

# GOOD PRACTICE FOR ASSURING THE POST-HARVEST QUALITY OF EXOTIC TREE FRUIT CROPS PRODUCED IN JAMAICA

*A TECHNICAL GUIDE*

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# Good practice for assuring the post-harvest quality of exotic tree fruit crops produced in Jamaica

*A TECHNICAL GUIDE*



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# Contents

<b>Acknowledgements</b>	<b>ix</b>
<b>Preface</b>	<b>xi</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Production and consumption of fruits in Jamaica	1
1.2 Marketing channels for tree fruits in Jamaica	1
1.3 Post-harvest losses in tree fruits in Jamaica	3
1.4 Causes of post-harvest losses in tree fruits	3
<b>2 Pre-harvest factors that impact on post-harvest quality</b>	<b>5</b>
<b>3 Harvesting</b>	<b>9</b>
3.1 Maturity at harvest	9
3.2 Commercial vs. physiological maturity	9
3.3 Maturity indices	10
3.4 Subjective criteria for assessing fruit maturity	10
3.5 Objective criteria for assessing fruit maturity	11
3.6 Time of harvest	12
3.7 Method of harvest	12
3.8 Harvesting tools	12
<b>4 The packing house</b>	<b>15</b>
4.1 Design and management of a packing house	15
<b>5 Packing house operations</b>	<b>21</b>
5.1 Basic packinghouse operations	21
5.2 Cleaning	22
5.3 Sizing	23
5.4 Specialized packinghouse operations	24
5.5 Surface coating with waxes	24
5.6 Treatment with fungicidal and bactericidal chemicals	25
<b>6 Packaging</b>	<b>31</b>
6.1 Packaging for transportation to domestic markets	31
6.2 Good practice for the use of plastic crates for transporting fruits	33
6.3 Packaging for export	34

<b>7</b>	<b>Storage</b>	<b>37</b>
7.1	Facts about fresh fruit storage	37
7.2	Cold storage	37
7.3	Design and construction of a cold storage facility	38
7.4	Good practice for the cold storage of fresh fruits	38
7.5	Appropriate technology for cooling fruit – a solar assisted cooling chamber	39
<b>8</b>	<b>Transportation</b>	<b>41</b>
8.1	Important considerations for fruit and vegetable transportation units	41
8.2	Refrigerated transportation	41
<b>9</b>	<b>Traceability in fresh fruit chains</b>	<b>43</b>
9.1	Traceability	43
9.2	Key components of a traceability system	43

### Harvesting and post-harvest handling of tree fruits produced in Jamaica

<i>Ackee (Blighia sapida)</i>	47
<i>Avocado (Persea americana)</i>	49
<i>Bread fruit (Artocarpus altilis)</i>	51
<i>Cashew apple (Anacardium occidentale)</i>	53
<i>Citrus tangerine (Citrus reticulata)</i>	54
<i>Guava (Psidium guajava)</i>	56
<i>Jackfruit (Artocarpus heterophyllus)</i>	57
<i>June plum (Spondias cytherea)</i>	59
<i>Naseberry/sapodilla (Manilkara zapota)</i>	60
<i>Mango (Mangifera indica)</i>	62
<i>Papaya (Carica papaya)</i>	64
<i>Soursop (Annona muricata)</i>	66
<i>Sweetsop or Sugar apple (Annona squamosa)</i>	67
<i>Tamarind (Tamarindus indica)</i>	68

<b>10</b>	<b>Processing of tree fruits for preservation and value addition</b>	<b>69</b>
10.1	Dried/dehydrated fruits	69
10.2	Fruit jams	73
10.3	Fruit cordials	74
10.4	Ready to serve drinks (RTS)	76
	<b>References</b>	<b>77</b>
	<b>Annexes</b>	<b>79</b>

## List of tables

1	Fruit exports from Jamaica – 2005	2
2	Export markets for Jamaica’s fruit and vegetable outputs – 2005	3
3	Some chemical treatments for controlling the microbial spoilage of harvested fruits	26
4	Climacteric and non-climacteric fruits produced in Jamaica	27
5	Ripening conditions for some tree fruits using ethylene	27
6	Additional income (J\$) generated by transporting fruit in plastic containers instead of crocus or poly-sacs in Jamaica	32
7	Recommended temperatures and relative humidity conditions for the storage of some fruits grown in Jamaica	38

## List of plates

1	Yeasty rot of pineapple	5
2	Black rot of pineapple	5
3	Anthracoise of banana	6
4	Crown rot of banana	6
5	Anthracoise of mango	6
6	Stem end rot of mango	6
7	Anthracoise of papaya	6
8	Green mould of papaya	6
9	Penicillium rot in citrus fruits	7
10	Lighting at eye level causes blinding and eye fatigue	18
11	Sizing rings for tomatoes	23
12	Sizing device for fresh fruits	23
13	Sizing of mangoes	23
14	Sizing of citrus	23
15	A fruit ripening chamber in the countryside of Jamaica	29
16	Plastic containers (crates) used for handling and transportation of fresh fruits	31
17	Stackable plastic containers for the handling and transportation of fruits	33
18	Nestable plastic containers for the handling and transportation of fruits	33
19	Design of a truck body for transportation of fruit in plastic containers	33

20	Pallet stabilization using mesh plastic tension netting	34
21	Pallet stabilization using corner posts and strapping	34
22	Chilling injury of bananas	37
23	Solar assisted evaporative coolers for storage of fresh fruits	39
24	Stage of maturity for harvesting of ackee	47
25	Stage of maturity for harvesting of avocado	49
26	Mature breadfruit/Cross section of the interior of a mature breadfruit	51
27	Cashew apples at different stages of maturity	53
28	Stage of maturity for harvesting of tangerines	54
29	Immature guava/Cross section of a ripe guava	56
30	Stage of maturity for harvesting of jack fruit	57
31	Stage of maturity for harvesting of june plum	59
32	Stage of maturity for harvesting of naseberry/sapodilla	60
33	Stage of maturity for harvesting of mango	62
34	Stage of maturity for harvesting of papaya	64
35	Stage of maturity for harvesting of sour sop	66
36	Stage of maturity for harvesting of sugar apple	67
37	Stage of maturity for harvesting of tamarind	68
38	IPHT multi-crop dryer, operated by agricultural waste, for dehydration of fruit	72
39	Jams prepared from tree fruits	73
40	Cordials prepared from tree fruits	74
41	Extraction of tamarind pulp	75
42	Bottle sealing device	75
43	Ready to serve drinks (RTS) prepared from tree fruits	76

## List of figures

1	Marketing channels for tree fruits in Jamaica	2
2	Causative agents of fruit deterioration	4
3	Commercial vs physiological maturity of fruit	9
4	Harvesting tool for plucking of tree fruits occurring in bunches	13
5	Harvesting tool for plucking of papaya	13
6	Harvesting tool for the plucking of tree fruits – I	13
7	Harvesting tool for plucking of tree fruits – II	13
8	Harvesting tool for plucking of tree fruits – III	14
9	Flow diagram of packing house operations	16



10	Basic floor plan design of a small-scale packing house facility	17
11	Sorting and packing stand for small operations	22
12	Different horizontal package dimensions to maximize utilization of a 100 x 120 cm pallet	35
13	Traceability in fruit supply chains	43
14	Sun/solar drying tray	71

## List of annexes

1	Fruit harvester – for mango and other fruits occurring in bunches	81
2	Fruit harvester – papaya	82
3	Fruit harvester – I	83
4	Fruit harvester – II	84
5	Fruit harvester – III	85
6	Solar assisted evaporative cooler for the storage of fresh fruits	86
7	IPHT multi crop dryer	87



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# Preface

The training guide is designed to serve as a learning and training resource for practitioners and trainers respectively, working on the post-harvest management of non-traditional tree fruit crops. The guide describes general post-harvest handling principles applicable to horticultural crops and documents good post-harvest handling practice for exotic fruit produced in Jamaica.

It is hoped that the guide will stimulate improvements in the supply chains for exotic fruit in Jamaica, leading to safer produce of higher quality and to better economic returns for small-scale producers.

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## Chapter 1

# Introduction

Fruits contribute aesthetic appeal and essential nutritional requirements to the human diet. Certain fruits also provide a supplementary source of carbohydrates, minerals and protein. The possible beneficial effects of dietary fiber derived from fruits is currently under scrutiny as part of a re-examination of human dietary requirements, with the objective of minimizing disease risks thought to be related to affluent life styles.

Tree fruit crops are very important constituents of the Jamaican diet and contribute to the nutrition of the general populace. They also make a significant economic contribution and provide a source of income for small farmers and plantation owners.

Jamaica produces both traditional “orchard” type fruits crops such as bananas and citrus and non-traditional fruits crops such as ackee, avocado, breadfruit, mango, June plum, papaya, cashew, guava, naseberry, jackfruit, tamarind and fruit of the *annonaceae* family (soursop, sweetsop and custard apple). Non-traditional fruits produced in Jamaica, generally lack a formal or organized marketing system.

Efforts must be geared toward the development of Jamaica’s fruit tree crop industry if the country is to competitively market its fruit outputs on local and international markets.

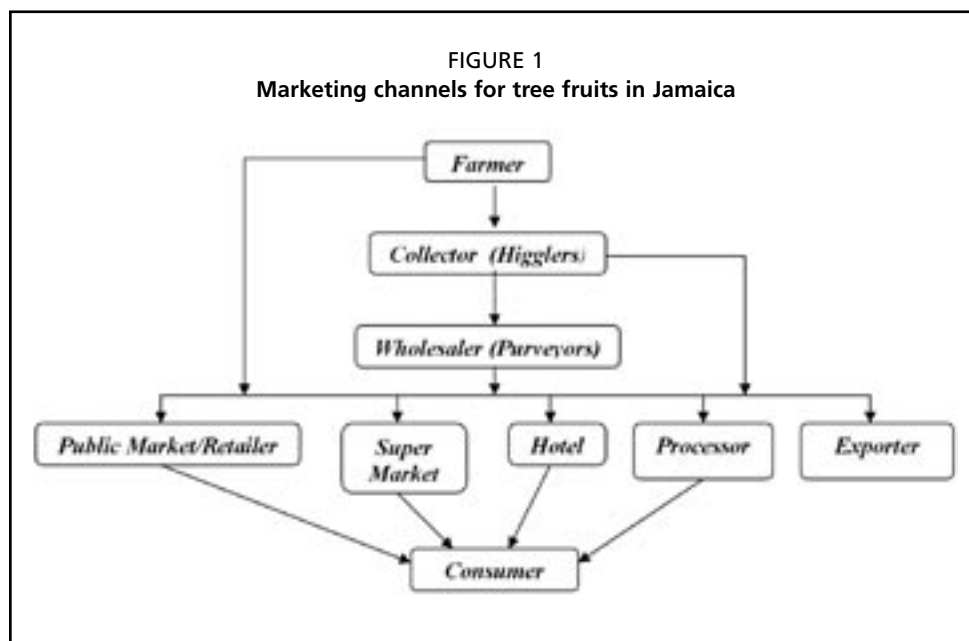
### 1.1 PRODUCTION AND CONSUMPTION OF FRUITS IN JAMAICA

The local demand for fruits in Jamaica is limited by availability, supply, seasonality, cost and socio-economic factors. Proper assessment of this demand is also limited by a paucity of data on local production and consumption trends. Based on available consumption and usage data, the demand for fruits in Jamaica was estimated at 80 million kilograms in 2005. At an average retail price of J\$ 100/kg for fruits this is equivalent to J\$ 8 billion or US\$ 123 million. Approximately 72 percent of Jamaica’s fruit production is consumed by the local populace, 11 percent is consumed within the tourism sector, 9 percent is used by the processing sector, while 6 percent is exported. Approximately 92 percent of the fruit consumed in Jamaica is locally grown. Jamaica’s per capita consumption of tree fruits in 2005 was estimated at 22 kg or 49 lb.

### 1.2 MARKETING CHANNELS FOR TREE FRUITS IN JAMAICA

Tree fruits are produced primarily on small holdings and in home gardens in Jamaica. As such, these commodities are marketed through long and complex chains prior to reaching the consumer. Marketing channels for tree fruit crops in Jamaica are shown in Figure 1. Intermediaries in the marketing chain include farmers, collectors (higglers), wholesalers (purveyors) and retailers. All of these intermediaries perform post harvest handling activities such as harvesting, sorting and grading, collecting, storing, transporting, and selling.

Farmers, however, sell most of their produce through middlemen (higglers or purveyors) and add little value to their primary produce. Fruit is then transported and sold to exporters, processors, hotels and guest houses, retail and food service outlets, vendors and in public markets.



Bananas were by far the largest fruit export, of Jamaica, followed by papayas in 2005 (Table 1). Mangoes, papayas, breadfruits and avocados are Jamaica's most important non-traditional fresh fruit exports, while ackee is the most important fruit exported in the processed state. The major markets supplied are the United States, the United Kingdom and Canada which together account for 90 percent of total exports (Table 2).

**TABLE 1**  
**Fruit exports from Jamaica – 2005**

Fruit crop	Net weight (kg)	Value of exports (US\$)	% Total
<i>Traditional</i>			
Banana	11 712 526	4 692 000	45
Oranges	1 200 286	550 221	5
<i>Non-traditional</i>			
Mango	415 564	921 000	9
Papaya	1 218 437	2 044 000	20
Ackee	9 236	9 604 000	0
Breadfruit	247 983	421 822	4
Avocadoes	36 315	84 697	1
Naseberry	12 251	21 835	0
Soursop	2 253	5 100	0
Juneplum	1 423	1 785	0

Source: Economic and Social Survey Jamaica 2005  
(Planning Institute of Jamaica)



**TABLE 2**  
**Export markets for Jamaica's fruit and vegetable outputs – 2005**

Country of destination	Net weight (kg)	US\$ CIF value	%
United States	10 606 664	24 050 142	51%
United Kingdom	15 275 578	12 728 087	27%
Canada	2 371 074	5 417 785	11%
Cayman islands	750 515	1 376 769	3%
Barbados	1 223 475	1 051 790	2%
Others	2 888 584	2 910 225	6%
<b>Total</b>	<b>33 115 890</b>	<b>47 534 798</b>	<b>100%</b>

Source: Data Bank & Evaluation Division – Ministry of Agriculture, Jamaica

### 1.3 POST-HARVEST LOSSES IN TREE FRUITS IN JAMAICA

Both quantitative and qualitative losses occur in tree fruits at various stages of the post-harvest handling chain in Jamaica. Quantitative losses in tree fruits during post harvest operations in Jamaica are estimated at around 30-35 percent of the total annual production. Improper packaging, rough handling and overloading of vehicles during transportation from production to consumption areas, account for approximately 20 per cent of losses within the post-production chain.

Improvement of post harvest handling practices to minimize these losses will not only contribute to increasing the income of rural farmers, but would also ensure the availability of superior quality produce to the consumer at a reasonable price.

### 1.4 CAUSES OF POST-HARVEST LOSSES IN TREE FRUITS

Harvested fruits are 'living' entities. They, therefore, continue to perform metabolic functions in the post-harvest state. Quality deterioration of harvested fruits is the result of a combination of physiological, mechanical, microbiological and environmental factors and conditions.

#### **Physiological factors**

Plants respire by taking up oxygen and giving off carbon dioxide and heat. They also lose water through the transpiration process. While attached to the plant, losses due to respiration and transpiration are replaced from the flow of sap within the plant, which contains water, photosynthates (principally sucrose and amino acids) and minerals. Respiration and transpiration continue after harvest, and since the produce is now removed from its normal source of water, photosynthates and minerals, it is dependent on its own food reserves and moisture content. These losses of respirable substrates and moisture, therefore, result in deterioration. Harvested fruits are, therefore, highly perishable.

#### **Mechanical factors**

Tree fruits are composed of soft tissue and are thus easily physically and mechanically damaged by improper or rough handling. Physically damaged or bruised fruits deteriorate rapidly.

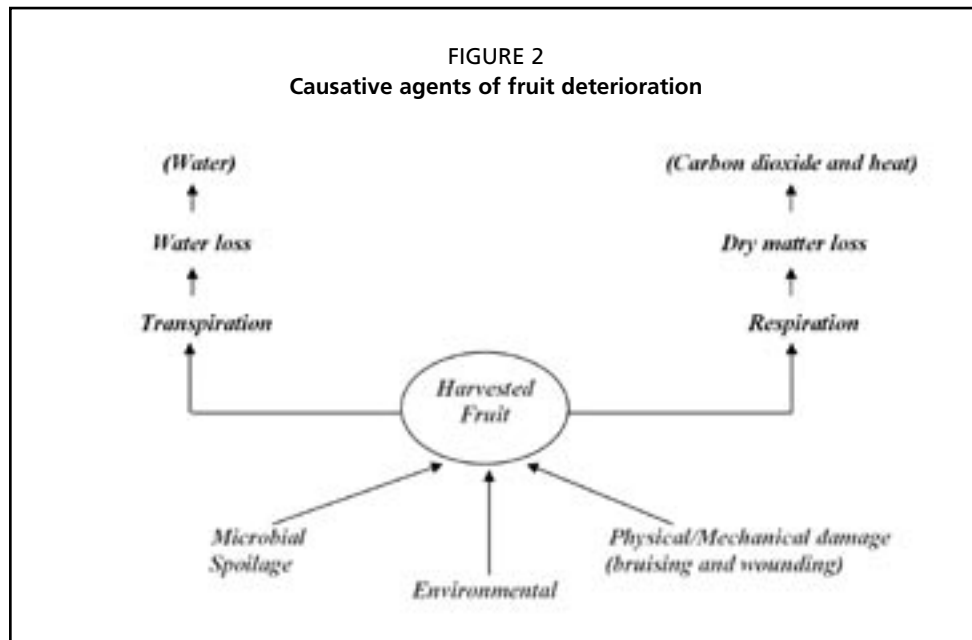
**Microbiological factors**

The high sugar and mineral content of fruits, renders them highly susceptible to microbial spoilage.

**Environmental factors**

Exposure of tree fruit crops to extreme conditions of temperature, humidity and gaseous concentrations can result in tissue damage and subsequent spoilage.

The causative agents of fruit deterioration are summarised in Figure 2.



Preserving the safety, quality and freshness of fruits necessitates proper temperature and relative humidity management and care during post-harvest handling operations in order to slow respiration rates and minimize microbial contamination and mechanical and physical injury.

## Chapter 2

# Pre-harvest factors that impact on post-harvest quality

Immature fruits can be infected by microorganisms while they are attached to the plant or during harvesting and subsequent handling and marketing operations. The pre-harvest infection of fruits by microorganisms may occur either by direct penetration of the skin, through natural openings such as stomata, lenticels and growth cracks on the produce or through surface injuries. Favourable weather conditions at the time of maturation or ripening of the crop, or both, can lead to major loss.

Several types of pathogenic fungi are able to initiate infection on the surface of the floral parts of plants and on sound developing fruit. This infection remains quiescent until after harvest when resistance decreases, as occurs when the fruit begins to ripen and conditions become favourable for growth. Such 'latent' infections lead to losses in many tropical fruits. Examples of fungal infections are shown in Plates 1 to 9.

PLATE 1  
Yeasty rot of pineapple



PLATE 2  
Black rot of pineapple



**PLATE 3**  
**Anthraxnose of banana**



**PLATE 4**  
**Crown rot of banana**



**PLATE 5**  
**Anthraxnose of mango**



**PLATE 6**  
**Stem end rot of mango**

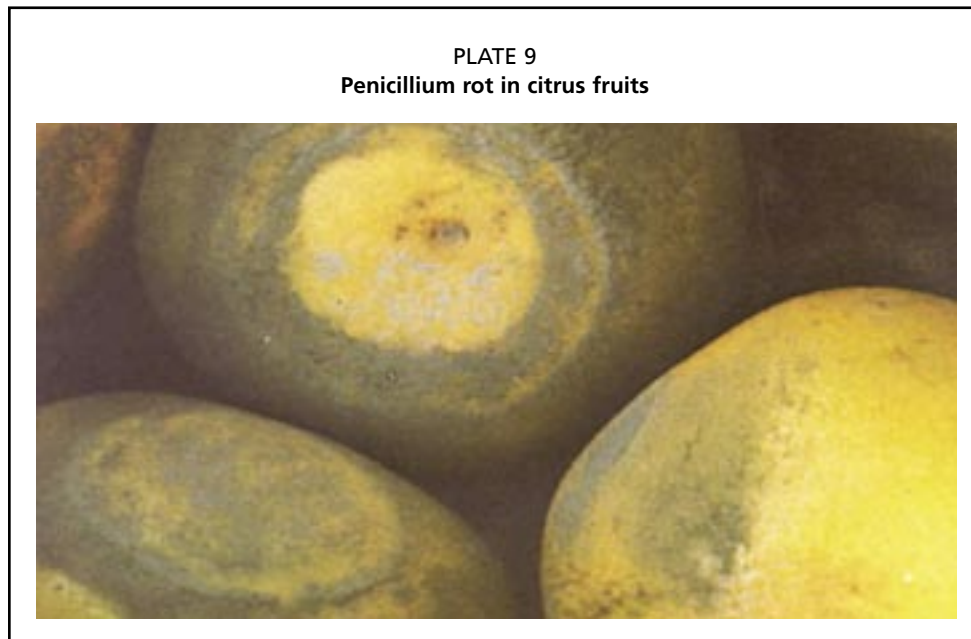


**PLATE 7**  
**Anthraxnose of papaya**



**PLATE 8**  
**Green mould of papaya**





PLATES 1– 9: PHOTOS BY E. ESGUERRA

Insect species, particularly the tephritid fruit flies can also attack tree fruits prior to harvesting resulting in major losses and the disruption of produce trade between countries. Prevention of post-harvest losses should, therefore, commence before harvest in the field or orchard. The adoption of the following ‘Good Agricultural Practices’ during pre-harvest activities would assist to a great extent in minimizing post harvest losses of tree fruits:

- **SELECTION OF THE CROP SITE**

Agricultural land and land that has been used for activities other than agriculture can be contaminated with pathogenic organisms or toxic chemical substances. It is, therefore, important to have a historical profile on land used for agricultural production in order to identify potential hazards in the production environment. This historical profile should include information on: prior use of fertilizers or pesticides, crop rotation patterns, occurrence of serious flooding of the land, whether the land was used for sanitary waste management, toxic waste disposal or for domestic animal production.

