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Postharvest Handling
Technical Bulletin

LIMES

Postharvest Care and Market Preparation

Technical Bulletin No. 12

January 2004

POSTHARVEST HANDLING TECHNICAL SERIES

LIMES

Postharvest Care and Market Preparation

Ministry of Fisheries, Crops and Livestock
New Guyana Marketing Corporation
National Agricultural Research Institute

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With the assistance of the United States Agency for International Development

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Preface

This publication is part of a series of technical bulletins that seek to provide specific recommendations for improvements in postharvesting and market preparation for selected non-traditional agricultural products. The intended audience for this series is primarily extension agents.

Initial market assessments in current export markets and visits with producers and exporters in Guyana have shown the quality of fresh produce currently exported is uneven and in some instances very poor. Stages all along the export chain from harvest and pre-harvest to transportation and final export are all in need of improvement. Pre-harvest practices, sanitation at the packinghouse, packaging, bacterial and fungal problems, and transportation were all identified as areas where improvement could benefit the quality and increase the shelf life of Guyana's fresh produce exports. The technical bulletins address these issues specific to each product. Harvesting techniques and crop maturity indices are provided. Preparation for market, including cleaning, sorting, packing and transportation are covered. The bulletins address and recommend specific storage conditions, covering temperature and humidity controls. Finally the bulletins address postharvest diseases and insect damage.

The undertaking of these technical bulletins is a joint effort of the Ministry of Fisheries, Crops and Livestock; the New Guyana Marketing Corporation (NGMC) and the National Agricultural Research Institute (NARI) to improve quality, increase production and promote exports. As a team, the three agencies are working on the problems, limitations, and constraints identified in the initial reconnaissance surveys, from production and postharvest handling problems, to packaging and transportation, to final market.

Introduction

Limes (*Citrus aurantifolia* and *Citrus latifolia*) are the third most important type of citrus produced in Guyana in terms of production volume, and are the leading citrus export. The seeded West Indian lime (also known as Mexican lime or Key lime) is the kind most widely grown. Small quantities of the seedless Tahiti lime (also known as Persian lime) and the Bears lime are also produced. Nearly all the limes are sold as fresh fruit in the domestic fresh market, although small volumes are exported to Barbados.

Harvest Maturity Indices

The quality of limes does not improve during storage, so it is important to harvest the fruit at the correct stage of maturity. Fruit size is not always correlated to maturity and due to the extended period of flowering and fruit set, days from flowering is not a reliable index of harvest maturity either. Several different external and internal indices may be used to determine harvest maturity. The most commonly used indices are external appearance and juice content.

The ideal harvest stage for export market limes is when the peel colour has changed from dark to light green (Figure 1), the surface is smooth, and the fruit feels slightly soft to the touch. If the fruit is picked too soon, the peel is likely to develop a dark rind scald. On the other hand, limes that are left on the tree for extended periods will start to turn yellow and are subject to stylar-end breakdown. Yellow coloured fruit are acceptable for the domestic market, but generally not for export. The postharvest life of yellow limes will be less than green coloured fruit. Limes that have over-matured and fallen to the ground are not acceptable for the fresh market.

Figure 1. Bears limes in various stages of maturity, with center fruit ideal for export.

Juice content should also be determined prior to the beginning of harvest. Random samples of fruit from various trees should be picked and separated into different size categories. The juice content (by volume) should be determined for each size category. Limes are mature enough for harvest when the juice content is 30% or higher. Limes of the size categories meeting the minimum juice content should be harvested.

Harvest Methods

Limes should be harvested by carefully twisting and pulling the fruit from the tree so the button (calyx and disk) remains attached to the fruit. Stems left on the fruit at picking should be cut off in order to avoid puncture damage to adjacent fruit. Careless picking

can result in plugging and is unacceptable. Plugging is when part of the peel tissue pulls loose from the rest of the fruit, creating an open wound at the top of the fruit. Avoid rough harvesting practices that cause fruit bruising. Pickers should wear protective gloves. Never shake the tree to harvest the fruit. Any fruit that falls to the ground is likely to be severely bruised and subject to postharvest decay. Ladders may be needed to facilitate harvesting of fruit borne on tall trees. The harvested fruit should be carefully put into padded field crates, well ventilated plastic containers, or picking sacks equipped with a quick-opening bottom. When filled, the sacks are emptied into larger field containers or the fruit may be taken to a collection site for preparation for market. At the collection site, the limes are separated by colour, cleaned, graded, and packed for market. The initial step in preparing the fruit for market involves eliminating the unmarketable fruit and separating the fruit by colour (Figure 2). Then the limes are cleaned, graded, possibly waxed, and packed.

Figure 2. Workers eliminating unmarketable fruit and separating the limes by colour.

Preparation for Market

Cleaning

The first step in preparing limes for market involves cleaning of the fruit surface to remove dirt, sooty mould, scale, spray residues, etc. In small-scale operations, the fruit can be cleaned by putting the fruit in a wash tank and gently rubbing with a soft cloth or soft brush. The wash water should be properly sanitized with 150 ppm hypochlorous acid (household bleach) and maintained at a pH of 6.5. 150 ppm is equal to 2 oz of household bleach (such as Marvex) per 5 gallons of water, or .3 liters of bleach per 100 liters of water. The water should also contain soap or a detergent.

