IICA

HARVESTING AND POST-HARVEST HANDLING OF PAPAYAS IN THE CARIBBEAN

Ena Harvey   Rafael Marte   Andrew Medlicott

IICA OFFICE IN BARBADOS

ISSN-0534-5391
A2/BB-90-001

IICA

HARVESTING AND POST-HARVEST HANDLING OF PAPAYAS IN THE CARIBBEAN

Ena Harvey
Rafael Marte
Andrew Medlicott

May, 1990
Bridgetown, Barbados

IICA OFFICE IN BARBADOS

MISCELLANEOUS PUBLICATIONS
SERIES

ISSN-0534-5391
A2/BB-90-001

Bridgetown, Barbados
April, 1990

ACKNOWLEDGEMENTS

We wish to acknowledge the assistance of the Caribbean Agricultural Trading Company Ltd. (CATCO), Constant Estates and the InterAmerican Institute for Cooperation on Agriculture (IICA) for providing staff inputs and information on commercial operations and trading activities for papaya.

We also thank Jerry La Gra and Dr. Stephen New for reviewing and editing the manual.

The logistical support provided by the Ministry of Agriculture, Food and Fisheries (MAFF) is also appreciated.

Authors

Ena C. Harvey - Postharvest and Food Technology Consultant, CASSE Consultants Ltd., Barbados.

Rafael Marte - Fruit Crop Specialist, InterAmerican Institute for Cooperation on Agriculture (IICA), Barbados.

Andrew Medlicott - Postharvest Technologist, Caribbean Agricultural Trading Company Limited (CATCO), Barbados.

TABLE OF CONTENTS

SECTION 3
FIELD HANDLING & TRANSPORTATION

SECTION 4
PREPARATION OF FRUIT FOR MARKET

SECTION 5
MARKETS FOR PAPAYA

SECTION 6
UTILIZATION

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

1. THE PRODUCTION OF PAPAYA IN THE CARIBBEAN REGION

Papaya plants can be found throughout the Caribbean Region growing in backyards, scattered or inter-mixed with other fruit trees, in commercial, pure-stand plantings, or growing isolated in the wild. Commercial development of papayas in the Caribbean does not, however, reflect the popularity of the fruit. Only a few countries, notably The Bahamas, Barbados, Cuba, Dominican Republic, Jamaica, Puerto Rico and Trinidad and Tobago have developed organized, commercial orchards. Moreover, in many orchards, the volume of high-quality papayas produced is insufficient for successful export market penetration. Pests and diseases, as well as poor quality and susceptibilities of the 'varieties' being cultivated, have been indicated as the major constraints to the poor commercial development of papayas in the Region.

Virus and virus-like diseases are by far the most important factors limiting papaya production in most of these countries. Among these, "Bunchy Top" caused by a mycoplasma is the most important, followed by "Distortion Ringspot", which is caused by a virus. Unfortunately, most of the commercial cultivars, particularly those within the "Solo" group, are extremely susceptible to both problems. Experience has shown that it is very difficult to obtain economic production in areas where these diseases exist. Attempts to develop Bunchy Top-resistant cultivars have commonly failed, but tolerant ones have recently been developed in Barbados (Marte, 1986). Nevertheless, the fight against this important disease has not ended, and the work to find resistant lines continues. On the other hand, cultivars showing resistance to Distortion Ringspot have been developed, but sizes and/or shipping quality of these fruits do not meet specifications for export to international markets.

From the quarantine point of view, the fruit fly is the most important pest in countries where they occur. A decline of papaya caused by Erwinia spp. has been reported to be very important economically in St. Lucia, the Virgin Islands, Dominica, Martinique, Guadeloupe and Trinidad & Tobago. Other biological problems such as anthracnose (Colletotrichum sp.), spider mites, and nematodes, although important, have been relatively easy to control in the field, especially if preventive measures are taken.

Within the Caribbean Region; Barbados, Jamaica, Dominican Republic, Puerto Rico, the Bahamas, and Cuba have been able to develop papaya to commercial levels and currently export to extra-regional markets. However, the supply continues to be erratic, and the planted acreage has never reached a significant amount to compete with countries such as Hawaii and Brazil. Rejection rates are very high in most countries where papaya is being produced for export markets. This is due mainly to pre-harvest and postharvest factors such as poor cultural practices (plant spacing, spray application, pest control), and careless postharvest handling.

1.1 BARBADOS

In 1989, 71 ha. (175 acres) of papaya were in production in this island. The Barbados government is aiming to develop a total of 162 ha (400 acres) as part of the Agricultural Diversification Programme included in its Development Plan for the period 1988-1992. The main lines being cultivated are "Barbados Yellow" and "Barbados Pink", both of which were locally developed and proven to be tolerant to "Bunchy Top". "Barbados Yellow" has small fruits (300 to 600 grams) with yellow pulp, and is targeted for the export market. The "Barbados Pink" produces a medium to large-sized fruit (650-1200 grams) with pink pulp, and is being produced mainly for the local market. Currently, two pink lines of smaller-sized fruit, locally developed, are being tested for integration into the export programme.

Barbados exports papayas to Europe, mainly to the U.K. and Holland, with small volumes being shipped to Canada and the USA. Local consumption of fresh fruit continues to increase, and the penetration of the domestic tourist market is expected to result in a doubling of the actual quantity consumed.

"Bunchy Top" continues to be the main problem since any stress on the plants, even when using tolerant lines, frequently results in the breaking of tolerance, and the rapid infection of a high percentage of the plants. Very few cases of Distortion Ringspot Virus have been reported in Barbados. Other biological problems reported to be important are anthracnose (Colletotrichum sp.), spider mites and root and foot rot (Phytophthora sp.).

1.2 JAMAICA

By mid 1988, at least 202 ha (500 acres) of papaya were growing in organized commercial orchards in Jamaica. Of these, approximately 121.5 ha (300 acres) were cultivated mainly for the export market. However, Hurricane Gilbert, which struck the island with winds of over 120 mph destroyed 95% of the plantings. Today, growers are planning the establishment of larger commercial orchards, which together, will amount to a total of over 607.5 ha (1500 acres) in the near future. The leading cultivar for the export market is "Sunrise Solo" (pink pulp), but "Kapoho" and "Waimanalo" are also being cultivated in commercial quantities. All of these cultivars have small fruits averaging 400 grams. Local types of relatively large-sized fruits continue to be cultivated for the local fresh and processing markets.

Jamaica exports both to Europe and the USA markets, with small volumes going to Canada.

"Bunchy Top" is important, but at present, the incidence of this disease is not as high as it has been in Barbados, Dominican Republic, and other countries of the Region. The occurrence of the "Distortion Ringspot Virus" and the "Papaya Mosaic Virus" has also been reported to cause economic damage. Thrips, mites and nematodes are the most important pests, while anthracnose, root and foot rot are also important diseases which result in economic loss (Marte, 1986).

1.3 DOMINICAN REPUBLIC

A minimum of 121.5 ha (300 acres) of papaya are maintained for the domestic market. An additional 40 ha (98 acres) are being cultivated for the USA market. Plans for expansion are underway.

For the local market, "Cartagena" and "Ombligua" are the leading cultivars. They both produce very large fruits of yellow pulp, which range from 1200 to 5000 grams. "Tainung", a cultivar originally imported from Taiwan, but known locally as "Hawaiana", is being produced for both the local as well as US market. Some plantings of "Sunrise Solo" have also been established and many other commercial cultivars are being tested, including "Kapoho", "Waimanalo" and "Califlora".

"Bunchy Top" as well as "Distortion Ringspot" are very important constraints to the production of papaya in the Dominican Republic. The traditional cultivation of Cartagena and Ombligua in areas where there is a high incidence of these pathological problems, and the fact that growers select their seeds from the best plants within their orchards, have been responsible for a certain degree of tolerance to these problems in the material currently being cultivated. Other important biological problems include anthracnose, the papaya fruit fly (Toxotripana curvicauda), mites and nematodes.

Each year the Dominican Republic processes a large volume of papaya fruits. Papaya chunks in syrup and other conserves are popular on the domestic market as well as on ethnic markets in the states of Florida, New York and Massachusetts.

1.4 PUERTO RICO

By 1988, Puerto Rico had 135 ha (300 acres) of papayas including 61 ha (150 ac) of "Solo" cultivars such as "Sunrise Solo" and "Waimanalo". Several local selections such as "P.R. 6-65", "P.R. 7-65" and "P.R. 6-55" are the main cultivars being grown for the local market. These local cultivars produce large-sized fruits which are unsuitable for export. Nevertheless, part of the production is processed and small amounts of products such as juice, nectars and conserves are exported to ethnic markets in the USA. It has been estimated that 60% of the "Solo" papayas being produced is exported to the US mainland (Sotomayor, 1988). The rest is marketed to the local tourist sector. Small quantities of papayas are imported from the Dominican Republic and Barbados which suggests scarcity during part of the year. There are plans to extend the area currently being planted but no specific target dates have been set.