- **SELECTION OF PLANTING MATERIAL AND CROP MANAGEMENT**

- Only disease free planting material and pest and disease resistant varieties should be used for planting;
- Proper pruning and training techniques should be used;
- Tree canopies should not be allowed to become dense and entangled. Trees should be skirted from year four to enable good air circulation through the canopy. Dead branches and infected fruit must be pruned off. Short-term windbreaks must be removed from year five and trees should be thinned out in order to prevent the blockage of sunlight;
- Leaves must be cut from the banana plant on a regular basis;
- Water stress must be avoided during fruit development and maturation;
- Fruit must be sprayed on a regular basis with a recommended protectant fungicide from fruit set to harvest: (fruit should be sprayed every four weeks in dry weather and every two weeks in wet weather);
- Fruit spotting insects that damage the skin of fruit must be controlled.

- **FIELD SANITATION**
  - Wherever possible, sources of infection should be eliminated by keeping the field clean;
  - Rotten fruit and organic debris which harbour pathogenic microorganisms and insect pests should be removed from the field;
  - Leaf litter and prunings should not be allowed to accumulate in the field.
  
- **FERTILIZER APPLICATION**
  - Manure must be properly composted if used as an organic fertilizer, in order to ensure the elimination of hazardous pathogens;
  - Manure must be stored away from areas where fresh produce is grown;
  - Organic fertilizers or manure must not be applied when the fruit is nearing maturity or harvest.
  
- **SOIL MANAGEMENT**
  - Raking exposes the pupae of fruit flies and other insects to sunlight and assists in their destruction.
  
- **CROP PROTECTION**
  - Resistant cultivars, varieties and cultural practices that maximize biological control of pests and diseases should be applied;
  - Only recommended chemicals at the appropriate dosages and intervals for the control of pests and diseases must be used in order to minimise pesticide residues on produce.

## Chapter 3

# Harvesting

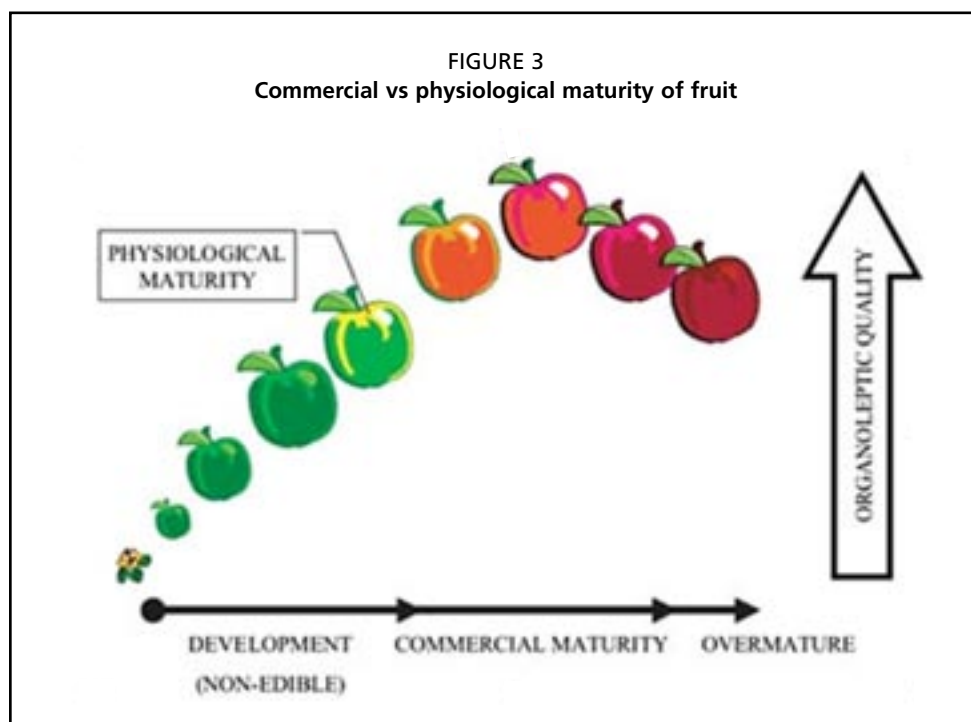
### 3.1 MATURITY AT HARVEST

Maturity at harvest is the most important determinant of storage-life and final fruit quality. Immature fruit are highly susceptible to shriveling and mechanical damage, and are of inferior flavour quality when ripe. Overripe fruit are likely to become soft and mealy with insipid flavour soon after harvest and become highly susceptible to damage during subsequent post harvest handling operations. Harvesting of tree fruits at the correct stage of maturity is important in preserving quality and for minimizing post-harvest losses.

### 3.2 COMMERCIAL VS. PHYSIOLOGICAL MATURITY

A fruit is *commercially mature* when it reaches a developmental stage at which it can be marketed for a specific purpose, e.g. for consumption in the fresh state, or for processing.

A fruit is *physiologically mature* when its development on the plant is over. A physiologically mature fruit may not necessarily be commercially mature (Figure 3).



### 3.3 MATURITY INDICES

Maturity indices give an indication of the stage of development or maturation of a crop and are determined on the basis of some characteristic known to change as the crop matures. Both subjective and objective criteria are used for assessing the maturity indices of fruits.

### 3.4 SUBJECTIVE CRITERIA FOR ASSESSING FRUIT MATURITY

- SKIN OR FLESH COLOUR

The loss of green colour (often referred to as the 'ground colour', or the background colour) of many fruits provides a valuable guide to maturity assessment. With maturation a gradual loss of color intensity from deep green to lighter green initially occurs. Complete loss of green color with the development of yellow, red or purple pigments occurs with many commodities. Ground color, as measured by prepared colour charts, provides a useful index for assessing the maturity for some fruits, in particular stone fruits. Ground color is not, however, entirely reliable as it is influenced by factors other than maturity.

- FLESH FIRMNESS

As fruit mature and ripen they soften. This softening can be estimated subjectively by finger or thumb pressure. A more precise objective measurement, giving a numerical expression of flesh firmness is possible with the use of a fruit pressure tester or penetrometer.

- SIZE AND SHAPE

Fruit shape may, in some cases, be used to evaluate maturity. Some cultivars, for example, become less angular in cross section as development and maturation progress.

The fullness of the 'cheeks' adjacent to the pedicel, as in the case of mangoes and stone fruit, may be used as a guide in assessing the maturity of mangoes. Size is generally of limited value in assessing fruit maturity, though it is used for fruits marketed in their early stages of development, e.g. June plum for processing.

- SOUND WHEN TAPPED

The sound made when tapped by fingers is used as an indicator of the maturity of fruits such as melons, breadfruit and jackfruit.

- FLAVOUR (*sweetness, sourness or bitterness*)

The conversion of starch to sugar and loss of acidity during maturation result in changes in flavour and can be used as an indicator of maturity.



- **TIME FROM FLOWERING OR PLANTING** (*calendar date*)

For perennial fruit crops grown in seasonal climates, which are uniform from year to year, the calendar date for harvest is a reliable guide to commercial maturity. This approach relies on a reproducible date for the time of flowering and a relatively constant growth period from flowering through to maturity.

### 3.5 OBJECTIVE CRITERIA FOR ASSESSING FRUIT MATURITY

- **CHEMICAL MEASUREMENTS**

Measurement of the chemical characteristics of fruits facilitates maturity determination, particularly as these characteristics can often be related to palatability.

*Iodine test.* The conversion of starch to sugar during maturation is used as the basis for assessing the maturity of some fruits. This assessment is based on the reaction between starch and iodine to produce a blue or purple color. The intensity of the blue colour correlates to the level of starch remaining in the fruit. This test can also be used to demonstrate the disappearance of starch from the pulp of ripening bananas.

*Measurement of sugar content.* Sugar content can be directly measured by chemical means. Given the fact that sugar is usually the major soluble solid constituent of fruits, the total soluble solids content of extracted fruit juice is generally used as a measure of the sugar content and is measured with the use of a refractometer.

*Measurement of dry matter content.* Changes in dry matter content can be used as an index for fruits which show a large increase in starch or sugar levels with fruit maturation. Dry matter can be conveniently and rapidly determined using a microwave or air oven to dry the material prior to weighing.

*Measurement of acidity.* Acidity can be readily determined on a sample of extracted juice through titrimetric methods.

*Sugar to acid ratios.* Given the rapidity of loss of acidity during maturation and ripening, the sugar to acid ratio or total soluble solids to acid ratio is often better related to the palatability of the fruit than either sugar or acid levels alone. Maturity standards for citrus fruits are commonly expressed as total soluble solids to acid ratios, both measurements being on a weight for weight basis.

*pH.* The pH of extracted juice can be easily measured with the use of a pH meter.

- PHYSICAL MEASUREMENTS

*Measurement of specific gravity.* Specific gravity is the relative gravity or weight of solids or liquids as compared to pure distilled water at ambient temperature, which is considered to have a specific gravity of one. As a fruit matures, its specific gravity increases.

In practice, the fruit is weighed in air, then in pure water.

$$\text{Fruit specific gravity} = \frac{\text{Fruit weight in air}}{\text{Fruit weight in water}}$$

Specific gravity is rarely used in practice to determine time of harvest, but could be used in cases where development of a suitable sampling technique is possible. It is used to grade crops according to different maturities post harvest. This is done by placing the fruit in a tank of water, wherein those that float are less mature than those that sink, as occurs in the case of mangoes.

### 3.6 TIME OF HARVEST

The time of the day and prevailing weather conditions can influence the quality and shelf life of produce.

- Harvest during the coolest time of the day, that is, early morning or late evening when physiological activities of the fruit are low.
- Do not harvest when the produce is wet from rain or dew; wet produce generates heat that will cause its rapid deterioration.
- Always keep harvested produce in cool and shady areas with adequate ventilation.

### 3.7 METHOD OF HARVEST

The method of harvest can significantly impact upon the post harvest quality and shelf life of fresh fruits. Mechanical injuries such as bruising, surface abrasions and cuts can accelerate loss of water and allow rotting fungi and bacteria to penetrate the produce, thus causing rapid deterioration. It is, therefore, important to prevent injury to produce during harvest.

- Minimize impact of the drop of fruit to the ground:
  - by using harvesting tools
  - by hand picking
  - by using picking poles and breaking the fall of fruit by spreading a crocus bag supported by hand.

### 3.8 HARVESTING TOOLS

Since harvesting is a labour intensive operation, not only does the use of properly designed harvesting tools prevent undue mechanical damage to produce but it also appreciably reduces the cost of production of tree fruits. Some simple harvesting tools for tree fruits are shown in Figures 4 to 8.

**FIGURE 4**  
**Harvesting tool for plucking of tree fruits occurring in bunches e.g. mango, avocado etc.**  
*(Design of the tool is given in Annex 1)*



**FIGURE 5**  
**Harvesting tool for plucking of papaya**  
*(Design of the tool is given in Annex 2)*



**FIGURE 6**  
**Harvesting tool for the plucking of tree fruits – I**  
*(Design of the tool is given in Annex 3)*

**Note:** affix net to the rim of the device to collect the detached fruit



**FIGURE 7**  
**Harvesting tool for plucking of tree fruits – II**  
*(Design of the tool is given in Annex 4)*

**Note:** affix net to the rim of the device to collect the detached fruit



FIGURE 8  
**Harvesting tool for plucking of tree fruits – III**  
 (Design of the tool is given in Annex 5)

**Note:** affix net to the rim of the device to collect the detached fruit



FIGURES 4-8: K. PALIPANE

Special considerations for the harvesting of some tree fruits:

- *Breadfruit*. Fruit stalks must be cut to a length of 1.5 cm and the latex must be drained in the field.
- *Jackfruit*. The fruit should be picked and not allowed to fall to the ground. The fruit can be separated from the tree either by cutting from the fruit stalk with a sharp bladed instrument or by twisting and turning. If the fruit is high up in the tree, a sack must be tied around the fruit with a rope, the stalk must be cut and the fruit slowly lowered to the ground. After harvest, the fruit stalk (peduncle) must be turned downward to drain off the latex in order to prevent discoloration of the skin.
- *Papaya*. The papaya is highly perishable and should be carefully handled. If the fruits are hand picked, the pickers should wear gloves to prevent bruising by the fingers. The stalk should not be broken off too close to the fruit, as this could damage the tissue at the stem end of the fruit, leading to spoilage.
- *Avocado*. The fruit should be harvested with the stalk. The stalk should subsequently be removed, leaving the butt.

## Chapter 4

# The packing house

### 4.1 DESIGN AND MANAGEMENT OF A PACKING HOUSE<sup>1</sup>

A packinghouse should be designed and managed in such a way as to ensure: maintenance of produce quality and safety by preventing physical/mechanical, chemical and microbial damage; effective utilization of labour and minimization of operational costs; and the safety and comfort of the operators.

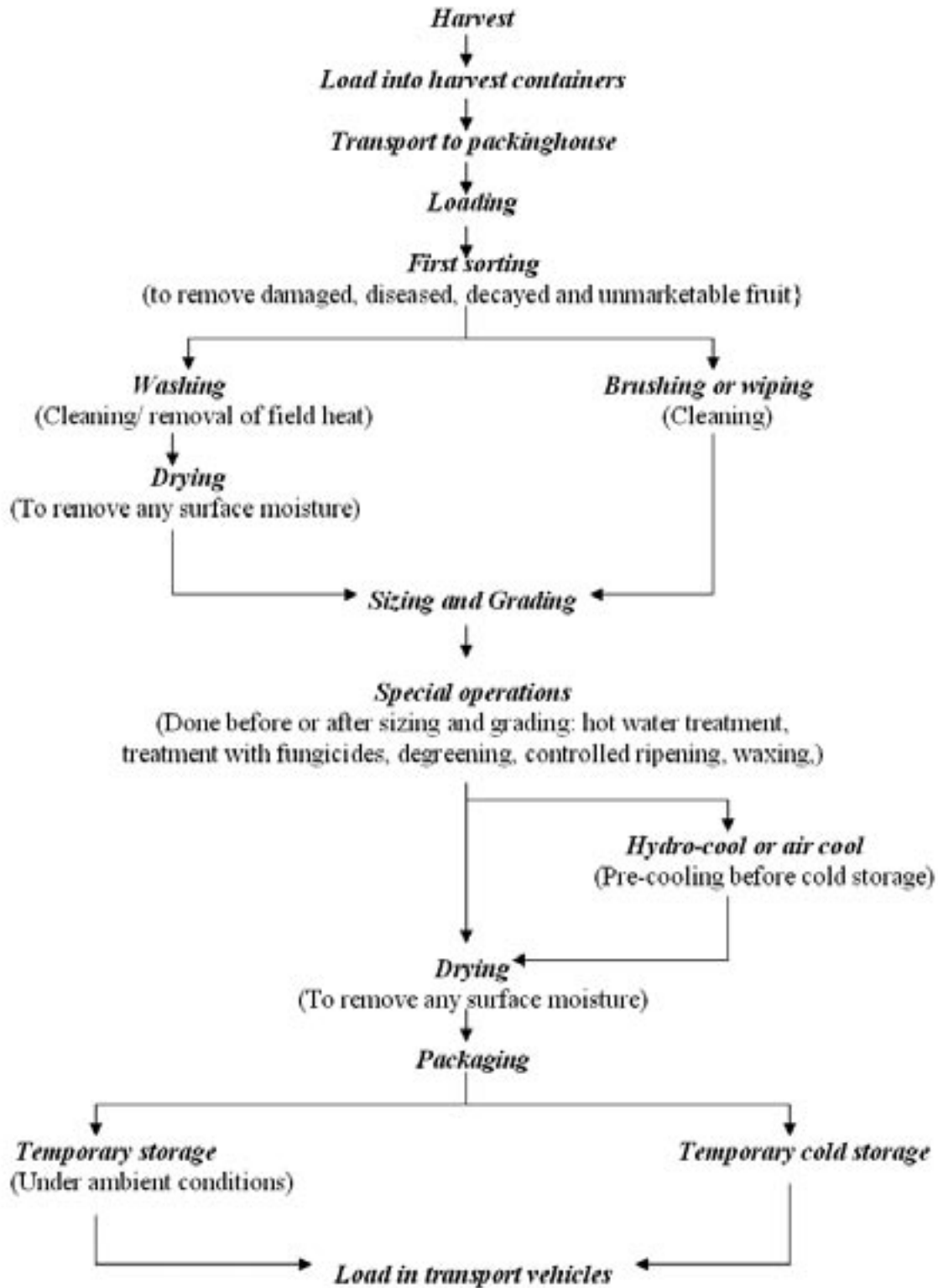
- **FACTORS TO BE CONSIDERED PRIOR TO THE CONSTRUCTION OF A PACKING HOUSE**
  - The volume and type of fruit that will be handled by the packing house must be identified as a basis for determining the level and scale of packing house equipment required and the size of the facility to be constructed;
  - Location of the packing house: the packing house should be located in close proximity of the production area and must be well connected by road;
  - Access to potable water;
  - Disposal of both solid and liquid waste.
- **SANITARY CONSTRUCTION CONSIDERATIONS FOR PACKING HOUSE FACILITIES**
  - Facilities should be designed and constructed to allow for easy cleaning and sanitation;
  - Buildings should be properly screened with barriers designed to exclude vermin, domestic and wild animals, birds and insects;
  - Windows should be closed or covered with mesh;
  - Walls, floors and ceilings should be in good condition and should be easily cleaned and sanitized;
  - Lamps and light bulbs should be covered so that, in the event of breakage, the product and the work area would not be contaminated with broken glass;
  - The floor should be slightly sloped in order to avoid water accumulation in production areas;
  - The sewage system should be constructed in such a manner as to prevent water backing up and accumulating in packing rooms.

Packing and storage facilities will vary depending on the produce being processed and the size of the operation. The packing house can be a small shed near the field or a large-scale building with many different processing and storage areas. Regardless of the size of the operation, good manufacturing practices are essential to prevent the physical facility from becoming a source of microbial, physical or chemical contamination and to ensure consistent fresh produce quality.

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FIGURE 9  
Flow diagram of packing house operations



- DESIGNING THE PACKING HOUSE OPERATION

- Develop a flow diagram of all the post harvest handling procedures that will be used with each crop. A diagram of this type will assist in designing the layout of the packing line (Figure 9). Produce must always move in one direction, with no crossover during packing house operations;
- The packing house design must include a receiving area with space for initial sorting to remove wounded, diseased and unmarketable fruits. This receiving area should be elevated so that the produce can be easily unloaded from the trucks or wagons carrying it from the field;
- A washing area must include a dump tank to initially clean and cool the produce and/or a spray washer/brusher. (The water used should be chlorinated at 100–200 ppm. This can be done using household bleach, swimming pool chlorine or compressed chlorine at the rate of 1–2 grams or 1–2 milliliters in 10 liters of water);
- An area for grading and sizing;
- An area for post harvest treatments;
- An area for packing produce.

The basic floor plan of a small-scale packing house is shown in Figure 10.



- **ADDITIONAL FACILITIES REQUIRED IN AN ALL-PURPOSE PACKINGHOUSE**
  - Lighting (intensity and quality) is a key factor in identifying defects on inspection tables. Lights should be placed below eye level to prevent glare and eye strain (Plate 10). Lighting fixtures should be covered to prevent glass shattering over produce if broken;
  - A packaging assembly area;
  - Rest rooms and washing facilities for workers;
  - Office: for record keeping, fax, telephone, time clock;
  - Workshop: to house tools for repairs and maintenance of packing line operations;
  - Laboratory: for microbial sampling.

