with mercuric chloride.

3.8.6.5 Ripening

Sweet peppers are sometimes ripened if the market requires red peppers. Uniform and rapid colouring can be achieved with ethylene gas treatment. Chili peppers are

often treated with Ethephon (250-1200 ppm) at the chocolate brown stage.

3.8.6.6 Packaging

Peppers are very prone to moisture loss and should be packaged in perforated polyethylene bags or in plastic-lined or wax-impregnated full telescope fibreboard cartons having a net capacity of 5 kg. Jumble packaging encourages bruising and reduces shelf life. Fruits should preferably be packed with stems pointing down.

3.8.7 Utilization

In the Caribbean, peppers are used extensively in the manufacture of a wide range of pickles and sauces. The peppers can also be dried or used for extraction of oils and oleoresins.

3.9 OKRA

3.9.1 Botanical Name: Hibiscus esculentus L., Abelmoschus esculentus

3.9.2 Descriptors: Gumbo, gombo, lady's finger, bhindi, bamiat, ochro

3.9.3 Importance

Nutritional. Ochro pods are a good source of vitamins A and C: a 100g serving supplies 10 and 50% RDA, repectively. The seeds are high in protein (26%) and seed oil(14-19%). The young leaves are also edible and contain more protein than the pods.

Economic. The ochro has considerable potential as an important oil and protein crop for the developing world. The plant is adaptable, dependable and resistant to hot, humid weather. Markets for good quality okra exist in North America and Europe. The seed oil is similar to good grade peanut oil, and the oil meal contains 44% protein and 32% carbohydrate.

3.9.4 Variety Selection

Varieties ar selected based on yield, uniformity, length and continuity of production period, spinelessness, fibre content and keeping quality. Recommended varieties for the Caribbean include Clemson spineless, Emerald Green Velvet, St. John, Annie Oakley Hybrid, and Better Five. Clemson spineless is suitable for both fresh market and processing.

3.9.5 Harvesting and Field Handling

The tender young fruits are picked when they are half size:- immature pods less than 5 cm long tend to wilt rapidly, while overmature fruits are fibrous, and have a dull, flaccid, yellowish appearance. Fruits should be bright green and free from blemishes. Pods can be removed by snapping or by cutting with a sharp knife or pruning shears, leaving 1-2 cm of stem intact. Gloves or similar protective garments should be worn to avoid contact with spiny plant surfaces. Regular harvesting on alternate days stimulates continued fruiting. When pods are not removed, the plants age rapidly with signs of reduced leaf production. The harvest period can extend up to 8 weeks.

Ochro pods are highly perishable. Dehydration and rough handling result in softening, shrivelling and blackening. Harvesting should be done in the cool hours of the morning and the pods should be shaded and kept cool. Handling is minimized by field packing directly into market boxes or, if grading is necessary, into shallow field boxes.

3.9.6 Postharvest Treatments

3.9.6.1 Cooling

Precooling of ochroes is limited by the incidence of water spotting and chilling injury. Forced-air cooling may result in excessive moisture loss unless a misting system is incorporated to increase humidity levels. Maintenance of high relative humidity, good field temperature management,

and rapid handling are critical to maintenance of quality.

3.9.6.2 Disease Control

No serious storage infections are reported for ochro.

3.9.6.3 Other Treatments

Methods for improving postharvest life of ochro include dipping in growth retardants, such as 2-chloroethyl trimethyl-ammonium chloride (CCC, Cycocel^{R} or Chloramquat^{R}), and waxing. Promising results have been obtained with a dip of 200 ppm morphactin, applied either as a pre- or postharvest treatment, followed by application of wax emulsion. The pods retained their green colour and losses in weight and soluble sugars were reduced (Singh et al., 1979). In addition, morphacatins degrade quickly leaving no toxic residues. Singh and Dhankhar (1980) showed that dipping of ochro pods in 250 ppm ascorbic acid resulted in reduced weight loss and chlorophyll retention.

3.9.6.4 Storage

Ochro is not well adapted to prolonged storage. Good quality pods can keep satisfactorily for 7-10 days at 7-10^{o}C and 90-95% relative humidity. At temperatures below 7^{o}C, pods show symptoms of chilling injury which include surface discolouration, pitting and decay. Above 13^{o}C, yellowing occurs rapidly and is accelerated by ethylene produced by other fruits.

3.9.6.5 Packaging

Ochroes should be packaged in shallow containers containing no more than 5 kg. Containers may be lined with perforated 150-20 gauge polyethylene for moisture retention. Packing in larger quantities leads to surface bruising, overheating and external blackening of pods. Prepackaging in perforated film (400 gauge thickness, 20, 6-mm holes/kg ochro) prolongs shelf life by retarding wilting and loss of green colour, and by minimising physical injury .