Both "Bunchy Top" and "Distortion Ringspot" are reported to be the major problems of papaya in Puerto Rico. Other pests of commercial importance are powdery mildew (Oidium caricae) and anthracnose (Colon and Vasquez, 1988).

1.5 THE BAHAMAS

In 1987, 41 ha (100 acres) of papayas were being cultivated in the Bahamas. However, plantings were destroyed due to virus and virus-like infections. "Sunrise Solo" was the main cultivar being grown, although a few acres of "Waimanalo" could be found. Part of the production was marketed locally in the tourist sector, with the majority targeted to the export market. Recent plans have been made to extend the current area under cultivation from 2 hectares (5 acres) to 40.5 hectares (100 acres).

Main problems reported are those caused by "Distortion Ringspot" virus and mites.

1.6 OTHER COUNTRIES IN THE CARIBBEAN BASIN

Among the other countries in the wider Caribbean which cultivate papayas on a commercial scale, Venezuela in South America, and Belize, Costa Rica, Honduras and Panama in Central America, are probably the most important.

Venezuela has traditionally cultivated a relatively large acreage, mainly for domestic consumption. By 1982, a total of 2700 ha (6,672 acres) were reported to be planted, and total yield estimated at 33,400 tonnes (Fusagri, 1984). No new plantings have reportedly been established. Among the cultivars grown, the most important are "Cubana", "Cartagena" and "Paraguanera". More recently, the area under cultivation with "Solo" papayas has been increasing, and the production is being exported to Europe. Major problems include "Bunchy Top", "Distortion Ringspot", the Mediterranean Fruit Fly (Ceratitis capitata), Bacterial Decline" (Erwinia sp.), nematodes, and the papaya fruit fly (Toxotripana curvicauda).

The area cultivated in the other countries is currently unknown. All of the countries produce papaya of the "Solo" group and export to the extra-regional markets. Belize and Honduras have exported both to Europe and the USA. Costa Rica and Panama ship their fruits mainly to Europe. This is due to the occurrence of the Mediterranean fruit fly and the ban imposed by the USA for countries where this pest occurs. More recently, pilot plots have been established in Antigua, Grenada, St. Lucia and St. Vincent, aiming to supply both local and US export markets.

2. HARVESTING

The goals of harvesting are to gather the fruit at the desired stage of maturity, with a minimum of loss and damage, as rapidly as possible, and at minimum cost. These goals can best be achieved through careful selection and handling of fruits, rapid movement out of the field, and efficient organization and supervision of labour, equipment and time.

The training and supervision of picking crews is one of the most critical factors in obtaining high quality fruit. Pickers must be able to recognize mature fruit and to use techniques and practices which minimize injury. These include the proper use of harvesting tools, filling of field containers within capacity limits, careful transfer of fruit out of containers, and protection against surface abrasions, cuts and scratches made by knives, fingernails and sharp edges.

2.1 ORGANIZATION OF HARVESTING OPERATIONS

Adequate labour, tools, containers and vehicles should be available in accordance with the layout of the field, and with the position of areas for collection, assembly and transport of fruits within and out of the field.

Harvesting operations differ with the size of the operation in terms of:

- Time at which fruits are harvested
- Size and composition of picking crews
- Method of transfer of harvested fruits out of the field
- Tools and equipment used

In the Caribbean, trees are usually harvested two to four times per week. Harvesting should preferably be done during the cool hours of the day. In small-scale systems (< 5 acres), fruits may be harvested up to 11.00 a.m. and after 3.00 p.m. In larger-scale systems >5 acres), all-day harvesting is more common. Overheating of the fruits is avoided by taking advantage of the cool micro-environment created by the natural shade within the orchard.

In small-scale systems, picking crews are small and usually consist of family labour. Containers and harvesting aids such as poles and simple ladders are carried into the field by the pickers. Full containers are normally taken directly out of the field into a central area where they are either stored or emptied. The picker then returns to the field with an empty container.

In larger-scale systems, containers are transported between the field and the packhouse or storage area in unit loads by pick-ups, tractor/trailers or by All Terrain Vehicles (ATVs) with trailers. In one system in Barbados, an ATV/trailer combination is used to transport 1 to 3 trailer loads (40 crates/load) between papaya fields and the packhouse. Empty crates are dropped within the area being harvested and filled crates are left under trees for pick-up by the ATV.

2.2 MATURITY CHARACTERISTICS OF PAPAYA FRUIT

Picking of fruits at the required maturity ensures good quality for consumption, suitability for storage and transport, normal ripening, and conformity with market specifications. In the Caribbean, papayas are generally ready for harvest 9 months after sowing, 7 months after transplanting, or 3 months after anthesis. These periods vary with cultivar, location, and cultural practices. For example, in Hawaii, fruits are ready for harvest 13 to 14 months from sowing.

2.2.1 Fruit Maturity Indices

Common indices used for determining maturity include skin colouration, sweetness (measured as Brix), and texture.

2.2.1.1 Peel Colouration

This is the most commonly applied index of maturity. In general, fruits should be picked on the appearance of a skin colour change from deep to light green with one yellow streak at the blossom end. These firm, mature-green fruits are easier to handle than riper fruit, and ripen within five to ten days at ambient tropical conditions (25-30°C, 80-90% relative humidity (r.h.)). This facilitates flexibility in storage, distribution and marketing operations. Storage of these mature-green fruit under controlled environmental conditions (10-12°C, 85-90% r.h.) can further extend storage life to 14 days. An additional period of 4-5 days at 20°C is required for development of good colouration and flavour.

Subjective colour charts, based on the degree of surface colouring have been derived for the Solo group of varieties. The degree of colouration can be determined in thirds, quarters and fifth or on a per cent colouration scale (Plate 1).

2.2.1.2 Sweetness

The sweetness of the papaya pulp or juice can be measured by sampling a representative number of fruits. The test involves the removal of a small portion of the pulp, and measurement of the soluble solids (sugar) content of the juice with a refractometer, which gives the direct sweetness level in Brix (% sugar). The test can be carried out in the field or packhouse with a portable refractometer (Plate 2).

The desired level of Brix depends on the form in which the fruit is traded (ie. fresh or processed) and on market specifications. Most domestic fresh fruit markets in the Caribbean accept fruits having a minimum Brix of 9%, while the majority of extra-regional markets require a minimum of 11%. Under normal conditions, the Brix will be higher during the dry season and lower in the wet season. Acceptable Brix levels have, however, been achieved for fruits harvested throughout the year in the Bahamas, Barbados, Cuba, the Dominican Republic, Jamaica, Puerto Rico, and Trinidad & Tobago when high quality varieties were used.

Brix levels greater than 12% are difficult to attain in Hawaii where the use of hot water treatments (as an alternative to Ethylene DiBromide (EDB) treatment for fruit fly control) has necessitated harvest of fruits at earlier stages of maturity in order to avoid hot water damage. By comparison, in the Caribbean where such treatments are not used, Brix levels of 13-14% are readily obtained with the same varieties, especially during the dry season.

The use of sugar content as a maturity

index is not as easily applied in the field as is surface colouration. The measurement of Brix during the production cycle is necessary, however, as a quality control check which enables the grower to guarantee minimum sweetness levels, and to monitor and modify the cultural practices accordingly.

2.2.1.3 Texture

The use of texture as a maturity index is not recommended for papaya, since 'feeling' the fruit may cause injury and soft fruit are rejected.

2.3 HARVESTING METHODS

Papayas can be harvested either directly by hand or with the use of various types of harvesting aids and equipment. Fully mechanized systems are not common and they generally result in losses in yield due to damage to both trees and fruits.

2.3.1 Manual Harvesting

Manual methods predominate in the harvesting of papayas. Although they tend to be slow and, in some countries, very costly, they do offer the advantages of accurate selection for maturity and low levels of fruit damage. Unfortunately, harvesting by hand can only be done in the first phase of production when the fruits are still within the reach of the picker.

On short trees, the lowermost fruits can be removed either by manually twisting and breaking, or cutting the peduncle with a knife (Plates 3a & 3b). Care must be taken not to detach fruit too close to either of the abscission layers (point of attachment of peduncle to stem or to the fruit) since this may lead to infection of both the plant and the fruit. Ideally, the peduncle should be cut midway along its length. Pickers should also be careful when using knives or cutting tools, not to scratch adjacent fruit. Gloves may be worn to minimise thumb and finger pressure.

2.3.2 Using Harvesting Aids

As the papaya tree continues to grow, the use of harvesting aids becomes necessary. Such aids include various types of picking poles, ladders, and picking platforms.

