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Optimizing Postharvest Handling and Maintaining Quality of Fresh Pineapples (*Ananas cosmosus* (L.))

Majeed Mohammed, PhD.

Department of Food Production,
Faculty of Agriculture and Natural Sciences
University of the West Indies, St Augustine

Coordination & Editing: Naitram Ramnanan
Aaron Parke

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Foreword

The Inter-American Institute for Cooperation on Agriculture (IICA) is pleased to provide pineapple industry players in Trinidad and Tobago with this manual “Optimizing Postharvest Handling and Quality of Fresh Pineapples (*Ananas cosmosus* L)”. It is hoped that this document will be widely used by stakeholders to transform the pineapple industry in Trinidad and Tobago.

IICA’s efforts to support the Caribbean countries to develop the fruit sub-sector and expand the fruit industry began in 1989. In 2001, The Ministry of Agriculture, Land and Marine Resources requested IICA’s support in developing a sustainable pineapple industry in Trinidad and Tobago. IICA collaborated with CIRAD in Guadeloupe and engaged a CIRAD pineapple specialist to undertake a rapid assessment of the industry. Subsequently, IICA sponsored a postgraduate student from the University of the West Indies, St. Augustine Campus to undertake an in-depth analysis of the pineapple commodity chain. Both studies showed that post harvest handling of pineapples in Trinidad and Tobago was a critical problem that needed to be addressed.

IICA subsequently contracted the University to study and conduct Laboratory analyses on pineapples with a view to identifying the underlying causes of the postharvest problems and make recommendations. This manual has been developed based on the results of that study. We encourage our readers to use the information here to address the postharvest problems of pineapple in Trinidad and Tobago to ensure that the pineapple industry can grow and compete globally.

Aaron Parke
IICA Representative in Trinidad and Tobago

Preface

Pineapple is the third most important tropical fruit in world production after banana and citrus. As much as seventy percent of the pineapple produced in the world is consumed as fresh fruit in the country of origin. Accordingly, the significance of reducing postharvest losses and maintaining quality from the point of harvest as the fruit travels through the various marketing channels until consumption cannot be underscored and is the responsibility of producers, handlers, packinghouse personnel, marketeers and consumers.

In an attempt to optimize the postharvest handling system and quality of pineapple fruits, a comprehensive study was commissioned by the Inter-American Institute for Cooperation on Agriculture (IICA) Office in Trinidad and Tobago to determine the major causes of postharvest losses and quality deterioration at each step of the handling system. The study was undertaken by the Department of Food Production, University of the West Indies (UWI), St. Augustine Campus. Fruit samples were collected in the field, packinghouse, retail markets, wholesale markets, mobile markets and supermarkets with and without chain stores as well as from among fruits destined for export and various physical and chemical quality attributes were analyzed.

The main problems identified were:

- (i) variations in fruit maturity and absence of harvesting guidelines associated with maturity indices;
- (ii) rough handling during harvesting;
- (iii) throwing of fruits at collection points;
- (iv) collection of fruits in heaps at row ends and placing fruit directly on soil surface;
- (v) overpacking of fruits in field containers;
- (vi) limited protection of fruits prior to and after harvesting operations;
- (vii) transport of fruit through hilly terrains;
- (viii) overpacking of fruits during transport;
- (ix) poor sanitary conditions at packinghouse;
- (x) failure to precool fruits;
- (xi) absence of the application of sanitizing agents on fruit;
- (xii) limited protection against pests, disease and rodents;
- (xiii) poor stacking methods in packinghouses and retail and wholesale markets;
- (xiv) overpacking as well as underpacking of fruits destined for foreign markets;
- (xv) failure to distinguish between physical, physiological and pathological causes of injury or damage;
- (xvi) limited use of refrigerated storage;
- (xvii) limited use of postharvest treatments to prolong shelf life and enhance appearance e.g. storage at low relative humidity and absence of wax application;
- (xviii) susceptibility to chilling injury particularly for fruits marketed by supermarkets;
- (xix) limited protection of fruits at roadside markets against climatic conditions and environmental pollutants.

The aim of this manual is to provide suitable guidelines to improve postharvest handling of fresh pineapple to ensure quality fruits of a satisfactory shelf-life are available for retailing, wholesaling and exporting while at the same time providing profitable returns to producers and marketeers.

Introduction

The pineapple (*Ananas cosmos* (L.) Merrill) is a non-climacteric fruit and is a terrestrial member of the diverse family Bromeliaceae. Each pineapple plant gives a single fruit before producing suckers which could be used for future planting. The plant is a perennial herb 50 - 100 cm high. It has narrow, tapering, pointed leaves up to 100cm long arranged in spiral rosette, crowded on and tightly clasping a central stem. The fruit is a terminal, cylindrical, compound structure at the apex of the stem and is formed by the fusion of the berry like fruitlets that develop from the flowers. At its apex, the fruit bears a compressed, leaf shoot called a crown. The typically yellow flesh is best eaten when sweet and moderately acid and may contain 10 - 18% sugar and 0.5 - 1.6% titratable acidity (Bartholomew et al. 2003).

