MANUAL ON POSTHARVEST MANAGEMENT STRATEGIES TO REDUCE LOSSES OF PERISHABLE CROPS

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BASIC PRINCIPLES OF POSTHARVEST TECHNOLOGY

PRODUCE IS ALIVE:

Fruit and vegetables are 'living' structures. One readily accepts that a fruit or vegetable is a living, biological entity when it is attached to the growing plant in its agricultural environment, but even after harvest the commodity is still living as it continues to perform most of its metabolic reactions and maintain the physiological systems that were present when it was attached to the mother plant.

An important feature of plants and by extension vegetables, fruits and ornamentals, is that they respire by taking up oxygen (O_2) and giving off carbon dioxide (CO_2) and heat. They also transpire, that is, lose water. While attached to the plant, losses due to respiration and transpiration are replaced from the flow of sap, which contains water, photosynthates (mainly sucrose and amino acids) and minerals. Respiration and transpiration continue after harvest, and since the fruit, vegetable or ornamental is now removed from its normal source of water, photosynthates and minerals, the commodity is dependent entirely on its own food reserves and moisture content. Therefore, losses of respiratable substrates and moisture are not replenished and deterioration commences. In other words, harvested vegetables and fruit and ornamentals are **perishable**. Thus the harvested plant part or organ must:

i. continue normal respiratory activity to provide the energy for maintenance of basic life processes;
ii. continue normal growth and developmental processes associated with its stage of maturation;
iii. undergo metabolic responses to changing physical environments depending on handling and storage systems utilised;
iv. respond to pathological invasion.

POSTHARVEST LOSSES ASSOCIATED WITH PERISHABLE CROPS

Postharvest losses can be classified as: **a) direct losses** i.e. those caused by waste or consumption by non-human agents, such as insects, rodents, birds, fungi, bacteria and others; **b) indirect losses** i.e. those due to deterioration in quality or acceptability of the product up to the point of complete rejection by the consumer, eg. changes in its appearance, texture, and colour caused by climate, improper handling, transportation, or infrastructure; and **c) economic losses** i.e. those losses brought about by changes in market conditions and expressed in economic terms, eg. losses due to changes in demand and supply.

CAUSES OF POSTHARVEST LOSSES

This can be categorised as follows:

Physical or mechanical losses can be caused by improper harvest methods, poor packaging, and transportation resulting in cuts, abrasions, bruises, breakage or leakage.

i. **Physical** damage can be normal or abnormal. **Normal** deterioration is due to the natural aging process or **senescence** of the products. **Abnormal** deterioration is that which occurs due to adverse conditions such as unfavourable temperatures at either extremes, i.e. too low but above freezing (above 0^oC but below $10\text{-}12^oC$) resulting in **chilling injury** or too high (above $30\text{-}32^oC$) resulting in heat injury. Other examples of physiological damage include sprouting in yams during storage, blossom end rot in tomatoes, internal rind spot on watermelons, tip burn in lettuce, etc.

ii. **Pathological damage** can be to fungal, bacterial or viral infections, e.g. Anthracnose in tomato, pepper, cucumber or watermelon, bacterial soft rot in melongene, mango, papaya or cucumber, or Gemini virus in pepper, melongene or tomato.

iii. **Entomological damage** is caused by mole crickets, fruit flies, white flies or mealy bugs.

BIOLOGICAL FACTORS AFFECTING QUALITY

This manual identifies the major biological factors which affect the postharvest behaviour of horticultural produce, recognising that knowledge of those factors is necessary for the development of successful postharvest management/handling and storage systems that would lead to postharvest maintenance of quality through extension of shelf life. In addition, it briefly examines important interactions between biological and environmental factors, and their effects on modification of postharvest behaviour.

BIOLOGICAL FACTORS

i. **Respiratory metabolism:** Respiration is the process by which stored organic materials (carbohydrates, proteins, and fats) are broken into simple end products with a release of energy. Oxygen is used in this process, and CO_2 is produced. The loss of food reserves during respiration results in: hastening of senescence or aging, as this energy supplies are exhausted to maintain the commodity's living status; reduced nutritional value; loss of flavour quality, especially sweetness; and loss of salable weight and by extension profits to the producer and or marketer. The energy released as heat, known as vital heat, affects postharvest technology consideration, such as estimations of refrigeration and ventilation requirements. The rate of perishability of harvested commodities is generally proportional to the respiration rate. Based on their respiration and ethylene production patterns during maturation and ripening, commodities are classified either as climacteric or non-climacteric. Climacteric commodities, such as hot pepper, tomato, bitter melon, mango, banana, passion fruit etc., show a large increase in CO_2

and ethylene production rates coincident with ripening, while non-climacteric commodities, such as melongene, cucumber, yard long beans, okra, lettuce etc., show no change in their generally low carbon and ethylene production rates during ripening. Figure 1 shows the relative changes during growth and development associated with the climacteric and non-climacteric patterns of respiration. More details on respiratory metabolism are provided by Salveit (2008) in relation to: i) postharvest factors affecting respiration such as temperature, atmosphere composition, and physical stress; ii) stages in development of a typical climacteric curve; iii) significance of respiration; and iv) respiratory biochemistry.

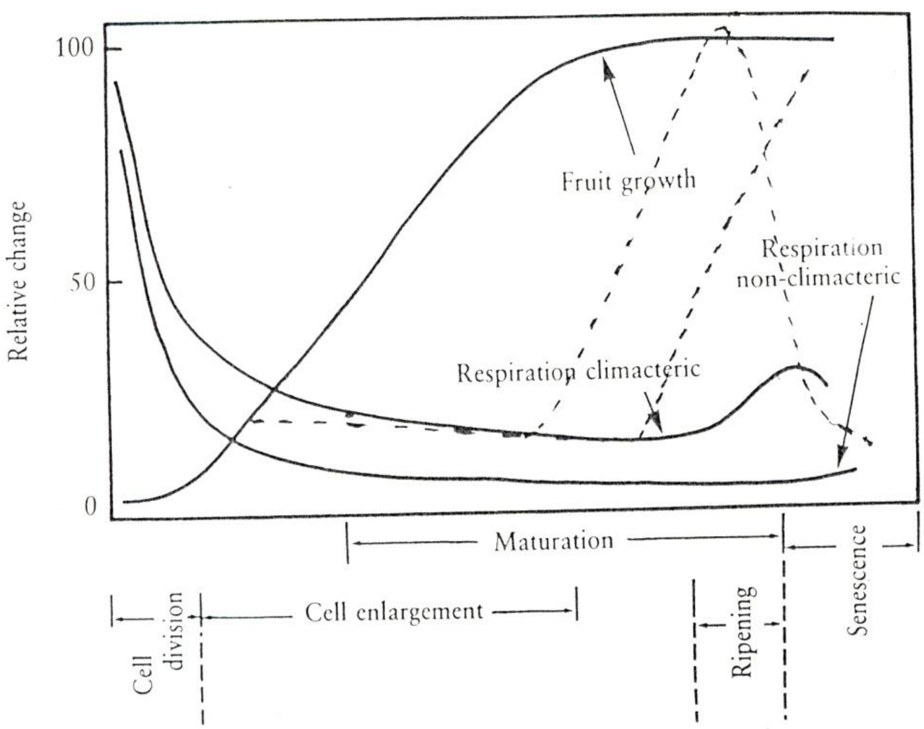

Fig. 1: Growth and Respiration patterns during development (Biale, 1964).

ii. **Ethylene production:** Ethylene (C_2H_4) - a naturally occurring, gaseous plant hormone - is produced in a range of plant parts of various physiological ages. Rate and extent of ethylene produced varies considerably and is dependent on several factors such as i) species and cultivar; ii) plant part; iii) stage of maturation; iv) temperature; v) physical, physiological or pathological stress; and vi). presence of ethylene itself and other hydrocarbons. Ethylene production plays a particularly important role in postharvest behaviour determination. Although more importantly recognised as the ripening hormone, ethylene is also known for its effects on senescence. Storage of high ethylene commodities such as as mango, banana, tomatoes or bitter melons can be detrimental to the quality of ethylene sensitive commodities such as yard long beans, seime and okra resulting in chlorophyll degradation (green to yellow colour and eventual darkening of skin), toughening of tissues, poor flavour and rapid deterioration. Ethylene sources include ripened and decayed fruits and produce, volatiles from internal combustion engines, propane powered equipment, decomposed or wounded commodities, cigarette smoke and rubber materials exposed to ultra violet light. Salveit (2008) provides further details on the biological attributes of ethylene, biological processes that it stimulates and inhibits, beneficial and detrimental effects of ethylene, measures to reduce and increase the effects of ethylene, and suitable and proven methods to manage ethylene during handling, storage, transport, distribution and display of fresh produce.

iii. **Transpiration or water loss:** Control of water loss is very important in maintaining freshness of fruits and vegetables after harvest. The moisture content of the air in the intercellular spaces of most commodities remains close to 100%. Moisture loss is influenced most by the difference between vapour pressures inside and outside of the commodities. When vapour pressures are almost equal, little water is lost. Since water vapour moves from areas of higher to areas of lower concentration, water is lost from commodities when they are subjected to most marketing conditions.

Water loss can be reduced by: i) maintaining high moisture content in the air around the vegetables; ii) precooling; iii) reducing air movement; iv) protective packaging; v) applying a surface coating; vi) trimming; and vii) Curing, eg. root crops.

Water loss or transpiration results in the following effects on harvested vegetables:

i. Losses in appearance due to wilting, and shrivelling. This results in a loss of snapping quality of yard long beans and okra.

ii. Losses in textural quality: softening, flaccidity, limpness, loss of crispness, juiciness and nutritional quality. Actual water content is dependent on the availability of water to the tissue at the time of harvest, therefore the water content of the produce will vary during the day if there are diurnal fluctuations in temperature. For most produce, it is desirable to harvest when the maximum possible water content is present as this results in a crisp texture. Hence the time of harvest can be an important consideration, particularly with leafy vegetables, which exhibit large and rapid variations in water content in response to changes in the environment.

iv. Composition changes

The following changes may continue after harvest and this can be desirable or undesirable.

i. Loss of chlorophyll (green colour) is desirable in fruits but not in vegetables.

ii. Development of carotenoids (yellow and orange colours): desirable in fruits such as citrus and papaya. Red colour development in tomatoes is due to a specific carotenoid (lycopene); beta-carotene - provitamin A - is very important in nutritional quality.

iii. Development of anthocyanins (red and blue colours): desirable in fruits such as cherries; pigments are water soluble and are much less stable than carotenoids.

iv. Changes in anthocyanins and other phenolic compounds: may result in tissue browning which is undesirable from appearance quality standpoint.

v. Changes in carbohydrates include:

i. Starch to sugar conversion (undesirable in potatoes, desirable in fruits).

ii. Sugar to starch conversion (undesirable in peas and sweet corn).

iii. Conversion of starch and sugars to CO_2 and water through respiration. Breakdown in pectins and other polysaccharides results in softening of fruits and consequent increase in susceptibility to physical injuries.