2.3.2.1 Picking Poles

These range from simple lengths of wood or bamboo, to pole-and-cup/bag devices. In the case of simple poles, during actual picking, one hand is used to hold the pole and prod the peduncle of the fruit, while the other tries to catch the papaya when it falls.

2.3.2.2 Pole and Cup Pickers

A simple pole-and-cup device can be made using a household plunger or plumber's helper (longhandled suction cup) in which the regular handle is replaced by a long pole (Plate 4).

The picker places the rubber cup against the bottom of the papaya and pushes the pole upward with one hand. This action causes the fruit to snap from its stem and the picker catches the fruit with the other hand. The rate of picking is highly dependent on the picker's skill. In Jamaica where the plunger is used, growers have complained that many fruit fall to the ground before the pickers can catch them. Such fruits become bruised and cannot be exported (Marte, 1986). The rate of harvesting will therefore be significantly slowed using this device if a reduction in the number of fallen fruit is to be achieved. Picking rates with pole-and-cup pickers average

400-500 kg per day in Hawaii, the Philippines and the Caribbean.

A general disadvantage of pole-and-cup devices is that fruits are lost in cases where multiple fruiting occurs. When one peduncle has two fruits attached, it is a very agile picker who can catch both fruit and frequently, one of the fruits is not ready for picking.

2.3.2.3 Pole-and-Bag Devices

Pole-and-bag devices are more appropriate than pole-and-cup pickers. They usually consist of three parts: a circular metal frame, a bag made of canvas or netting, and a pole, made of light metal, wood or bamboo. They range in sophistication from 'home-made' bags sewn onto metal rings nailed to long poles, to commercially available types. One such type is the 'papaya picker', originally developed in Thailand. It consists of a pole fitted with a narrow flat blade which can be easily manoeuvered to cut the peduncle of the fruit without damaging the peel. The harvested fruit is caught in a wide-mouthed canvas/mesh or nylon mesh bag, which enables the picker to look up through the netting and accurately position the cutting edge (Plates 5a & 5b). This picker has been used in papaya orchards in Barbados with excellent results with picking rates of 400-500 kg/day. With proper care, the picker should last for several years. The bag should be changed when heavily stained with latex or when damaged.

2.3.2.4 Ladders

Simple ladders and step ladders can be used for picking papayas. Simple ladders were commonly used in Jamaica where the picker propped the ladder against the plant, climbed up, picked the fruit and passed it to a second person on the ground who placed it in a container. This method was very time-consuming and the pressure of the ladder also damaged the plant. It is therefore, not recommended (Plate 6).

In the Dominican Republic, Hawaii, Jamaica and Puerto Rico, step ladders are currently used. The use of step ladders has, however, been reported to be tedious, time consuming and costly.

2.3.2.5 Platforms

In large-scale orchard systems in Hawaii, worker positioners are used. These mechanical aids are either standard or self-propelled tractors upon which the picker platforms are elevated on booms. One prototype of this platform, developed by the University of Hawaii, is designed with a conveyor running the length of the boom to a bin. Each bin holds about 900 lb of papayas, and the machine capacity is eight bins. This harvesting arrangement is only applicable to gently-sloping or level land, and requires large inter-row spacings.

The relative advantages and disadvantages of the above harvesting aids are given in Table 1.

3. FIELD HANDLING AND TRANSPORTATION

3.1 FIELD HANDLING

The effects of good harvesting techniques on fruit quality can be easily nullified by poor field handling practices. Good field management should focus primarily on minimising heat stress (temperature management) and on protection against injury.

Table 1. Comparison of Harvesting Aids

Type of Aid	Advantages	Disadvantages
Picking Poles		
Bamboo/Wood	Cheap	Requires good hand to eye co-ordination
	Easily available	High level of injury to adjacent fruit
Suction Cup (Plumber's Helper)	Low cost Easily modified Easily available	Requires good hand to eye co-ordination to catch falling fruit
Thailand Picker	Simple to operate Durable	Difficult to locate the peduncle beyond certain heights
Ladders		
Step Ladder	Durable Easily available	Movement of ladder and climbing are time consuming and cumbersome
Simple	Easily made Easily repaired	Trees may be damaged from pressure of ladder and climber
Platform	High speed Easy field handling	Not well suited to small-scale systems
		Low plant densities have to be used to allow for tractors to pass
		High initial cost

3.1.1 Minimising Heat Stress

Temperature management in the field encompasses many methods and techniques which minimise the effects of temperature on quality loss at harvest and during subsequent field handling. Temperature management thus involves harvesting and holding fruit under conditions which do not promote the build-up of heat, the use of properly vented containers and filling of these containers within their capacity limits to allow for easy dissipation of heat.

Fruits left standing in the sun too long suffer sunburn and scald and cannot be marketed. Overheating also results in rapid quality loss and poorly ripened fruit which may not be marketable. The presence of rainwater on the surface of fruits can also encourage infection and spoilage. Full containers awaiting transfer out of the field should therefore be kept in cool, shaded areas. Shade can be provided naturally by trees or artificially, using a thatched-roof shack, canvas covering, beach-type umbrella or shed.

3.1.2 Minimising Injury in the Field

Injuries to harvested fruits can be reduced by removal of fruit stems, careful handling and through the use of properly designed containers. Containers used for harvested fruits should provide:

- convenience for handling
- protection against compression and
- abrasions
- protection against the build-up of heat and moisture
- protection against infection
- durability and economy (cost effectiveness)

3.1.2.1 Field Containers

Field containers used for papaya in the Caribbean include woven baskets, sacks and bags, plastic lugs and crates, wooden crates and bins. Often the fruit may be transported without containers of any type.

Baskets and Sacks

Woven baskets and sacks are used throughout the Caribbean and Latin America as field containers for harvested papaya. They have the advantages of high capacity and economy, but are flexible and have poor compression strength. Baskets which are conical in shape are unstable when filled and do not utilize space efficiently when stacked. Fruits in these containers therefore often suffer bruises, soft spots and abrasions. This situation is aggravated by the fact that baskets and sacks are difficult to clean and may harbour spores of spoilage organisms which can easily infect damaged fruit. Deep, closely-woven baskets and sacks also promote the build-up of heat and humidity which can lead to rapid quality loss (Plate 7).

Plastic Lugs and Crates

Solid plastic lugs such as those shown in Plate 7 are commonly used in Jamaica and Barbados. They are sturdy, durable, stackable (within limits), washable and easily carried. It should be noted, however, that these types of lugs are not well ventilated and should therefore not be overfilled or allowed to stand filled for extended periods.

Moulded plastic crates offer many advantages and are preferable to the above types of containers. Plastic crates available in the Region are light, durable, ventilated, and can nest when empty and stack when filled without damaging top layers of fruit. They thus utilize space efficiently and can be transported into and out of the field conveniently.

Wooden Crates

Wooden crates are rigid, durable and strong but, like baskets and sacks, are difficult to clean. In addition, poorly-made crates often cause punctures and scratches because of jutting

Table 2. Comparison of Container Types

Type	Advantages	Disadvantages
Crates		
Plastic	Light, durable, ventilated Stackable, nesting, easily cleaned, readily available, re-usable, convenient size	Relatively high initial capital investment
Wirebound	Light, durable, inexpensive	Low compression strength Promotes abrasions
Wooden	Strong, durable, ventilated, stackable, easily built and repaired, re-usable	Difficult to clean, splinters cause damage
Plastic Buckets	Light, durable, inexpensive easy to clean, convenient size	Crack easily Not ventilated
Woven Baskets	High capacity, durable re-usable, easily repaired	Not easily stacked inefficient utilization of space, difficult to clean, unstable, low compression and wet strength
Jute Bags	Cheap, re-usable, easily repaired	Difficult to clean, rots when wet, low compression strength, Poorly ventilated
Woven polypropylene	Cheap, re-usable easily available	Low compression strength

nails and splinters. Overfilling and indiscriminate stacking also expose the fruits to the risk of overheating, injury, spoilage and infection. Possible improvements can be achieved by using supplemental packaging materials such as sponge and blister plastic liners and pads. Newspaper is often used to line wooden crates. It is not recommended, however, since it blackens the fruit and offers little or no protection.

The relative advantages and disadvantages of the various container types are summarized in Table 2.

3.2 IN-FIELD TRANSPORT

In the Caribbean, in-field transport ranges from donkeys and oxen, to carts and motorized vehicles - trucks, vans, pick-ups, All Terrain Vehicles (ATVs). Regardless of the mode of transport, fruits should be protected from injury by improving farm roads to eliminate ruts, potholes, bumps. Where necessary, containers should be lined with cushioning materials.

During transport, loads of harvested fruits should be covered with a clean, light-coloured canvas or tarpaulin to reduce heat and moisture stress. The lower sides and top front area of the transport vehicle should be left uncovered to allow for air flow over the stacked fruit. Wetting of the canvas or tarpaulin further reduces warming by providing an evaporative cooling surface.