Varieties

Cultivated types of pineapple are called "clones", because they are vegetatively propagated. There are many named clones, classed in 4 - 5 groups including 'Cayenne', 'Spanish', 'Queen' and 'Pernambuco', which may represent botanical varieties. Commercial production is based mainly on clones in the 'Cayenne' group, also known as 'Smooth Cayenne'.

Cultural Practices

It is important that fruits are produced under optimum conditions as the internal and external quality of fruit at harvest is determined by several factors. These include: quality planting material, optimum nutrition, adequate irrigation, drainage and spacing and proper management of pest and disease.

Development and Maturation

Pineapple has three distinct phases of growth:

- (i) the vegetative phase of leaf growth;
- (ii) the generative phase of fruit growth; and
- (iii) another vegetative phase of shoot growth.

These three phases usually occur in two to two and a half years. Fruit mass increases in a continuous sigmoid fashion once inflorescence has been initiated. It increases about 20-fold from the time of flowering until maturation is achieved. However, the rate of fruit shell development is slow during the last 40 days of fruit growth.

The Smooth Cayenne pineapple is an excellent fruit to eat at optimum ripeness, but it has two undesirable characteristics when marketed as a fresh fruit. Firstly, it does not ripen or improve in eating quality after harvesting. Secondly, the internal maturity of the fruit is difficult to estimate by the colour of the skin or any other external characteristics. The eyes mature progressively from bottom to top, the lower part of the fruit being riper than the upper part. Fruit maturity is generally judged by the extent of fruit 'eye' flatness and skin yellowing. The degree of skin yellowing observed at optimum ripeness, varies with season, rainfall, microclimate and field conditions.

Pineapples contain negligible starch reserves for sugar metabolism after separation from the plant, and any acid reduction or flavour development after harvest is minor. In order for the fruit to attain its maximum sugar content and its best flavour it must be allowed to ripen completely on the plant. If harvested too early, the pineapple fruit would be flavourless with poor aroma and the almost colourless flesh would be very acidic and extremely susceptible to internal browning and chilling injury. Fruit harvested too late, would be very sweet, with low acidity and with a distinct yellow colour flesh. These fruits are very fragile, and susceptible to fungal attack with the possibility of the onset of fermentation taking place.

Maturity Indices

Table 1 lists the physico-chemical properties of the four stages of maturity; M1 - M4 which were determined for the Smooth Cayenne.

Table 1 Physico-chemical attributes of 'Smooth Cayenne' pineapple fruits at different stages of maturity

Stage of Maturity	Mean Fruit Weight (kg)	Shell Colour	Flesh Translucency Rating z	Total Soluble Solids °Brix	Total Titratable Acidity (%)	Vitamin C mg/100g
M1	1.2 - 1.3	5-10% yellow eyes	1.0	8.5	1.10	7.60
M2	1.7 - 1.9	10-35% yellow eyes	2.6	12.5	0.73	4.32
M3	2.0 - 2.2	35-70% yellow eyes	3.3	13.5	0.94	4.16
M4	2.1 - 2.3	70-80% yellow eyes	3.6	15.5	1.30	3.70

^z Translucency Rating: 1 = opaque; 2 = slight - 5 to 10%; 3 = moderate up to 50% and 4 = high 100%

Plate 1 shows four stages of fruit maturity (M1 to M4) as judged by the level of yellow maturation of 'eyes' of the fruit. Plates 2 - 7 provide a comparison of flesh colour according to the stage of maturity. Pineapple at M1 stage (Plate 1), if picked and allowed to develop a full yellow colour is of no better eating quality than when first harvested. Thus pineapple for the fresh market must be close to optimum ripeness when picked (Plate 1, M2 or M3). For the export market where air-shipments are used, fruit should be harvested at M2 stage. For the local market where consumption is done in 1 or 2 days M3 and M4 stages are desirable.

The full-yellow mature fruits of 'Smooth Cayenne' are unsuitable for transporting to distant or foreign markets because of the short shelf-life. Immature fruits should not be exported either, since they do not develop good flavour, have low total soluble solids (TSS) and are more prone to chilling injury.