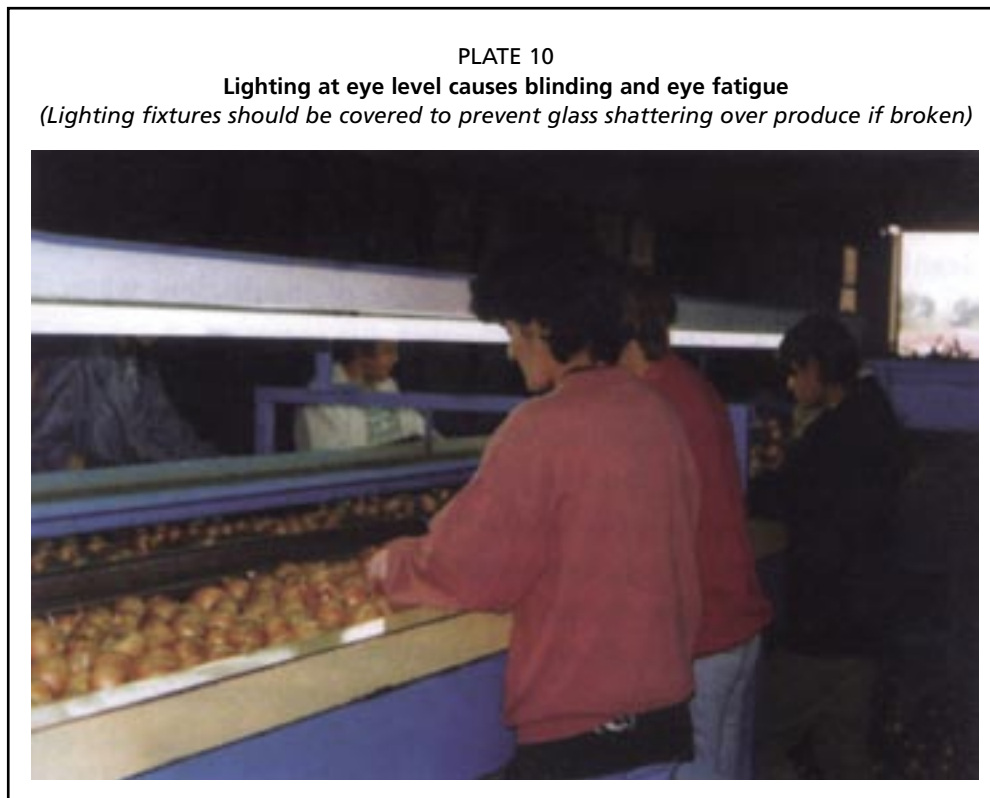


PHOTO: LOPEZ-CARMELO (2004)

- **PACKINGHOUSE SANITATION**

Fresh produce handling methods must include procedures and practices to safeguard against contamination by human pathogens.

  - Action must be taken to prevent contamination and recontamination of produce: dirty fruit from the field must be separated from clean fruit;
  - A potable water source and adequate facilities must be available;
  - Produce must be washed with potable water. The produce wash water should be chlorinated to a level of 100–200 ppm or 1–2 grams in 10 liters of water to kill pathogens that cause produce decay, and the chlorine level should be checked throughout the day;
  - Solid waste must be properly disposed of, either by composting, spreading on fallow fields or sold as animal feed;
  - All packing areas, storage rooms, fruit bins and equipment must be cleaned and sanitized;
  - All employees must observe Good Hygienic Practice.



- **ADDITIONAL RECOMMENDATIONS FOR THE PROPER MAINTENANCE OF PACKING HOUSE FACILITIES**

- All chemical agents, such as fuels, additives, fertilizers, pesticides, sanitizers, etc. must be packed in durable containers that are properly labeled and stored in dry, clean, closed places, separated from food products and packing material;

These supplies must be handled only by authorized personnel and should never come into direct contact with the fruits;

- Packing and storage areas should be separated and, ideally, different personnel should handle separate tasks to avoid cross-contamination;
- Comprehensive Sanitation Standards Operating Procedures (SSOPs) and maintenance procedures should be implemented;
- Pest control and monitoring should be in place;
- Culls (e.g. rejects and trimmings) should not be allowed to accumulate for any length of time in or near packing and storage buildings;
- All packing and storage areas must be maintained free from chemicals, trash, machinery, harvest residues and waste materials to discourage pests and to prevent produce contamination.

- **SANITARY CONSIDERATIONS FOR PACKINGHOUSE EQUIPMENT**

- All equipment and containers that come in direct contact with the produce should be stainless steel or plastic, if possible, since these materials can easily be cleaned, disinfected and hygienically maintained;
- Equipment must have smooth surfaces and must be placed in locations that can be easily cleaned;
- Equipment should not have loose bolts, knobs, or movable parts that could accidentally fall off;
- All equipment should be painted with paint that is approved for food processing equipment and which does not chip easily. Rust should be removed in order to prevent it from flaking onto the produce;
- Oil leaks and over-lubrication must be avoided. Only food grade oil and lubricants should be used.

- **ADDITIONAL CONSIDERATIONS FOR PACKING HOUSE EQUIPMENT**

- A complete equipment cleaning and maintenance programme should be implemented to prevent hazards to the operator and the consumer;
- Equipment malfunctions should be reported as soon as they start to develop, so that the necessary precautions can be taken before a small problem becomes more serious;
- It is a good practice to assign a responsible individual to each piece of equipment so that the person can become familiar with the equipment and its proper operation.

- **GOOD MANUFACTURING PRACTICES RELATED TO TRASH AND WASTE HANDLING IN A PACKING HOUSE**

Trash and fruit waste can be a source of microbial contamination. Decomposing organic matter can serve to spread microorganisms around the facility, produce offensive odours and attract insects and other pests bearing pathogenic organisms.

- It is important to designate a specific secure, confined area outside the packing house facility for the temporary storage of trash and produce waste;

- The trash and waste collection centre should be constructed to facilitate cleaning and to avoid contamination of residues and bad odours. This area must be well away from the product-handling perimeter. Trash and waste must be stored in closed containers and consideration must be given to the direction of dominant winds to avoid bad odours in the production and packing facilities and the surrounding neighborhood;
  - Trash containers and wastebaskets used inside the produce handling and packing areas must be conveniently located, properly identified, should be tightly closeable, and should not be easily overturned;
  - Trash and waste material should be frequently removed. A trash collection schedule should be included as an important part of the daily cleaning activities of the packinghouse;
  - Separation of organic and inorganic waste material with appropriate recycling is recommended.
- **STORAGE OF PACKING MATERIAL**
    - The storage area must be clean, dry, and free from trash, insects, and animals;
    - The ceiling should be checked for leaks before placing the material in storage;
    - The storage location should be well separated from all chemical agents and from storage areas used for chemicals or other hazardous material;
    - Storing packing materials on pallets is a good practice to avoid direct contact of the packing materials with floor.

## Chapter 5

# Packing house operations

Packinghouse operations involve preparation of fruits for transport, storage or market and include: pre-cooling, sizing, grading, cleaning (dry/wet); trimming, waxing, de-greening, chemical treatments and forced ripening. Packing house operations in Jamaica are performed to various degrees by all stakeholders in the fresh fruit supply chain, namely, the farmer, collector (higgler) wholesaler (purveyor), retailer, supermarket and exporter.

### 5.1 BASIC PACKINGHOUSE OPERATIONS

#### *Pre-cooling of harvested fruit*

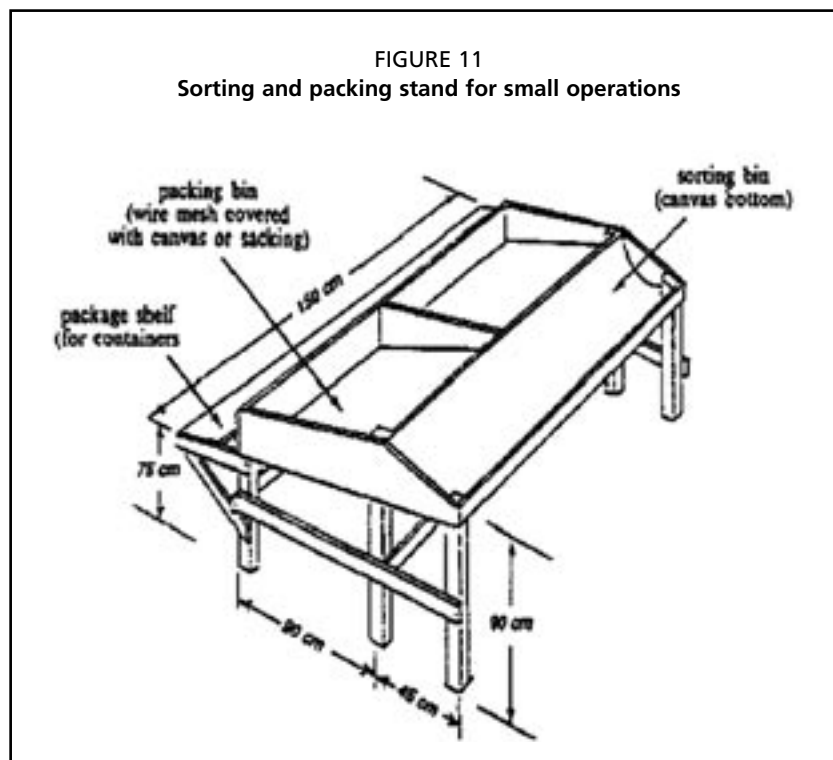
The temperature of fruit at harvest is close to that of ambient air and could be as high as 40 °C in Jamaica. Under such high temperature conditions, the respiration rate of produce is extremely high and storage life is very short. Early morning harvesting to take advantage of the lower temperatures prevailing at that time may not be feasible for larger growers. Furthermore morning temperatures may still be relatively high. Rapid cooling of the fruit immediately after harvest in order to remove field heat, referred to as pre-cooling, can therefore slow down the rate of post-harvest deterioration.

- **RAPID COOLING**
  - Reduces the heat produced by respiration;
  - Slows ethylene production and hence the rate of ripening;
  - Reduces water loss;
  - Limits the growth of decay organisms;
  - Decreases the rate of deterioration of fruit.
  
- **SIMPLE METHODS OF PRE-COOLING**
  - Dump harvested fruit in wash tanks (leave for 1 to 2 hr);
  - Transfer to an ice water bath at 10–12 °C (leave for 15 to 30 min);
  - Use of a conveyed sprinkler system.

Pre-cooling is essential for rapidly respiring fruits, such as, breadfruit, jackfruit and soursop. Washed commodities must be dried in order to prevent growth of microorganisms. This can be done by spreading on racks under shaded conditions with adequate ventilation.

### Sorting

Sorting involves grouping of produce in accordance the uniformity of their size, shape, ripeness, texture and the removal of diseased, insect infested and mechanically damaged commodities and other unmarketable produce. Sorting is usually done manually (Figure 11).



HARRIS (1988)

## 5.2 CLEANING

After removal of rejects, the fruits should be cleaned in order to remove any foreign material, e.g. dust, plant debris, soil, latex, insects, pesticides etc., associated with the fruit. This can be achieved by washing or brushing/wiping or both.

- WASHING, BEFORE OR AFTER SORTING:
  - Cleans produce: removes soil, scale insects, sooty moulds, chemical residues, harmful pathogens;
  - Improves appearance.
- PRECAUTIONS TO BE TAKEN DURING WASHING
  - Promptly remove decaying fruit;
  - Replenish water on a continuous basis;
  - Use water containing a low level of sanitizer (e.g. chlorinate the water at the rate of 100–200 ppm or 1–2 grams in 10 liter of water using either household bleach, swimming pool chlorine or compressed chlorine gas);
  - Do not prolong washing of fruits that can easily become water soaked.

It is important to dry the surface moisture of washed commodities in order to minimize the opportunity for microbial growth. This can be done by spreading the fruit on racks under shady, cool conditions with adequate ventilation.

### 5.3 SIZING

Sizing of fruits for uniformity (as extra small, small, medium, large and extra large) is carried out to increase consumer appeal and market demand. Manual sizing with the aid of simple hand held devices is often done in small-scale operations (Plate 11).

Mechanical sizing devices that can be used for sorting fruits according to size, and which can reduce cost and increase the efficiency of sizing, are shown in Plates 12 to 14.

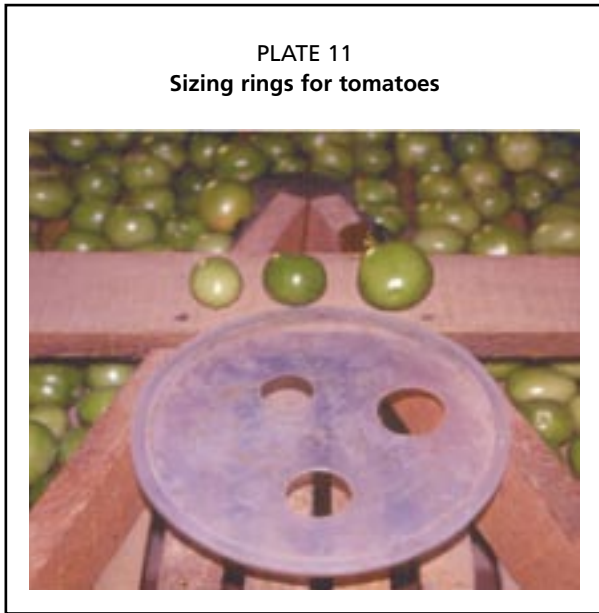


PHOTO: E. ESGUERRA



PHOTO: INSTITUTE OF POST HARVEST TECHNOLOGY, SRI LANKA (2004)

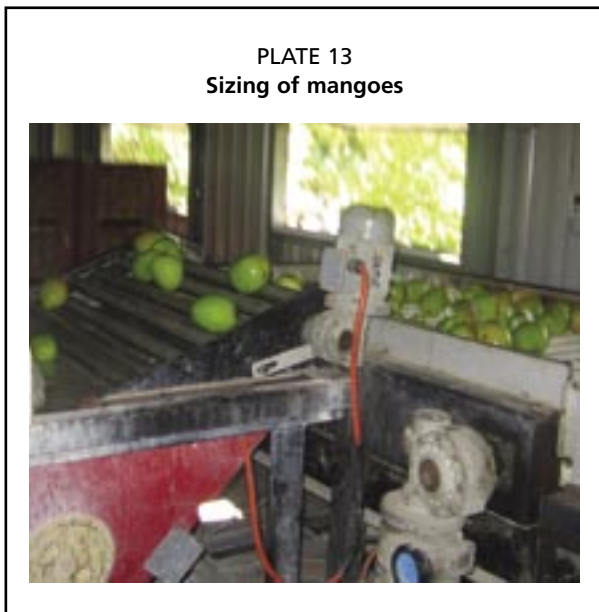


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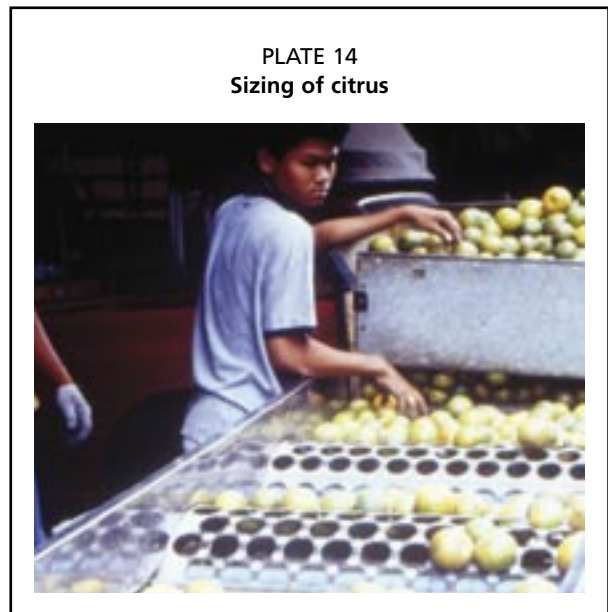


PHOTO: E. ESGUERRA

**Grading**

Grading relates to sorting of the fruit based on market quality. The following are the advantages of grading fruit:

- The buyer can purchase based on grade;
  - The buyer is assured of consistency in quality at every purchase;
  - The seller is able to meet consumer requirements;
  - Price differentials can be established between grades.
- **QUALITY CRITERIA USED FOR THE GRADING OF FRUITS**
    - Varietal characteristics
    - Level of maturity
    - Cleanliness of fruit – i.e. freedom from adhering soil, chemical residues and other foreign matter
    - Freedom from mechanical injury – bruises and cuts
    - Freedom from disease
    - Shape/form
    - Uniformity in size

**5.4 SPECIALIZED PACKINGHOUSE OPERATIONS****Hot water treatment**

Mangoes are highly susceptible to stem end rot. Dipping in hot water is, therefore, used to control decay of the fruit due to stem end rot. Control of the temperature and duration of the hot water treatment are critical to assuring destruction of the pathogen while maintaining the quality of the fruit.

- **METHODS OF HOT WATER TREATMENT**
  - Dip in water containing 5 percent sodium bicarbonate at 52 °C, for 5 minutes;
  - or
  - Dip in water containing 5 percent calcium chloride at room temperature, for 10 minutes.

**5.5 SURFACE COATING WITH WAXES**

Waxing with synthetic food grade resins:

- Reduces moisture loss;
- Prevents wilting and shriveling;
- Provides protection against decay organisms;
- Improves appearance/gloss.

Types of waxes:

- Fruit wax e.g. *Semperfresh*

Method of application:

- Wax can be applied either by foaming, spraying, dipping or brushing.

## 5.6 TREATMENT WITH FUNGICIDAL AND BACTERICIDAL CHEMICALS

Treatment with fungicidal and bactericidal agents is sometimes required to limit the growth and spread of pathogens in harvested fruit, to inhibit spore formation and to reduce the rate of germination of spores.

- **PROPERTIES OF AN IDEAL POST HARVEST FUNGICIDE**

- Water soluble
- Broad spectrum of activity
- Non phytotoxic
- Safe to use
- No effect on produce palatability
- Retains activity over long periods
- Leaves no visible residue
- Effective at low concentrations
- Low cost

- **SAFE USE OF FUNGICIDES**

Proper management and use must be assured in order to protect the:

- Worker
- Consumer
- Environment

When using fungicides, instructions must be carefully read to ensure proper usage. Minimum residue levels for importing countries must also be known and observed.

- **IMPORTANT FACTORS UNDER ‘GLOBALGAP’**

Records must be kept of all post harvest pesticide applications including:

- Crop name
- Location of application
- Application date
- Type of treatment
- Pesticide trade name
- Product quantity applied
- Operator’s name
- Justification for and type of application machinery can be recorded

- FACTORS THAT GOVERN THE EFFICACY OF FUNGICIDE USE
  - Fungicides can only be effective if other crop management and handling procedures are observed;
  - The inoculum within the packing house must be low;
  - Correct handling procedures and optimum storage conditions will reduce the incidence of infection allowing the fungicide to work more effectively.
  
- METHODS OF APPLYING FUNGICIDES AND BACTERICIDES
  - Spraying
  - Dipping
  - Use of fungicide impregnated wraps or pads
  - As fumigants, dusts and wax formulations

TABLE 3  
Some chemical treatments for controlling  
the microbial spoilage of harvested fruits

Produce	Chemical
Breadfruit	Fruit coating
Avocado	
Citrus	Fungicides:
Mango	<i>Thiabendazole (TBZ)</i>
Papaya	<i>Prochlorus</i>
Banana	<i>Carbendazine</i>

### **Degreening**

Degreening is the removal of the green colour of the peel, particularly from citrus, banana and mango by treatment with ethylene under controlled conditions. Degreening is a 'cosmetic' treatment designed to give the fruit a ripe appearance by hastening the loss of chlorophyll from the fruit peel. It does not result in significant changes in pulp composition if correctly administered.

The conditions of batch degreening – 20 to 200 microliters per liter ethylene, 25 to 30 °C and 90 to 95 per cent relative humidity – are maintained for two to three days with regular ventilation of the chamber to prevent the build up of carbon dioxide (citrus is injured by carbon dioxide concentrations exceeding 1 per cent).

Degreening of fruit can also be achieved by using ethylene-releasing compounds such as ethephon or ethrel.

### **Controlled ripening**

Tree fruits can be broadly categorized as being either climacteric or non-climacteric fruits (Table 4). Climacteric fruits produce large quantities of ethylene coincident with the ripening process, while non-climacteric fruit produce minute quantities of ethylene during development. Ripening of climacteric fruits can, therefore, be triggered with the application of ethylene. Ethylene gas applied at concentrations as low as 0.1–1.0 microliters per liter (10–100 ppm) for one day is normally sufficient to hasten full ripening of climacteric fruit.



TABLE 4  
Climacteric and non-climacteric fruits  
produced in Jamaica

Climacteric	Non climacteric
Avocado	
Banana	Ackee
Breadfruit	Cashew apple
Guava	Lemon
Jackfruit	Lime
June plum	Orange
Mango	Pineapple
Papaya	Lychee
Plantain	Longan
Sapodilla	Pomegranate
Annomar	Carambola
Cocona	Jaboticaba
Naranjilla	

Climacteric fruits, particularly tropical and subtropical species, such as those grown in Jamaica, are frequently harvested when less than fully ripe. They are subsequently transported, often over considerable distances, to areas of consumption where they are ripened to optimum quality under controlled conditions of temperature, relative humidity, and in some cases through the addition of ripening gases. This controlled ripening improves the uniformity of ripening of the fruit.

Controlled ripening is carried out in purpose-built rooms which allow for the control of temperature and relative humidity conditions and for the removal of ethylene when the operation is complete. The operation involves initial heating to reach the desired pulp temperature. This is followed by an injection of ethylene gas at the desired concentration (Table 5). The fruit is maintained under these conditions for a specified period following which the room is ventilated in order to remove accumulated gases (Table 5). The rate of ripening is influenced by the concentration of ethylene applied, the time of exposure, temperature and the fruit species.