Injury during transport caused by bumping, compression and abrasion, can be reduced by restricting transport speeds to levels which minimise free movement of fruits. In addition, the reduction of tyre pressures minimizes bouncing of fruits so reducing surface abrasions. Suspension systems (preferably air, and not spring) should be installed on all transport equipment. Loads of stacked fruits can be stabilized by using sturdy containers which are stackable.

Alternatively, containers may be placed on removable shelves which can be made using wooden planks (10-15 cm wide) placed 5-15 cm apart and extending from one side of the transport vehicle to the other. The vertical distance between the planks can be made adjustable to suit the height of the containers. The practicality of using shelves is, however, questionable since vehicles used on a farm are often multi-purpose. The removal and placement of shelves, therefore, may be not only time consuming, but may also limit the flexibility of the vehicle.

4. PREPARATION OF FRUIT FOR MARKET

Papayas brought out of the field undergo a series of postharvest handling operations before being distributed: weighing, sorting, washing, chemical treatment, grading and packing. These operations are normally carried out in a packhouse.

4.1 PACKHOUSE DESIGN CONSIDERATIONS

The following points need to be considered when designing a packhouse for papaya:

- amount and optimum utilization of space
- flow of fruit
- future expansion and flexibility of operations
- optimum utilization of equipment and manpower
- safety and comfort of employees
- required supervision

Plate 1. Change in peel colouration from harvesting at 5% to 100% (full ripeness) in Solo papaya.

Plate 2. Measurement of sugar content using field refractometer.

Plates 3a & 3b Hand harvesting; twisting and cutting with a knife. Used for fruits within reach.

Plate 4. Pole and cup picker; requires considerable skill to catch the fruit.

Plates 5a & 5b Papaya pole and bag picker. The blade is positioned against the peduncle and the fruit falls into the bag.

Plate 6. Use of simple ladder as a harvesting aid. Not recommended as the tree may be damaged.

Plate 7. Three of the most commonly used containers for field transport: plastic crate, woven basket and sacks.

Plate 8. Commercial papaya packingline showing major equipment components.

Plate 10. Typical effects of Chilling Injury.

Plates 9a & 9b Typical export package showing the use of shredded paper with tissue and polystyrene sleeves.

Plate 11. Canned and candied papaya slices.

Plate 12. Damage caused by severe attack of mites.

Plate 13. Thrip damage, typically characterised by sunken circular areas.

Plate 14. Bird damage - causes complete destruction in ripe fruit.

Plates 15a & 15b Anthracnose disease develops in the field or post harvest.

(a) Early Stage

(b) Advanced Stage.

Plate 16. Phytophthora neck rot - can occur in the field or packhouse.

Plate 17. Catface - a physiological or genetic problem.

Plate 18. Abrasion caused poor in-field and packhouse handling.

Plate 19. Fingernail damage. Most often caused during packhouse handling.

Plate 20. Damage caused during harvesting by blade of pole and bag picker.

Plate 21. Spray damage caused by high nozzle pressure and high concentration of inappropriate chemicals.

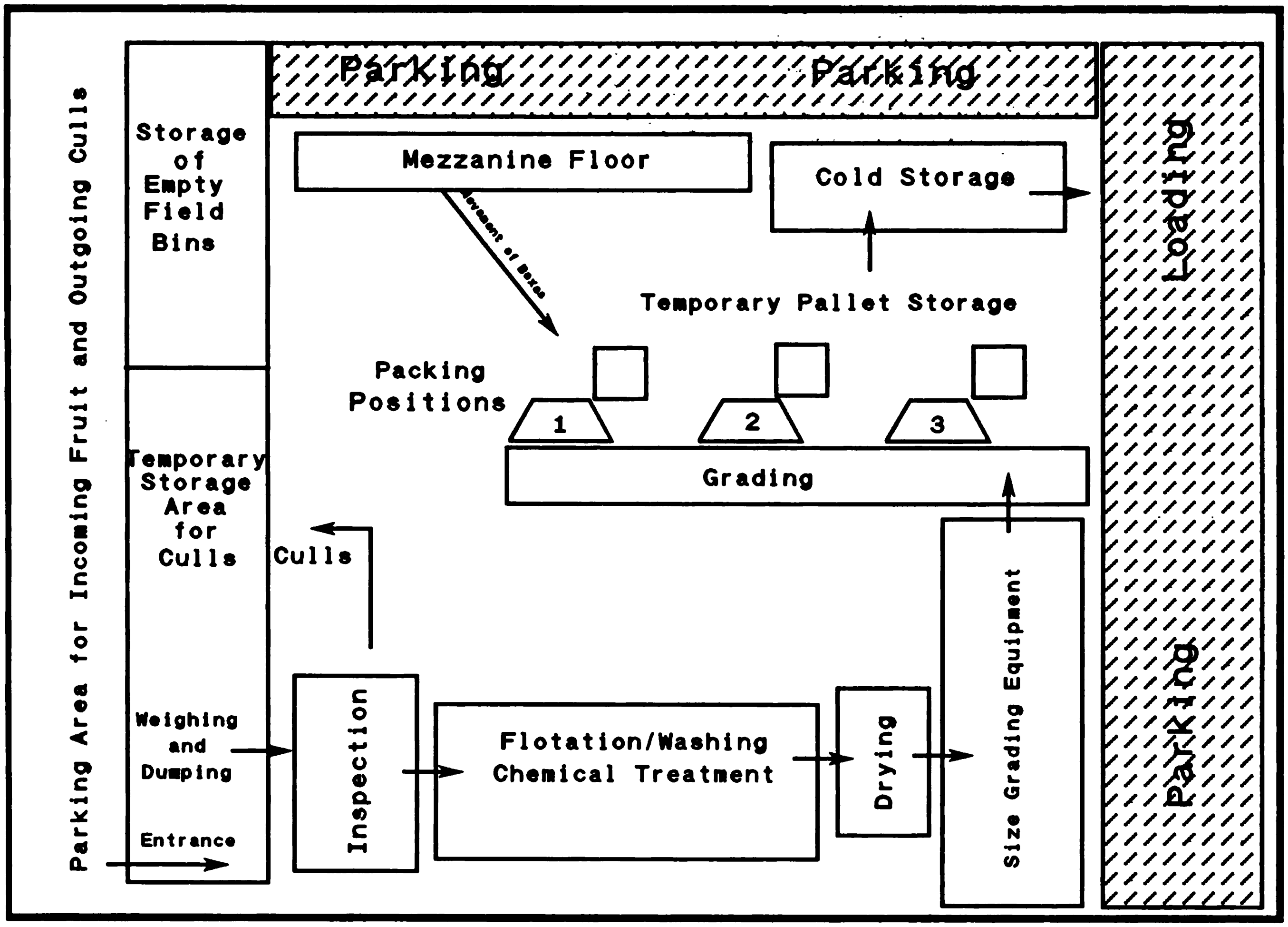

Figure 1. Typical Papaya Packhouse showing Layout and Basic Equipment Components

4.1.1 Location

The packhouse should be located as near as possible to the production area in order to maximize the efficiency of transfer of papayas from the field. Roads should be designed for heavy duty vehicles and there should also be adequate vehicle turn-around space. Densely populated areas should be avoided. The packhouse should be constructed on elevated ground so as to avoid flooding and the build-up of mud, especially in the delivery area.

4.1.2 Internal Structures

4.1.2.1 Floors and Floor Area

In general, floors should be graded, well-drained and easily cleaned. Adequate load bearing for equipment is important especially where fork lifts are used. The dimensions of the floor should be determined based on equipment sizes and space needed for holding and storage of fruits and packaging materials.

Layout

A well-designed packhouse layout which allows for efficient interaction of operations can significantly reduce floor area requirements. A straight or U-shaped floor pattern is commonly used. These types of designs are very simple, economical to construct and also facilitate supervision from a focal point near the centre of the pattern. A typical layout and the major equipment components are shown in Figure 1 and Plate 8.

The following points should be noted in the design of the layout.

a. In general, it is preferable for all fruit handling operations to be carried out on a single level. This is especially appropriate in the case of small-scale operations where produce may be delivered by a range of vehicle types and each load is relatively small. The construction of a depressed bay for loading of containerized vehicles can also be considered. Within the packhouse itself, use may be made of a mezzanine level or the areas on top of ground-floor offices or storage rooms for holding packaging materials or for additional office space. It should be noted that construction of the entire packing house at an elevation can significantly increase costs.

b. The delivery area should be protected from prevailing weather conditions by an overhang and it should be organized to allow for efficient movement of papayas arriving from the field into the preparation area. The loading and unloading areas should preferably be at separate locations in order to avoid cross-contamination of fruits.