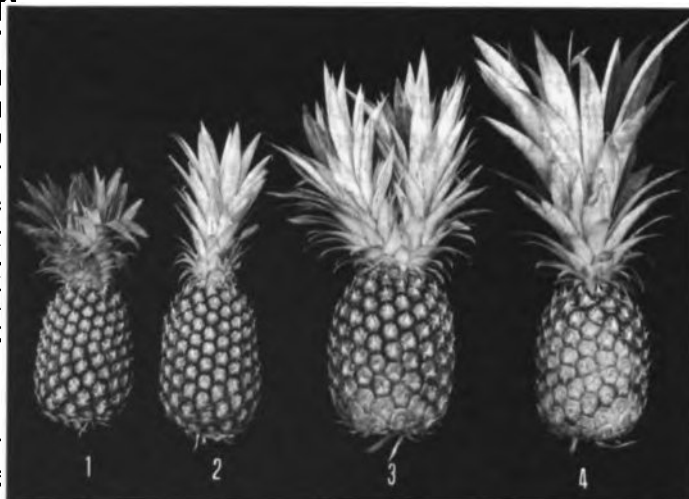


Plate 1: Fruits at different stages of maturity

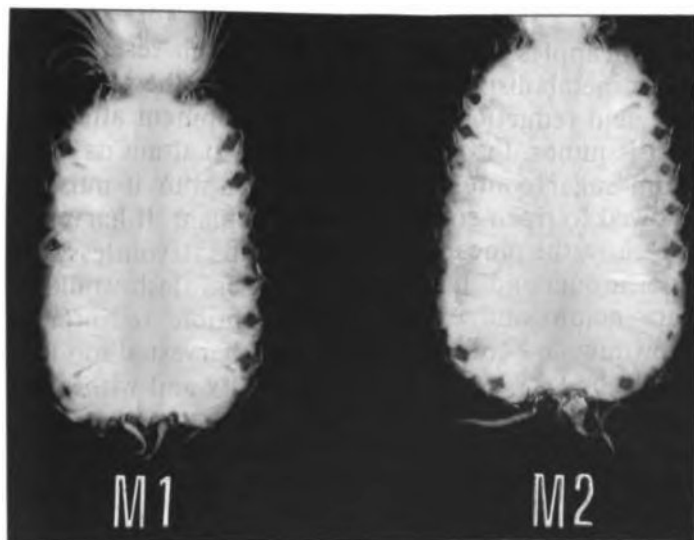


Plate 2: Comparing M1 and M2 flesh colour and translucency

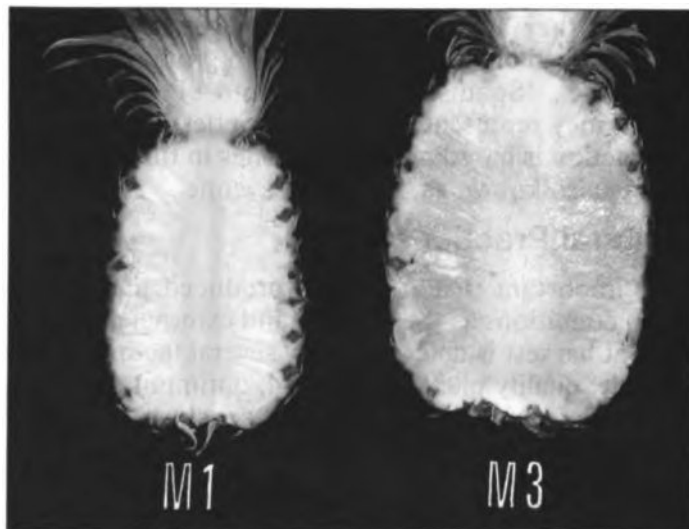


Plate 3: Comparing M1 and M3 flesh colour and translucency

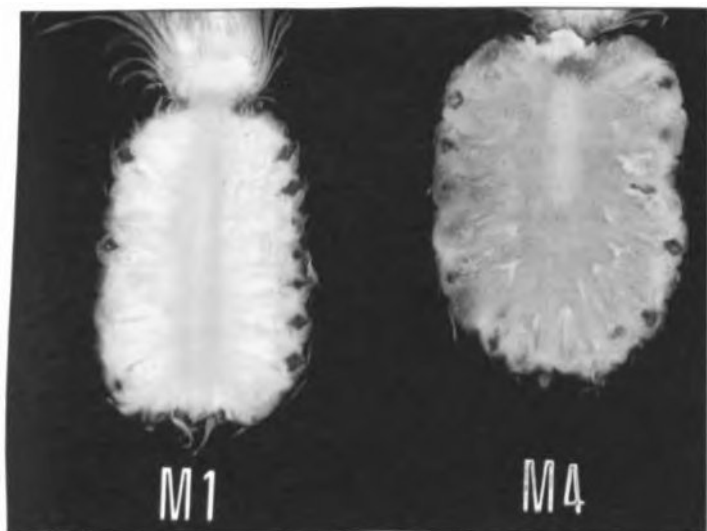


Plate 4: Comparing M1 and M4 flesh colour and translucency

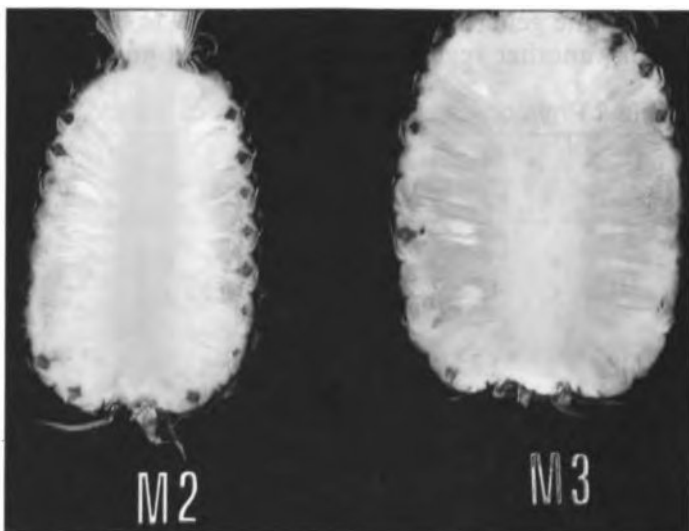


Plate 5: Comparing M2 and M3 flesh colour and translucency

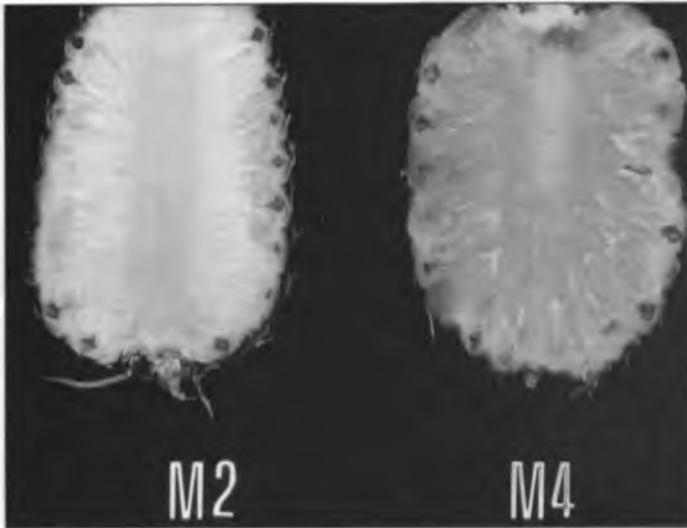


Plate 6: Comparing M2 and M4 flesh colour and translucency

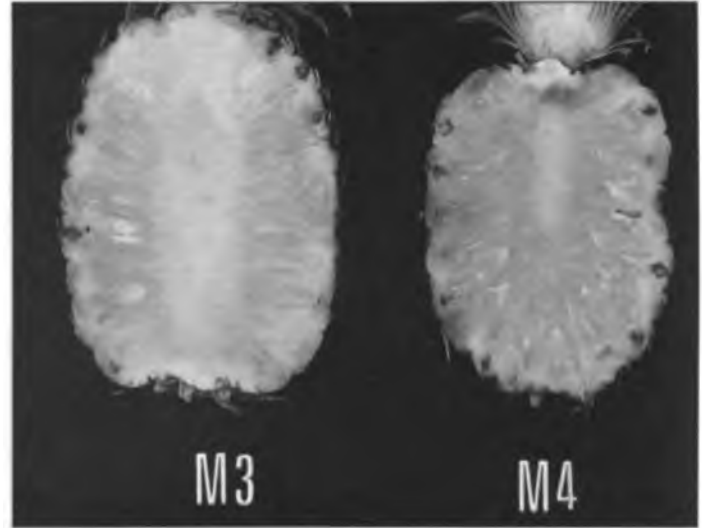


Plate 7: Comparing M3 and M4 flesh colour and translucency.

Quality Indices

The fruit must be:

- i. normally developed, sound and undeformed;
- ii. of a satisfactory maturity and colour;
- iii. free from any abnormal flavour or colour;
- iv. exempt from parasites or physiological diseases;
- v. free from holes, bruises or signs of shocks due to careless handling;
- vi. free from deep cracks;
- vii. exempt from sunburn symptoms;
- viii. topped by a symmetrical crown with no visible scar if it has been shortened;
- ix. in possession of clearly-sectioned peduncle measuring 5 - 20 mm long.

Harvesting

Harvesting pineapple fruits early in the morning or late in the evening or during the night would provide protection from the sun and this could reduce the heat load on harvested fruits during precooling. Pineapple fruits are harvested by bending them over and twisting to remove fruits from the stalk. The quality of the crown (Plate 1) is an indicator of freshness and therefore crowns should be green with turgescient leaves. The crowns should not have a withered appearance, which may be due to insufficient irrigation, extensive refrigerated storage, storage at temperatures below 7 - 8°C, low relative humidity, delays during marketing and incorrect application of ethephon.