3.9.7 Utilization

Okra may be prepared in a variety of ways for use as a fresh vegetable. It is also commercially preserved by salting for use in the manufacture of certain canned products. Dried, powdered seeds can be used in the preparation of soups, cheese spreads, salad dressing, ice cream and candy. The seed oil can be used in the manufacture of cooking oil and margarine.

3.10 PUMPKIN

3.10.1 Botanical Name: Cucurbita maxima

3.10.2 Descriptors: pumpkin, squash

3.10.3 Importance

Nutritional. Pumpkins are good sources of carbohydrates, beta-carotene, vitamin C and minerals.

Economic. Markets exist in Europe for Caribbean pumpkins. At present, the vegetables are exported from Jamaica, Barbados, St. Lucia and Trinidad & Tobago.

3.10.4 Variety Selection

Local propagation material (seeds, cuttings) tend to be utilized throughout the Caribbean. In Barbados for example, Garden pumpkin and Belly pumpkin are recognized varieties.

3.10.5 Harvesting and Field Handling

Pumpkins should be allowed to attain full size and maturity. The following are some characteristics which are used to indicate maturity:

- the leaf immediately above the fruit dries up
- the tendrils of the fruit dry up
- the stem turns yellowish near the fruit
- the fruit sounds hollow when tapped
- the fruit is dense and heavy

The stem of the pumpkin should be cut with a sharp knife or secateurs. Careful handling ensures maximum storage life.

3.10.6 Postharvest Treatments

3.10.6.1 Curing

Curing is often recommended for the promotion of wound healing and skin thickening in some pumpkin cultivars. A heat treatment of 26-28°C for 10-20 days before storage is recommended (Lutz and Hardenburg, 1977). Prolonged curing may, however, be not only unnecessary but also harmful to some cultivars.

3.10.6.2 Disease Control

Common storage diseases include rots caused by wound-invading organisms. Careful handling and good temperature management retard the development of disease. Waxing can be used to reduce decay. Chemical treatment, using a 0.2% dicloran dip, was found to be effective in controlling decay in squashes caused by S. Sclerotium and Botrytis spp.

3.10.6.3 Storage

Good quality, wholesome pumpkins can be stored satisfactorily at room temperature for a few weeks. Recommended low temperature storage conditions are 10-13°C and 50-60% relative humidity.

3.10.6.4 Packaging

Pumpkins can be packaged in woven polypropylene bags (25 kg capacity) or in double-walled fibreboard boxes, with or without dividers.

3.10.7 Utilization

Pumpkin can be used in a variety of ways as a fresh vegetable. It is well suited to processing into canned and dehydrated products which can be incorporated into a number of food items.

3.11 TOMATO

3.11.1 Botanical Name: Lycopersicon esculentum

3.11.2 Descriptors: Tomato

3.11.3 Importance

Nutritional. Tomatoes make a significant contribution to nutrition due to their widespread consumption and to the concentration and availability of several nutrients in the fresh and processed products. Tomatoes provide vitamin C, vitamin A, and small amounts of the B-complex vitamins, thiamine, niacin and riboflavin. Of the minerals present in tomato, iron is the most important.

Economic. The tomato is an important commercial crop in the U.S.A., U.S.S.R., Italy, China and Egypt. In the Caribbean, the tomato is important in domestic marketing and fruits are consumed mainly in the fresh state. Almost all processed tomato products are imported. There is tremendous scope for the development of tomato processing in the Caribbean.

3.11.4 Variety Selection

Recommended varieties for use in the Caribbean include

- Hybrid Early Set, Hybrid Starpack, Early Cascade, Celebrity
- Calypso, Walter, Tropi Red: All of these have a determinate habit; produce firm fruit which handle well; are tolerant to Fusarium wilt.
- Caraibe, which produces well at high temperatures
- Floradel which produces good leaf coverage for fruit

against bird attack and sunscald and which has some resistance to Alternaria and Fusarium wilt.

In Trinidad, local green or 'white skin' varieties (Manalucie, Manapal, Marglobe, Ponderosa) are used.

3.11.5 Harvesting and Field Handling

The stage at which tomatoes are harvested depends on the market requirements viz. fresh market, processing, local or export. Colour is the single most important physical characteristic used for determining quality in tomatoes. Immature green tomatoes tend to be angular with a dull green skin. Fruits picked at this stage ripen poorly and are unpalatable. Mature green fruits are more rounded and are whitish green in colour with a waxy, glossy surface. Fruits picked at this stage ripen normally. They separate easily from the stem and show a corky stem scar. They have well developed seeds and skin.

As tomatoes ripen, they gradually become increasingly red and this change has been arbitrarily subdivided into the following stages:

Breaking - Not more than 10% of the surface is tannish-yellow, pink or red.