Changes in organic acids, proteins, amino-acids and liquids can influence flavour quality of the commodity. Loss of vitamin content, especially Vitamin C, is detrimental to nutritional quality.

vi. Changes associated with physical damage

Physical injuries during harvest are not only unsightly but also accelerate water loss, provide locations for fungal infection and stimulate CO_2 and ethylene production by the commodity.

vii. Changes associated with physiological breakdown

Exposure of the commodity to undesirable temperatures can result in physiological disorders e.g.

- **i.** Chilling injury – depending on the commodity could cause the following undesirable changes: surface and internal discoloration, pitting, water-soaking, uneven ripening or failure to ripen, off-flavour development, and accelerated incidence of surface moulds and decay.
- **ii.** Heat injury – exposure to direct sunlight or high temperatures can cause bleaching, surface burning or scalding, uneven ripening, excessive softening and desiccation.
- **iii.** Other types of physiological disorders include sprouting in yams and vascular streaking in cassava.

viii. Changes associated with pathological breakdown

Attack by most organisms (fungi, bacteria) follow physical or physiological breakdown of the commodity. In some cases pathogens can infect apparently healthy tissues and become the primary cause of deterioration. The onset of ripening in fruits, and senescence in all commodities, results in their becoming susceptible to infections by pathogens. Stresses such as physical, chilling and sunscald lower the resistance of the commodity to pathogens.

NON-BIOLOGICAL FACTORS AFFECTING QUALITY

Temperature is the environmental factor that most influences the deterioration rate of harvested commodities. For each increase of 10^0C above optimum, the rate of deterioration increases by two to threefold. Exposure to undesirable temperatures results in many physiological disorders such as chilling injury and heat injury. Temperature also influences the effect of ethylene, reduced O_2 and elevated CO_2.

i. **Relative humidity:** In order to minimise vegetable water loss, both vegetable temperature and moisture in the surrounding air must be controlled. Relative humidity equals the saturation percentage of air with the water vapour at a given temperature. As the temperature decreases, so does the water holding capacity of the air. Hence, air at 59^0C with a relative humidity of 95% contains water at a lower vapour pressure than air at 21^0C with the same relative humidity. Water loss is generally highest in freshly harvested vegetables and will continue as long as the commodity temperature or vapour pressure is higher than that of the surrounding air. This will occur, even if the cooler air has a relative humidity of 100%, because the vapour pressure is higher inside the vegetable.

ii. **Atmospheric composition:** Reduction of O_2 and elevation of CO_2, whether intentional or not, can either delay or accelerate the deterioration of fresh horticultural crops. The magnitude of these effects depends on the commodity, cultivar, physiological age, O_2 and CO_2 levels, temperature and duration of storage.

iii. **Ethylene:** The detrimental and beneficial effects of ethylene have been described previously, with specific details on how to manage this colourless and odourless gas provided by Salveit (2008).

PRE-HARVEST FACTORS AFFECTING QUALITY

i. **Cultivar and rootstock genotype:** Cultivar and rootstock genotype have an important role in determining the taste quality, nutrient composition, and postharvest life of fresh commodities. The incidence of and severity of decay, insect damage, and physiological disorders can be reduced by choosing the correct genotype for given environmental conditions.

ii. **Mineral nutrition:** Nutritional status is an important factor in quality at harvest and postharvest life of various fruits and vegetables. Deficiencies, excesses, or imbalances of various nutrients are known to result in disorders that can limit the storage life of many fruits and vegetables. The nutrient with the single greatest effect on quality is nitrogen. High nitrogen levels can stimulate vigorous vegetative growth but at the same time cause a reduction in ascorbic acid content, lower sugar content, increase tissue softening, lower acidity, and altered levels of essential amino-acids. In green leafy vegetables such as spinach, lettuce, celery and cabbage, high nitrogen application under low light conditions can result in the accumulation of nitrates in plant tissues to unhealthy levels.

iii. **Irrigation and drainage:** Management of water frequently poses a dilemma between yield and postharvest quality. A deficiency or excess of water may influence postharvest quality. Extreme water stress reduces yield and quality, mild water stress reduces crop yield but may improve some quality attributes, and no water stress increases yield but may reduce postharvest quality.

iv. **Crop rotations:** Crop rotation may be an effective management practice to minimise postharvest losses by reducing decay inoculums in a production field. Four-year rotations with non-cucurbit crops are routinely recommended for cucurbit disease management.

v. **Fruit canopy position:** Vine vigour for bitter melon and yard long beans, for example, can be controlled by stem training and by avoiding high levels of nitrogen. This improves light penetration to leave, ensuring that they continue to photosynthesise and do not prematurely senesce and become pathogen hosts. An open canopy lowers the relative humidity around the plant, reduces wetting periods, and improves spray penetration, which reduces disease and insect problems and improves foliar nutrient applications. An open canopy also enables the harvesters to pick fruits and vegetables more rapidly, decreasing the likelihood of overripe commodities.

HARVESTING AND MATURITY INDICES

INTRODUCTION

Harvesting and rough handling at the farm directly affects market quality. Bruises and injuries show up as brown and black patches making the commodities unattractive. Injuries to the peel serve as avenues for microorganisms and lead to rotting. Moreover, respiration is increased markedly by the damage, and storage life is shortened. Lack of knowledge about the principles of proper harvesting will result in a waste of vegetables and fruits. After all, harvest means an abrupt termination of life: in the field or human law, this would be called 'murder'.

HARVEST INDICES

Good quality is obtained when harvesting is done at the proper stage of maturity. Immature melongene or bitter melons when harvested will give poor quality and erratic ripening. On the other hand, delayed harvesting of vegetables and fruits may increase their susceptibility to decay, resulting in poor quality and hence low market value. The specific harvesting and maturity indices for the six vegetables selected for this course will be presented in the section dealing with postharvest handling systems for each commodity.

Physiological maturity: This is the stage at which a commodity has reached a sufficient stage of development that after harvesting and postharvest harvest handling (including ripening where required). Its quality will be at least the minimum acceptable standard to the ultimate consumer.

Horticultural maturity: This is the stage of development at which a plant or plant part possesses the prerequisites for use by consumers for a particular purpose.

Developing a maturity index is done to:

i. Determine changes in the commodity throughout its development;
ii. To look for a feature (size, shape, colour, solidity, etc.) whose changes correlate with the stages of the commodity's development;
iii. To use storage trials and taste panels to determine the value of the maturity index that defines minimum acceptable maturity.

MINIMISING CHANGES IN COMMODITIES AFTER HARVEST

In order to minimise changes that occur in agricultural produce after harvest it is imperative that the following practices be adopted:

i. **Harvest at optimum maturity for best eating quality.** Both immaturity and overmaturity cause quality problems. Immaturity increases water loss and shrivelling. When harvested too immature, some fruits such as tomatoes may never ripen satisfactorily; others such as watermelons and sweet corn may be low in sugars. When harvested overmature, most crops such as beans, maize and celery become tough. Overmature sweet corn will be low in sugars and starch, but immature and overmature produce are more susceptible to decay.
ii. **Harvest frequently:** Harvesting throughout the day to replace produce that has been sold will prevent quality deterioration between the harvest and sale. Fewer pickers are required to harvest continuously throughout the day.

iii. **Harvest during the coolest part of the day:** To minimise the spread of certain diseases, harvest should begin as soon as the foliage has dried. This practice is most important for highly perishable products, because high temperatures lead to rapid deterioration. Harvesting continuously during the day decreases the importance of this factor.

iv. **Keep harvested products in the shade:** This simple practice will minimise wilting, sunburn damage, and prevent unnecessary heating of the produce. On a sunny hot day, tomato fruit in the sun for an hour can be as must $14^{o}C$ hotter than fruit in the shade.

v. **Wash harvest containers daily:** Use water containing about 70ppm chlorine to thoroughly clean containers. This serves two purposes. First, chlorine kills decay-causing organisms on the container surface. Secondly, washing removes sand and other waste that may puncture or injure the produce. Plastic containers with smooth surfaces are easier to keep clean than wooden containers.

vi. **Handle all produce gently:** Many fruits and vegetables have a natural protective surface. Careful handling helps maintain this surface and results in a more attractive, better quality product. Watermelons that have been handled roughly may appear undamaged but internal bruising may have occurred. Bruises, punctures, and other wounds increase susceptibility to decay and water loss.

vii. **Avoid rough roads:** When transporting produce from the field to the market, avoid rough roads. Many operators forget that vibration during transit can cause considerable damage to produce. Tie or wedge the load securely to help reduce damage. Grading of field roads may be worthwhile.

PRE-COOLING METHODS AND TECHNIQUES TO OPTIMISE QUALITY

The primary objective in pre-cooling perishable commodities is to remove field heat prior to shipment, storage and display. Proper pre-cooling of freshly harvested commodities can:

i. suppress enzymatic degradation and respiratory activity (softening);
ii. slow or inhibit water loss (wilting);
iii. slow or inhibit the growth of decay-producing microorganisms;
iv. reduce production of ethylene;
v. provide market flexibility by making it possible to market at an optimum time.

The rate fresh produce cools depends on several factors:

i. the rate of heat transfer from the produce to the air or water used to cool it;
ii. the difference in temperature between the commodity and the cooling medium, i.e. the greater the difference between the two the faster the product cools;
iii. the nature of the cooling medium, i.e. cold water has a greater capacity to absorb heat than cold air;
iv. the nature of the commodity which influences the rate heat is lost, i.e. leafy vegetables have a greater thermal conductivity than root crops and so cools faster.

Please note that the rate a commodity cools is not constant. It starts cooling rapidly and then quickly slows down. As the difference in temperature between the product and the cooling medium falls the rate of cooling slows down. So it takes longer for the product to cool the last 5^{0}C than the first 5^{0}C.

PACKINGHOUSE: PURPOSE, OPERATIONS, DESIGN AND SANITATION

Introduction: Following harvest, most crops must be cleaned, sorted, sized, and packaged if they are to be sold in the fresh produce market. These procedures are normally done in packinghouses which could be a small shelter located in the field or an automated packing line located in a centralised area.

Purpose of packinghouses: They serve as a sheltered working site for the produce and the packers, and should create an orderly assembly and flow of produce which can be well managed and centrally supervised. They can also serve as a storage point for packing equipment and materials and, if large enough, can house office and communication facilities. For export of fresh commodities, packinghouses are an essential part of the operation where selection, grading, and quality control must be implemented and monitored.