The height of the crown should also correspond to the dimensions of the packaging that will be used. For small fruit, the size of the crown should be between a

third and two-thirds the height of the fruit. For market requirements, it is possible to limit the size of the crown. This operation must be done two months before harvest by destroying the heart of the crown with a "gouge", without leaving a visible scar. For larger fruits, the crown should be between a quarter to a half the size of the fruit. The crown should not be shortened at the time of harvesting because this practice would leave a wide wound which spoils the appearance of the fruit, favours the growth of fungi and could cause fruit rot.

The manner in which the peduncle is cut at harvest is important to optimize overall quality and appearance. Peduncles should have a clean cut and be 5 - 20 mm long, especially when fruits have to be transported in a vertical position.

Sunburn is common during hotter periods (>35°C), when the fruits are not shaded. Sun scorched fruits show a bleached yellow-white skin, which turns pale grey or brown, and damage to the flesh underneath. These damaged areas are more susceptible to attack by disease organisms, particularly yeast and bacteria. Plate 8 shows how fruits are protected by outer leaves to prevent sunburn in the field.

Harvested fruits are placed in baskets, crates or bags by hand, upside down on the crown to avoid injury (Plate 9). When harvesting containers are filled they should be transported as soon as possible to the packing house.

Disinfection of the peduncle should be carried out less than three hours after harvest to efficiently prevent the penetration of the fungus *Thielaviopsis paradoxa* which is responsible for black rot (water blister)



Plate 8: Protection of fruits against sunburn.



Plate 9: Harvesting of pineapple fruits.

of the fruit. The dry leaves at the base of the fruit should be trimmed before disinfection. They may contain mealy bugs or fungi (Plate 10).

Packinghouse Operations

(i) Precooling

On arrival at the packinghouse, fruits are unloaded by hand and submerged in water or allowed to slide out of the container into the water. The water in the dump tanks should be chlorinated and replaced frequently to prevent a build-up of disease organisms. Fruits with high flesh translucency (Plate 4, M4) are called "sinkers" and must be separated at this stage. The "sinkers" are very fragile and have limited shelf life. High translucency is also associated with bacterial and yeast fermentation and acetic acid souring during handling, shipping and marketing. Care must be

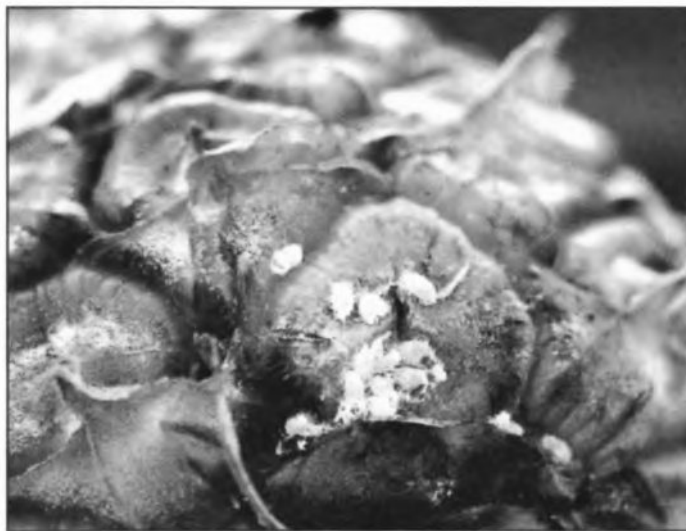


Plate 10: Fruits with mealy bugs. Soler, A. (1993)



Plate 11: Sorting of fruits in packinghouse.

taken to avoid mechanical damage to the crown and mechanical injury to the fruit shell.

The purpose of precooling is to remove field heat. If pineapples are to be exported to the destination within 2 - 3 days of harvesting, as with air-shipments, then pre-cooling is advisable. Pineapples transported by sea should preferably be pre-cooled prior to loading into containers. By submerging fruits in water as described previously, hydrocooling is being achieved. Temperature controlled rooms can also be used but cooling rate is slow particularly if stacking and spacing are not adequate to allow free and even air flow or if the refrigeration capacity is inadequate. A forced air cooling system is more efficient but this requires a specially designed unit and compatible packaging. Pineapples should be pre-cooled to a minimum of 8°C.

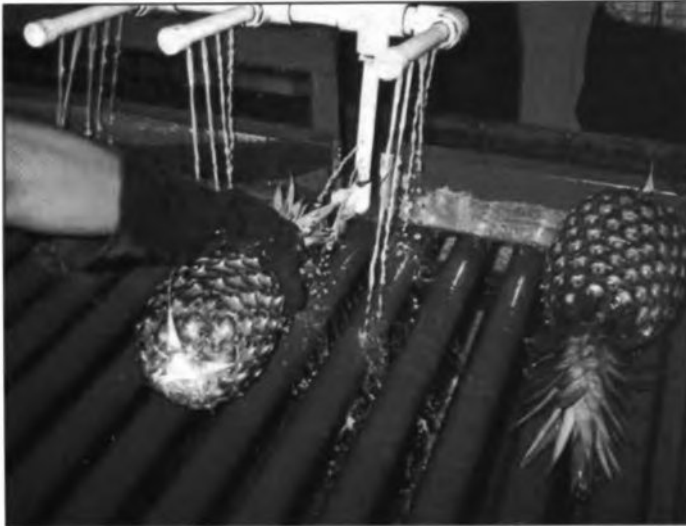


Plate 12: Application of wax coating on fruits.