Equipment for recording dates, and weights or numbers of containers of incoming fruit should be located in the delivery area. An area should also be allocated for quality control and shelf life checks on samples taken from the line.

c. The preparation area should be organized for an efficient flow of the fruit from washing and sorting through to packaging. Areas for temporary storage (for fruit awaiting preparation, culls and packed fruit), worker positions on the line and within the area, also need to be planned for.

4.1.2.2 Walls and Ceilings

Walls should be treated with materials which inhibit mould growth and which are easily cleaned. Working areas must be well-lit, particularly where grading is carried out. Daylight is best for grading, and artificial light is necessary for early morning and evening work.

Transparent roof panels can be inserted into roofs for additional lighting. Window openings should be sited in order to allow for adequate ventilation and to avoid entry of rain and direct sunlight which leads to overheating of the building. Window area usually approximates twenty percent of the floor area.

4.1.2.3 Doors

Doors should be large enough to allow for entry of vehicles delivering and collecting fruit. It is advisable to have packhouse personnel pass through a separate door in order to streamline traffic flow within the packhouse. A separate door should also be provided for removal of culls for dumping.

4.1.2.4 Utilities

The packhouse should be adequately supplied with water, electricity and fuel. Proper drainage for the disposal of wash water and chemical dip solutions should also be provided. Good access to communications (telephone, radio and/or mail) is necessary.

4.2 PACKHOUSE OPERATIONS

Papayas are brought into the packing area from the field. The optimum series of packhouse operations comprises the following: weighing, preliminary sorting (culling), stem removal, washing, postharvest treatments, drying, grading and packing, storage and ripening. All operations should be carried out irrespective of production volumes although the level of mechanization may increase with high-volume production. Fruits should be moved through the packhouse operations rapidly and delays should be avoided. In so doing fruit quality is maximized and operations flow smoothly from receipt to delivery. Each of the individual operations is discussed individually.

4.2.1 Weighing

All produce entering the packhouse should be weighed to enable calculation of production volumes, percentage of Grade 1 (export), Grade 2 (local) and reject fruit, and the picking efficiency.

4.2.2 Preliminary Sorting (Culling)

Preliminary sorting should be carried out prior to washing so as to remove fruit which are undersized, over-ripe, decaying, insect-damaged or infested, infected by fungus or mechanically damaged. Washing of fungus-infected fruit in large tanks will increase the possibility of disease transfer from fruit to fruit.

At this point, remaining long stems of individual fruit should be cut with a clean, sharp knife. Removal using thumb pressure is not advisable as this may lead to bruising and eventual decay. Rapid removal of reject fruit from the packhouse is essential. Culls can be used for processing or for animal feed. Discarded fruit should preferably be buried in an area remote from the packhouse and orchards. All saleable fruit should be transferred into water tanks for washing.

4.2.3 Dumping

Dumping (transfer into water or on to a conveyor) can be carried out manually or by mechanical unloading of bulk bins. For the fresh fruit market, manual systems are preferable. Individual fruit with the stems removed are placed directly into the water tank, thus limiting the possibility of skin damage or bruising. Bulk bin systems generally result in bruising, splitting or skin damage, but are suitable for processing operations. Volumes of 500-600 kg are loaded directly into tanks or onto conveyors.

4.2.4 Washing

Washing is a critical operation required for the removal of latex exuded from the stem, soil and debris. Depending on the size of the operation, flotation in or movement through a purpose-built water tank is generally adequate. If essential, the fruit may be gently washed using sponges (although this is not appropriate for high-volume operations). In low-volume static tanks, the fruit may be left in the field crates. Generally, a washing/soaking time of 1 to 2 minutes is required. A mild soap or bleach may be included (0.1%). Field crates are removed and the fruit allowed to dry. In mechanized systems, the papayas are moved through a tank, then passed over rollers to allow removal of surface water, then over sponge driers for rapid drying. Fans may be used as an alternative to sponge driers. Dry fruit can then be graded and packed.

4.2.5 Postharvest Treatments

Papayas are susceptible to infestations and infections which generally appear during storage and ripening (See Section 4.2.7). Infections caused by Colletotrichum gloeosporoides (anthracnose), Phytophthora sp. and Rhizopus stolonifer, and infestation by fruit flies are of major importance. The diseases can be controlled by fungicides incorporated in the washing tank. The refinement and efficiency of the treatments are dependent on the level of capital investment in equipment and on the level of disease in the orchard. Anthracnose control may be achieved by incorporating Benomyl or Thiabendazole (1.2 g/litre) in the water tank. Improved control is obtained by treating the fruit in a hot water dip containing the fungicide. The papaya are treated with hot water at 47°C for 20 minutes, followed by cooling. Care should be taken to avoid heat injury by either excessive exposure or too high temperatures. Heat-injured fruit fail to degreen and are often susceptible to blossom end rot caused by Dothiorella spp (Sommer, 1985).

Controlled hot water treatment generally requires the purchase of specialized equipment. Phytophthora sp. can be controlled post-harvest by Propamocarb hydrochloride (Previncur N) at a concentration of 0.1%.

Papaya exports to the USA require post-harvest treatments for eradication of fruit flies. Existing treatment in commercial operations consists of a double-dip hot water treatment: 20 minutes at 46°C followed by 20 minutes at 42°C.

4.2.6 Grading

Grading and packing requirements are dependent on the market requirements ie. export (regional and extra-regional) and local market. Specifications between the markets vary in terms of the size requirements, stage of ripeness, degree of acceptance of defects and the packing and packaging requirements. Although the market does not normally specify the Brix required, experience shows that fruit with less than 10% Brix are not well accepted in most markets. Ripe fruit of sweet cultivars should have at least 12% sugar content.

After washing and drying, the fruit should be graded onto packing tables, differentiating between local market and export market. This is generally based on size, shape and external quality. Grading tables on their own or in association with a simple conveyor system are suitable where fruits are graded visually. With high-volume systems, a weight grader, either mechanical or electronic, increases efficiency and reduces error in size grading. Regardless of the system used, careful handling must be employed during grading to avoid bruising or damaging the skin. Importers of papaya (and other agricultural commodities) in industrialized countries generally impose strict quality and packing requirements. These requirements are normally less stringent for regional and local market fruit. Details of the individual market requirements are given in Table 3. Grading for the export market is critical: fruit in each carton should be of same size and colour, with little or no variation between fruit. This process is not as critical for local and regional-destined fruit. Additional packaging material is required for fruit destined for extra-regional markets to protect it from bruising and damage due to the additional handling, and also to improve presentation. Shredded paper in the base of the box and wrapping of fruit in tissue, to prevent fruit rubbing against each other, are both recommended (Plates 9a & 9b).

Table 3. Grading and Packing Requirements for Local, Regional and Extra Regional Markets[1]

Requirement	Extra-Regional	Regional	Local
Packing weight	4 kg (9 lbs)	5 kg (11 lbs)	5 kg (11 lbs)
Size Requirement	350-600 g	600-1200 g	700-1200 g
Shape Requirement	Pear-shaped Limited round	Pear-shaped or round	Pear-shaped or round
Size grading	Necessary	Necessary	Optional but Advised
Colour	20-25% yellow	15-30% yellow	>60% yellow
Additional Packaging	Shredded paper Tissue paper Expandable poly styrene	None	None
Defects[2] (subject to change)	5%	15%	25%

[1] CATCO data
[2] For details, See Table 4, pg. 22

4.2.7 Ripening

All retail buyers of papaya prefer to receive fruit in a firm-ripe condition ready for sale, generally indicated by 60-80% yellow colour. Fruit shipped by air should therefore be harvested with 5-10% yellow colour and shipped with 20-50% yellow colour. This generally implies that the fruit are stored at ambient (25-30°C) for 24 hours prior to shipment to allow for colour development. Pre-cooling to 12°C for 18-24 hours prior to shipment is sometimes necessary depending on ambient temperatures in importing countries (ie. in the summer months).

Fruits with 10-30% yellow colour can be successfully stored for up to 2-3 weeks under low temperature conditions (12°C, 85-95% relative humidity) provided that they are treated against fungal infection (Medlicott, 1988).

Ripening may be carried out very simply and economically in small-scale systems by covering the containers of fruit with a tarpaulin and exposing them to ethylene gas produced by splashing liquid ethylene formulas such as Ethrel on the floors. Alternatively, standard ripening rooms with appropriate temperature and relative humidity controls can be used for ripening. Within these rooms, ethylene applied either directly as a gas or indirectly generated from liquid formulations is introduced into the room at regulated rates over a specified number of days, depending on the stage of ripeness desired in the fruits.

4.2.8 Storage

Fruit harvested and packed with 5-10% yellow colour should be placed immediately at low temperature (12°C) and shipped within 36 hours. Storage conditions during shipment should be 10-12°C and 85-90% relative humidity. Under these conditions, the papaya will store successfully for 12-15 days and ripen subsequently when transferred to higher temperatures. Storage temperatures below 10°C are not recommended since this will induce Chilling Injury (CI) symptoms. These include inability to ripen or degreen, abnormal loss of firmness, accumulation of water in the tissues and increased susceptibility to fungal attack (Plate 10). Papayas should not be stored with other fruits or vegetables during shipment as this increases the risk of spoilage. Disease control measures immediately after harvest are essential for sea-shipped fruit as fungi and microorganisms will have an extended time to develop and the risk of spoilage is therefore higher.