Operations of packinghouses: These include some or all of the following:

i. Receival area: Here the commodities, upon arrival at the packinghouse, are counted, weighed and, in some cases, sampled for quality and labelled to identify the date and source.

ii. Packing lines: Packing lines differ greatly according to the type and quantity of the crop load. Thus a packing line may consist of simple sloping tables where the commodities are trimmed, cleaned, sized and packed. This is suitable for a small-scale facility. For large-scale operations a packinghouse with full mechanisation is necessary to include one or more packing lines (Figure 2). The packing line may include the following features:

a. **receiver belt** where the commodities are carefully transferred from the harvesting container. To reduce physical damages such as bruising, compression and abrasions to commodities it is essential to have the conveyor belt on the receiver line well padded to minimise the negative impact of drop heights. The receiver belt must never be overloaded. At this point commodities must also be subjected to an initial sorting procedure to eliminate those that are unmarketable due to defects such as decay, insect damage, physical damage, undersize, and heat injuries etc.

b. **cleaning:** Wash commodities in chlorinated water (100-250 ppm). The soft rotating brushes located inside the washer (Figure 2) are used to remove surface debris and other unwanted contaminants. Commodities are then allowed to dry naturally after washing or dried artificially using air blowers which are sometimes heated.

c. **special treatments:** After washing some crops receive special treatments to extend their storage and market life, or to make them more attractive to the consumer. Postharvest treatments may include waxing to reduce shrivelling and improve appearance or bactericidal or fungicidal dips to control pathogens.

d. **sorting and grading:** Almost all commodities are sorted, graded and sized in the packinghouse to meet the quality and size standards of the markets being served. Sorting to remove substandard commodities and grading into different classes could be done manually. Sizing according to weight, length or diameter is more often a mechanised procedure which can be done with sizing equipment attached to the packing line.

e. **packing and packaging:** Packing stations may supply commodities to different buyers and markets, each having different quality and packaging requirements. Flexibility in packing methods and materials employed should therefore be built into the system, even though standardisation of the commodities should lead to a reduction of the number of different packages.

Storage: After commodities are packaged they should be immediately placed in chill rooms at the recommended temperature and relative humidity. Please refer to the section on handling systems of the six selected vegetables for these conditions of storage.

Despatch: At the point of dispatch, commodities are handled in the condition that they will reach the buyer. It is therefore essential that rough handling, overloading of trucks, infestation and exposure to extreme weather conditions are kept to a minimum. The dispatch area should be cool, clean and spacious to allow for temporary storage of packed produce and permit unrestricted movement of loading staff and their vehicles.

Packinghouse design and sanitation protocols

The overall design of a packinghouse should ensure that: floor space is adequate for easy movement; doors are wide enough for passage of vehicles and pallets; storage areas are sufficient for packaging materials; all surfaces can be easily washed and drained; there is a relatively clean and quiet administration office; and the workforce have a clean area where they can wash and eat in reasonable comfort. All components of the packing line should be sanitised regularly because they are prime sites for pathogen growth. Employees should be mandated to follow good hygiene practices. Hand sanitising stations and well-supplied toilets and sinks must be provided. All partially decayed plant materials and wastes should be removed and burnt away from the packinghouse. Maintain an effective pest control program. Domesticated animals should not be allowed in the packinghouse. Footbaths with sanitisers should be placed at entry points in the packinghouse.

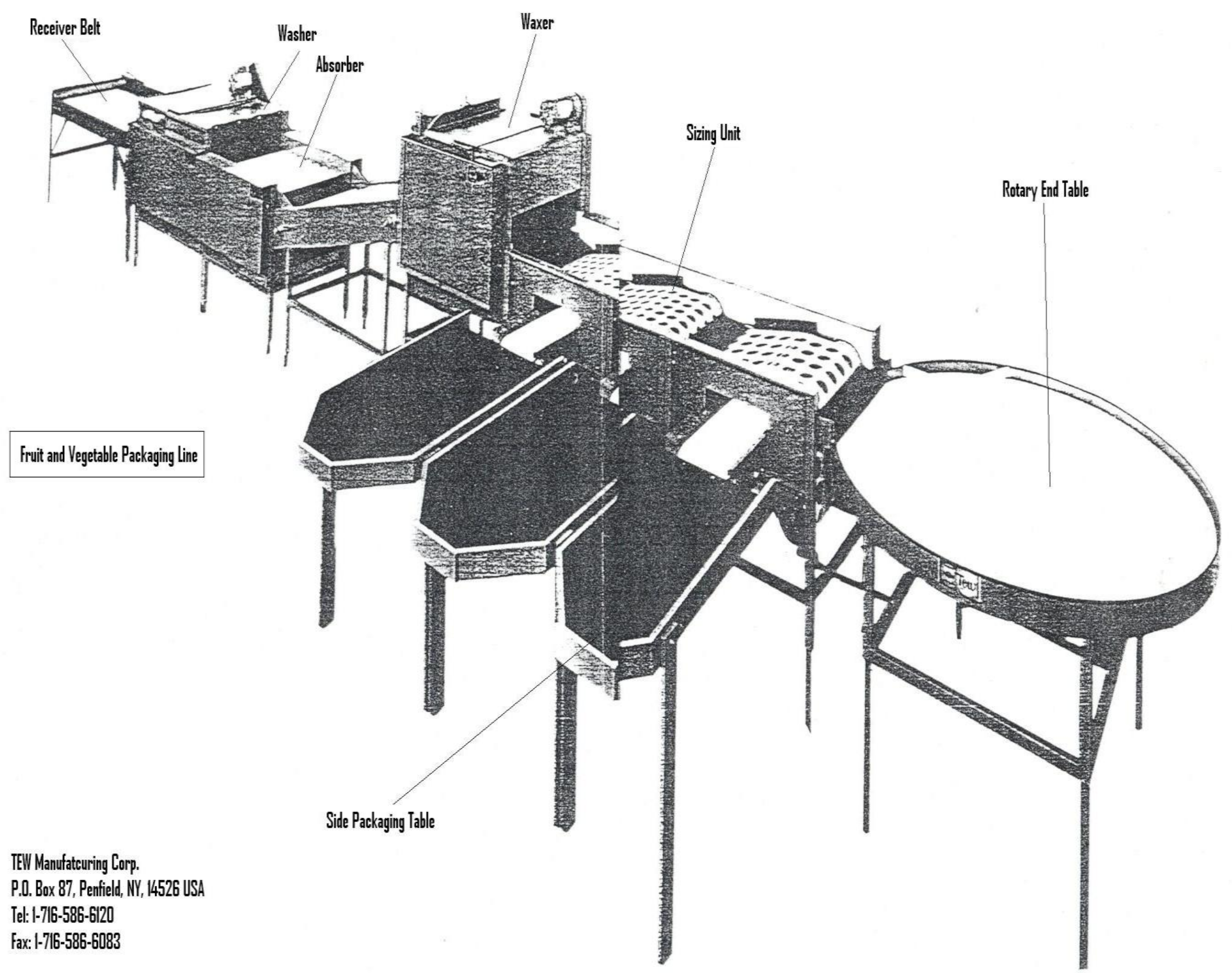

Figure 2: Packing Life

STORAGE SYSTEMS

The goals of storage are to:

i. slow biological activity of the product by maintaining the lowest temperature that will not cause freezing or chilling injury by controlling atmospheric composition;

ii. slow the growth and spread of microorganisms by maintaining low temperatures and minimising surface moisture on the product;

iii. reduce product susceptibility to damage from ethylene.

It is important to note that high quality produce will come out of storage only if it is of high quality on entering the store, and if management of the storage facility is of a high standard.

MODIFIED ATMOSPHERE STORAGE (MAS) AND CONTROLLED ATMOSPHERE STORAGE (CAS)

In modified atmospheres or controlled atmospheres, gases are removed or added to create an atmospheric composition around the commodity that is different from that of air (78.08% N_2, 20.95% O_2, and 0.03% CO_2). Usually this involves reduction of O_2, and/or elevations of CO_2 concentrations. MAS and CAS differ only in the degree of control; CAS is more exact.

POTENTIAL BENEFICIAL AND HARMFUL EFFECTS OF MAS AND CAS

Potential benefits: MAS and CAS can only supplement proper temperature management and can result in one or more of the following benefits:

i. retardation of senescence occurs, along with associated biochemical and physiological changes, represented by slowed respiration and ethylene production rates, softening, and compositional changes;
ii. reduction of commodity sensitivity to ethylene action occurs at O_2 levels below about 8% or CO_2 levels above 1% or their combinations;
iii. alleviation of chilling injury in certain crops;
iv. can be useful for insect control;
v. directly or indirectly affect postharvest pathogens.

Potential harmful effects:

i. initiation or aggravation of certain physiological disorders, e.g. Brown stain on lettuce;
ii. off-flavours and off-odours at very low O_2 or very high CO_2 concentrations.

Commodity-generated or passive MAS: Bitter melons or bitter gourds, individually shrink-wrapped and stored at 5-7^{0}C and 85-95% relative humidity, lasted 21 days (Mohammed and Wickham, 1993). Melongene individually sealed in low density or high density polyethylene films and stored at 7-8 ^{0}C lasted 15 days (Mohammed and Sealy, 1988). In both instances the authors hypothesised that the modified atmosphere as well as the saturated microenvironment created within the polyethylene bags accounted for the extended shelf life and to a large extent the reduction in moisture loss and alleviation of chilling injury damage.

QUALITY AND SAFETY

Quality is defined as any of the features that make something what it is, or the degree of excellence or superiority. The quality of fresh commodities is defined by a combination of characteristics, attributes, and properties that give the commodity value as food. Producers are concerned that their commodities have a good appearance and few visual defects, but for them a useful cultivar must score high in yield, disease resistance, ease of harvest and shipping quality. To receivers and market distributors, appearance quality is most important; they are also keenly interested in firmness and long storage life. Consumers consider good quality fruits and vegetables to be those that look good, are firm, and offer good flavour and nutritional value. Assurance of safety of the products sold is extremely important to consumers. If a product is not safe it does not matter what its quality; it should be eliminated from the produce distribution system.

POSTHARVEST PATHOLOGY

Introduction

Wastage of horticultural commodities by microorganisms between harvest and consumption can be rapid and severe, particularly in tropical countries where high temperatures and high humidity favour rapid microbial growth. Furthermore, ethylene produced by rotting produce can cause premature ripening and senescence of other produce in the same storage and transport environment, and sound produce can be contaminated by rotting produce. Apart from actual losses due to wastage, further economic loss occurs if the market requirements necessitate sorting and separating partially contaminated consignments.