(ii) Grading

Fruits are graded (Plate 11) based upon certain characteristics: degree of skin colouration, size (weight), absence of defects and diseases, and in keeping with other market requirements.

(iii) Application of fungicides and waxing

Pineapple fruits are commercially treated with a fungicide such as Dovicide A (Sodium 2-phenyl phenolate) at a concentration of 7g per litre of water in either a dip or a spray application to control postharvest fruit rot.

A wax, which may contain polyethylene/paraffin or carnauba/paraffin-based could also be applied to the fruit with the fungicide (Plate 12). Waxing could reduce internal browning, a symptom of chilling injury. Waxing also reduces postharvest water loss and improves fruit appearance.

(iv) Degreening of fruit shell

Postharvest use of ethephon could result in uniform skin degreening but this could also lead to a shortened shelf-life. The need to degreen is related to the consumer's perception that a ripe pineapple must have a yellow skin. Ethylene treatment has no significant effect on flesh TSS or acidity.

(v) Packaging

Pineapple fruits could be packed into cartons of two different sizes. A large carton (20 kg) containing 10 - 16 fruits for surface or air shipment and a smaller carton (10 kg) for air shipment with 5 - 6 fruits. Whichever type of package is used, certain precautions must be followed:

- (a) the package should be dry, odourless and sufficiently rigid to permit stacking;

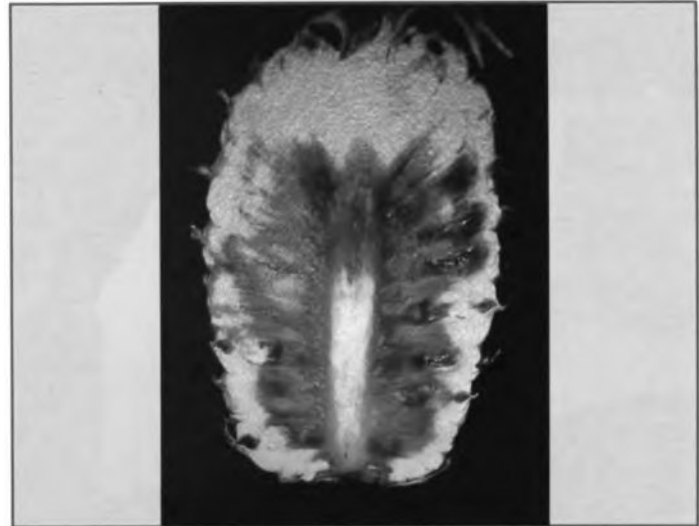


Plate 13: Internal Browning

- (b) cartons must be adapted to the size of the fruit to avoid crushing (bulging cases) or crushing the crown;
- (c) dimensions of the cartons must be compatible with the modern techniques of palletisation and the use of the containers, which contributes to the quality of the fruit; and
- (d) there should be no transfer of toxic matter from the package to fruit.

Transportation of fruits packed in a horizontal position is more liable to lateral shocks (Plate 14). Absorbent pads are placed at the bottom of the carton and between layers if fruit are alternated horizontally within the carton.

(vi) Sanitation of packinghouse

Packinghouse sanitation is an absolute requirement for controlling postharvest diseases of pineapple fruits. Dirty or soil-contaminated fruit should be



Plate 14: Pineapple fruits displayed for sale in retail market



Plate 15: Packingline being washed and sterilized.

washed outside the packinghouse, as partially decayed fruits are loaded with microbes and are noted for sticking to surfaces. The water used in fruit dumps, flumes, or washers must be kept free of postharvest pathogens. If the water becomes contaminated with decay pathogens, the fruits will become inoculated and a large number of fruits would decay before they can be marketed or consumed. Chlorine is the principal chemical used in sanitizing solutions mainly because it is safe, effective, inexpensive and leaves no chemical residues on the fruit (Plate 15).

Clean and sanitize packing areas, storage rooms, fruit containers and equipment. Prime sites for pathogen growth are areas that remain wet e.g. brush/sponge rolls and floors. Remove all plant debris left on the packing line or packinghouse floor. Plant residues in an environment where moisture is available plus microbes at warm temperatures form biofilms. While sanitizers can prevent biofilm formation, they do not penetrate biofilms that have built up over time.