TABLE 5  
Ripening conditions for some tree fruits using ethylene<sup>1</sup>

Fruit	Temperature (°C)	Ethylene concentration (µL/L)	Treatment time (hours)
Avocado	18-21	10	24-72
Banana	15-21	10	24
Mango	29-31	10	24
Papaya	21-27	10	24
Stone fruits	13-25	10	24-72

<sup>1</sup>Relative humidity is normally maintained at 85 to 90 per cent.

- **ETHREL INDUCED RIPENING**

Fruit can also be ripened with the ethylene releasing compound 'ethrel' (2-chloroethyl phosphonic acid). Ethrel can be easily applied in small/medium scale operations.

Requirements for ethrel-induced ripening are:

- An air tight ripening chamber;
- Ethrel solution – 1ml ethrel per 1liter water;
- Lime solution – 100 grams sodium hydroxide, potassium hydroxide or calcium hydroxide in 1 liter of water.

Method of application:

- Pack fruits in the chamber, leaving 1/5<sup>th</sup> of the chamber empty;
- Apply ethrel: 3–4 ml ethrel solution per 1 cubic foot of the chamber or 0.3–0.4 milliliter ethrel solution for every kilogram of fruit;
- Pour solution into a plastic or earthenware container and keep inside the chamber;
- To initiate the ripening process, add prepared lime solution: 5 ml lime solution per cubic foot of the chamber or 0.5 milliliter lime solution per 1 kilogram of fruit;
- Immediately close the door of the chamber following addition of the lime solution to the ethrel solution and open after 24 hours to provide adequate ventilation.

- **CALCIUM CARBIDE INDUCED RIPENING**

Calcium carbide generates acetylene gas, which hastens the ripening of climacteric fruit by inducing ethylene biosynthesis. Calcium carbide is advantageous in use for small-scale operations given that it is inexpensive and is freely available. *The chemical should be applied in such a way that it does not come in contact with the fruits, given that residues of calcium carbide are toxic to humans.* Acetylene gas is explosive.

Method of application:

- Place fruits in a container that could be sealed, leaving 1/5<sup>th</sup> of the container empty;
- Weigh the required quantity of calcium carbide (1gram per 1 kilogram of fruit), wrap with newspaper and place at the bottom of the container so that the chemical does not come in contact with the produce;
- Seal the container and leave for 24 hours;
- Open the container and allow the fruits to ripen.

PLATE 15

**A fruit ripening chamber in the countryside of Jamaica**



PHOTO: K. PALIPANE



## Chapter 6

# Packaging

Packaging involves putting the produce into a container along with packing materials so as to prevent its movement and to cushion and to protect it.

Packaging must satisfy three basic objectives:

- 1 **Contain** the produce and facilitate its handling and marketing by standardizing the number of units or weight inside the package;
- 2 **Protect the produce** from injury (impact, compression, abrasion and wounds) and adverse environmental conditions (temperature and relative humidity) during transport storage and marketing;
- 3 **Provide information** on variety, weight, number of units, quality grade, producer's name, country and area of origin, to buyers.

Recipes, nutritional value, bar codes or any other relevant information on traceability are also included on packaging.

### 6.1 PACKAGING FOR TRANSPORTATION TO DOMESTIC MARKETS

Fruits often have to be transported over considerable distances after harvest in Jamaica, in order to reach the market. The use of crocus and woven polypropylene sacs for the transportation of fruits, often results in serious quantitative and qualitative losses owing to physical or mechanical damage such as bruising and wounding, and subsequent rotting of the produce.

Post-harvest losses can be minimized by using plastic crates (Plate 16) for the handling and transportation of fruits.



PHOTO: FAO/R. RAPUSAS

While the use of plastic crates may reduce the transportation capacity of fresh fruit by half, savings realized from reduced losses make up for the higher transport cost due to reduced transport capacity (Table 6).

TABLE 6  
Additional income (J\$) generated by transporting fruit in plastic containers  
instead of crocus or poly-sacs in Jamaica

Price per 100 lb. fruit bag	1 000.00
Income per 100 lb. fruit bag transported in crocus or poly-sacs (loss during transportation is 20%)	800.00
Transport cost per 100 lb. fruit bag	20.00
Transport cost per 100 lb. Fruit in plastic containers (Transportation capacity reduced by 50%)	40.00
Additional income per 100 lb. fruit when transported in plastic containers due to loss reduction from 20 to 3%	170.00
Net additional income per 100 lb. fruit when plastic containers are used for transportation	150.00

- SPECIFICATIONS FOR PLASTIC CONTAINERS

- Both stackable and nestable plastic containers are appropriate in use for the transportation of fruits. Stackable containers can be placed on top of each other (Plate 19), while nestable containers fit into each other, thus reducing storage space requirements during the transportation of empty crates (Plate 20).
- The bottom and sides of the container should be perforated to allow for proper ventilation.
- Size uniformity is important to allow for the exchange of containers:

*Jumbo sized containers.* (Close to 700 mm x 500 mm x 400 mm)

Are appropriate in use for the transportation of breadfruit, banana, papaya, banana and soursop.

*Large containers.* (Close to 600 mm x 400 mm x 300 mm)

Are appropriate in use for mango, citrus, ackee, June plum, avocado, guava, naseberry, sweetsop and tamarind.

*Medium sized containers.* (Close to 600 mm x 400 mm x 230 mm)

Are appropriate in use for ripe fruit; to avoid damage of the bottom layers due to fruit weight of the top layers).

Crates should:

- be made of food grade recyclable plastic (heavy metals such as cadmium should not be incorporated to achieve colour etc.) of UV resistant quality;
- be resistant, to environmental stress, i.e. should be tough and long lasting with sufficient impact resistance and compression strength. They should be crack, chip and corrosion resistant;
- be able to withstand temperatures ranging from -18 to 75 °C;
- be of hygienic design, made of non-toxic material and should be resistant to bacterial and fungal growth;
- be well lodged and stable when stacked and leave no room for movement. This is important, in reducing damage due to vibration and abrasion during transport;
- Allow good ventilation.



PHOTO: INSTITUTE OF POST-HARVEST TECHNOLOGY, SRI LANKA (2004)

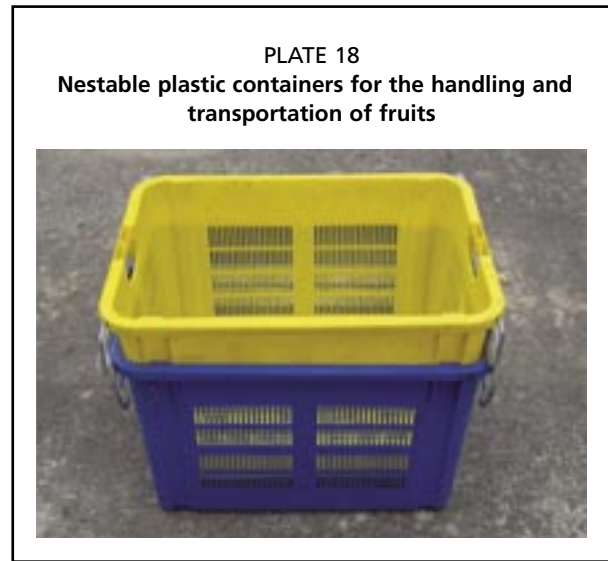


PHOTO: INSTITUTE OF POST-HARVEST TECHNOLOGY, SRI LANKA (2004)

The design of a truck body that is suitable for transportation of fruit in plastic containers under ambient conditions is given in Plate 19.

## 6.2 GOOD PRACTICE FOR THE USE OF PLASTIC CRATES FOR TRANSPORTING FRUITS

- Crates should be easily cleaned and sanitized;
- Damaged crates should be discarded when cleaning becomes difficult or when the damage is such that there is a risk of bruising the produce;
- Containers/trucks used for transporting the crates should be cleaned and disinfected prior to loading;
- Crates that have been in direct contact with soil, mud, compost, or fecal material should be properly marked and should not enter the receiving or packing house facility at any time. A second set of crates must be used for produce entering the packing house facility in order to avoid cross contamination;
- Containers used for fresh fruit should not be used to transport any other items.



PHOTO: K. PALIPANE

### 6.3 PACKAGING FOR EXPORT

Fruits for export are normally packed in corrugated cardboard (fiberboard) boxes, sometimes with partitions for the separation of individual fruit, with cushioning material to prevent mechanical injury (cuts, compressions, impacts, and vibrations) to the fruit. The corrugated fiberboard used in cartons is often given a surface coating of wax, which affords some protection from exposure to free water or to high humidity over short duration.

Pallets have become the main unit loads of packaging, particularly at the international level. Pallet dimensions correspond to those of maritime containers, trucks, forklifts, storage facilities, etc. When pallets are used as unit loads, handling is reduced at all steps of the distribution chain. Although different sizes of pallets exist, the most commonly used pallet internationally, measures 120 x 100 cm, and may be made from plastic. Depending on the dimensions of the packaging units, a pallet may hold from 20 to 100 unit boxes. To ensure stability, pallet loads are secured with wide-mesh plastic tension netting (Plate 20) or a combination of corner post protectors and horizontal and vertical plastic wrapping (Plate 21). In many cases individual packages are glued to each other with low tensile strength glue which allows for separate units but which prevents sliding. Cross-wise stacking or interlocking of units also contributes to the stability of the load.



PHOTO: LOPEZ – CARMELO, 2004

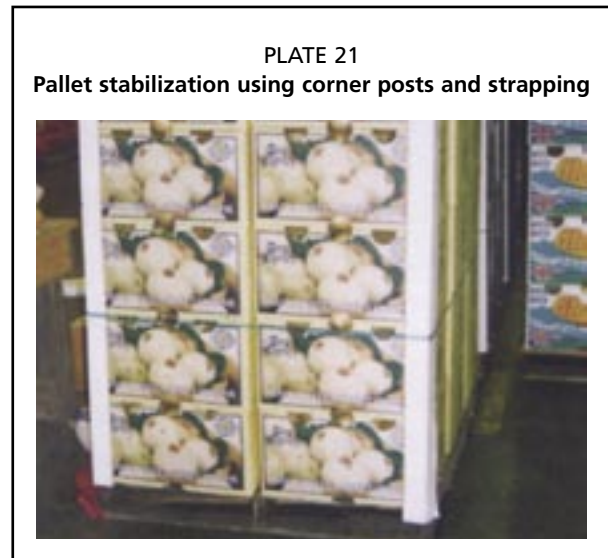


PHOTO: LOPEZ – CARMELO, 2004



There is a trend towards standardization of pallet size owing to the range variety of shapes and sizes of packaging for fruits. The main purpose of standardization is to maximize utilization of the surface of the pallet based on the standard size 120 x 100 cm. The ISO (International Standards Organization) module sets 60 and 40 cm as basic horizontal dimensions divided in sub-units of 40 x 30 cm and 30 x 20 cm (Figure 12). There are no regulations regarding the height of individual packages. However, to ensure safe handling, the palletized load should not exceed 2.05 meters.

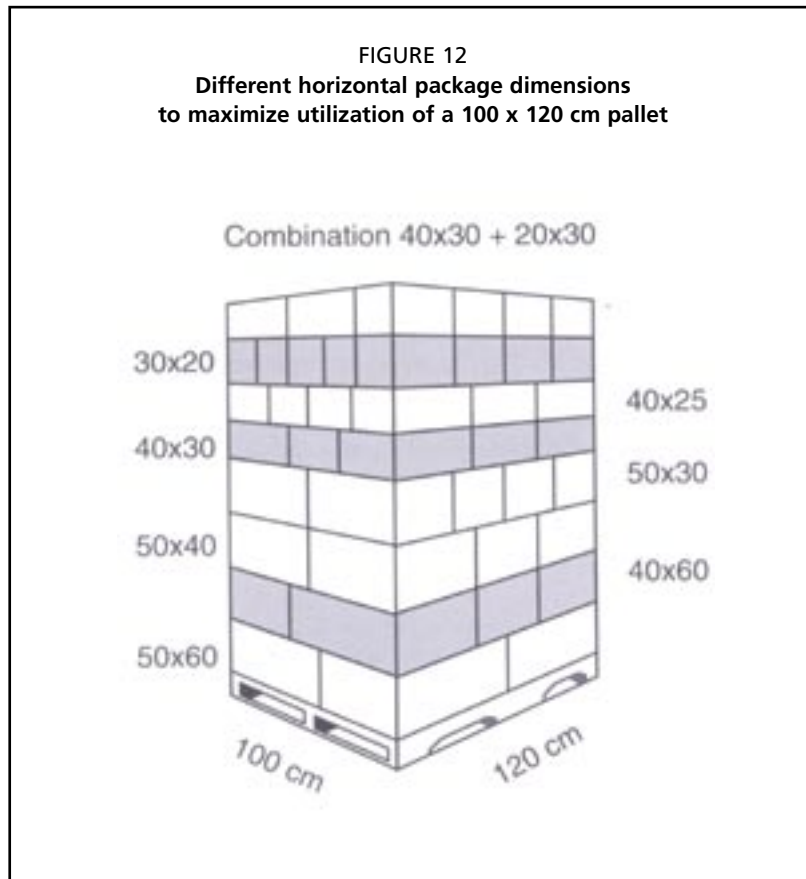


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## Chapter 7

# Storage

### 7.1 FACTS ABOUT FRESH FRUIT STORAGE

Fresh fruit:

- keep better under refrigerated conditions;
- shrivel or wilt under dry air conditions due to moisture loss;
- are damaged by freezing.

### 7.2 COLD STORAGE

Temperature control is one of the main tools for extending the post harvest life of fresh fruit. Low temperatures slow the rate of produce metabolism and the growth of microorganisms responsible for quality deterioration. Low temperature, in addition, minimizes the vapour pressure between the produce and the external environment, reduces water loss and thereby contributes toward maintaining freshness.

Tropical fruits, such as those grown in Jamaica when stored at temperatures below 15 °C but above 0 °C are easily damaged by ‘chilling injury,’ a disorder that results from the exposure of susceptible tissues to temperatures below 15 °C (Plate 22). It is, therefore, important to store fruits that are susceptible to “chilling injury” at temperatures above 10 °C. The susceptibility of a fruit to chilling injury is influenced by the species, variety and conditions under which it is grown.

High humidity conditions are required in order to prevent moisture loss and to preserve the freshness of fruit during low temperature storage. Given the fact that most fungi cease to grow under relative humidity conditions of less than about 90 per cent and only a few can grow at 85 per cent relative humidity, a relative humidity of 90 per cent is usually the best compromise condition for the storage of fruit.

Optimal storage conditions for fruits produced in Jamaica are summarized in Table 7.

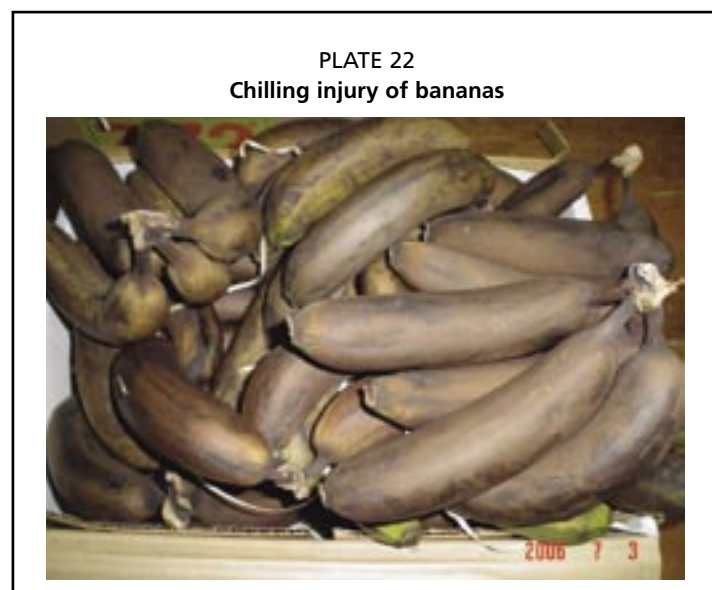


TABLE 7  
Recommended temperatures and relative humidity conditions  
for the storage of some fruits grown in Jamaica

Fruit	Temperature (°C)	Relative humidity (%)	Storage life (days)
Avocado			
<i>Green mature fruit</i>	3-7	85-90	14-56
<i>Ripening fruit</i>	13-15		
Banana	13-15	90-95	7-28
Breadfruit	13-15	85-90	14-42
Cashew apple	0-2	85-90	35
Guava	5-10	90	14-21
Jackfruit	13	85-90	14-42
Mandarin	4-7	90-95	14-28
Mango	13	90-95	14-21
Orange	0-9	85-90	56-84
Papaya	7-13	85-90	7-21
Sapodilla (Naseberry)	15-20	85-90	14-21
Tamarind	7	90-95	21-28
Sweet or sour sop	5-7	85-90	28-42

Source: Beattie et al., 1989

### 7.3 DESIGN AND CONSTRUCTION OF A COLD STORAGE FACILITY

A cold storage facility is a large, thermally insulated box, with doors for entry and some means of cooling the interior. Cool stores for fruit have special requirements when compared with other refrigerated stores. These include a high cooling capacity, temperature control, and the maintenance of relative humidity conditions of around 90 per cent. A common minimum design criterion is to provide capacity to cool a daily intake of 10 per cent of the capacity of the store at an initial rate of not less than 0.5 °C per hour.

The relative humidity of the air stream within the cold store can be increased by spraying water as a fine mist. The addition of water vapour to a cool store can be automatically controlled with the use of a humidistat. Wetting the floor of the cool store or the storage of open containers of water within the cool store also increases relative humidity.

### 7.4 GOOD PRACTICE FOR THE COLD STORAGE OF FRESH FRUITS

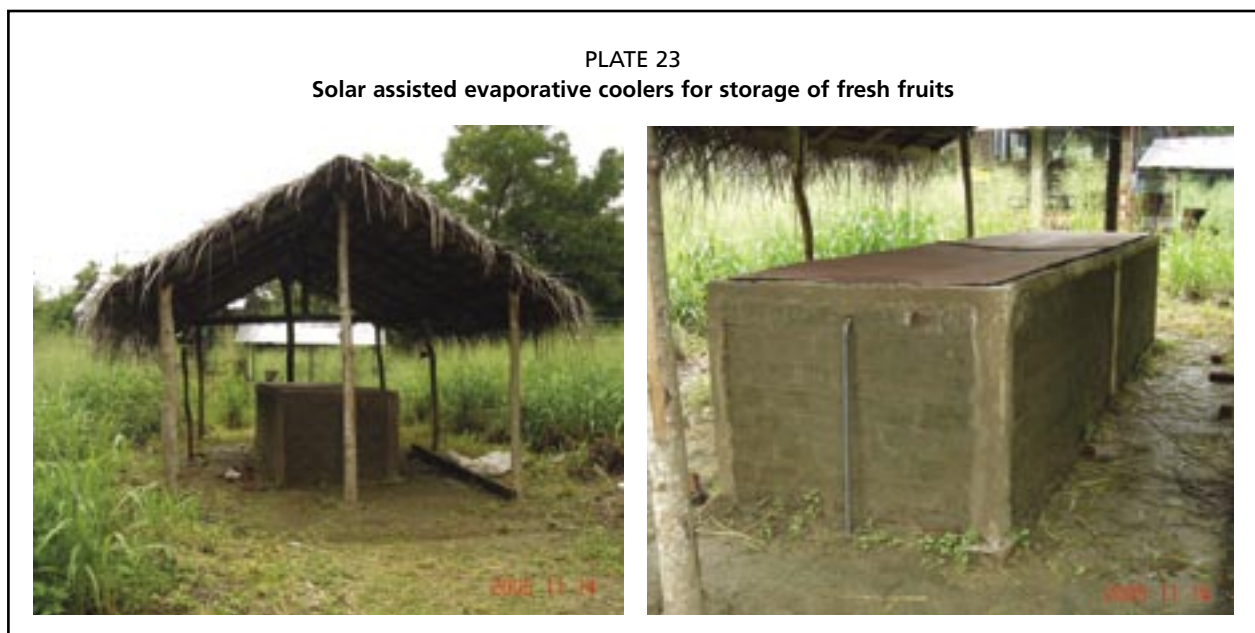
- Never expose harvested produce to direct sunlight; keep in cool, shady places with adequate ventilation;
- Store only good quality fruit: i.e. produce that is clean, mature and free from disease and injury;
- Store tropical fruits that are susceptible to “chilling injury” at temperatures above 10 °C (for non chill sensitive produce: 0–5 °C);
- Store ripe fruits separately from unripe ones;
- Do not mix fruits of different kinds in one cold store (This could lead to the absorption of off flavors, as well as to rapid deterioration of ethylene sensitive fruits);
- Store fruit in containers that can withstand stacking without getting deformed or without injuring the commodity;

- Fruits must be stored in clean containers (i.e. they do not harbor contamination that could serve as a source of inoculum);
- Place containers of produce on pallets to avoid direct contact with the floor;
- Allow adequate clearance between the walls and floor of the storage container so as to allow for ventilation, air circulation and cleaning – 45 cm (17.5 inches) between pallets and walls and 10 cm (4 inches) between pallets and floors;
- Use an organized system for managing inventory within the cold store. Codes and inventory rotation are important in minimizing the time that the commodity is stored and to facilitate recall, should problems arise later in the food chain;
- Do not store chemicals, trash, waste or odorous materials in the vicinity of produce.
- Maintain the cold store in a hygienic condition by systematically and periodically cleaning the walls, floors and ceilings to avoid contamination with filth;
- Monitor and maintain records of the temperature and relative humidity of the cold store in order to prevent or delay microbial growth;
- Remove produce from cold storage during the cool part of the day in order to prevent “sweating,” i.e. moisture condensation on the commodity, which provides a good environment for microbial growth.