Turning - 10-30% of the surface has changed colour

Pink - 30-60% of the surface is pink or red with no yellow colour remaining.

Light red - More than 60% of the surface is pinkish-red, but not more than 90% of the surface is fully red.

Red - More than 90% of the surface is fully red.

Tomatoes should not be harvested before the mature green stage. For domestic marketing, fruits may be picked almost fully ripe. "Vine-ripened" tomatoes have a superior flavour, although the danger of bird damage and susceptibility to damage are increased. For storage or transportation to distant markets, mature-green or turning fruit can be harvested and ripened either naturally or with applied ethylene.

Manual harvesting allows for careful handling, good selection and multiple harvests. Fruits are removed from the vine by a half turn or twist. Any picking container which does not damage the fruit's skin is acceptable, and fruit can be safely collected in bulkbins or shallow trailers up to 300 kg capacity. Protection from the sun is essential to prevent sun scald after harvest, therefore fruit awaiting field transport should be kept cool and shaded.

3.11.6 Postharvest Treatments

3.11.6.1 Cooling

The need for precooling of mature-green tomatoes depends on the initial temperature of the fruits and on the ripening methods used. If the fruit temperature is above 27^{o}C and ripening is delayed, there is no need for rapid precooling. If cooling is necessary, hydrocooling can be used to reduce the temperature from 30^{o}C to 1^{o}C in 15 minutes using water at 1-4^{o}C. Spraying is preferable to immersion methods which can lead to imbibition of water via

the style, skin splitting and decay. Where hydrocooling is not feasible, forced-air cooling for a maximum of 24 h using air at 4.4°C is effective.

3.11.6.2 Washing

Fruits should be washed to remove all traces of soil, debris and chemical residues. If washing operations involve recycling of water, care should be taken to maintain the levels of free chlorine at 200 ppm. Fruit should not be packed wet.

3.11.6.3 Ripening

In general, tomatoes picked at the mature-green or turning stages are allowed to ripen naturally at room temperature. However, ripening at temperatures above 25°C results in the development of orange and yellow, instead of red colours. The ripening guide, shown in Figure 3, should be used. Mature-green tomatoes take about 10 days to ripen at 24°C, 14 days at 18°C and 18 days at 13°C. Fruit harvested at the pink stage take 4-6 days less to ripen at each temperature.

Ripening can be promoted by using the ethylene evolved naturally from already ripening tomatoes, by application of commercial forms of ethylene (liquid or gas), or by using carbide. Ethrel (liquid ethylene formulation) is often applied as a spray using small bottles with atomizers or a knapsack sprayer. Care should be taken not to contaminate the solution by using a dirty spray can. In small farmer

systems, the tomatoes are often placed on a bed of straw in a hut or under a house and sprayed with the Ethrel. They are turned frequently during the ripening period.

Ripening with acetylene can be done by placing a small amount (25 g) of crushed, moistened calcium carbide in a muslin cloth which is then put into the ripening box. The acetylene released is not as potent as ethylene and fruits may take longer to ripen. Frequent opening and venting of the ripening box is necessary in order to prevent the build-up of carbon dioxide.

3.11.6.4 Storage

Mature-green tomatoes can be held for up to 2-3 weeks at 12-15^{o}C. Below this range, fruits suffer chilling injury, developing an abnormal amount of decay and failing to ripen properly. As fruits ripen, they become less susceptible to chilling injury:- fully ripe fruits can be held for up to 6 weeks at 2^{o}C. However, it should be noted that , under these conditions, fruits lose colour, characteristic aroma, flavour and texture.

3.11.6.5 Other Treatments

Various treatments have been used on tomatoes to delay ripening and senescence and correct physiological disorders. Blossom-end rot can be markedly reduced by the application of calcium nitrate and gypsum or by spraying with calcium chloride solution. Effective chemical dips include 1% calcium chloride, borax (6 oz in a gallon of water) and

formaldehyde (Salunkhe and Desai, 1984). The addition of the ethylene chemisorbent, Purafil^{R} to packaged tomatoes, reportedly delayed ripening for a week (Ben Yehoshua et al., 1978).