5. MARKETS FOR PAPAYA

5.1 EXTRA-REGIONAL MARKETS

World trade in papaya has increased rapidly over the last 10 years. The major producing countries contributing to papaya exports are Brazil, Hawaii, South Africa, Jamaica, Israel and East Africa. The major importing countries are the USA, UK, Canada, Europe and Japan.

Imports of papaya have increased rapidly, showing an 11-fold increase between 1980 and 1987 to a total of 1,029 tonnes in 1987 (Commonwealth Secretariat, 1988). The European market in total, has shown increases from 424 tonnes in 1980 to 1,755 tonnes in 1986 (Joy, 1987). The market share of suppliers is dominated by Brazil which accounts for 80% to 90% of the total volume. Brazil supplies on a year-round basis while other countries generally supply fluctuating volumes dependent on seasonal production. Main Caribbean suppliers Jamaica, Barbados, and the Dominican Republic.

Continued demands for increasing volumes are anticipated if the following criteria can be achieved:

- high quality fruit, in consistent volumes over regular supply periods;
- utilisation of appropriate packaging;
- presentation of fruit to the consumer at the correct state of ripeness;
- promotional activities to educate the retailers and consumers;
- introduction of sea-freight to enable reduction in prices while enabling good or acceptable quality.

The export market specifications generally require small-sized hermaphrodite (elongated) fruit (330-450 g) with orange or red flesh. These include fruit of the sunrise 'Solo Kapoho" and "Amazon Red". Fruits should be packed in single layer fiberboard cartons, at net weights of 4 kg with preferred counts ranging from 9s to 12s. Importers require size-graded fruit, with a minimum of 40% and a maximum of 70% yellow colouration on arrival at the market. This enables sale of fruit with acceptable quality and sufficient shelf-life.

5.2 REGIONAL MARKETS

Exports within the Caribbean region are dependent on the demand, the level of local production and the price. Where imports are made, the quality of the fruit has to be high in terms of appearance, and condition, as the unit price will be higher than locally produced fruit. For this reason, regionally exported fruit should be packed to a standard weight (4.5 kg) in fiberboard cartons and be graded by size and colour. Demand for exports to the regional market is limited, especially in light of diversification programs which may involve planting of papaya in the importing island. No figures are available for inter-island trade: an FAO report (Schuur-Castenmiller, 1988) indicated that no significant regional trade in papaya is apparent. No individual figures are given for recent regional exports from any of the islands (Grenada exported 126 and 97 tonnes of papaya to Trinidad in 1984 and 1985, although this trade is now reported as negligible). Regional trade cannot be therefore seen as a major area for the marketing of papaya.

5.3 DOMESTIC MARKETS

Requirements for locally produced papaya vary within the Caribbean countries, according to population, size of tourism industry, awareness of the fruit, existence of competing fruit types and price. Local market sales do not generally offer potential for significant volumes. Fruit produced for export, but which fail to meet the specifications are generally marketed locally. Demand in Barbados is estimated at 6 tonnes per week. There is, however, significant potential to be tapped.

Specifications relating to size and quality are less stringent than for extra-regional markets. Local markets require large fruit (0.5 -1.5 kg) with less preference being given to round or elongated (hermaphrodite) fruit. Size grading is not required and badly damaged or scarred fruit are not acceptable. Colour stage on sale is not critical since the fruit will ripen naturally, although riper fruit (50% yellow colour) tend to be preferred. No standard package and net weight are needed as sales are usually on a per pound or per kilogram basis. Fiberboard carton or plastic crates can be used as packaging.

6. UTILIZATION

Papaya fruits can be processed into pureed, dehydrated, canned, frozen and concentrated products. These products can, in turn, be used in the manufacture of a number of food products including preserves (jams, jellies, confectionery), beverages, and flavour bases for dairy products such as yogurt and ice creams.

6.1 PAPAYA PUREE

Several deleterious chemical and biochemical changes are initiated in papayas on pulping of the fruit. Some of these include the development of off-odours and off-flavours and gelation of the puree. These changes are caused by enzymatic activity, which is accelerated by the papaya's low acid content. In addition, the papaya contains many seeds which, if damaged, can lead to the development of pungent, bitter flavours in the puree.

The selection of a process for the production of papaya puree must therefore incorporate unit operations for:

- the control of the acidity to a level which effectively inhibits enzymatic activity initiated during pulping;
- minimization of seed damage, and
- heat inactivation of enzymes in order to render the puree stable during subsequent storage and distribution.

A relatively new method for producing papaya puree has been developed which overcomes the enzymatically induced changes. This method has been proven to be superior to others in that the puree produced is devoid of off-flavours and odours, does not gel during frozen storage, is lower in microbial counts and possesses less seed particles. The process described below has been used with great success over the last 5-10 years for the commercial production of papaya puree which has been marketed in Europe, Japan and the United States.

6.1.1 Process Line Operations

Ripened papayas are gently dumped onto a sorting table. Decayed and green fruits are removed and the ripe fruits placed on a conveyor to the steam tunnel. Green fruits are returned to a ripening bin.

The fruits are steamed for approximately 2 minutes. The length of exposure to steam is determined by examining random samples of fruit until a heat ring (3-4 mm deep) develops immediately below the surface of the skin. Steaming has the dual effect of preventing bleeding of the latex from the skin during slicing and of softening the outer 3-4 mm of the fruit thus increasing puree yield by 4-10%. Steaming also serves to sterilize the surface of the fruit thereby lowering the microbial load. The steamed fruits are spray-cooled after which they are sliced.

The sliced fruit is then fed to a crusher-scraper where the flesh and seeds are loosened and removed from the peel by the action of a rapidly rotating cylinder. Breakage of the seeds and development of bitter flavours in the puree are therefore minimized. The material that issues from the crusher-scraper is a mixture of papaya peel, seeds and pulp. The peel and seeds are separated from the crushed pulp in a centrifugal separator which further minimizes breakage of skins and seeds and their inclusion in the puree.

The crushed flesh is pulped in a paddle-pulper and acidified with citric acid to a pH of 3.5. Acidification inhibits (a) the enzymatic reactions that result in the development of off-flavours, off-odours and gelation and (b) the growth of certain microorganisms that cause spoilage.

The acidified pulp is then pumped to a finisher which eliminates coarse fibres, seed coat particles and black specks to yield a smooth puree. The puree then undergoes a heat treatment which is essential to the production of a stable product. In the case of frozen puree, the puree is heated for 1 to 2 minutes at 92-95°C. Aseptically processed puree is heated for 60 seconds at 93°C. The cooled puree is then either packaged into 25-lb containers and frozen at -18°C or pumped to an aseptic filler which fills the product into 1 to 300-gallon sterilized multi-ply aluminized polyester bags. A summarized process flow and typical equipment line are shown in Figure 2 and Figure 3 respectively.

6.2 DEHYDRATED PRODUCTS

Dehydrated products cover a broad range from intermediate moisture and candied products, in which a portion of the moisture is removed to powders and fruit leathers which have a very low moisture content (5-8%).

Whole ripe fruit, pieces or puree can be used as starting material. The whole fruit is deseeded and cut into slices (4.8 mm thick) which are then dried by at 60-66°C to a moisture content of 6%. The candying process involves placing blanched, tenderized slices into sugar solutions of increasing concentration, at a specific temperature and over a fixed time period. The final product is rinsed, dried and may be glazed or dusted with a layer of sugar.

Papaya fruit leathers can be made by dehydrating papaya puree. The puree is first mixed with sugar and the mixture is poured into shallow drying pans. Antioxidants may be added to protect against colour and flavour loss during storage.