### 7.5 APPROPRIATE TECHNOLOGY FOR COOLING FRUIT – A SOLAR ASSISTED COOLING CHAMBER

The solar assisted cooling chamber (Plate 23) is an appropriate level of technology for the temporary storage of fresh fruits at the farm level. The hollow walls of the chamber are constructed from porous clay bricks and are kept moist by a water source. As moisture evaporates from the outer surfaces of the walls due to solar energy carried by the wind, the temperature within the chamber falls below that of ambient temperature by 4–5 °C. The moist walls of the chamber in the interim, maintain a relative humidity of 85–90 per cent within the chamber.

The storage life of fresh fruit can be prolonged by 2–3 weeks within the chamber. Design specifications for the construction of a solar assisted cooling chamber are given in Annex 6.





## Chapter 8

# Transportation

Proper handling of fruits during transportation is critical to the avoidance of injury to produce. All of the time and effort taken to minimize microbial contamination and to monitor quality during field production, harvest, washing and packing will be wasted if the conditions for transportation are unsuitable or inadequate.

### 8.1 IMPORTANT CONSIDERATIONS FOR FRUIT AND VEGETABLE TRANSPORTATION UNITS

- Trucks and containers must be free of visible filth, odors and food particles and should be properly ventilated;
- Transportation units should be free of condensate and should be dry;
- All containers and transport units should be thoroughly cleaned and sanitized prior to loading in order to minimize microbial contamination (the wash water should be chlorinated at 100–200 ppm to kill pathogens that cause produce decay);
- Containers should not be overloaded. Overloading of containers damages produce and leads to microbial infestation;
- In situations where the previous load history indicates that the transportation unit had been used for transporting animals, raw foods, or chemical substances, fruit should not be placed in the unit until appropriate cleaning and sanitizing measures have been taken. The trailer or container should be washed and decontaminated using procedures similar to those described for packing house equipment.

### 8.2 REFRIGERATED TRANSPORTATION

Storage under ‘optimum temperature’ conditions, enhances the shelf-life of fruits, improves the attractiveness of their appearance and maintains their quality. Low temperature during transportation also inhibits or greatly retards the growth of pathogens.

Recommended ‘optimum’ temperature and relative humidity conditions for the transportation of tree fruits are summarized in Table 7.

- **ADDITIONAL GOOD PRACTICES FOR THE OPERATION OF REFRIGERATED TRANSPORT SYSTEMS**
  - Inspect refrigeration and cooling systems before each trip to ensure they are in proper working order. These systems should also be under a scheduled maintenance plan;
  - Staging time, i.e. time between removal from cold storage and loading into refrigerated containers should be minimized. Consider turning on refrigeration units and cooling the transportation container prior to loading;
  - Allow for proper air circulation in the trailer or container by properly stacking, and not overloading;
  - Maintain temperature records during transportation;
  - Temperature recorders must be calibrated and tamper-proof to ensure that the proper storage temperature is maintained;
  - Refrigeration coils should be clean and should not drip condensate on the load.





## Chapter 9

# Traceability in fresh fruit chains<sup>2</sup>

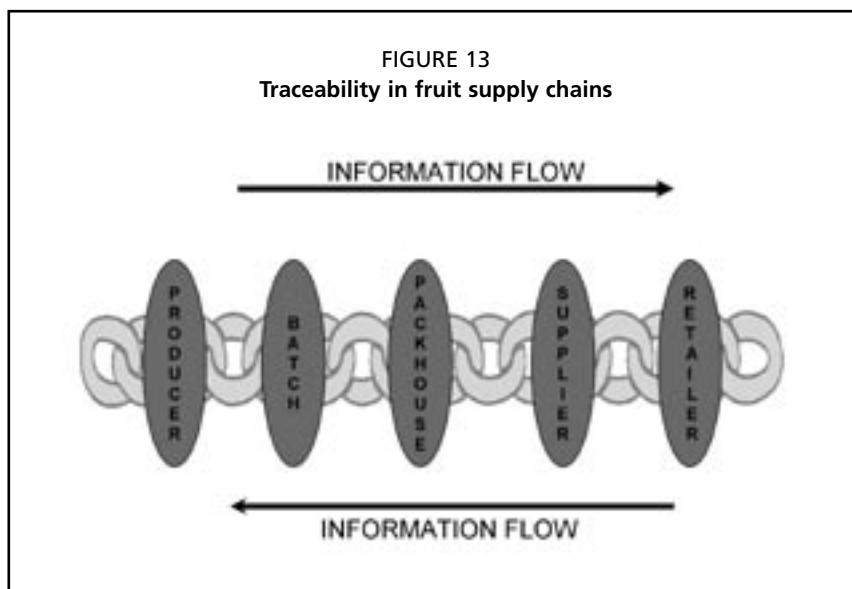
### 9.1 TRACEABILITY

Traceability provides an important element of quality and safety assurance in the fruit chain. It allows the history of produce to be traced back through the supply chain to the site of production, including inputs used, operations undertaken during production, post-harvest handling and marketing, as well as to be tracked as it moves through the chain from producer to consumer (Figure 13). In so doing, traceability facilitates efficient recall of fruits and assists in identifying the origin of food safety problems, in complying with legal requirements and in meeting consumer expectations for the safety and quality of fresh produce.

Traceability systems are growing in importance with growth in export trade as well as with growth in supermarkets.

### 9.2 KEY COMPONENTS OF A TRACEABILITY SYSTEM

At a minimum, an effective traceability system includes a documentation system and a mechanism for marking or uniquely identifying the fruit, thereby allowing it to be followed from the farm to the consumer. Records must be kept at every step of the fruit supply chain, i.e. in the field, at the pack house, at the supplier, the retailer and during transit between each of these points.



<sup>2</sup> This Chapter is reproduced from Horticultural Chain Management for Eastern and Southern Africa – A Theoretical Manual. FAO and the Commonwealth Secretariat, 2008

Various systems have been developed to deliver these requirements. A simple traceability system may consist of simple, hand written product labels and hand-written records held at the various steps of the chain, while a more sophisticated system makes use of a computerised system for data recording along with machine readable barcodes that can be electronically transferred within a computerised information system. The most sophisticated computerised systems now employ radio frequency identification (RFID) tags which continuously transmit data on the location of the product in real time. While simple hand-written records are inexpensive, they are slower, less accurate and prone to human error. Electronic systems allow for fast and accurate data transfer. RFID tags usually carry sensors that can be used for real-time monitoring of temperature, relative humidity and other parameters of the environment surrounding the produce in question.

# **Harvesting and post-harvest handling of tree fruits produced in Jamaica**



**ACKEE (*BLIGHIA SAPIDA*)****PLATE 24****Stage of maturity for harvesting of ackee**

SOURCE: © S. CHIN-CHANCE

*Ackee is a bright red tropical fruit that, when ripe and ready to harvest, bursts open while attached to the tree to reveal three large black seeds that are individually attached to a soft, creamy yellow flesh.*

*The consumption of ackee has long been associated with an illness, which was eventually named Jamaica Vomiting Sickness (JVS). Hypoglycin, a naturally occurring toxic constituent of the ackee, is the main cause of JVS. This compound is found mainly in the aril, the edible portion of the ackee. The concentration of this toxic compound decreases as the fruit matures. Ripened fruits, i.e. fruit that have opened on the trees, therefore have the lowest levels or are free of the toxin.*

*Harvesting at the correct stage of maturity is very critical to assuring the safety of ackee fruit. Ackee fruit must be harvested after opening. However, for the purpose of processing and in order to avoid wastage during handling, fruits can be harvested when they are fully mature and about to open.*

---

**Maturity Indices**

- Harvest when the fruits are opened on the trees, i.e., when the fruit is bright red or cream to yellow in colour depending on the cultivar and looks plump and rounded at the blossom end. This stage is determined by examination of the fruits.
- Ackees to be preserved in brine, should be harvested when the fruit is slightly open or is not open but mature, rounded in shape, cream or reddish pink depending on variety. The fruits should be transferred to racks for three days and allowed to open.

### Harvesting

---

- Ackees must be harvested with the use of appropriate tools.
- Fruits detached from the trees should not be allowed to fall to the ground.

### Post-harvest handling

---

- Care must be taken to avoid rough handling of harvested fruit.
- Harvested pods must be kept under cool shady conditions and must not be exposed to sunlight.
- Clean and dry containers must be used for the collection of harvested fruit. Fruit must never be stacked above three feet.
- Defective ackees must be removed. These include:
  - those that are diseased, mechanically damaged and which have deep red raphe that could stain the aril;
  - those with seeds that are not tough and are not black or brown in colour depending on variety;
  - those in which removal of the aril from the pod is difficult;
  - those in which the raphe is not easily detached from the aril.
- Harvested ackees must be transported in clean, dry plastic crates with perforated bottoms and sides to allow for good ventilation.
- Harvested ackees must be transported in a clean dry vehicle.
- Ackee fruit must be transported in a well ventilated vehicle during the cooler part of the day, i.e. early morning or at nights.
- Fruit must be transported as quickly as possible to the final destination, to prevent spoilage.

### Storage

---

- Ackee can be temporarily stored in a cool dry place with adequate ventilation.

## AVOCADO (*PERSEA AMERICANA*)

PLATE 25  
Stage of maturity for harvesting of avocado



PHOTO: ©TOPTROPICALS.COM

### Maturity Indices

Harvest when:

- Fruit is full in size.
- The surface of the fruit is smooth and the skin color changes to a lighter green color.
- The sound of the seed is heard when shaken (for some varieties only).
- The seed coat is brown (immature fruits have pink seed coats).
- The colour of the flesh is cream (if immature – the flesh is green in color).

### Harvesting

- Fruit must be harvested with care during the cooler part of the day, using appropriate harvesting equipment.
- Fruit must be harvested preferably by hand, leaving the stalk attached.
- Wet fruit must not be harvested.
- Harvested fruits must not be allowed to fall to the ground.

### Post-harvest handling

---

- Fruit must be carefully handled in order to prevent bruising and wounding.
- Harvested fruit must be kept away from direct sunlight, and preferably under shade.
- Clean and dry plastic crates must be used for the collection of harvested fruit.
- Fruit stalks must be trimmed to approximately 1 cm in length in order to reduce the risk of injury to the fruit.
- Fruit must be cleaned using a soft clean cloth containing a mild solution of bleach.
- Fruit must be dipped in 0.05% thiabendazole – a fungicide.
- Surface moisture must be removed from the fruit. This can be done by spreading on racks under shady conditions with adequate ventilation.
- Avocados for export should be packed in single layers in cartons lined with shredded paper to reduce the level of damage during packing. Alternate fruits should be wrapped in tissue paper to minimize abrasion damage.

### Storage

---

- *Ambient storage.* Avocados must be stored in a cool, dry place with adequate ventilation.
- *Cool storage.* West Indian type avocado cultivars should be stored at 12–13 °C for maximum shelf life. The fruit is susceptible to chilling injury at temperatures below 12 °C.

### Ripening

---

- *Ambient conditions.* West Indian avocados ripen best at 16–24 °C.
- *Controlled conditions.* Avocados can be ripened by treatment with 100 ppm ethylene at 20 °C (68 °F) for 24 to 48 hours.



## BREAD FRUIT (*ARTOCARPUS ALTILIS*)

PLATE 26

Mature breadfruit (left); Cross section of the interior of a mature breadfruit (right)



PHOTOS: © S. CHIN-CHANCE

### Maturity Indices

Harvest when:

- White latex appears on the skin of the fruit.
- Fruit segments and the spur are flattened.
- The fruits are rounded and smooth.
- The fruits appear dark green in colour with light browning and a lack of sheen.

*Immature fruits appear green in colour; the peel segments are close together and are angular in shape. They, therefore, appear ridged/sharp. There are no latex stains on the skin of the fruit and heavy latex flows when the fruit stem is broken from the tree.*

### Harvesting practices

- Harvest the fruit with the use of appropriate harvesting tools.
- Fruit must never be allowed to fall to the ground.

### Post-harvest handling

---

- Avoid rough handling of the harvested fruit.
- Clean and dry containers must be used for the collection of harvested fruit. Fruit must never be stacked above three feet.
- Harvested fruit must be kept away from direct sunlight, in a cool shaded area.
- Defective fruits, i.e., those that are diseased, mechanically damaged, and immature and over mature must be removed.
- Fruit stalks must be cut to 1.5 cm long and the latex allowed to drain.
- Harvested fruit can be pre-cooled by dumping in wash tanks containing water at ambient temperature and left for two hours or alternatively in ice water and left for half an hour to remove field heat.
- Fruit can be cleaned by washing in water with disinfectant (chlorinated water) to remove dirt.
- Surface moisture can be removed by spreading on racks under shade, with adequate ventilation.
- Fruit must be transported under clean and dry conditions, in jumbo sized stackable plastic crates with perforated bottoms and sides to allow proper ventilation during transportation.
- Fruit must be transported during the coolest part of the day, i.e. early morning or at night.
- Fruit must be transported as quickly as possible to the final destination in order to prevent spoilage.

### Storage

---

- *Temporary ambient storage.* Store in a cool, dry place with adequate ventilation.
- *Refrigerated storage.* Store at 13–15 °C and 85–90% relative humidity.

### CASHEW APPLE (*ANACARDIUM OCCIDENTALE*)

PLATE 27

Cashew apples at different stages of maturity



PHOTO: ©TOPTROPICALS.COM

#### Maturity Indices

Harvest when:

- The outer skin of the cashew apple turns yellow/yellowish red.
- Nuts turn from green to gray-brown in color.

#### Harvesting

- Intact fruit (i.e. fruit with the nut attached) should be harvested by cutting from the tree.
- Fruits should not be allowed to fall to the ground.

#### Storage

- **Ambient conditions.** Cashew apples will keep for 24 hours after harvest under ambient temperature conditions.
- **Cool storage conditions.** Cashew apples can be stored for five weeks at 0–2 °C and 85–90% relative humidity.

**CITRUS TANGERINE  
(CITRUS RETICULATE)**

## PLATE 28

## Stage of maturity for harvesting of tangerines



PHOTO: © S. CHIN-CHANCE

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**Maturity Indices**

Harvest when:

- The colour of the fruit peel changes from deep green to lighter green.
- Fruit is full in size.
- Peel thickness is reduced.
- Fruit juice percentage is 50 per cent (after peeling).
- Sweet orange – 0.3 per cent acidity, 12 °Brix.
- Mandarin – 0.4 per cent acidity, 12-14 °Brix.

---

**Harvesting**

- Fruit must be harvested using a pair of clippers or by carefully twisting and pulling the fruit from the tree so that the button remains attached to the fruit.
- Detached fruits must not be allowed to fall to the ground.

---

### Post-harvest handling

---

- Rough handling of harvested fruit must be avoided in order to prevent bruising and wounding.
- Harvested fruit must not be exposed to direct sunlight, but must be kept under shade.
- Harvested fruits must be collected in clean and dry plastic crates.
- Defective fruits, i.e. those that are diseased, mechanically damaged and otherwise not marketable must be separated out.
- Fruit must be cleaned by brushing or washing in water containing a disinfectant, (150 ppm hypochlorous acid, i.e. household bleach) maintained at a pH of 6.5, to remove dirt.
- Surface moisture must be removed. This can be done by spreading on racks under shade, with adequate ventilation.
- Fruits must be transported under clean and dry conditions in well ventilated stackable crates during the cooler part of the day, i.e. early morning and late evening.
- Fruit must be loosely covered with a tarpaulin, to avoid wetting during transportation.
- Fruit must be transported as quickly as possible to the final destination in order to prevent spoilage.
- Citrus destined for export should be packed in cardboard cartons padded with shredded paper.

---

### Storage

---

- **Ambient storage.** For temporary storage under ambient conditions, fruit must be stored in a cool, dry place with adequate ventilation.
- **Cold storage.** Oranges can be stored over the temperature range of 2–3 °C for up to 4 months. For short-term storage of several weeks and during transit a storage temperature of 10 °C and 90–95% relative humidity is adequate.

---

### Degreening

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- The external color of oranges can be improved by exposure to ethylene (1–10 ppm) at 20 °C to 25 °C and 90% relative humidity over three days.

## GUAVA (*PSIDIUM GUAJAVA*)

PLATE 29  
Immature guava (left); Cross section of a ripe guava (right)



PHOTOS: © S. CHIN-CHANCE

---

### Maturity Indices

Harvest when:

- Fruit colour changes from dark green to yellow green and before fruit turn yellow.

---

### Harvesting

- Fruit should be harvested at the correct stage of maturity.
- Detached fruits should not be allowed to fall to the ground.

---

### Post-harvest handling

- Harvested fruits should be transferred to cushioned boxes or crates in order to avoid mechanical damage or bruising.
- Harvested fruit should not be exposed to direct sunlight, but should be kept under shade.
- Individual fruit should be wrapped in soft packing material and packaged in well-ventilated cardboard boxes.

---

### Storage

- **Ambient conditions.** Fruit should be stored under ambient conditions in a cool dry environment with adequate ventilation.
- **Cool storage.** Fruit should be stored at 5–10 °C and 90% relative humidity.

**JACKFRUIT (*ARTOCARPUS HETEROPHYLLUS*)**

PLATE 30

Stage of maturity for harvesting of jack fruit



PHOTO: ©TOPTROPICALS.COM

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### Maturity Indices

Harvest when:

- Fruit is firm, mature and well formed.
- Fruit changes colour from dark green to lighter green.
- Peel segments widen, fruit spines become flattened and the distance between them increases.
- Yellowing of the last leaf of the peduncle (stalk) occurs.
- A resonant sound is given when tapped.
- Fruit is free from growth cracks.
- The rind yields to finger pressure, as the flesh becomes soft in some varieties.

---

### Harvesting

- Fruit should be harvested by cutting from the stalk using sharp bladed equipment. In situations where fruit is high up in the tree, a sack should be tied around the fruit with a rope, the stalk should be cut and the fruit should be gently lowered to the ground.

### Post-harvest handling

---

- Harvested fruit should be carefully handled in order to prevent bruising and wounding.
- Harvested fruit should be transferred to bulk plastic containers and stored under shade.
- Defective fruits, i.e. those that are diseased, mechanically damaged and otherwise not marketable should be separated.
- Fruit should be washed using chlorinated water to remove latex stains, dirt and any other contamination.

### Ripening

---

- *Ambient conditions.* Jackfruit ripen naturally at ambient temperature within 3-4 days.
- *Controlled conditions.* Jackfruit can be ripened by treatment with 50 ppm ethylene gas for 25 hour at 25 °C. The fruit will ripen within 3–4 days of treatment.

### Storage

---

- *Ambient conditions.* Jackfruit can be stored under ambient conditions, away from sunlight, with proper ventilation.
- *Cool storage conditions.* Jackfruit can be stored for two to four weeks at 13 °C and 85–90% relative humidity.



## JUNE PLUM (*SPONDIAS CYTHEREA*)

PLATE 31

Stage of maturity for harvesting of june plum



PHOTOS: ©TOPTROPICALS.COM

### Maturity Indices

Harvest when:

- The intensity of the 'ground colour' decreases from deep green to lighter green.

### Harvesting

- Fruit must be harvested using the appropriate harvesting tools.
- Fruits must not be detached from the trees or fall to the ground.

### Post-harvest handling

- Rough handling of harvested fruit must be avoided in order to prevent bruising, cracking and wounding.
- Fruit must not be exposed to direct sunlight. They should be kept under shade.
- Harvested fruits must be transferred to clean and dry plastic crates.
- Defective fruits, i.e., those that are diseased, mechanically damaged and otherwise not marketable must be separated out.
- Fruit must be cleaned by washing in water containing 100–120 ppm sodium hypochlorite and 0.05% thiabendazole.
- Surface moisture must be removed by spreading fruit on racks under shade with adequate ventilation.
- Fruits can be packed into fiberboard waxed cartons.

### Storage

- **Ambient conditions.** For temporary storage under ambient conditions, store in a cool, dry place with adequate ventilation, away from sources of ethylene.
- **Cool storage.** Transport and store at 13–15 °C and 85–90% relative humidity.

**NASEBERRY/SAPODILLA (MANILKARA ZAPOTA)**

PLATE 32

Stage of maturity for harvesting of naseberry/sapodilla



PHOTO: ©TOPTROPICALS.COM

---

**Maturity Indices**

Harvest when:

- The brown scaly external material from the fruit sheds off.
- Fruit becomes corky brown in color.
- Latex does not flow when the fruit is scratched with the finger nail.

---

**Harvesting**

- Harvest with the use of appropriate harvesting tools.
- Detached fruits must not be allowed to fall to the ground.