Many bacteria and fungi can cause postharvest decay. Most of these organisms are weak pathogens in that they can only invade damaged produce. A few, such as *Colletotrichum sp.*, are able to penetrate the skin of healthy produce. Often the relationship between the host (fruit or vegetable) and the pathogen is reasonably specific e.g. *Pencillium digitatum* rots only citrus and *P. expansum* rots pears and apples but not citrus.

Disease development may be divided into two stages:

1. infection, followed by
2. manifestation of symptoms, either directly or after a period of time.

Bacteria gain entry through wounds or natural openings e.g. stomata, lenticels or hydathodes and multiply in the spaces between plant cells. Entry via wounds or natural openings is also characteristic of many fungi. Certain species of fungi, however, are capable of direct penetration of the intact cuticle, the waxy outermost layer possessed by leaves, stems and fruits. The fungi produce a swelling called the appressorium from the underside of which a thin strand grows through the cuticle and into or between plant cells. Penetration is achieved by mechanical pressure and by an array of enzymes specific to the fungus involved.

Factors affecting development of infection:

1. Environment: high temperature and high humidity. Low temperatures can induce chilling injury and secondary infections.

2. Low O_2 and high CO_2 can restrict the rate of decay by either retarding the rate of ripening or senescence, depressing the growth of the pathogen, or both.
3. Host tissue: pH of fruit tissue is usually below 4.5 and therefore are mainly attacked and rotted by fungi, but many vegetables where the pH is above 4.5 can highly be susceptible to bacterial rot.
4. Fruit maturity: ripening fruits are more susceptible to wastage than immature fruits. Thus treatments aimed at retarding the rate of ripening, such a refrigerated temperature, may also withstand the growth of decay organisms.
5. Formation of periderm layer at the site of injury for underground storage organs such as cassava, potato and sweet potato.

DEVELOPING HIGH QUALITY POSTHARVEST EXTENSION PROGRGAMMES

The objectives of a postharvest extension programme are to improve the quality and value of horticultural crops available to consumers, reduce marketing losses, and improve efficiency. All of these relate to maximising profit motives. Specific extension objectives will focus on solving a particular problem affecting one commodity or a group of related commodities in a specific location or commodity system. These could be focused on any aspect of postharvest extension, from ensuring quality and food safety at harvest to helping clients meet consumer preferences and the level of demand in new markets. Here are six useful steps that can be implemented to develop high quality postharvest extension programmes:

i. Identify the postharvest problems to be targeted and work with stakeholders to determine their priorities. Determine what are the most important postharvest needs (harvesting techniques, maturity indices, sorting, grading, packaging, storage, transportation etc.) for a given audience (growers, produce handlers, exporters etc) and how those needs can be realistically resolved by providing relevant educational information on postharvest principles/or practices.

ii. Develop long-term and short-term objectives for extension programmes and the programme's theory of action. Follow the model developed by Bennett in 1979: **inputs** and resources to get the programme stated; **activities** are then implemented to **involve** people; allow participants to **react** to what they experience; which leads to **changes** in **knowledge**, **skills**, **attitudes**, and **aspirations**; **practice changes**; and **end results** or overall impacts.

iii. Describe the specific postharvest principles, practices and technologies to be offered during the programme.

iv. Describe the extension methods that will be employed (group, individual, mass media, or based on computer technology) to meet the programme's objectives. Identify information sources and available teaching materials.

v. Determine the resources (manpower, equipment, facilities) needed to conduct the programme.

vi. Develop a plan for evaluating the programme during implementation to determine whether objectives are being met and how the programme might be improved.

POSTHARVEST HANDLING AND QUALITY MANAGEMENT OF CITRUS

Introduction

The citrus genus includes several important fruits such as oranges, mandarins, limes, lemons, and grapefruits. The demand for citrus fruits and products has increased and is likely to increase further because of an increasingly nutrition-conscious public and the distinctive flavour of citrus. Citrus fruit is fast becoming a staple food product in the daily diet of many people, and large consumption of citrus fruit is also attributed to other types of food and beverage industries which use the flavour (Kale and Adsule, 1995). Accordingly, maintenance of good external appearance, without visible injuries or defects, and preservation of internal organoleptic and nutritional quality, are essential quality attributes for maintaining high quality citrus fruit for domestic and foreign markets (Plate 1).

However, throughout the postharvest chain, fruit are subjected to many environmental and handling factors that may influence their storage life and quality. Suitable non-chilling temperatures (7-8°C) and high relative humidity (90-95%) are the two main factors to optimise postharvest storage of citrus fruit. On the other hand factors such as mechanical damage or atmospheric conditions may have adverse effects and limit fruit postharvest life. This article focuses on optimum handling methods to maintain quality at various stages in the postharvest handling system of citrus fruits that is essential for a citrus rehabilitation programme.

Maturity indices

A citrus fruit stays on the tree from 6-12 months. Fruit colour is not a reliable indicator to determine optimum harvest time for citrus fruits in the tropics. The development of the orange colour requires cool nights, yet in the Caribbean there is a colour break from hard green to light green that usually coincides with maturity. Afterwards the fruit becomes yellow. Owing to their reliability, objective standards are preferred to taste and colour. The percentage total soluble solids (TSS) and the percentage of water-free citric acid of the juice (TTA) are generally used. Sometimes, the percentage of juice may also be used as a maturity index, which should be about 50%.

Maturity of the rind and maturity of the flesh of citrus fruits are not synchronised. The fruit is edible even when the rind still remains green. Mature fruit vary in size, even those on the same tree. With sweet oranges, such as Valencia, harvesting should begin with the smaller fruit which mature first. With mandarins, it is the fruit furthest from the stem which turns yellow first and harvesting should begin with the larger fruit. Smaller fruit, or those which are slow to turn colour, should be harvested later on in the season.

As long as the fruit hangs on the tree, the TSS continues to increase, rapidly at first, then gradually: slowly it may rise to a TSS of 13 or even higher. Meanwhile the acid (TTA) content steadily decreases from 2.5% to 1% or lower. The majority of consumers prefer a TSS:TTA ratio of between 10 and 16.

In contrast to other fruits – which can be picked fully mature but not ripe and be ripened postharvest – citrus fruit contain no starch and cannot be picked and ripened postharvest. It is therefore a non-climacteric fruit. It has to be fully mature on the tree before harvest. However, internally mature fruit but with greenish rind can be harvested and degreened postharvest for it to attain a colour that is more attractive to the consumer.

Harvest time

It is best to harvest citrus on a clear, sunny day with low relative humidity. The fruit should be harvested as soon as the dew has evaporated. On a cloudy day, the fruit should be harvested in the afternoon.

Harvesting method

To prevent physical damage to the fruit, workers should wear gloves, and use special harvesting scissors with rounded ends to cut the fruit. To harvest the fruit, it should be held in one hand, and the other hand used to cut the fruit stem together with a few leaves. Then the fruit is brought close to the chest and the rest of the stem is cut off smoothly close to the fruit (Plate 2).

Harvesting containers

The container used for freshly harvested fruit should be solid, with good ventilation. Fruit in flexible containers tend to crush each other, causing bruises. The bottom of wood or plastic containers should be lined with newspapers, or a paper bag. It is important to move containers as little as possible, and not to leave them standing in the sun. Another useful harvesting aid is shown in Plate 3.

Postharvest factors affecting quality

Minimising water loss

Fresh citrus fruits are composed of roughly 90% water, which is vital for normal biochemical processes and is responsible for important textural qualities such as firmness. Following harvest, fruit are separated from their source of water. Excessive water loss during handling and storage will accelerate softening and promote the development of stem-end rind breakdown and symptoms of other physiological disorders such as chilling injury. Thus, minimising water loss after harvest is critical for maintaining fruit quality. Water loss from fresh citrus fruit occurs through evaporation into the surrounding air. Natural barriers, such as the peel and waxy cuticle covering it, help prevent water loss. Plugs, cuts, and abrasions break these natural barriers and increase water loss. Thus, reducing injury through careful harvest and postharvest handling is the first step in reducing water loss of fresh citrus. However, even undamaged fruit will lose some water during handling and storage. The rate of water loss depends on the fruit's contact with surrounding air and the dryness of the air. At a given temperature, air can only hold so much water vapour. If air is holding all the water vapour it can, we say it is saturated. Relative humidity (RH) is the ratio of actual water vapour content within the air to the maximum possible water content at a given temperature. Therefore, saturated air is at 100% RH. When the air contains half as much water at the same temperature, the RH is 50%. At a given temperature, the lower the RH of the air, the faster water is lost from the fruit. For example, at 16^{o}C, increasing storage RH from 80% to 91% reduced water loss in grapefruit by 57%. Therefore, to minimise water loss, RH should be maintained between 90% to 95% during degreening, and at about 90% during storage and transport. Humidifiers are the most effective means for adding moisture to the air; wetting the floor in storage rooms has some benefit, but also promotes development of decay organisms and is a safety hazard to workers. During degreening or other times when greater than 90% RH is required, bins and containers must be constructed of rigid, water resistant materials (such as plastic) to prevent container deterioration. It is also important to consider that warmer air holds much more water vapour than cooler air. Or, to put it another way, it takes much less water vapour to saturate cooler air than warmer air. Thus, air at 10^{o}C and 100% RH will only be at about 50% RH after warming to 20^{o}C, and 20^{o}C air at 50% RH will be saturated after cooling to 10^{o}C. This is why, at the same RH, Valencia oranges held at 3^{o}C develop much less stem-end rind breakdown than when held at 21^{o}C: warmer air can extract more water from the oranges than colder air at the same RH. Once the fruits are cool, air movement around the commodity should be minimised. This allows a thin layer of saturated air (known as a boundary layer) to form around the fruit, slowing water loss. Thus, water loss can be minimised by quickly cooling the product and keeping it at its lowest safe temperature (minimising temperature fluctuations) during handling and shipping operations.

Methods to reduce water loss:

- Handle fresh citrus fruits carefully.
- Harvested fruit should be shaded in the grove and at the packinghouse.
- Minimise time between harvest and waxing, especially during hot, dry, or windy weather.
- Avoid excessive brushing during packing operations. Keep brush speeds below 100 rpm and use automatic wipeouts to prevent fruit abrasion while sitting idle on the brushes.
- Use waxes or other surface coatings, wraps, plastic carton liners, and other packaging to slow water loss.
- Quickly cool the fruit and maintain temperatures at the lowest safe temperature (i.e. non-chilling or freezing temperatures).
- Minimise fluctuations in fruit and air temperatures.
- Reduce fan speeds when fruit are not being degreened or cooled.
- Add moisture to the air through the use of humidifiers to maintain RH at the highest recommended level without causing commodity or container deterioration. This is especially important during degreening when the air is warm and able to hold more water.
- Design cooling systems so that the evaporator coils run within 1^{o}C of the air temperature to minimise dehumidification (condensation forming on the coils).