Some important sanitation tips for packinghouses include: (i) pre-rinse equipment or walls (ii) visually inspect surfaces (iii) scrub from top downward (iv) handle fruit carefully to prevent wounds (v) remove injured fruits from facilities (vi) maintain an effective pest control programme (vii) prepare cartons only as needed (viii) monitor worker hygiene (ix) apply strict temperature management guidelines.

(vii) Storage of pineapples

Store pineapple fruit at 7.5 - 12°C and 90 - 95% relative humidity. At 0 - 4°C, fruits may store for weeks, but upon transfer to non-refrigerated conditions, the fruit would not ripen and severe chilling injury symptoms would appear. Half-ripe (M2 - M3) "Smooth Cayenne" fruit can be held for about 10 days at 7.5 - 12.5°C and still have about a week of shelf life with no



Plate 16: Fresh-cut portions of pineapple fruit.

chilling-induced browning. The maximum storage life at 7°C is about 4 weeks, but when transferred to ambient conditions, chilling injury develops within 2 - 3 days. Symptoms of chilling injury include: wilting, drying and discoloration of crown leaves, failure of green shell to turn yellow, browning and dulling of yellow fruit, internal flesh browning. Susceptible fruits are generally lower in ascorbic acid and sugars and are opaque. Partial to complete control of chilling injury symptoms has been achieved by waxing, heat treatment, modified atmosphere packaging, ascorbic acid and application of the ethylene inhibitor 1-methylcyclopropene (1-MCP).

(viii) Palletisation

Palletisation is essential to minimize fruit damage due to multiple handling. Movement of fruits within packinghouses or during temporary storage should be aided by palletisation.

Preparation Of Pineapple For Fresh-Cut Purposes

Fresh pineapples at the M2 or M3 stages of maturity are suitable for fresh-cut purposes (Plate 16). Studies conducted by Mohammed and Wickham (2002) indicated that fresh-cut pineapple slices treated with antioxidants in a combined form of 300ppm ascorbic acid plus 200ppm 4-hexylresorcinol effectively reduced browning and microbial spoilage during refrigerated storage.

Potential Postharvest Losses

(i) Fruit bruising

Fruit bruising is a major problem during harvesting and packing. The bruised area leads to leakage of cell content and provides openings for saprophytes and disease organisms. Translucent fruits are highly suscepti-



Plate 17: Compression damage on fruit

ble to bruising. The bruised flesh appears slightly straw-coloured and becomes gray with time (Plate 17).

(ii) Black Rot

Black rot caused by *Ceratocystis* results in a black watery rot of the flesh and a thin brittle skin (Plate 18). Infection usually occurs through the cut stem or through damaged areas, but can generally be controlled by prompt treatment with either Dovicide A or Benlate.

(iii) Black Spot or Brown Spot

Black spot (Plate 19) or brown spot caused by *Penicillium finiculosum* and *Fusarium moniliformae* results in browning and sinking of the eyes and a browning of the internal fruitlets. Incidence is not usually detected until the fruit is cut. The diseases are believed to be caused by mite damage in the field allowing entry of

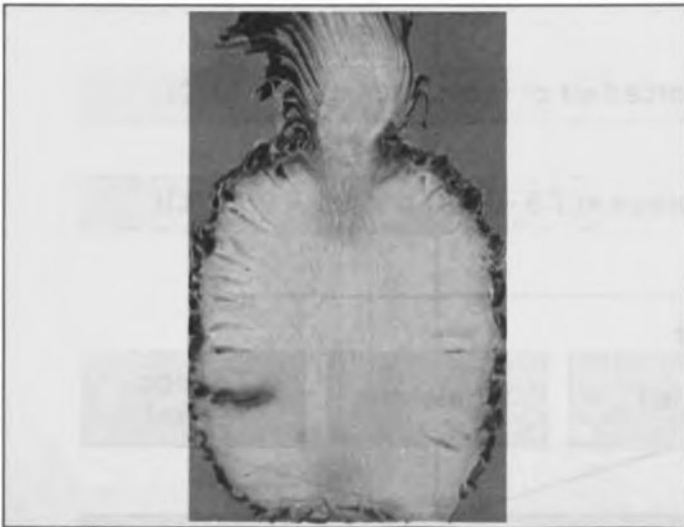


Plate 19: Fruitlet core rot of pineapple fruit.



Plate 18: Black rot of pineapple fruit.

the fungi. Pre-harvest spray regimes are required to control the mite population.

(iv) Endogenous Brown Spot:

This is a physiological disorder characterized by watery spots which eventually coalesce and turn brown. The incidence is found in certain varieties and production areas and is generally enhanced during long term storage.

(v) Flesh Translucency

This is a physiological disorder where the pineapple fruit flesh shows water soaking symptoms. Opacity as opposed to translucency (Plate 4) lacks the presence of small air bubbles in the intercellular spaces of the fruit flesh tissue. The causes of translucency are unknown but it has been associated with high nitrogen, clones, treatment with fruit-enlarging agents, irrigation rate, planting density, larger crowns and environmental factors (Soler, 1993).