---

### Post-harvest handling

---

- Fruit must be carefully handled in order to prevent bruising and wounding.
- Harvested fruit must not be exposed to direct sunlight, but should be kept under shade.
- Harvested fruit must be collected in clean and dry plastic crates.
- Defective fruits, i.e., those that are diseased, mechanically damaged and not marketable must be separated out.
- Fruits must be cleaned by wiping or brushing. They must not be immersed in water as the corky fruit peel can retain moisture.
- Fruits must be transported during the cooler part of the day, in well ventilated plastic crates under clean and dry conditions.
- Wetting of fruit during transportation must be avoided.
- Fruit must be transported as quickly as possible to the final destination, to prevent spoilage.
- Fruit destined for export must be packed in cardboard cartons lined with shredded paper to protect against injury.

---

### Storage

---

- **Ambient conditions.** For temporary storage under ambient conditions, fruit must be stored in a cool, dry place with adequate ventilation.
- **Cool storage.** The naseberry/sapodilla can be transported and stored at 13–15 °C and a relative humidity 85–90%.

**MANGO (*MANGIFERA INDICA*)**

PLATE 33  
Stage of maturity for harvesting of mango



PHOTO: © S. CHIN-CHANCE

---

**Maturity Indices**

Harvest when:

- Shoulders of the fruit extend from the stem end (cheeks adjacent to the pedicel are full).
- Fruit colour changes from deep green to lighter green or from green to red depending on cultivar.
- Outer gloss of the fruit disappears.
- Specific gravity of the fruit is between 1.01–1.02.

---

**Harvesting**

- Fruit must be harvested with the appropriate harvesting tools.
- Fruits must not be allowed to fall to the ground.
- Fruits must be harvested with the stalk in order to avoid the exudation of latex.

### Post-harvest handling

---

- The stalk of the harvested fruit must be trimmed, leaving 1–2 cm length.
- Rough handling of harvested fruit must be avoided.
- Harvested fruit must be kept under cool shaded conditions and collected into clean and dry containers.
- Defective fruits, i.e., those that are diseased, mechanically damaged and otherwise not marketable must be separated out.
- Mangoes may be pre-cooled either by:
  - dumping the fruit in wash tanks containing water at ambient temperature and leaving for two hours;
  - dumping in ice water for 30 minutes.
- Fruit can be cleaned by washing in water, preferably with disinfectant (chlorine), to remove dirt. Water in the wash tank must be changed when a high level of organic material builds up in order to assure the efficacy of the disinfectant.
- In order to control decay due to stem end rot, transfer mangoes to a hot water bath (50 °C) containing 0.05% thiabendazole and allow to sit for a minimum of 3 minutes and a maximum of 5 min. The hot water bath should be regularly cleaned in order to avoid the build up of microorganisms and fruit sap.
- Surface moisture can be removed by spreading on racks under shade, with adequate ventilation.
- Mangoes can be packed in clean, dry, stackable plastic crates with perforated bottoms and sides to allow for adequate ventilation during transportation.
- Fruit must be transported in a clean dry vehicle during the cooler part of the day (i.e. early morning or at night).
- Proper ventilation of fruit must be allowed during transportation.
- Fruit must be loosely covered with a light colored tarpaulin, in order to avoid wetting during transportation.
- Fruit must be transported as quickly as possible to the final destination, to prevent spoilage.
- Mangoes destined for export can be packed in single layers in ventilated cardboard cartons with the use of shredded paper as padding material within the boxes.

### Ripening

---

- Mangoes can be ripened at 20–25 °C and 90–95% relative humidity, with of ethylene at concentrations ranging between 10 and 100 ppm (0.001–0.01 percent).

### Storage

---

- **Ambient storage.** Mangoes can be temporarily stored in a cool, dry place with adequate ventilation.
- **Cool storage.** Mangoes can be transported and cool stored at 12 °C and 85–95% relative humidity.

**PAPAYA (CARICA PAPAYA)**

PLATE 34  
Stage of maturity for harvesting of papaya



PHOTO: © S. CHIN-CHANCE

---

**Maturity Indices**

Harvest when:

- 25% of the peel colour changes from green to yellow, from apical end (for export: 10 per cent peel colour development).
- Latex flow is low.
- Brix of 10–14%.

---

**Harvesting**

- Fruit must be harvested with the use of an appropriate harvesting tool.
- Detached fruit must never be allowed to fall to the ground.
- Gloves should be worn during the hand-picking of fruits, in order to prevent bruising and scratching.
- Fruit stalks must not be broken, as this will damage the tissue leading to spoilage.
- Harvested fruit must be handled with care in order to avoid mechanical injury.
- Harvested fruit must be stored under shade.
- Defective fruits, i.e. those that are diseased, mechanically damaged and otherwise not marketable must be separated out.
- Fruit must be cleaned by washing in water, preferably with disinfectant (chlorine), to remove dirt.
- Fruit must be submerged in hot water (49 °C) for 20 minutes, followed by a cool rinse.

- Surface moisture must be removed from the fruit. This can be done by spreading on racks under shade with adequate ventilation.
- Papayas should be packed in single layer cartons lined with shredded paper. They are best packed on their sides in rows with the stem end at an angle.

---

### Storage

- **Ambient storage.** For temporary storage under ambient conditions, papayas must be stored in a cool, dry place with adequate ventilation.
- **Refrigerated storage.** Papayas must be cold stored and transported at 7–13° C and 85–95% relative humidity.

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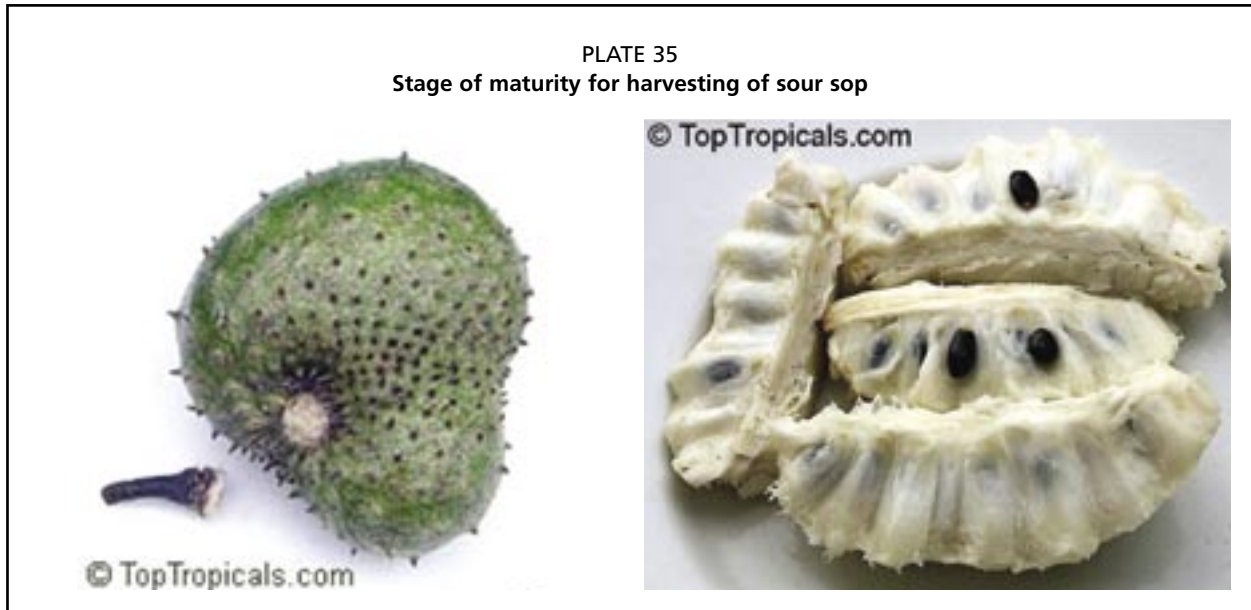
### Ripening

- **Ambient conditions.** Fruits harvested at the proper harvesting stage will ripen to 60–70% yellow within 4 to 6 days, under ambient conditions.
- **Controlled conditions.** Papayas can be ripened by exposure to 100 ppm ethylene at 20 to 25 °C (68 to 77 °F) and 90–95% relative humidity over 24–48 hours.

## SOURSOP (*ANNONA MURICATA*)

PLATE 35

Stage of maturity for harvesting of sour sop



PHOTOS: ©TOPTROPICALS.COM

### Maturity Indices

Harvest when:

- The fruit is fully developed and is still firm.
- The color of the fruit peel changes from dark green to pale green.
- The short soft spines on the peel become flattened and the distance between them increases (when approximately 6 to 7 spines span 12 square centimeters, the fruit can be considered to be mature).
- The fruit segments become wider loosely packed and flattened.
- The fruit is still firm when pressed with the thumb or finger.

### Harvesting

- Fruit must be harvested at the correct stage of maturity by cutting from the branch, leaving 0.5 to 1 cm of the peduncle attached to avoid weight loss and fungal diseases.
- Detached fruit from the trees must not be allowed to fall to the ground.

### Post-harvest handling

- Harvested fruits must be transferred to cushioned boxes or crates in order to avoid mechanical damage or bruising.
- Harvested fruit should not be exposed to direct sunlight, but should be kept under shade.
- Individual fruit should be wrapped in soft packing material and transported in well-ventilated cardboard boxes.

### Storage

- **Ambient conditions.** Fruit must be stored under ambient conditions in a cool dry environment.
- **Cool storage.** Fruit are best transported and stored at 15 °C and 90% relative humidity.



**SWEETSOP OR SUGAR APPLE  
(ANNONA SQUAMOSA)**

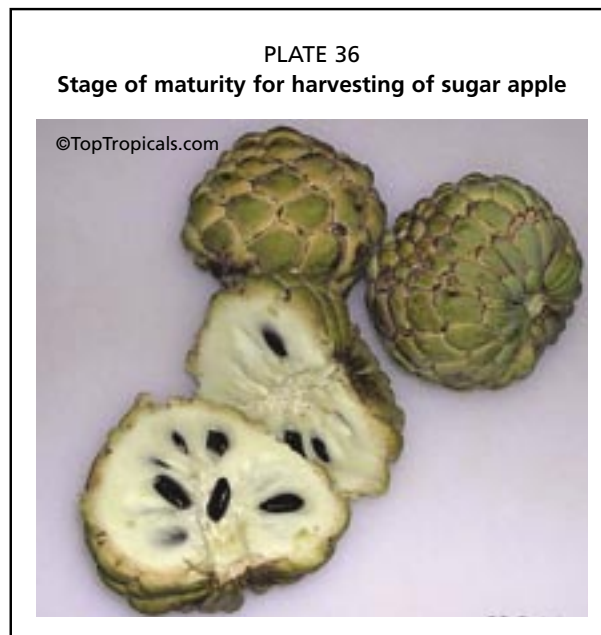


PHOTO: ©TOPTROPICALS.COM

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### Maturity Indices

Harvest when:

- The knobbly scales on the fruit surface become flattened and broadened.
- There is a resonant sound when tapped by fingers.

---

### Harvesting

- Fruits must be harvested at the correct stage of maturity by cutting from the branch, leaving 0.5 to 1 cm of the peduncle attached so as to avoid weight loss and fungal diseases.
- Detached fruit must not be allowed to fall to the ground.

---

### Post-harvest handling

- Harvested fruits must be transferred to cushioned boxes or crates in order to avoid mechanical damage or bruising.
- Harvested fruit must not be exposed to direct sunlight, but should be kept under shade.
- Fruit should be individually wrapped in soft packing material and packaged in well-ventilated cardboard boxes.

---

### Storage

- **Ambient conditions.** Fruit should be stored under ambient conditions in a cool dry environment.
- **Cool storage.** Fruits can alternatively be stored at 15 °C and 90% relative humidity.

## TAMARIND (*TAMARINDUS INDICA*)

PLATE 37

Stage of maturity for harvesting of tamarind



PHOTOS: ©TOPTROPICALS.COM

### Maturity Indices

- Harvest when the shell becomes brittle and the pulp shrinks within the shell.

### Harvesting

- Fruit should be harvested by clipping from the branches, in order to avoid damage to the brittle shell.
- Fruit should be trimmed to remove any vegetative parts attached to the pods.

### Post-harvest handling

- Fruits should be carefully handled in order to prevent damage to the shell.
- Harvested fruit should not be exposed to direct sunlight, but should be kept under cool dry conditions.
- Harvested fruit should be collected in clean and dry plastic crates.
- Defective fruits, i.e. those that are diseased, mechanically damaged and otherwise unmarketable should be separated out.
- Pods should be cleaned by wiping or brushing.
- Fruit should be packaged in boxes.

### Storage

- *Ambient conditions.* Fruit should be stored in a cool dry place with adequate ventilation.
- *Cool storage.* Fruit should be stored at a temperature of 7 °C and a relative humidity of 90–95%.

## Chapter 10

# Processing of tree fruits for preservation and value addition

Much of the fruit produced in Jamaica is marketed in the fresh form with marginal returns to farmers, given the high cost of agricultural and labour inputs. Currently, relatively little agro-processing is done at the farm level. One effective way of increasing the income generated from farming is to develop agro-food-processing micro-enterprises at the farm level. It has now been realized that if farmers themselves at the rural level could “add value” to their raw material outputs through processing, they could increase market demand for their farm outputs, reduce waste and significantly increase their incomes.

Tree fruit production is seasonal in nature. During peak harvesting periods a glut in production exists and hence the prices of these commodities fall to unprecedented levels. Farmers are, therefore, compelled to dispose of their produce soon after harvest at low prices owing to the lack of facilities to preserve their crop for future sale. Furthermore, large quantities of these fruits go to waste owing to the lack of markets. Improvement of processing and preservation facilities, as an important component of the post harvest system, would enable farmers to sell their commodities during the off season at attractive prices, thus increasing their incomes.

It is often argued that farmers lack access to urban markets where demand exists for value added processed products. It must, however, be emphasized that in Jamaica, like in most developing countries the rural sector comprises the majority of the population and hence, there is a ready demand for processed food products in local rural markets.

Any processing or value adding technology that is introduced into Jamaica should be affordable and manageable by the rural sector, and particularly by rural women, and should bring about a significant increase in their incomes. Women make a significant contribution in the agro-food processing sector and are involved with harvesting, handling, drying, cleaning and processing activities, while attending to laborious operations at the household level such as food preparation, family care, etc. The selection of appropriate technologies that would eliminate drudgery of the rural woman, therefore, assumes importance. In this context, some viable value adding technologies that can be introduced for tree fruit crops in Jamaica include the manufacture of:

- Dehydrated fruit
- Fruit jams
- Fruit cordials and ready to serve drinks

### 10.1 DRIED/DEHYDRATED FRUITS

The technique of drying is probably the oldest method of food preservation practiced by mankind. Moisture removal from produce prevents the growth of spoilage-causing microorganisms and minimizes many of the moisture mediated deterioration reactions. It brings about substantial reduction in weight and volume, hence minimizing packing, storage and transportation costs, while enabling storability of the product at ambient temperatures. These features are particularly important for developing countries. The safest moisture content for the preservation of dehydrated fruit is less than 10 per cent.

- **SUN DRYING TECHNIQUES FOR THE PRESERVATION OF FRUITS**

Sun drying is a highly feasible and cost effective method of fruit preservation. The production of sun dried fruits is simple and relatively inexpensive.

*Selection and preparation of fruits*

- Some fruit varieties are better suited to natural drying than are others. Fruits must be able to withstand natural drying without toughening of their texture, so that they are not difficult to reconstitute. Mango varieties with few fibers, should, for example, be selected for drying;
- Fresh fruit selected for drying should be of optimal ripeness and of good quality. Different lots of fruit at various stages of ripeness must not be mixed together as this would result in poor quality dried product;
- Damaged fruit parts that have been attacked by insects, rodents, diseases etc. and parts, which have been discolored or which have a bad appearance or colour must be removed by trimming. Fruit must be washed prior to trimming;
- Trimmed fruit must be either cut into 5 to 10 mm thick slices or cut in halves/quarters etc.;
- All slices/parts must be dried in one uniform drying lot (i.e. one lot having slices of the same thickness). The actual thickness of the slices will depend on the kind of material. Uneven slices of different sizes will dry at different rates, resulting in quality end products;
- Stainless steel knives would best be used for trimming and cutting of fruits.

*Pretreatment of fruits*

Some fruits, in particular bananas, brown very quickly when exposed to the air after peeling or slicing. This discolouration is due to the presence of an active enzyme in the fruit, called phenoloxidase. Discoloration of fruits also occurs during the drying process. In order to prevent discolouration and to improve keeping quality, fruits are subjected to a chemical pretreatment either by exposing to fumes of sulphur dioxide (sulphuring) or dipping in a dilute solution of potassium metabisulphite (KMS) immediately after slicing as follows:

- Prepare a preservative solution containing 500 ppm (500 mg in 1 liter of water) potassium metabisulphite in either an enamel, plastic or stainless steel vessel. The fruit to solution ratio should be 1:4;
- Place the sliced fruit on a square piece of clean cloth; tie the corners of the cloth together and put a stick through the tied corners of the cloth; dip the cloth into the vessel containing sodium metabisulphite solution, while allowing the stick to rest across the top of the pan thus providing support for the cloth bag;
- The bag should be removed after about 5 minutes, and the liquid should be allowed to drain out. The liquid that drains out of the bag should not go back in to the preservative solution as it would dilute the solution;
- Care must be taken after each dip to refill the container to the original level with fresh preservative solution;
- The preservative solution should be discarded after five lots of material have been dipped;
- The slices must then be rinsed in pure water for about one minute.

Breadfruit and unripe jackfruit must be dipped in hot water (60 °C) containing 2 per cent sodium chloride (NaCl) for 3–5 minutes, in order to prevent discoloration due to browning.

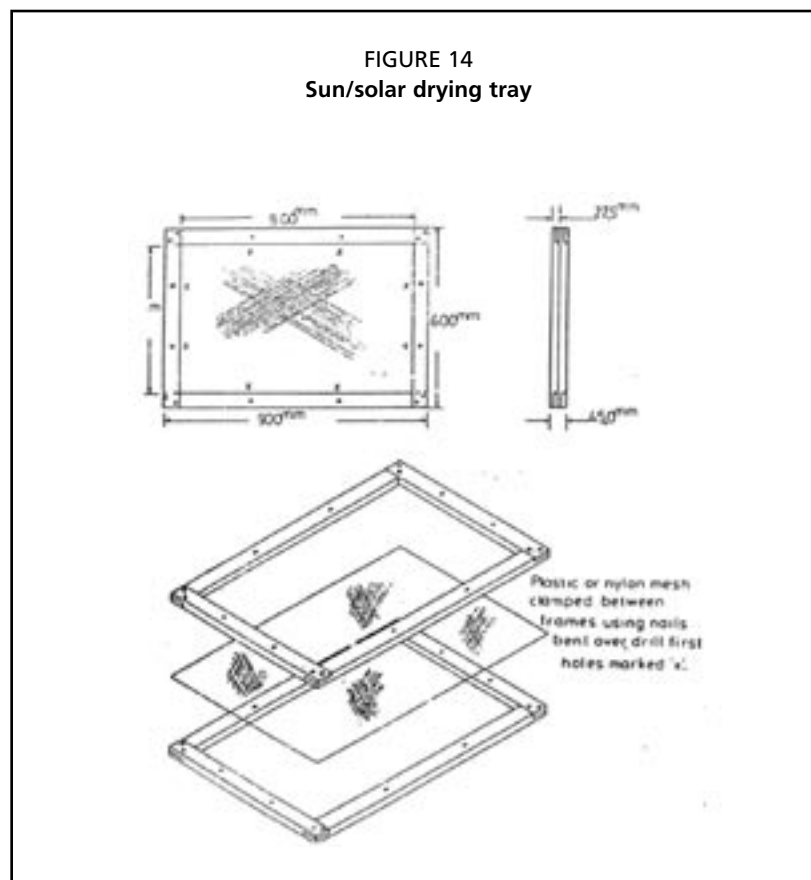
*Sun drying of fruits*

- The main problem associated with the sun drying of produce is the dust, rain and cloudy weather. Drying areas should, therefore, be dust free and whenever there is a threat of a dust storm or rain, the drying trays should be stacked together and placed under cover;

- In order to produce dust-free hygienic products, fruit material should be dried well above ground level so that they are not contaminated by dust, insects, livestock or people;
- All materials should be dried on trays. The most commonly used drying trays consist of wooden frames with a fitted base of nylon mosquito netting. Metal netting must not be used given that it can contribute to discoloration of the product. The approximate load for an 80 × 50 cm tray is 3 kg;
- The material should be spread in even layers;
- Overlaying the loaded tray with a wire mesh or an empty tray protects the drying produce from wind and damage by insects and birds;
- During the first part of the drying period, the material should be stirred and turned over at least once every hour; this helps improve the uniformity and rate of drying, prevents the produce from sticking together and improves the quality of the finished product;
- Products for sun drying should be prepared early in the day in order to ensure that the material enjoys the full effect of the sun during the early stages of drying;
- At night the trays should be stacked in a ventilated room or covered with canvas or a clean white cloth, but never with a plastic sheet.

#### *Sun drying tray*

The drying tray described requires 6 meters of seasoned timber 22.5 mm thick × 50 mm wide. Figure 14 depicts elements of tray design.