Grading

Citrus are graded by size. This can be done by hand or by machine. If the grower is grading citrus manually, it is best not to judge the size only by eye, but to use some kind of measuring device. A simple way to check fruit size is to cut a series of round holes in a thin wooden board or a piece of thick cardboard, according to standard market sizes for that variety. A revolving drum type machine is often used by farmers. Other low-cost grading machines are also available. Fruit of different sizes should not be mixed together, or the market price the grower gets may be only that of the smallest fruit. The optimum size for fruit varies from one variety to another. In the case of Valencia orange, the total soluble solids and acid content fall as fruit become larger. Small fruit (6 - 6.5 cm in diameter) have a thin rind and high total soluble sugars and acid content, but also are more likely to rot in storage. They should be consumed fresh. Medium sized fruit (7 - 7.5 cm in diameter) have a low incidence of fruit rot after storage. Tests have shown they still have a good flavour after two months of storage. Large fruits (more than 7.5 cm in diameter) have a low incidence of fruit rot but a poor flavour after storage, because of their low level of total soluble sugars and their low acid content.

Postharvest treatments

Only fruit which have not been damaged in harvest are used for storage, although it is difficult to harvest fruit without some minor damage. Sometimes a chemical treatment is applied to the fruit before storage, to reduce the incidence of postharvest diseases.

Citrus fruit age during storage. The stem becomes yellow, then brown. Finally, it drops off, leaving a vulnerable place on the fruit which may be infected by fungus diseases. A treatment of 10 to 40 ppm 2,4-D can prevent the fruit stem from drying and dropping off.

The chemical thiabendazole (40%, diluted at 500X) can be sprayed onto fruit one or two weeks before harvest. Alternatively, fruit can be soaked for three minutes immediately after harvest. The treatment reduces the incidence of fruit rot during storage. Iminoctodine (25%, diluted at 2000X) can be used as a spray four days before harvest, or used to soak the fruit before they are packed. It also reduces the incidence of fruit rot (Plate 4).

Packaging

After harvest or chemical treatment, fruit should be kept in the shade for a few days before they are put into a polyethylene plastic bag. The bag should be 0.02 - 0.03 mm thick. Keeping the fruit in the shade in this way is a curing treatment, to reduce the water content of the peel. This reduces cell activity in the peel.

The time needed for water loss or evaporation depends on the temperature, the length of time the fruit is to be stored, and the thickness of the peel. If temperatures are high, citrus fruit need a longer period of curing. They also need a longer period of curing if they are to be stored for a long time, or if they have a thick peel.

On average, it takes from three to seven days to reduce the fruit weight by about 3%. Higher water content causes condensation inside the plastic bag, leading to stem rot (Plate 2). Water loss may cure minor wounds on the peel and reduce the incidence of rot during storage.

Fruit which are to be stored for a long period are wrapped in plastic, to reduce water loss. If the fruit are to be stored for more than two months, polyethylene film is used, often wrapped around stacked crates of fruit.

Storage

Proper temperature management is probably the most critical factor in reducing postharvest losses of citrus fruits and extending their postharvest life. Citrus fruits are sensitive to chilling injury (CI). CI symptoms are usually manifested by pitting and darkening of the peel, which reduces external quality and marketability of the fruit (Plate 5). Grapefruits and lemons are the most susceptible to CI, whereas mandarins and oranges are more resistant. Recommended temperatures for storing Valencia oranges and mandarins are 5-7^{0}C, limes 8-10^{0}C and grapefruits 10-12^{0}C.

How do citrus wax coatings affect CI? Exposure to high CO_2 concentrations (e.g. 10%) reduces CI of citrus. Fruit respiration uses O_2 and gives off CO_2. Covering fruit with a semipermeable film or wax coating slows the movement of O_2 into the fruit and CO_2 out of the fruit so that internal O_2 concentration decreases while CO_2 levels rise. The extent of tolerance that coated fruit have to CI is related to the coating's gas permeability: lower gas permeability results in higher internal CO_2 levels and a reduced tendency to develop CI. Thus, waxes that form a stronger barrier to gas exchange (e.g., shellac) reduce CI more than waxes that 'breathe' more (e.g., carnauba). However, too little gas exchange leads to off flavours (anaerobic respiration) and the development of other physiological disorders (such as postharvest pitting). The take-home message: when changing the wax coating used for fresh citrus, re-evaluate storage and transit temperatures, taking into consideration the gas permeability of the coating. Use of waxes that allows fruit to 'breathe' more, often require storage and shipment at warmer temperatures.

Plastic crates or boxes are used for storing fruit. Mandarins should be stored with only one or two layers per box. Sweet oranges such as Valencia should be stored with three or four layers per box. Too many layers in one box may cause bruising.

Boxes should be stacked inside the storage room in a way that maintains good ventilation. The roof and walls should have good heat insulation, to keep temperatures as cool as possible. The storage room should be insect-proof and rat-proof. A good storage room is the key for extending shelf life while maintaining fruit quality. The room should be kept clean, and all rotting fruits should be removed. Before storage, the room should be sanitised by washing the walls and floor with a recommended sanitiser.

Citrus packing line

A complete citrus packing line with the various components (Figure 3) described above is a useful investment.