(vi) Broken and Hollow Core

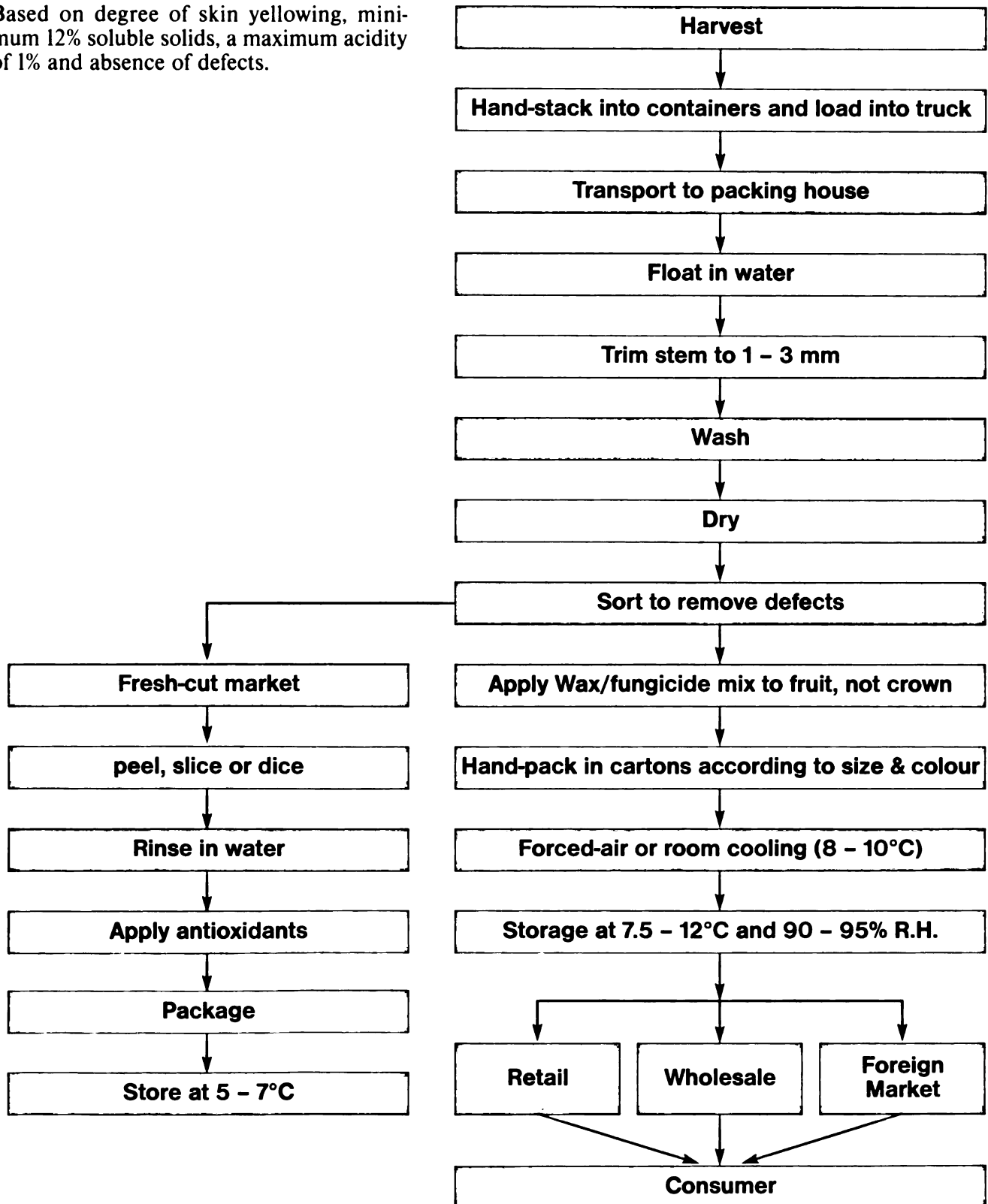
A transverse break in fruit flesh that occurs early in development is marked by a slight depression on the outside of the fruit. The break leaves a gap of 2 - 10 mm in the flesh and the tissue becomes corked and brown, sometimes accompanied by rot. Hollow core is a vertical crack in the core that becomes dry and leathery and it may extend to the peduncle. The fruits are usually opaque and the conditions is thought to be due to desiccation.

(vii) Rodents, Birds and Insect Damage

Rodents, birds, insects (crickets and grasshopper) and wind may cause wounding in young fruit that will heal over with hard, corky, scar tissue. Fruit growth may tear open this injury and lead to misshaped fruit.

Fig. 1 Postharvest system for pineapples

Based on degree of skin yellowing, minimum 12% soluble solids, a maximum acidity of 1% and absence of defects.



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