### Packaging

Dried fruits must be packaged in a film that offers good moisture barrier properties. Heat sealed polypropylene films can be used for this purpose.

#### • USE OF DRYERS/DEHYDRATORS FOR FRUIT DEHYDRATION

Tray-type dryers, with indirect heating systems are generally used for fruit dehydration. Electricity, gas or biomass/agricultural waste can be used as the energy source for this purpose. A low cost tray-type dryer equipped with an indirect heating system which utilizes rice husk, saw dust, nutmeg shell, peat or any other biomass/agricultural waste for heat generation, for dehydration of fruit is shown in Plate 38. The design details of the unit are given in Annex 7.

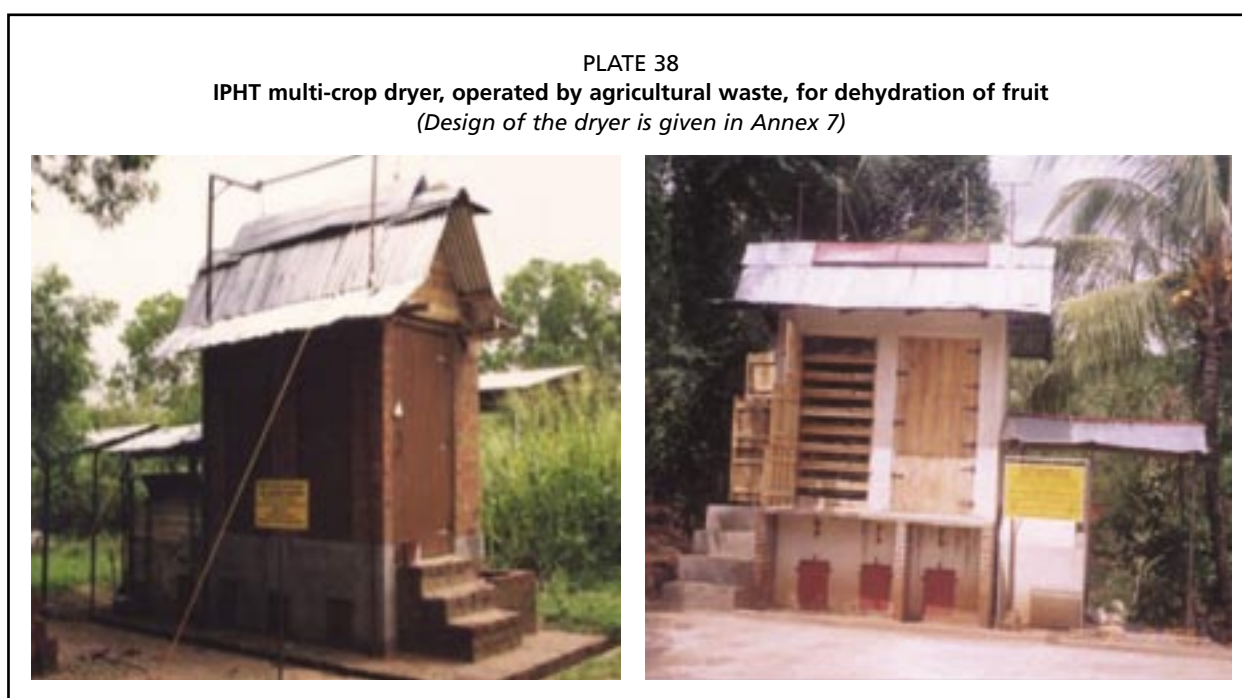


PHOTO: INSTITUTE OF POST HARVEST TECHNOLOGY, SRI LANKA (2004)

Table 8 summarizes the performance of multi-crop dryers for the dehydration of selected tree fruits.

**TABLE 8**  
**Performance of the IPHT multi-crop dryer in dehydration of some tree fruits**

Fruit	Capacity (kg)	Temperature (°C)	Drying time (hr)	Drying ratio	Final moisture content (%)
Jackfruit (ripe)	100	55	10-15	5:1	12
Jack (unripe)	100	55	8-10	4:1	7-8
Bread- fruit	100	55	8-10	4:1	7-8
Mango	100	55	8-10	5:1	12
Papaya	100	55	10-15	5:1	12

### Selection, preparation, pre-treatment and packaging

Methods used for the selection, preparation and pre-treatment of fruit for dehydration in tray-type dryers and for packaging dehydrated products are similar to those used for sun drying.

- **OSMOTIC DRYING/DEHYDRATION**

Fruits such as ripe papayas, mangoes, bananas and jackfruit can be preserved by osmotic dehydration whereby the fruit is immersed in a sugar solution of 40 °Brix (600 ml water + 400 g sugar) for 5 hours prior to air drying to a moisture content of less than 12 per cent. Osmotically dehydrated fruits are sweeter than air dried fruits and are used as ingredients in the production of ice cream, jelly, cake preparations etc.

## 10.2 FRUIT JAMS

Surplus fruit can also be processed into jams.



PHOTO: K. PALIPANE

Below is a simple and cost effective method for the manufacture of jam from tree fruits, that can be adopted as a profitable rural level cottage industry by women.

- 1 **Selection of fruits.** Only fully ripe fruits having good colour and flavour should be selected for jam preparation. The fruits should be thoroughly washed in fresh water and the stems and leaves, if any should be removed. Bruised and blemished portions of the fruit should be trimmed;
- 2 **Preparation of fruits.** Fruits must be peeled, cored and cut fruit into small pieces. Fruit that are of a tough texture can be softened by boiling in a small quantity of water to soften;
- 3 **Addition of sugar.** For sour fruits, add 1 part sugar by weight to 1 part fruit by weight. In the case of sweeter fruit varieties, add three parts sugar by weight to four parts fruit by weight. Citric acid must be added to sweeter fruits at a rate of 2–2.5 g/kg of fruit (Citric acid is added to obtain a pH of 3 to 3.3);
- 4 **Addition of pectin.** Pectin must be added at the rate of 20 grams of pectin per kilogram of fruit (pectin is added to obtain the required gel consistency or spoonability);

- 5 **Cooking.** The mixture must be slowly cooked with occasional stirring and crushing, to attain a temperature of 105 °C or till the cooking mass approaches the desired consistency. (The soluble solids content of the jam should reach 68–72 per cent, as measured with the use of a refractometer);
- 6 **Filling and sealing.** The product should be filled into sterile glass bottles or jars (sterilized by boiling in water for 10 minutes). The hot jam must be transferred to the sterile (while the bottles are still hot to prevent breakage) placed on an insulated surface such as a wooden board or a thick pad of cloth, to prevent breakage of the glass. The sterile lid must be kept in the inverted position on the mouth of the filled bottle until the jam sets. The lid must then be wiped and the bottle must be tightly closed;
- 7 **Cooling and storage.** The bottles must be inverted for about 5 minutes allowed to cool and stored in a cool and dry place.

### 10.3 FRUIT CORDIALS

The production of fruit cordials is another method for preserving and adding value to tree fruits such as tamarind, mango, papaya, sweetsop, soursop, June plum, citrus, guava, cashew apple etc. (Plate 40).

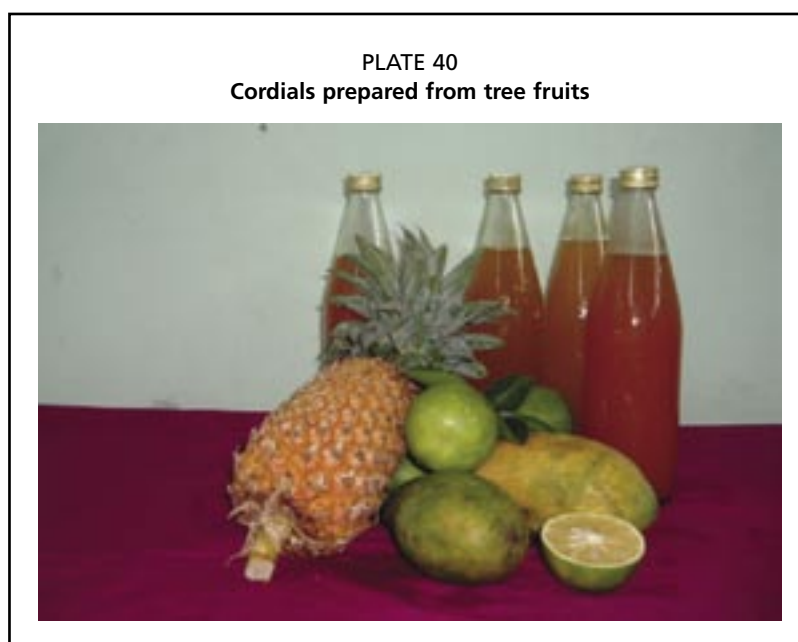


PHOTO: K. PALIPANE

- METHOD OF PREPARATION

- 1 **Selection of fruits.** Fruits must be selected as for jams.
- 2 **Preparation of fruit.** Fruit must be peeled, cored and cut into small pieces. The fruit pieces must be blended. In the case of juicy fruits, the juice may be manually extracted or extracted using a juice extractor. For preparation of tamarind pulp, one portion of water must be added to two portions of shelled tamarind fruit and boiled for 10 minutes. The pulp must be extracted by rubbing the boiled fruits, using a plastic brush, on a stainless steel or plastic sieve or screen of (pore size No. 12; Plate 41).



- 3 **Mixing of ingredients.** Prepare a sugar solution containing carboxymethyl cellulose, as follows: dissolve 1.2 kilogram sugar and 3.4 grams Carboxy methyl cellulose (CMC) in 1.2 litres of water – CMC prevents sedimentation of prepared cordial).
- 4 **Heating.** The mixture must be heated for approximately 10 minutes in order to dissolve the sugar.
- 5 **Addition of prepared fruit.** Prepared fruit (1 kg) and 3.4 grams of citric acid must be added to the mixture (for sour fruits the addition of citric acid is not required).
- 6 **Pasteurization.** The mixture must be heated at 85–90 °C for 20–25 minutes.
- 7 **Addition of preservative.** Sodium benzoate (1.1 grams) must be added to the pasteurized cordial.
- 8 **Filling and sealing.** The hot product should be filled into sterile glass bottles (sterilize bottles and lids by boiling in water for 10 minutes), while the bottles are still hot to prevent breakage and placed on an insulated surface such as a wooden board or a thick pad of cloth in order to prevent breakage of the glass. The bottles must be sealed with the lids using a bottle sealer (Plate 42).
- 9 **Cooling and storage.** The bottles must be allowed to cool and stored in a cool and dry place.



PHOTO: K. PALIPANE



PHOTO: K. PALIPANE

#### 10.4 READY TO SERVE DRINKS (RTS)

Ready to serve drinks can also be prepared from a range of tree fruits (Plate 43).



- 1 *Selection of fruits.* Same as for jams and cordials.
- 2 *Preparation of fruits.* Same as for cordials.
- 3 *Mixing of ingredients.* A sugar solution is prepared by adding 6.25 liters of potable water to 8.75 kilograms sugar and heating for approximately 10 minutes to dissolve the sugar.
- 4 *Addition of prepared fruit.* Prepared fruit (1 kg) along with 8.1 grams of citric acid, must be added to the mixture (for acidic fruits citric acid is not added).
- 5 *Pasteurization.* The mixture must be heated at 85–90 °C for 20–25 minutes.
- 6 *Addition of preservative.* Sodium benzoate (0.65 grams) must be added to the pasteurized drink.
- 7 *Filling and sealing.* The product should be transferred to sterilized (bottles and lids sterilized by boiling in water for 10 minutes) glass bottles while the bottles are still hot. The bottles should be placed on an insulating material like a wooden board or a thick pad of cloth, to prevent breakage of the glass. The bottles should be sealed with the use of a bottle sealer (Plate 41).
- 8 *Cooling and storage.* The bottles should be cooled and stored in a cool and dry place.

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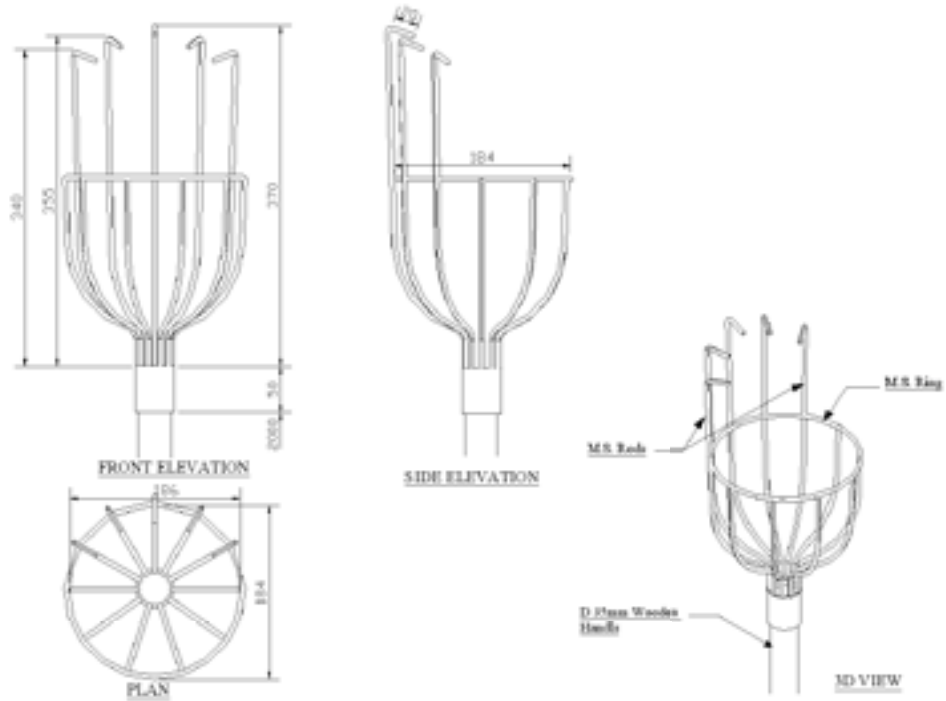
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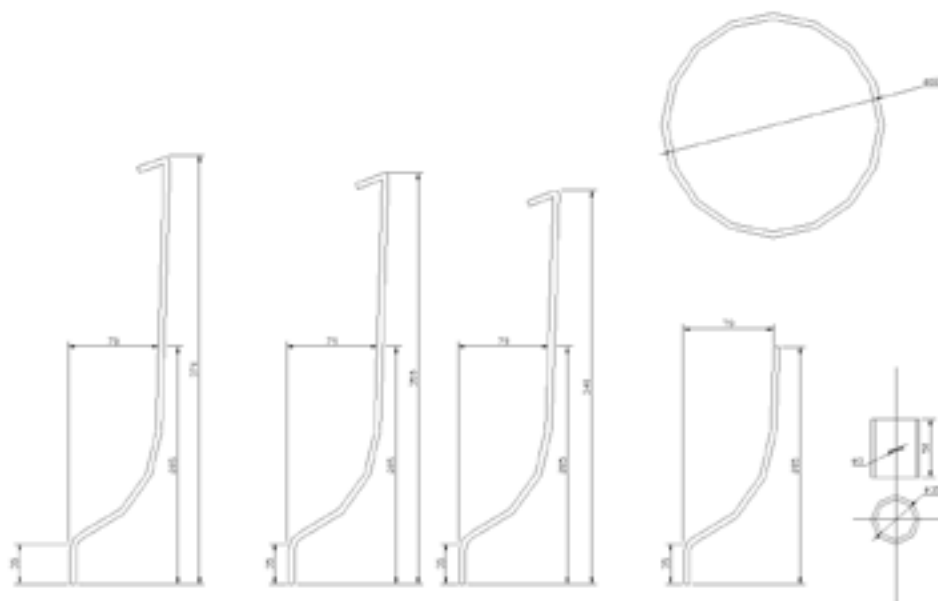
# Annexes



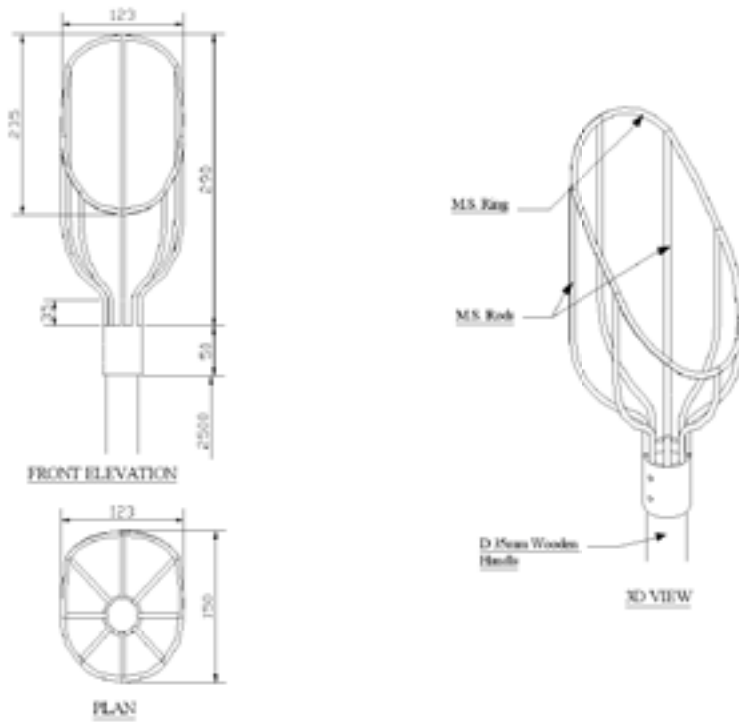
ANNEX 1  
Fruit harvester – for mango and other fruits occurring in bunches  
(corresponding to Figure 4)



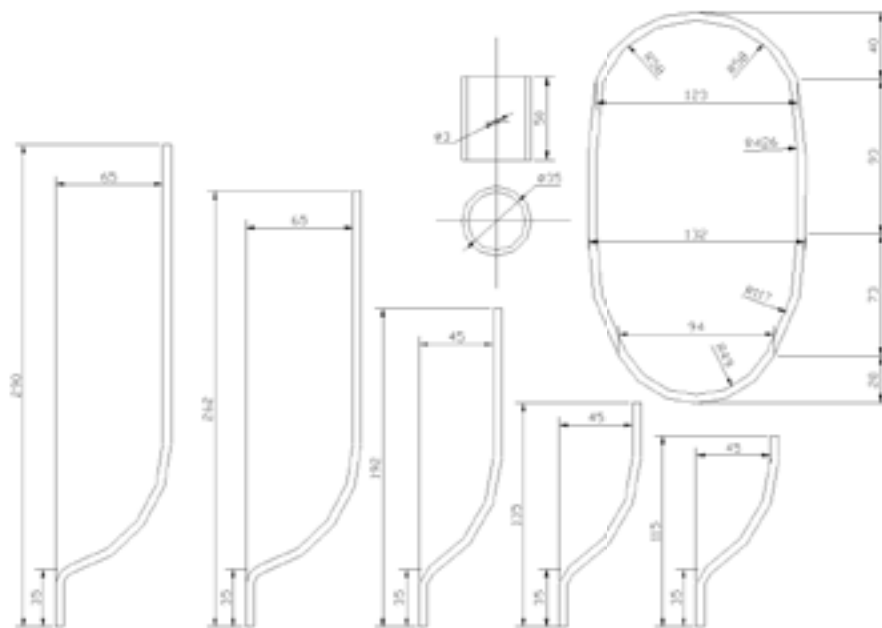
ANNEX 1  
Fruit harvester – for mango and other fruits occurring in bunches  
(continued)