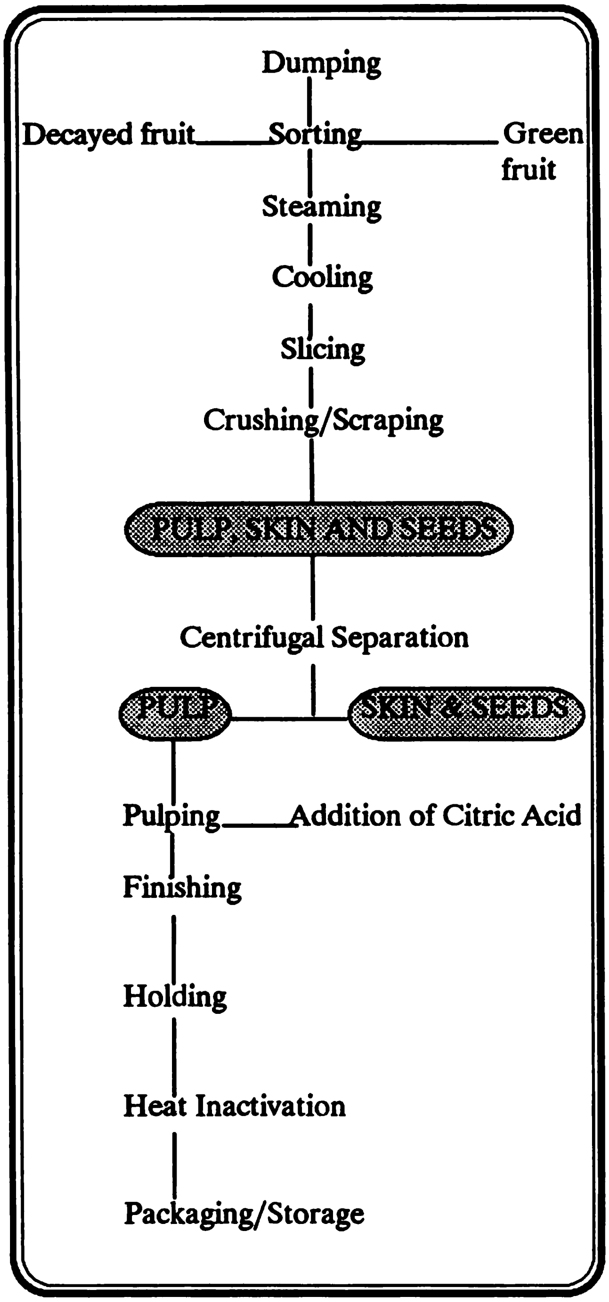

Figure 2. Process line unit operations for papaya puree production (Chan, 1977)

6.3 CANNED PAPAYA

The procedure for the production of canned papaya is illustrated in Figure 4. Dried and canned papaya are shown in Plate 11.

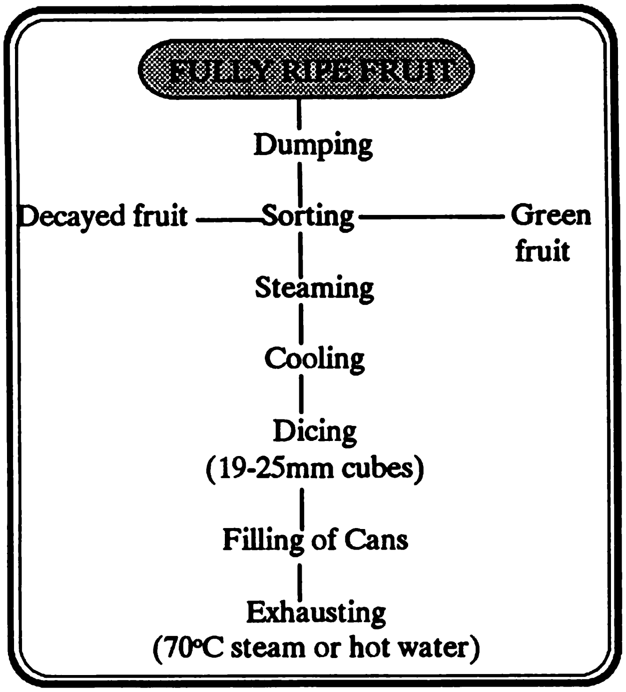

Figure 4. Process Flow for Canning of Papaya

6.4 FROZEN PAPAYA

Frozen papaya products have limited commercial potential since ripe fruit lose texture and flavour when frozen, and greener fruit require peeling and deseeding, operations which have to be done manually.

6.5 CONCENTRATES

Papaya purees can be concentrated by first treating with a pectinolytic enzyme to reduce its viscosity and then concentrating in a vacuum evaporator.

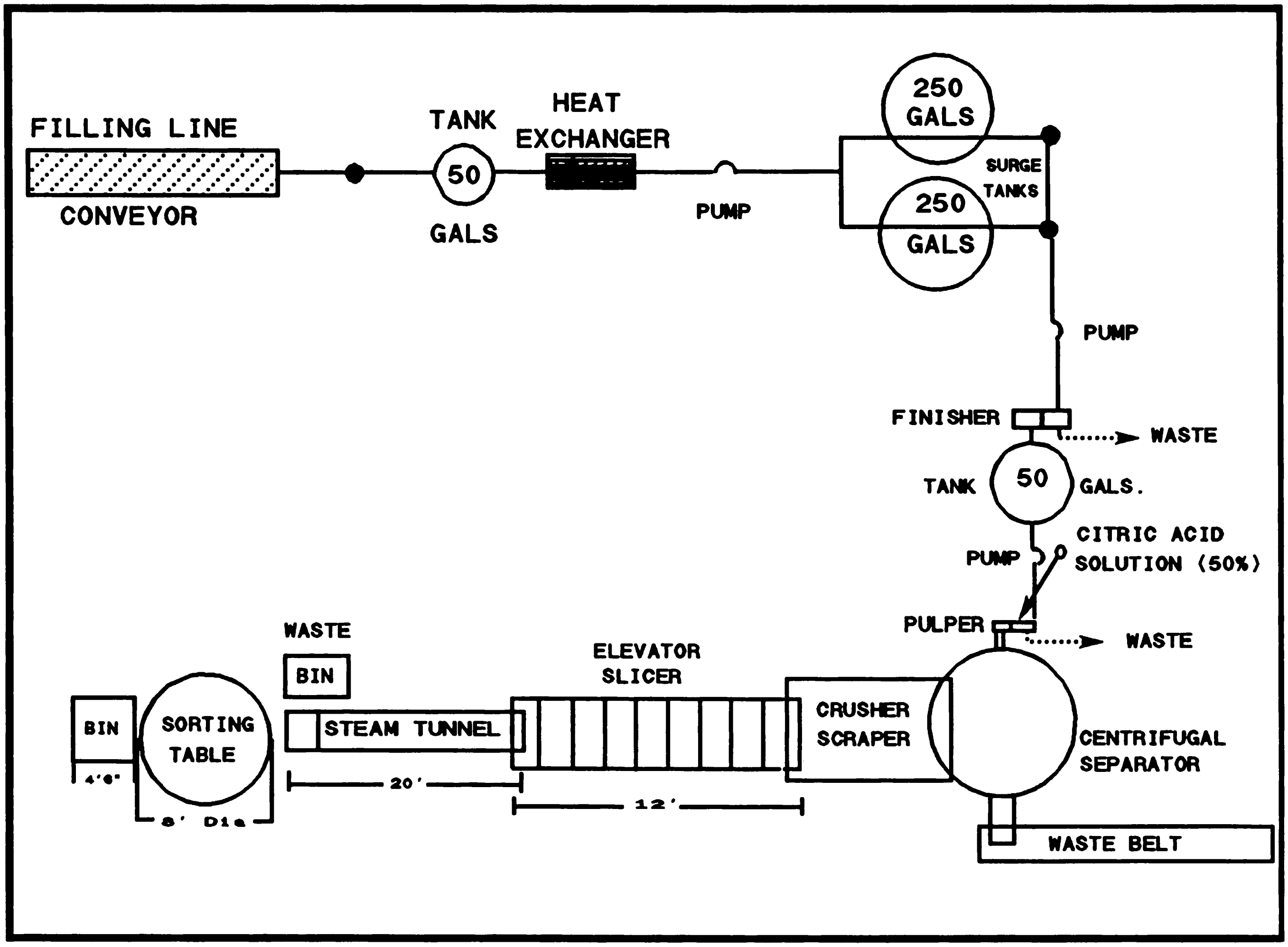

Figure 3. Typical Equipment Line for processing of Papaya Puree (after Brekke *et al.*, 1977)

6.6 OTHER PAPAYA PRODUCTS

6.6.1 Seed Products

Papaya seeds constitute approximately 22% of processing waste. Chemical analysis has shown that papaya seeds contain oil that is relatively low in polyunsaturated fatty acids. Defatted papaya seed meal was also found to have high amounts of crude protein (40%) and crude fibre (49.9%). Papaya seeds are sometimes used as a substitute for pepper and as an adulterant in ground pepper because of their spicy, pungent flavour. The young seeds are used as a gourmet item in exclusive restaurants in Asia. The seeds contain benzylisothiocyanate which is used as a germicide and an insecticide.

6.6.2 Skin Products

Papain, found in the skin of green papayas, is an important proteolytic enzyme used in the food and cosmetic industries (viz. chill-proofing of beer, meat tenderizers).

7. COMMON CAUSES OF FRUIT DAMAGE

In a commercial operation for the production and marketing of papaya, benefits are achieved not only by increasing the total yield but also by keeping to a minimum, the damage to the fruits. This damage may have a physical, chemical or biological/physiological origin and can occur in the field during the production or harvesting operations, or during the postharvest handling processes. Fruit damage may affect only the external quality, only the internal quality, or it may affect both the external and internal quality of the fruit. Plates 12 to 21 illustrate the most common forms of external fruit damage.