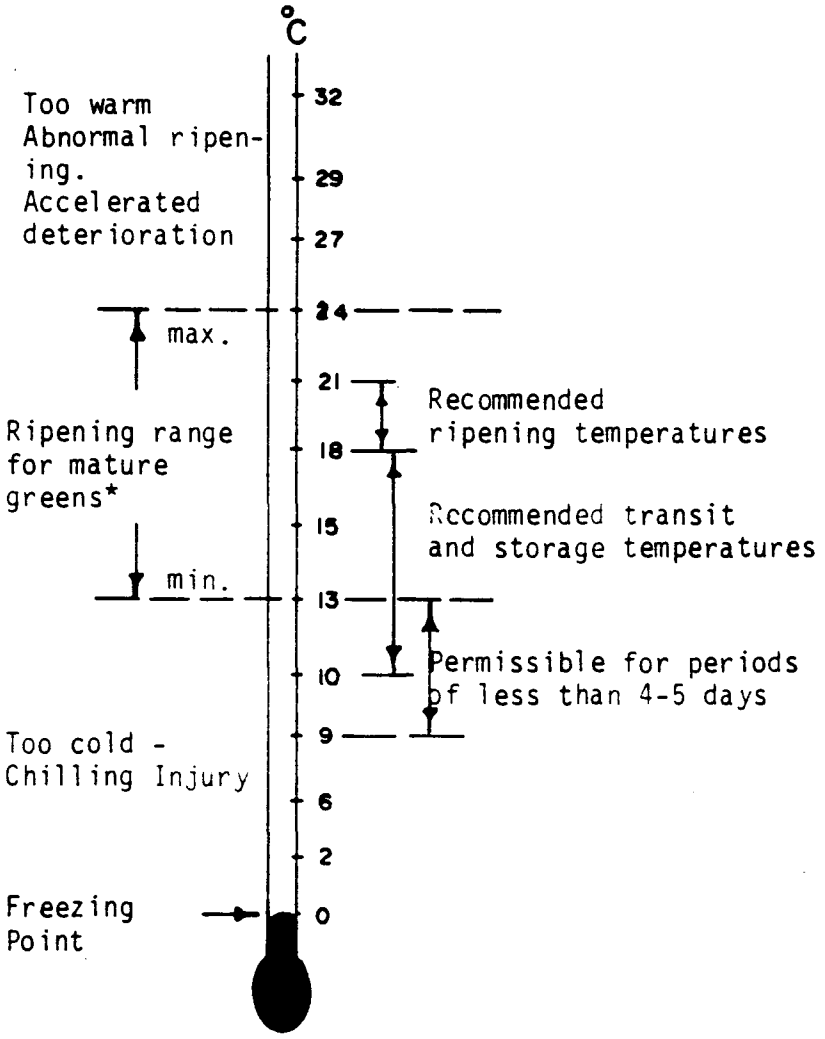

Figure 3. Ripening Guide for Tomatoes

3.11.6.6 Disease Control

Tomatoes may be infected with a number of storage rots which include *Alternaria* rot, bacterial soft rot, *Rhizopus* rot, sour or watery rot, buck-eye rot, and soil rot. Rapid cooling, careful handling, adequate precooling and good temperature management to avoid chilling injury are recommended for minimization of these infections. Some measure of control of soil and buck-eye rot can be achieved using cultural methods. These include crop rotation, staking to keep the fruits off the soil, ridging of beds, and chemical treatments with copper fungicides or Polyram-combi (Brathwaite, 1985).

3.11.6.7 Packaging

Protection from physical injury is the chief benefit derived from packaging of tomatoes. Mature-green fruit can be jumble packed into 20-kg fibreboard cartons. Fruits marketed at more advanced stages of ripeness should be packed in flat cartons containing up to 100 fruits packed no deeper than 3 layers. Each layer should be separated by a sheet of polyethylene film or corrugated paper.

Individual seal packaging of tomatoes in 10 m-thick polyethylene has beneficial effects on shelf life and fruit quality.

3.11.7 Utilization

Tomatoes are used in both the fresh raw state and in processed form. Products include purees and pulps, sauces, paste, juice and preserves. Processing varieties of tomatoes should be medium to large in size, smooth and uniformly ripened, and should have a high yield of solid flesh with good flavour.

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5. WHERE TO LOOK FOR FURTHER ASSISTANCE

1. Ministries of Agriculture throughout the Region

2. Caribbean Agricultural Research and Development Institute (CARDI), Regional Offices

3. Caribbean Industrial Research Institute (CARIRI), UWI Campus, St. Augustine, Trinidad

4. Department of Crop Science, Faculty of Agriculture, University of the West Indies, St. Augustine, Trinidad

5. Department of Agricultural Extension, Faculty of Agriculture, University of the West Indies, St. Augustine, Trinidad.

6. Postharvest Institute for Perishables (PIP), Idaho, USA.

7. The Technology and Energy Unit, Caribbean Development Bank, Barbados

6. NEEDS FOR FURTHER RESEARCH

Research is needed on:

1. Application of surface treatments which would minimize moisture loss at ambient conditions (to include the use of plastics, natural preservatives, growth regulators).

2. Development of cost-effective in-field cooling systems using hydrocooling and evaporative cooling.

3. Investigation into maximum residue levels of chemical residues, especially in vegetables intended for export markets.

4. Development of packages, using locally available raw material, for domestic and intra-regional marketing.

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.

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

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