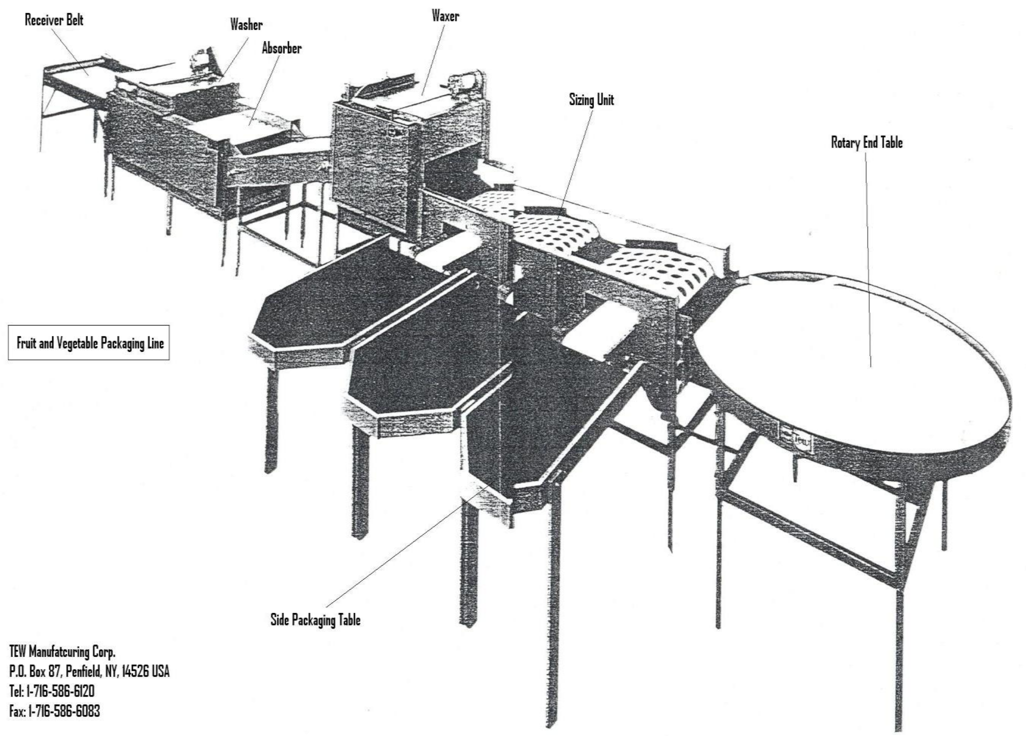

Figure 3. Complete citrus packingline

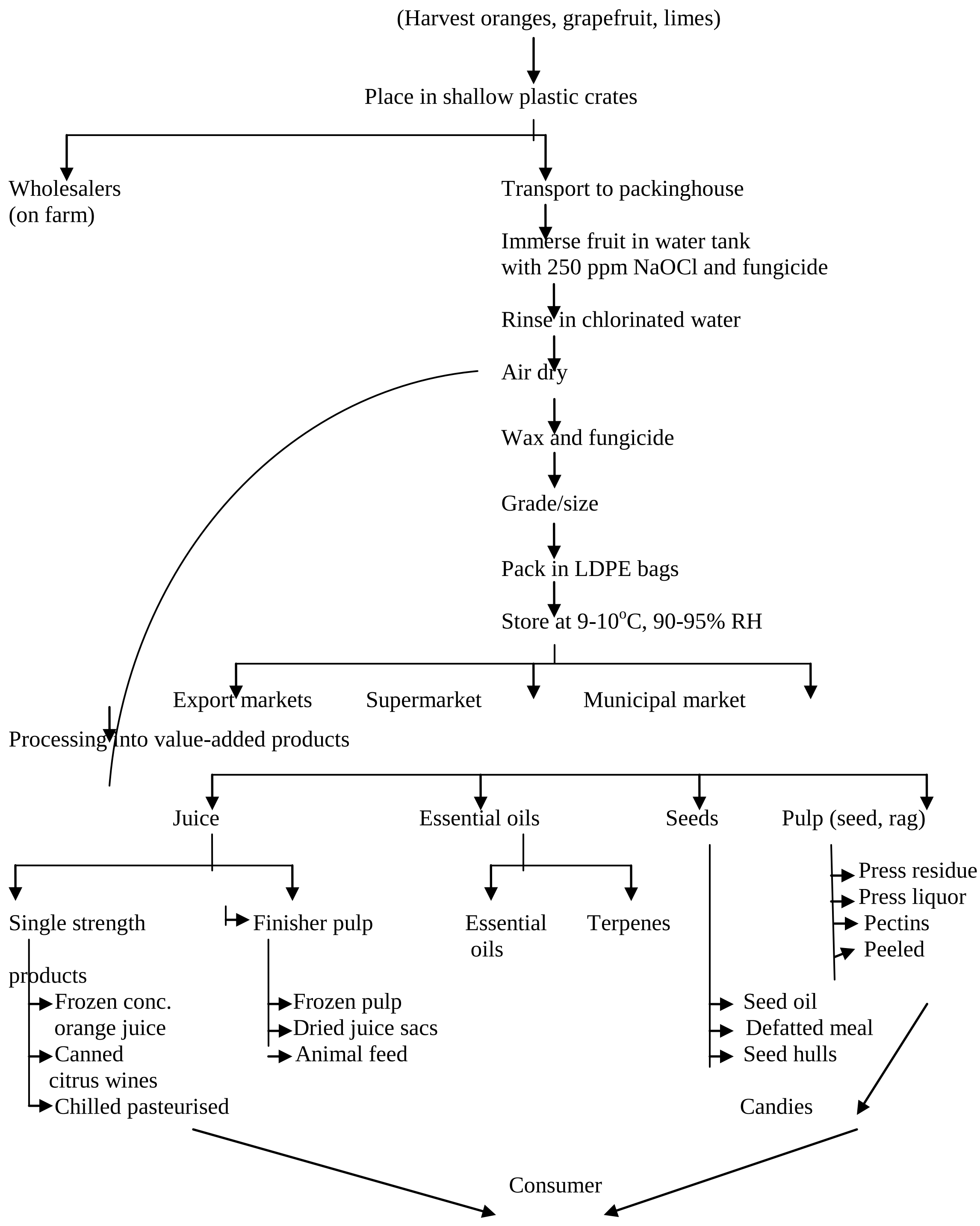

Figure 4. Citrus postharvest handling system and value-added products

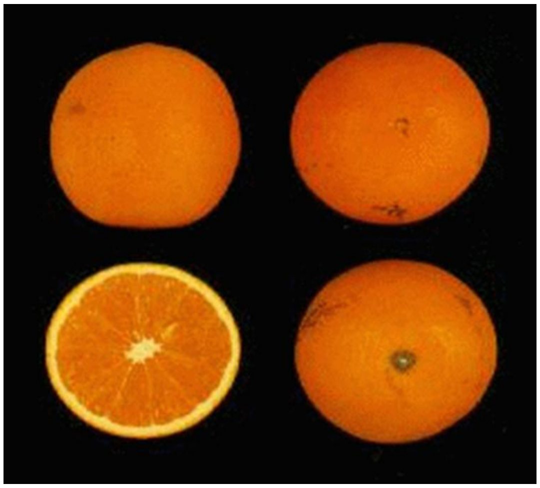

Plate 1. Internal and external quality of Valencia oranges.

Plate 2. Harvesting method and container.

Plate 3. Harvesting rod.

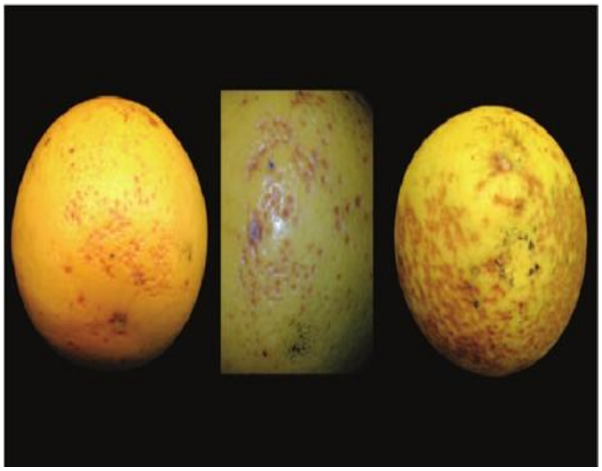

Plate 4. Chilling injury symptoms.

Sour Rot

Plate 5. Stem Rot

Extension Fact Sheet

The University of the West Indies, Faculty of Science and Agriculture

Postharvest Handling and Quality Management of Bitter Gourds (*Momordica charantia* L.)

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Introduction

Bitter gourd (*Momordica charantia* L) is a member of the *Cucurbitaceae* family and is also called, depending on the country where it is cultivated, bitter melon, African cucumber, karela, carille, art pumpkin, balsam pear, maiden apple or koe. Perhaps better known for the use of the leaf, root and fruit for medicinal uses, the commodity has great potential as a food source in both developing and industrialized countries and is rich in iron, phosphorus and ascorbic acid. The fruit is intensely bitter, green and warty in appearance, and is highly fragile and perishable.

Quality indices

There are three horticultural groups or types of bitter melons: (i) the small fruit type, 10-20 cm long, 0.1-0.3 kg in weight, usually dark green, fruit are very bitter; (ii) long fruit type, 30-60 cm long, 0.2-0.6 kg in weight, light green in colour with medium size protuberances, and only slightly bitter; and (iii) triangular fruit type, cone-shaped, 9-12 cm long, 0.3-0.6 kg in weight, light to dark green with prominent tubercles and moderately bitter. The bitter principle, is due to the alkaloid momordicine and not to cucurbitacins as in other members of the *Cucurbitaceae*. Immature fruits are less bitter than the mature but unripe fruits.

Good quality bitter gourd fruits should have a fresh appearance and the peel should be of uniform green colour and free from visual defects. The developing fruit should be firm without excessive seed development, and free of defects such as decay and splitting, both associated with fruit ripening. When the fruit begins to ripen, the exterior colour changes from green to yellow and the pulp becomes gelatinous and orange-red. The seed arils also change colour from white-cream to bright red. Among the more than 14 carotenoids identified during the ripening process, the principal carotenoid is cryptoxanthin. Coincident with colour changes, the fruit pulp loses bitterness and becomes sweet.

Ripening of bitter gourd

Harvesting

Fruits can be harvested at any stage of development, but are typically harvested full sized but green, about two weeks after anthesis. At this stage of maturity, the pulp and seed colour is white to creamy-white. Bitter gourd is a rapidly growing monoecious herbaceous vine which needs to be trellised. The fruits are normally harvested manually by cutting the stem vine with a knife or secateur. Pulling the fruit vine stem could incur root damage leading to senescence of the leaves, flowers and developing fruits. Placing each stem vine between the index and forefinger and using a sharp instrument example pair scissors or knife to cut the stem vine eliminates root damages and potential senescence of leaves, flowers and fruits. Fruits should be handled with extreme care in order to avoid damages to the skin and surface protuberances. The bitter gourd fruit has high moisture content, a large surface: volume ratio and a relatively thin cuticle, which makes it very susceptible to moisture loss and physical injury.

Pre-cooling

Bitter gourds have a relatively high respiration rate and therefore prompt removal of the field heat via hydro-cooling or room cooling is recommended.

Grading and packing

After selecting for size and uniformity of fruit surface characteristics, fruits are carefully packed in cartons or wooden boxes containing 5, 10, or 20 kg. All fruits showing signs of over-maturity (yellow-orange colour of skin, splitting of skin, intense red pigmentation of arils), softening, decay, insect damage, abrasions, splitting, bruises, transit abrasions and misshapen fruits, are to be rejected prior to packing.

Storage

Stretched-wrapped bitter gourd with no chilling injury symptoms compared to unwrapped fruit

Bitter gourds fruits have a marketable shelf-life of 7-12 days when stored at 10-12.5°C, 85-90% relative humidity. However, individually film-wrapped fruits stored at 5-7°C were marketable up to 21 days. Fruits stored at 15°C continued to develop, showing undesirable changes including seed development, loss of green colour and fruit splitting. Immature fruit maintained postharvest quality better than fruit harvested at the fully developed green stage. Bitter gourd fruits can be classified as moderately sensitive to chilling injury. Fruits stored at 5-7°C developed visible symptoms of pitting which eventually coalesced to form larger sunken dark brown pits in the ribbed regions. Other chilling injury symptoms include surface discolouration from green to dark brown, secondary infections, rusetting and internal tissue breakdown.

Chilling injury symptoms of bitter gourd

Pathological problems

Major causal organisms associated with decay in bitter gourd are secondary to the inception of severe chilling injury damage. These include *Fusarium* sp.; *Gloesporium* sp.; *Chaetomella* sp.; *Erwinia* sp. and *Curvularia* sp.

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Extension Fact Sheet

Postharvest Handling of Golden Apple

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A ripe golden apple

The golden apple (*Spondias cytherea* L.) is a highly perishable fruit grown mainly in the Caribbean islands of Grenada, Barbados and Trinidad and Tobago and exported to North America and Europe. The fruits, which are borne in clusters at the tips of branches, have a thin skin that is green and shiny, which changes to golden yellow upon ripening.

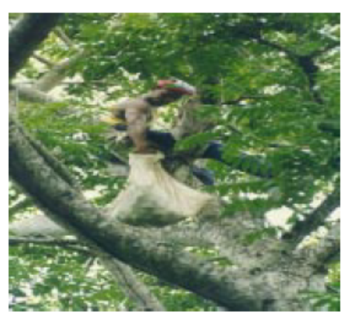
Golden apples are required in the market in the green, unripe condition, as well as clean and free of mechanical damage and disease. Harvesting fruits at the required stage of maturity, together with proper handling, grading and storage practices ensure the maintenance of high quality produce with minimum postharvest losses.

Harvesting

Traditional trees vary from 6 to 20 m in height with a trunk width of 50 cm in diameter. Fruits therefore have to be harvested by climbing or using a picking pole with a bag. A pouch bag could also be used when climbing or using a ladder. A rope-pulley system device can also be used to harvest larger loads. Mechanical devices such as an automatic platform trough could be adapted, but these require heavy capital investment and maintenance costs. These devices are further constrained by their inability to access trees on high and uneven terrain.

Whatever harvesting aid is used, fruits should not be thrown or dropped to the ground. Golden apples crack or split easily on impact and this could result in postharvest losses.

Harvesting should be timed on the day of, or the day prior to shipment. Immediately upon harvest, fruits should be placed in durable, light coloured plastic crates and kept in a cool place. Field crates are preferable to sacks or mesh bags for transport from the field to the packinghouse.



Harvesting golden apple by hand

Sorting, Grading and Packing

Golden apples should be washed in water containing 100-120 ppm sodium hypochlorite solution and a recommended fungicide. Wash fruits to remove dirt, stains, sooty mold and surface debris and air-dry prior to packing. Insect scarring, as indicated by distinct brown scars on the fruit's surface, must not exceed 15% of the surface. Pack all sized fruits into 9 to 18kg (20 to 40 lbs) boxes. Fruits must weigh more than 140 g (5 oz) and be more than 6 cm (2.5in) in length.

Packaging

Use two-piece, full-telescopic or half-telescopic fibreboard cartons or one piece waxed cartons. Where staples are used, care should be taken to ensure complete staple closure to avoid fruit damage.

Internal carton dimensions should be:

i. 20 x 55 x 34 cm or
ii. 29.5 x 44 x 29.5 cm or
iii. 16 x 37.7 x 27.9 cm

Storage and Transportation

Golden apples can be stored under ambient conditions for 24 hours prior to shipment, although precooling to 12°C is preferable. Storage of fruits below 12°C can result in chilling injury. Chilling injury symptoms include pitting, peel and flesh discolouration and secondary infections. Under ambient conditions, golden apples will commence ripening 2 to 4 days after harvest. Avoid storing golden apples together with fruits like passion fruits, bananas, plantains, and papayas, which are prolific producers of ethylene. The presence of ethylene will promote ripening and senescence.