The level of damage accepted on the fresh fruit depends on the market, which, in turn, is influenced by consumer demand, the amount being offered in the market and the price of the product. Extra-regional markets are more sophisticated in term of standards than regional or domestic ones. Nevertheless, regardless of the type of market, fruit damage results in high rejection rates and consequently, less economic returns from the commercial operation. Table 4 lists the common factors and causes of fruit rejection, when they occur, and their effect on fruit quality.

Table 4. Most Common Causes of Fruit Damage and their Relation to Production, Harvesting and Postharvest Handling

Factors	Causes	Description of Damage	Occurrence: On Tree	Occurrence: At Harvest	Occurrence: Post Harvest	Effect of Damage: Yield	Effect of Damage: Quality Int.	Effect of Damage: Quality Ext.	Recommendations
BIOLOGICAL									
Fruit flies	Inefficient spray programme	Puncturing, pulp destruction larvae in pulp	x				x	x	Improve spray programme
Caterpillars	Same as above	Holes and pulp destruction Fungi develop in debris	x			x[1]	x	x	Same as above
Mites	Same as above	Fruit scarring	x			x[1]	x[1]	x	Same as above
Thrips	Same as above	Sunken spots, scalds	x			x[1]	x[1]	x	Same as above
Aphids	Same as above	Puncturing facilitates anthracnose	x			x[2]	x[2]	x	Same as above
Scales	Same as above	Scars, discolourations facilitate disease development on debris	x			x[1]	x[1]	x	Same as above
Rats	Dirty fields and packhouses; fruits allowed to over-ripen or rot in fields Lack of control programme.	Holes in fruits	x			x	x	x	Maintain field and packhouses clean. Do not allow fruit to ripen on tree or rot in field. Use control programme.
Birds	Fruit allowed to ripen on trees.	Holes in fruits	x				x	x	Harvest on time.
Anthracnose	Inefficient control program; fruits allowed to ripen on trees.	Necrotic spots on whole area	x	x		x	x	x	Improve spray programme. Harvest on time
Phytophthora	Same as above	Necrotic areas	x			x	x	x	Same as above.
Ringspot Virus	Inefficient control of vectors; use of susceptible cultivars.	C-shaped scars, Low Brix. Light pulp colour.	x			x	x	x	Control of vectors. Use tolerant cultivars
Bunchy Top	Same as above.	Low Brix, light pulp	x			x	x	x	Same as above.

1/ Mainly through defoliation
2/ Mainly indirectly, by transmission of viruses

Table 4. Most Common Causes of Fruit Damage and their Relation to Production, Harvesting and Postharvest Handling

Factors	Causes	Description of Damage	Occurrence: On Tree	Occurrence: At Harvest	Occurrence: Post Harvest	Effect of Damage: Yield	Effect of Damage: Quality Int.	Effect of Damage: Quality Ext.	Recommendations
NUTRITIONAL / ENVIRONMENTAL & GENETIC									
Excess Potassium	Excess soil fertility or over-fertilization	Very hard pulp.	x				x		Soil and foliar analyais. Monitor and balance nutrients.
Excess	Same as above. Nitrogen	Low Brix, External burning.	x Oversized fruits,				x		Same as above.
Excess Salts	Salty soils or water; wrong fertilization.	Salty flavour. External burining and discolorations.	x			x	x	x	Soil, water and foliar analysis. Improve fertilization practices.
Excess Water	High rainfall; poor drainage	Low Brix, lighter pulp color. Facilitates secondary damage.	x			x	x		Avoid areas with high rainfall or heavy soil. improve drainage.
Excess heat or direct sunlight	Very high temper- defoliation.	Latex flow discoloration.	x				x		Avoid defoliation. Improve leaf growth.
Deficient Potassium	Poor soils and inefficient fertilization.	Low Brix.	x			x	x		Better selction of soils. Monitor and control level of potassium on leaves.
Deficient nitrogen	Poor soils; Inefficient fertiliz- ation; N Lost by leaching.	Undersized fruits hard pulps.	x			x	x	x	Better fertilization practices.
Deficient boron	Poor soils; insuficient fertilization.	Nipples or bumps on fruits	x			x		x	Same as above.
Cat face	Very high temp- erature. Genetic.	Ridges and folded areas	x				x	x	Avoid for seed selection.
Internal fruit growth	Second fruit develops inside, seed abortion seed germination.	A mass of pulp inside the seed cavity; decay of seeds; embroyo growth.	x				x		Avoid for see selection.

Table 4. Most Common Causes of Fruit Damage and their Relation to Production, Harvesting and Postharvest Handling

Factors	Causes	Description of Damage	Occurrence: On Tree	Occurrence: At Harvest	Occurrence: Post Harvest	Effect of Damage: Yield	Effect of Damage: Quality Int.	Effect of Damage: Quality Ext.	Recommendations
PHYSICAL									
Windscar	Wind causing rubbing of tree parts with fruits.	Light brown healed scars.	x					x	Use windbreak
Leaf-rub	Leaf or petiole against fruits.	Light brown scars or light green areas.	x					x	Remove dead leaves
Fruit-rub	Fruit rubbing against adjacent fruits	Same as above.	x					x	Avoid multiple seed selections.
Abrasion	Incorrect use of harvest instruments Contact with rough surface.	Latex staining; small cuts or roughening of peel surface.		x			x	x	Train and supervise field staff. Handle carefully. Use cushioning mat.
Puncturing	Harvesting instruments; adjacent fruit stems fingernails; rough surfaces.	Hole made in the fruit surface.		x			x	x	Same as above. Remove stems in field. Use gloves.
Cutting	Harvest instruments; knife when peduncle cut	Cutting or puncturing of fruits, slicing of fruits.		x			x	x	Same as above.
Bruising	Dropping of fruit; excessive movement fruits during transport.	Fruits visible as dark green staining area which will soften and decay rapidly.		x			x	x	Handle carefully. Transport at low speeds. Use cushion material.
Chilling injury.	Storage at low temperature eg. <10° C., for extended period of time.	Pitting, peel and pulp discloration. Increased disease incidence.		x			x	x	Do not store below 10°C.
Spray damage	Inappropriate spray product or concentration. Excessive spray force.	Light or dark brown-grey scald-like discoloration		x				x	Follow recommendations for concentrations, frequency, nozzle pressure.
Excessive hot water treatment.	High water temperature. Prolonged exposure of fruits to hot water	Skin shrivelling, skin. discoloration increased disease incidence.			x		x	x	Utilize appropriate equipment and ensure temperature maintenance.

REFERENCES

Brekke, J.E., Chan, H.T., Hibbard, K.L., Nakayama, T.O.M., Someda, R.C., Myers, A.E., and Cavaletto, C.G. 1977 Operating Manual for Papaya Puree Processing, University of Hawaii, College of Tropical Agriculture, Departmental Paper 47.

Colon, W. and Vasquez, F. 1988. Performance of the Solo Papaya Cultivar 'Sunrise' in Puerto Rico. Proc. 24th Annual Conf. of CFCS, Ocho Rios, Jamaica, August 1988 (in print).

Commonwealth Science Council, 1988. Fruit and Tropical Products, June 1988

FUSAGRI. 1984. Lechosa. Serie Petroleo y Agricultura No. 6. Publ. Gremeica Editores, Venezuela, 70 pp.

Joy, C. 1987. Selected European Markets for Specialty and Tropical Fruits and Vegetables. TDRI Report G201 pp 42-43.

Marte, R. 1986. Production of papaya (Carica papaya L.) in Barbados. IICA Miscellaneous Publication No. 593.

Marte, R. 1986. Evaluation of the papaya industry in Jamaica (unpublished report).

Medlicott, A. P. 1988. Storage trials on Papaya Sea Shipment, CATCO Internal Report (unpublished).

Schuur-Castenmiller, J. 1988. Trade of Fresh Produce in the Eastern Caribbean, FAO Field Document PFL/RLA/001/PFL, September, 1988.

Sommer, N.F. 1985. Strategies for Control of Postharvest Diseases of Selected Commodities. In Postharvest Technology of Horticultural Crops, Special Publication 3311, Coop. Ext., Univ. of Calif, Div. Agric. and Nat. Res.

Sotomayor, R. 1988. A Glance at the Papaya Industry in Puerto Rico: Present Situation and Outlook. Proc. 24th Annual Conf. of CFCS, Ocho Rios, Jamaica, August 1988 (in print)

INTER-AMERICAN INSTITUTE FOR COOPERATION ON AGRICULTURE
P.O. Box 705, Bridgetown, Barbados
Tel.: (809) 427-4740/1/2