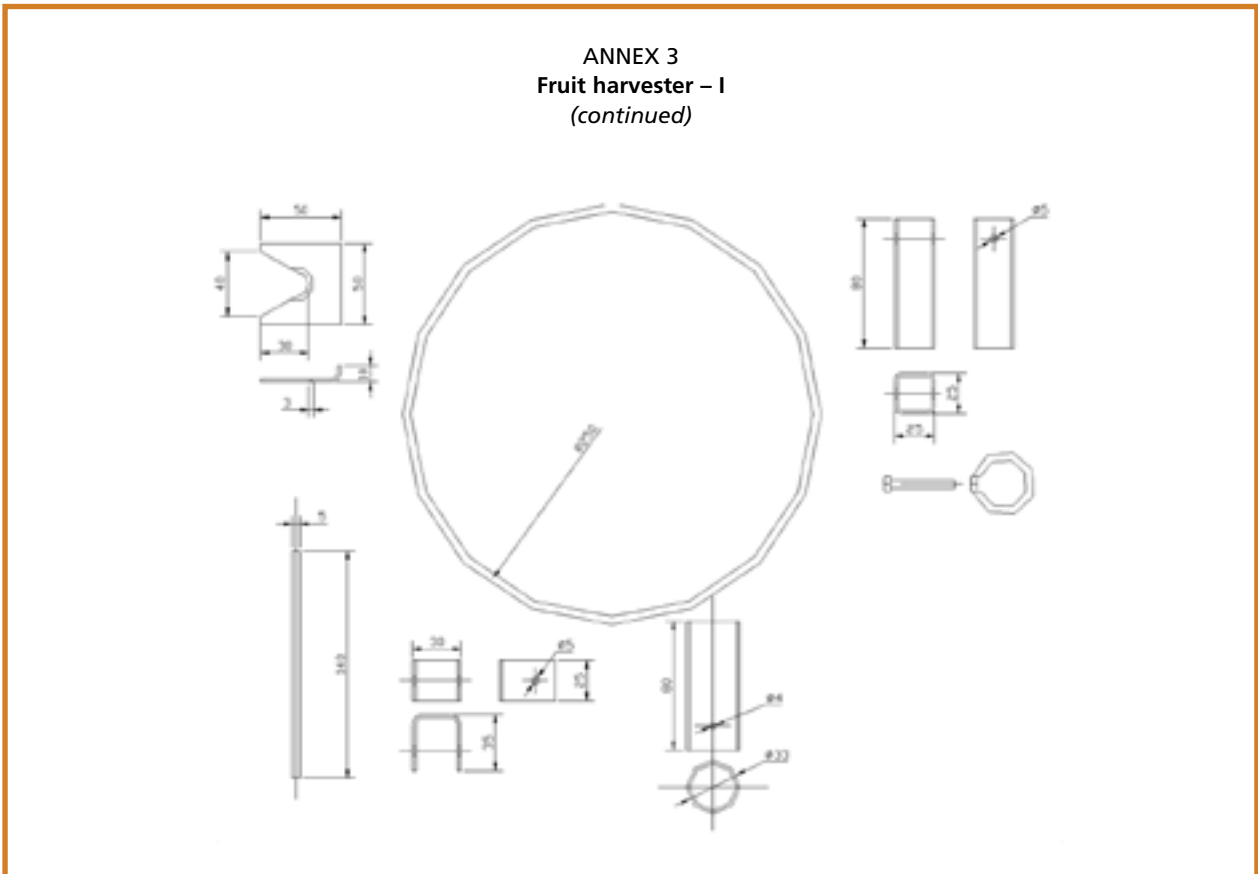
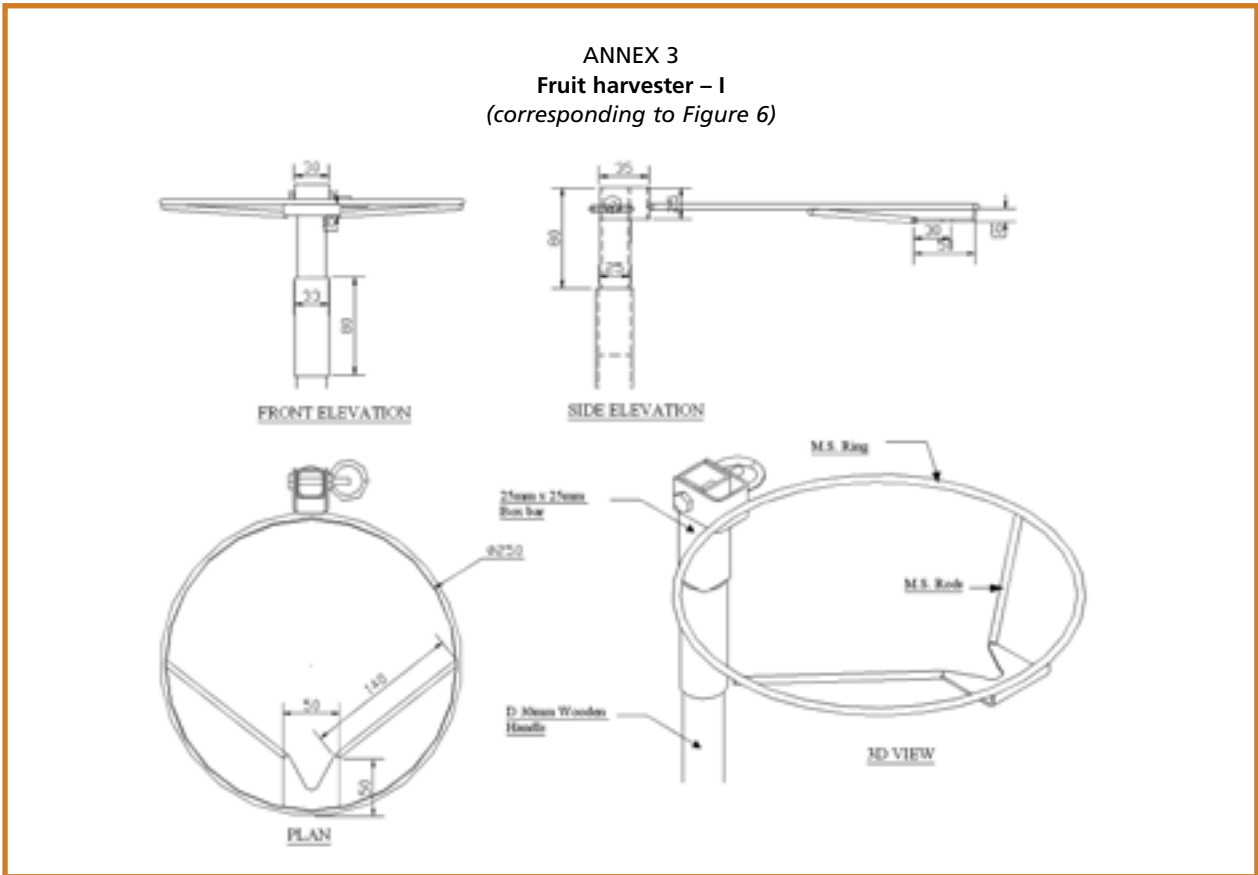
ANNEX 2  
**Fruit harvester – papaya**  
 (corresponding to Figure 5)



ANNEX 2  
**Fruit harvester – papaya**  
 (continued)

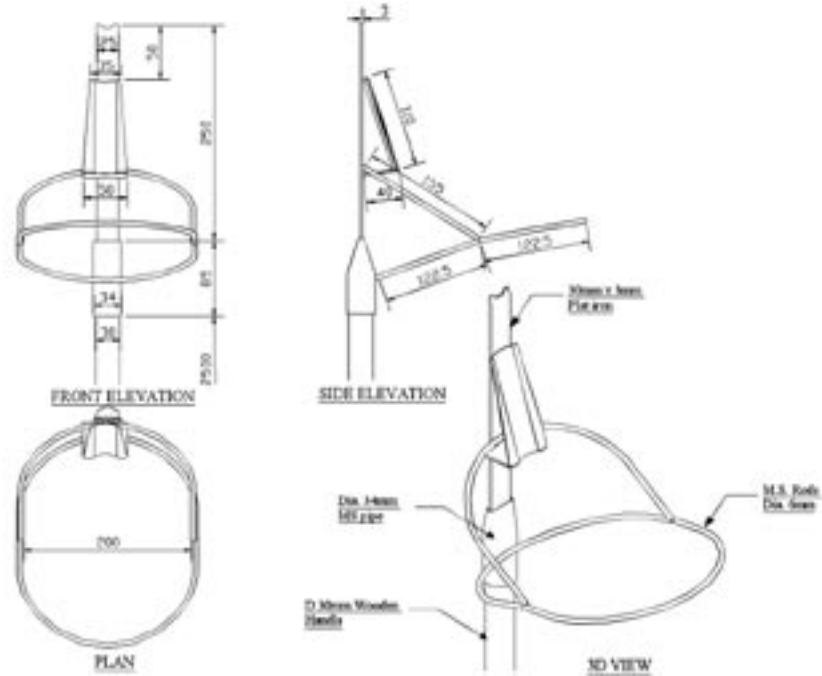




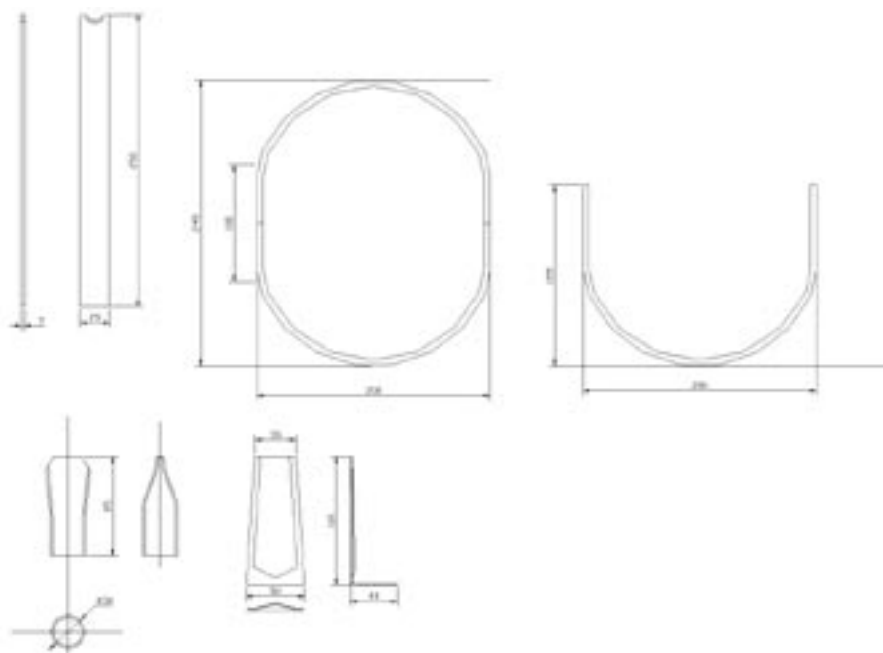


FIGURES: K. PALIPANE

ANNEX 4  
**Fruit harvester – II**  
 (corresponding to Figure 7)

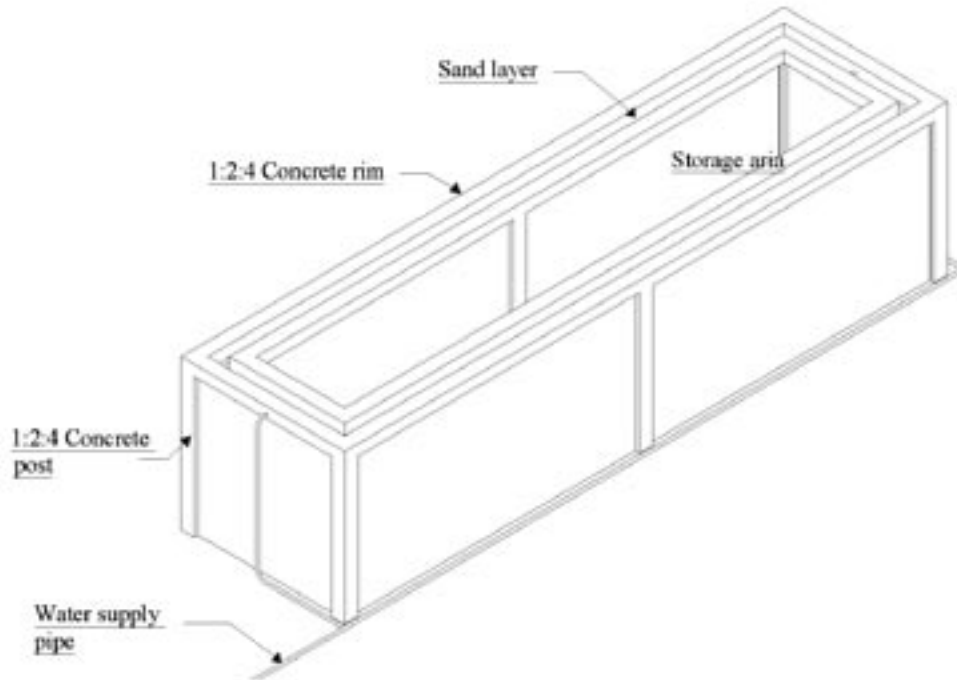


ANNEX 4  
**Fruit harvester – II**  
 (continued)

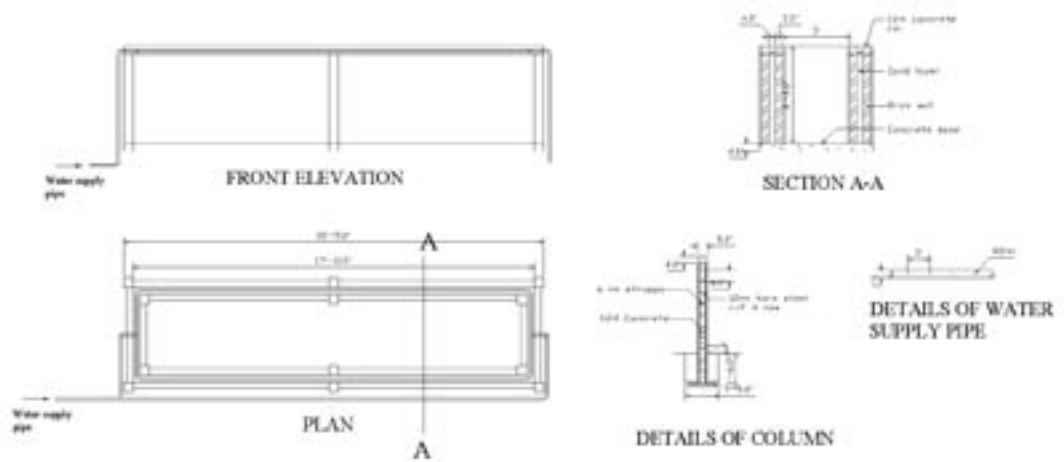




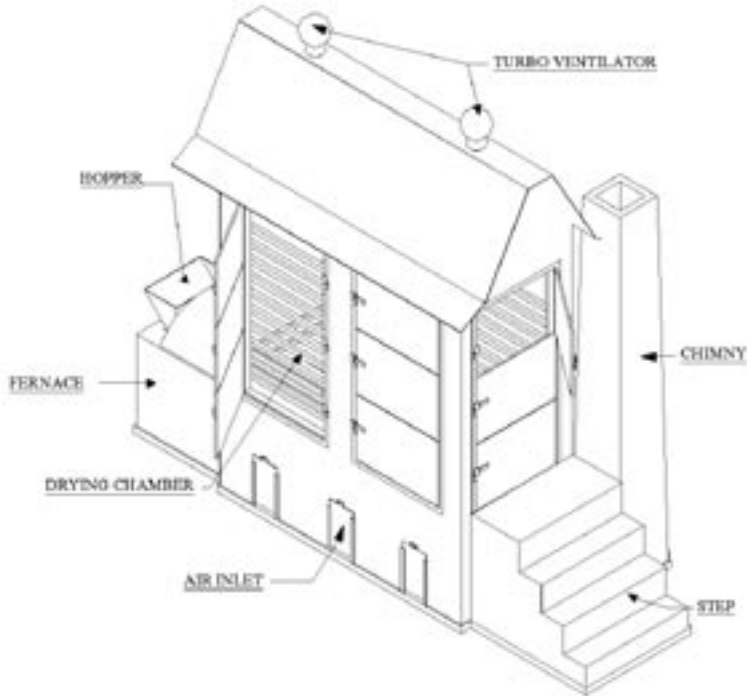
ANNEX 6  
Solar assisted evaporative cooler  
for the storage of fresh fruits



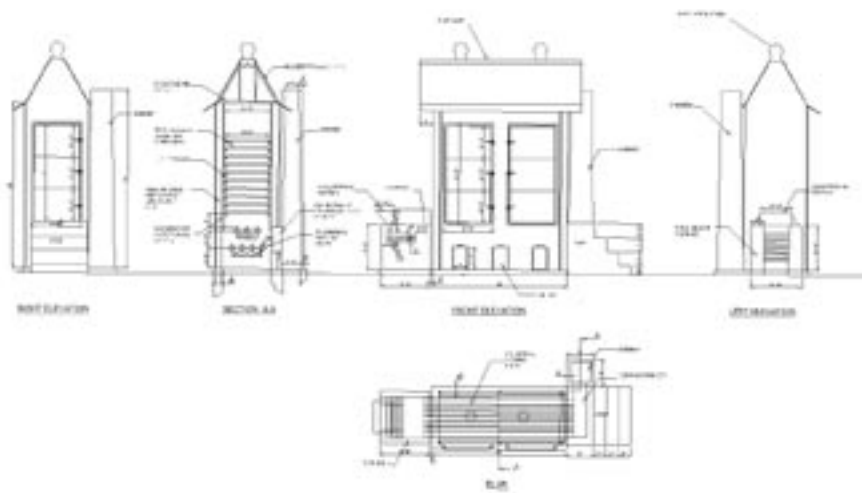
ANNEX 6  
Solar assisted evaporative cooler  
for the storage of fresh fruits  
(continued)



ANNEX 7  
IPHT multi crop dryer  
(corresponding to Plate 38)



ANNEX 7  
IPHT multi crop dryer  
(continued)



ANNEX 7  
 IPHT multi crop dryer – step grate bio-mass furnace  
 (continued)

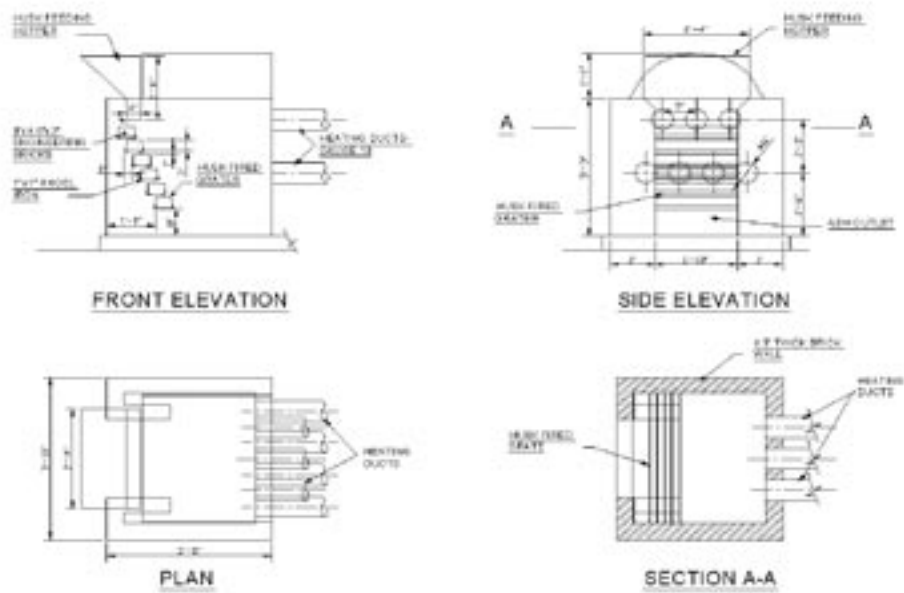


FIGURE: K. PALIPANE

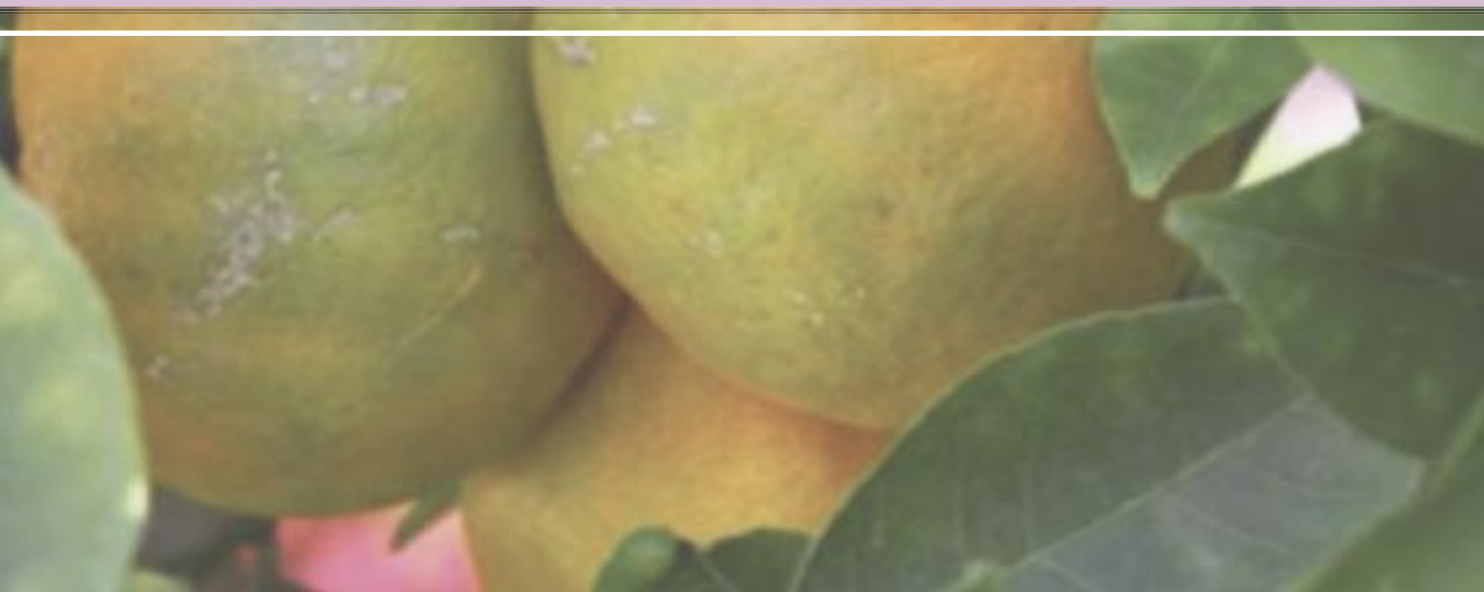


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