Golden apples should be transported in containers at temperature 12 to 14°C and relative humidity between 85 to 90%. For export markets, air shipments should be utilized, as the storage life is insufficient for sea transport. Ensure cartons are adequately stacked, allowing for proper movement of cool air in and around cartons.

Pathological Problems

Postharvest losses can increase rapidly if fruits with mechanical damage are not graded out. Fungal diseases can also cause severe losses when the fruit begins to ripe. Fungal disease symptoms include small black, circular spots, which gradually grow larger with time. Soft rot problems due to bacterial proliferation on wounded sites and soil contamination also result in postharvest losses.

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Extension Fact Sheet

Postharvest Handling and Storage of Hot Peppers

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Hot peppers are assuming increasing importance as a vegetable crop in the Caribbean, both for the fresh market and for processing. The rapid expansion of hot pepper production is due to the increased demand created in the ethnic markets in the United Kingdom and North America for the fresh fruit. In addition, it is a source of foreign exchange earnings for the farmers and exporters. However, in order to meet the requirements of these foreign markets, it is important that fruits are picked and handled carefully to maintain the quality which would stimulate repeat sales and increased consumption.

Handling

Hot peppers are easily damaged and should be handled carefully. Every puncture or bruise is a potential site for decay. Fruits with decay should not be placed in picking aprons or field crates because they are sources of disease that can infect healthy peppers. Cleaning and disinfecting harvesting containers will minimize the spread of diseases.

Peppers should be collected in aprons, bags or buckets and transferred to plastic crates for transport to the packinghouse. All containers should be light coloured, ventilated and shallow. Covering all containers with a light coloured cloth will minimize absorption and radiation from sunlight and so limit heat build up.

Hot peppers should always be stacked in the shade upon arrival at the packinghouse, to prevent overheating and the possibility of bacterial soft rot. Hot peppers should be spray-washed with chlorinated water at a concentration of 75 to 100ppm of free chlorine.

All fruits must be completely dried after washing, because water droplets that are trapped within ridges, can cause fruit decay. The use of air blowers can be used to dry water droplets prior to packaging.

Sorting and Grading

A proper sorting and grading system ensures that growers, wholesalers, retailers and exporters adhere to specifications in order to monitor the quality, size and maturity of peppers. The supply of high quality fruit is particularly important in meeting the demands of the export market. Bruised, punctured, insect infested, off-sized and immature fruits must be discarded. For market purposes hot peppers are divided into two classes:

Class 1 – Class 1 peppers must be of normal shape, development and colour for the specific variety. It should also be firm and blemish free, with the stem and calyx attached and at least 40 mm in diameter.

Class 2 – Class 2 peppers may show slight defect in shape and development and should be at least 30 mm in diameter. Slight injuries may exist, however they should not exceed 1 cm^2 per fruit. The stem may be slightly damaged.

However, the minimum requirements for both classes should be mature fruits that are fresh in appearance, with no rotting or deterioration. The fruits should also be clean and free of foreign matter, injuries and foreign smell.

Packaging

Proper packaging of hot peppers is essential in order to maintain quality during transportation and marketing. In addition, packaging must be able to withstand:

1. Rough handling during loading
2. Compression from overhead weight of other containers
3. Impact and vibration during transport
4. High humidity during precooling, transit and storage

Packages for export must therefore be strong and moisture resistant. Importers prefer to receive hot peppers in 5 to 7 kg (11 to 15 lbs) packages. Under normal circumstances, net weight should not exceed 9 kg (20 lbs) since overheating can occur. The use of larger boxes could encourage rough handling, fruit damage and package failure. Packages must be of the correct size and filled properly, since over-filling causes bruising. Under- filling can also cause bruising, since fruits move around inside the package during transportation and handling. To improve handling efficiency, a standard container should be adopted, that would safely contain the product and be able to stack properly on the typical 120 by 100 cm pallet.

Storage

Unless hot peppers are precooled to 12 to 15ºC soon after being packed, the heat of respiration will cause the temperature of the product to rise rapidly and cause deterioration.

A bleached appearance, indicating heat injury, may develop on fruits which are kept in uncovered field containers for more than 5 to 8 hours exposed to the sun and more than 20 to 30 hours without refrigeration.

Hydrocooling hot peppers in chlorinated water (8 to 10ºC) or water plus a bactericide, sodium hypochlorite (500 ppm), for 30 minutes reduces field heat and decay. Fruits of the red cultivar are more perishable than those of the yellow cultivar, but generally, sodium hypochlorite treated fruits packaged in microperforated high density polyethylene bags at 8-10ºC can be marketable for up to 25 days.

Once hot peppers are cooled, they should be held at 8 to 10ºC and 90 to 95% relative humidity. At higher temperatures fruit ripening is accelerated and decay is rapid. Hot peppers are very susceptible to water loss. Wilting symptoms may become evident with as little as 5% fresh weight loss. To avoid wilting, hot peppers should be held in an atmosphere with 90 to 95% relative humidity. Hot peppers stored below 8 to 10ºC show symptoms of chilling injury. Chilling injury symptoms are pitting; dark brown colouration of stem, calyx and seeds; increased susceptibility to secondary infections; water soaked tissue; and translucency of pericarp.

Chilling Injury

Transportation

In domestic marketing, hot peppers transported to various outlets should be protected from the direct rays of the sun in order to reduce fresh weight losses, shriveling and loss of fruit quality. Fruits should therefore be transported during the cooler part of the day in crates covered with a damp, light coloured material. For export markets, where transit time is much longer, it is essential that in order to maintain quality, hot peppers should be loaded and transported at the recommended temperature of 8 to 10ºC and relative humidity of 90 to 95%.

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Extension Fact Sheet

Postharvest Handling and Quality Management of Melongene (*Solanum melongena* L)

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Introduction

Melongene is an annual in temperate zones and perennial in the tropics. Plants grow to a height of 60-120 cm and produce a few large fruits which are oval shaped or elongated oval. Growth is indeterminate. Most cultivars are purple to blackish purple (Suriname Long Purple, Black Beauty) in skin colour, but some are white, green or mottled, green skinned with white flesh.

Harvesting

Quality melongene fruits should be firm and glossy, with a dark green calyx and stem, have relatively tender skin, flesh that is firm instead of soft or spongy, and succulent seeds. Fruit could be harvested at different stages. Depending on the cultivar and temperature, the time from flowering to harvest vary from 10 to 40 days. Generally fruits are harvested immature before seeds begin to significantly enlarge and harden. Melongene fruits are immature if an indentation remains after pressing the tissue with the thumb. Bitterness in melongene is generally associated with over-maturity or production during periods of high temperatures.

Fruits of marketable size should be clipped from the plant, leaving the calyx attached to the fruit. The fruit stems are heavy and tough, and if not cut, excessive breaking of the branches or damage to the fruit will occur. Over mature fruits should be removed from the plant and discarded to stimulate further flowering and fruit set. On harvesting, 2.5 cm and 5 cm of stem should be left attached to the fruits of Black Beauty and the Long Purple types, respectively. Harvested fruits, especially the Purple skinned types, should be protected from the direct rays of the sun because they are highly susceptible to sunscald. Under conditions of high solar radiation, an exposure period of one hour is sufficient to render fruits unmarketable.

Pre-cooling

Rapid cooling, primarily to remove field heat and to reduce water loss, soon after harvest, is essential for optimal postharvest keeping quality. The pre-cooling endpoint is typically 10°C. Forced-air cooling is the most effective practice. Room cooling after washing or hydro-cooling is the most common practice. Hydro-cooler water should be managed to maintain 100 ppm sodium hypochlorite.

Grading and packing

Fruits should be transferred from field crates at the packinghouse on a well-padded conveyor belt for sorting and grading. Fruits are wiped clean with a damp cloth to remove soil and residues. The cloth should be regularly rinsed in a solution of 100 ppm sodium hypochlorite. Out-grading requirements based on the level of scarring and scabs (caused by aphids, mites, trips or windscar) vary between varieties. Black Beauty type melongene is unacceptable for the export market if scars and scabs are present with dimensions greater that 3 mm wide and a cumulative length of 4 cm.

Green streaking from the stem is unacceptable in the Black Beauty type. The out-grading requirements for the Long Purple type are slightly less stringent than the Black Beauty. Long Purple fruits with light coloured scars, exceeding 1.0 cm in diameter and cumulative length of 7 cm and for dark coloured scars exceeding 1.0 cm, and 9 cm cumulative length, should be rejected. The grading may be less severe if the scarring is located around the base of the fruit.

Packaging

Melongene fruits should be loosely parked in full or half-telescopic two-piece fibreboard cartons to net weight of 4.5 to 9 kg.

Storage

Melongene fruits should be stored at 8-10°C, 90-95% relative humidity. Storage under these conditions will result in a shelf-life of 9-12 days. High air circulation rates with low relative humidity will cause rapid water loss, resulting in shrivelling and softening of the fruit. Melongene fruits are chilling-sensitive at temperatures below 8-10°C. At 5°C, chilling injury will occur in 6-8 days. Symptoms of chilling injury are pitting, surface bronzing, browning of seeds and pulp tissue. Individual seal packaging of melongene fruits in low density polyethylene bags, or high density polyethylene bags at 7-8°C, results in the creation of a modified atmosphere. This also results in a saturated microenvironment within the sealed bags, that would alleviate chilling injury damage and weight losses and lead to a longer shelf-life of up to 15 days.

Chilling injury symptoms of melongene

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Enzymatic browning of fresh-cut melongene

Storage compatability

Melongene fruits can be stored together with pumpkins, squash, sweet potatoes and watermelons. Exposure to ethylene for two or more days hastens deterioration. Calyx abscission may be a problem if fruits are exposed to more than 1 ppm ethylene during distribution and short-term storage. Odours from certain spices, for example ginger, are absorbed by melongene fruits and therefore should not be placed in close proximity.

Transportation

Maintaining the cool chain is imperative. Fruits should be kept at 8-10°C, 90-95% relative humidity throughout the handling system until consumption.

Postharvest decay

Diseases are an important source of postharvest losses, particularly in combination with chilling stress. Common fungal pathogens are *Alternaria* rot, *Rhizopus* rot (hairy rot) and *Phomopsis* rot.

Shrivelling, pitting and senescence of stem and calyx of melongene

Extension Fact Sheet

The University of the West Indies, Faculty of Science and Agriculture

Postharvest Handling and Quality Management of Okra (*Hibiscus esculentus*)

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Introduction

Okra belongs to the *Malvaceae* family. It is a herbaceous, shrub-like dicotyledonous annual plant with woody stems growing to heights of 1-2 m. Popular varieties cultivated in the Caribbean include Bindi, Clemson Spineless, Annie Oakley. The pods are highly perishable but with optimum postharvest handling systems, quality is maintained for 4-7 days.

Maturity Indices

Okra pods are generally ribbed, and are harvested while still tender and immature. Harvesting typically occurs 3 to 7 days after flowering. Okra should be harvested when the fruits are bright green, the pod is fleshy and seeds are small. After that period, the pod becomes pithy and tough, and the green color and mucilage content decrease.

Okra pods at different stages of maturity

Quality Indices

Okra pods should be tender and not fibrous, and have a colour typical of the cultivar (generally bright green). The pods should be well formed and straight, have a fresh appearance and not show signs of dehydration. Okra should be free of defects such as broken pods, insect damage, and mechanical injury. The tender pods are easily damaged during harvest, especially on the ridges and this leads to unsightly brown and black discolorations. Quality losses that occur during marketing are often associated with mechanical damage, water loss, chilling injury, and decay.

Harvesting

Due to the pod size requirements and the rapid rate of growth and development, okra has to be harvested every one or two days to ensure pods are within the size specification range. Okra should not be harvested in the rain or when excessively wet. Pods should be handled with care. Rubber gloves should be used during harvesting and handling. Secateurs and harvesting bags should be used for harvesting and collection respectively. Ventilated field crates should be used for transport. On harvesting, approximately 1 cm of stem should remain attached to the pod. Oversized and damaged pods are to be removed from the plant, but out-graded in the field. Field crates should be light in colour, ventilated and shallow. When full, crates should be placed in the shade and kept dry. Sacks or bags are not to be used as these incur damage and cause heat build-up. During transport from the field to the pack-house, the crates should be covered from the elements, but have sufficient ventilation to prevent heat build-up. Due to the perishable nature of okra, harvesting should take place on the day, or the day preceding shipment. Okra can be sprayed, washed, or placed in water dump tanks. Water for cleaning pods should be chlorinated at a concentration of 75 to 100 ppm of free chlorine. Following washing, excess water can be removed by sponge rollers or air blowers. Free water should be removed from the pods to prevent bleaching or discolouration. Prolonged contact of water on harvested okra causes spotting, therefore hydro-cooling is not generally recommended.

Export Grading and Packing

Removal of pods which show discolouration, bruising (blackening of the ridges), chemical residue or insect damage, is required during the grading procedures. All pods, meeting the size specifications, can be loosely packed into cartons (size grading is not required). Okra pods are graded by hand on moving conveyors or standard grading tables. Conveyor operation is more rapid than standard tables. Experienced graders line the conveyor to remove rejected pods, while the acceptable ones are allowed to continue and fill directly into the cartons. Net weights are dependent on the importers' requirements and vary from 3.5 to 4.5 kg (8 to 10lbs).

Packaging

Pods are packed in one or two-piece self-locking fibreboard carton; bursting strength 200 to 250 $1b/in^2$.

Carton internal dimensions:

- 10.9 x 34 x 26.9 cm (4.3" x 13.4" x 10.6")
- 16 x 37.6 x 27.9 cm (6.3" x 14.6" x 11")

Unless okra pods are cooled to 10-12°C soon after being packed, the heat of respiration will cause the temperature of the pods to rise rapidly and result in deterioration. Okra is very susceptible to water loss. Wilting symptoms may become evident with as little as 3% weight loss. To avoid wilting, okra should be held in an atmosphere with about 90-95% relative humidity. Containers with moisture barriers or pre-packaging in perforated film would aid in maintaining freshness.

Storage and Transportation

Okra in good condition can be stored satisfactorily for 7 to 10 days at 8-10°C. At higher temperatures toughening, yellowing, and decay are rapid.

For foreign markets, aircraft pallets should be used for transport. If aircraft containers are to be used for transport, where ventilation is absent, the okra should be removed from cool storage for two or three hours prior to loading of the container, to allow condensation to evaporate from the pods. If not, prolonged exposure to moisture and increase in pod temperature and high humidity will result in yellowing and blackening of the ridges. Mould will also develop on the cut stem and the pods will collapse.

Okra fruits are very sensitive to chilling injury. If pods are stored for more than 4 days below 4-6°C chilling injury symptoms develop very rapidly, particularly if transferred to 20-22°C. Chilling injury symptoms include skin discolouration, pitting, water-soaked lesions and secondary infections. Calcium dips and modified atmosphere packaging have been reported to reduce chilling injury symptoms.

Pathological problems

Decay on okra can be due to various common bacterial and fungal organisms, but chilling injury-enhanced rots are probably the most common causes of loss. *Rhizopus*, *Geotrichum* and *Rhizoctonia* fungal rots, as well as bacterial decays due to *Pseudomonas* sp., have been reported to cause postharvest losses.

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Extension Fact Sheet

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Postharvest Handling and Quality Management of Pumpkins

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Introduction

Pumpkins belong to the *Cucurbitaceae* family and are an important source of income for many growers in the Caribbean. Pumpkins are rich in the antioxidant beta-carotene, a plant carotenoid which is converted to vitamin A. Pumpkins are grown throughout the year with peak production from October to March. If pumpkins are harvested, handled and stored correctly, they can remain in a marketable condition for up to two months.

Maturity Indices

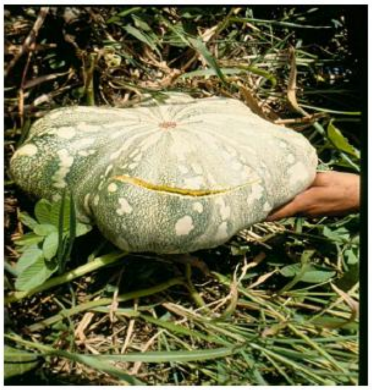
Pumpkins at different stages of maturity

Subtle changes in rind colour ranging from bright green to dull green and corking of the stem are indices of fruit maturity. Immature fruit normally have a fleshy stem, while maturing and well mature fruits have some stem corking and well corked stems respectively.

Harvesting

Pumpkins are harvested when the fruits are mature, based on the loss of surface sheen or gloss, and the die-back of the tendril nearest to the fruit. At this stage of maturity the rind or skin would have toughened and the stems would have lost their succulence. Dripping from the stems should be minimal when they are cut from the vine. Secateurs or knives are used to cut the stem from the vine, leaving 2.5 cm of the stem attached to the fruit. Upon removal from the plant, the pumpkins are placed in field crates for in-field and field to packhouse transport. During harvesting and transport, efforts should be made to handle the fruit with care, to avoid bruising, cracking, puncturing of the flesh, and to avoid exposure to direct sunlight, wind and rain.

Pumpkin with physical damage (puncture)



Fruit cracking due to high pre-harvest nitrogen fertilizers

Grading and Packing

Washing of fruits may be required to remove soil and debris and long stems cut to the required length. Pumpkins packed in mesh bags should not exceed more than 23 kg. Pumpkins shipped by sea should include an additional 5% weight to account for weight loss occurring during transport. Surface molds and rots can be reduced with a bleach and water solution (1 part bleach to 4 parts water) sprayed or wiped on the surface.

Storage and Transportation

Pumpkins stored in ventilated polyethylene following curing

Pumpkins may be shipped either by air or by sea. For sea shipment, fruits should be stored at 12-13^{0}C and 60-70 % relative humidity. Pumpkins shipped by sea will develop a deeper orange flesh colour during storage. Pumpkins exported by air will not develop more flesh colour and therefore the pulp should be yellow/orange on departure. Pumpkins are very chilling sensitive when stored below 10^{0}C . Symptoms of chilling injury are sunken pits on the surface and high levels of decay once fruits are removed from storage. During storage fruits must be kept dry, and storage areas should have good ventilation. Pumpkins can be subjected to a curing period by storing fruits at 25-30^{0}C and 80-85% relative humidity for 10 to 20 days, to help harden or cure the rind, before placing fruits under refrigerated conditions for long term storage.

Pathological Problems

Pumpkin with soil borne infection

Several fungi are associated with decay of pumpkins. These include Fusarium, Pythium, Anthracnose and gummy stem blight. Fruits that are over-mature at harvest, that is, more than two weeks beyond optimal harvest date will tend to have more storage decay.

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Extension Fact Sheet

Postharvest Handling and Quality Management of Bodie (*Vigna unguiculata* L)

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Introduction

Bodie or Yard-long bean is grown especially for the long immature pods and for the dry mature seeds. It is an annual trailing vine with trifoliate leaves. The pods range from 30-75cm in length, seeds are kidney-shaped and 8-12mm long. Vine support increases yield.

Quality requirements

Bodie pods should be whole, fresh in appearance, readily snaps at the distal end, and in particular, free from residues, including traces of chemicals, foreign smell or taste.

Harvesting

Bodie can be harvested at three different stages of maturity: green snaps, green mature and dry, based on the method of utilization. If harvested too early, the pods will wither quickly and yields will be poor. Over mature pods on the other hand tend to be discoloured, fibrous and distended. Pod length varies according to variety and growing conditions. Bodie pods should therefore be harvested when they have attained maximum length but before indentations on the pod's surface become evident. Fresh market bodie are ready for harvest 16-17 days after bloom or 60-90 days after planting. Pods should be harvested every 2-3 days but not less than twice weekly.

Harvesting of bodie

Pre-cooling

Bodie pods have a high rate of respiration particularly the immature pods. The high respiration rate coupled with the rapid rate of transpiration and the limited wax on the cuticle promote wilting and eventually pod deterioration. This becomes more pronounced when pods are packed in large containers where the respiratory heat is not adequately dissipated. Hydro-cooling is considered the most effective method of pre-cooling.

Storage

Bodie pods should be stored at 7-8°C and 95-100% relative humidity. Storage of pods below 4-5°C for more than 3 days would result in chilling injury. Chilling injury symptoms include pitting, pod discolouration, water soaked lesions and secondary infections.

Packaging

Pods can be field-packed directly into shallow light coloured, well-ventilated plastic crates or waxed cartons with a 10-15 kg capacity. Wilting could be arrested by storing pods in perforated polyethylene liners.

Pathological problems

Anthracnose is a fungal disease that occurs wherever bodie pods are grown in areas of high rainfall and relative humidity. The fungus is seed-borne as the disease can be prevented by planting disease-free seeds. Soil rot caused by *Rhizoctonia solani* is a soil-borne fungus where the decay during marketing develops from incipient infections present at harvest or active lesions that were overlooked during sorting. Prompt cooling to 6-8°C and maintenance in this range during marketing will reduce development and spread of the disease. Watery soft rot is caused by *Sclerotinia* sp., a soil-borne fungus. Incipient infections occurring in the field develop into active decay at temperatures favourable to growth.

Horticultural maturity of bodie

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