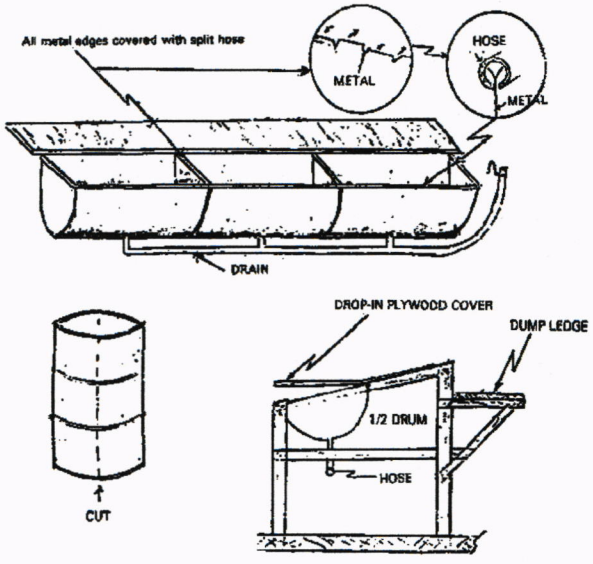

Figure 3. Steel drums cut in half serve as inexpensive and convenient wash tanks.

Steel drums can be used to make a simple washing stand. The drums are cut in half, fitted with drain holes, and all the metal

edges are covered with split rubber or plastic hose (Figure 3). The drums are then set into a sloped wooden table. The tabletop is constructed from wooden slats and is used as a drying rack before packing.

In larger scale operations, limes may be cleaned by passing the fruit along a series of revolving roller brushes. Initial rotating brushes will remove most debris, after which soap or detergent is sprayed onto the fruit to enhance cleaning as the fruit continues across the brushes. Adequate cleaning usually requires about 30 seconds on the brushes, rotating at about 100 rpm. The fruit is thoroughly rinsed as it passes over the last of the brushes and the excess water on the surface can be eliminated with sponge rubber rollers. A postharvest fungicide can be applied as an overhead spray following washing and water elimination. A spray wax application can also be made at this time.

Grading

Limes should be sorted and graded immediately following cleaning. The main fruit characteristics used in grading limes are size, colour, shape, and appearance of the peel. The minimum size requirement for marketing limes in the domestic market is a weight of 75 gm and diameter of 4 cm. There is no maximum limit for weight and diameter. Further sorting of limes into different size categories for domestic market sales may be worthwhile if a premium price can be obtained for certain sizes. For export markets, sizing of the fruit is essential. Limes should be separated into small, medium, and large sizes. In most small-scale operations, manual sizing is done with the use of standard size gauges made of wood or plastic. Examples of the different market sizes should be placed within view of the workers for easy reference. Mechanical sizers are also available for larger scale operations using conveyors fitted with rubber belts having openings of different sizes, with the smallest openings placed first and the largest openings put at the end of the line.

Within the size categories the fruit should also be separated according to peel colour and the amount of surface blemishes. Green and yellow coloured fruit should not be mixed in the same container. The limes in each carton should be uniform and consist of the same cultivar, quality, size, and grade. The fruit should not have any noticeable peel scarring, insect injury, decay, wounds, sunscald, oil spotting, and stylar-end breakdown. The fruit should also have a well-formed uniform shape typical of the cultivar. High quality limes are shiny, uniformly coloured, and free of surface injury, shriveling, and decay (Figure 4).

Figure 4. High quality uniformly coloured limes within each separate carton.

Waxing

Limes have a very thin peel cuticle (waxy covering) and are quite susceptible to moisture loss during storage. In addition, much of the lime's natural wax may be removed during washing. Limes will benefit significantly from a postharvest wax application, which will reduce the amount of dehydration during storage and give a shine to the fruit surface (Figure 5). The wax may be applied by hand rubbing, or mechanically as a foam, dip, spray or brush wipe. The wax is usually applied with water using an emulsifier, such as soap, to keep the wax soluble. Water-emulsion waxes do not require a completely dry fruit surface prior to application. Spray application is most commonly used in larger scale operations, using a pair of traveling spray nozzles over a bed of slowly rotating (not more than 100 rpm) horsehair-type brush rollers. The wax coating can be detrimental to limes if it is applied too thick. This may restrict oxygen absorption and cause off-flavor development of the juice. A fungicide can be incorporated in the wax to prevent postharvest decay. Recommended fungicides are thiabendazole or imazalil (2000 ppm) or benomyl (1000 ppm). The fungicide concentration incorporated in the wax is double the amount recommended in wash or spray water.

Figure 5. Waxed limes have a brilliant shine and attractive appearance.

Packing

Limes of uniform colour, size, and shape should be packed into each container. The packaging material used for limes depends on the intended market destination. The most commonly used container for domestic market sales are large sacks often filled with more than 30 kg (66 lb) of fruit. Mesh sacks are also commonly used for export shipments of limes to Barbados (Figure 6). However, sacks do not provide adequate protection against bruise damage and they cannot be stacked without causing compression injury to the fruit. Wooden crates provide much better protection to domestic marketed fruit. In order to avoid fruit compaction and compression injury, a maximum limit of 20 kg (44 lb) of fruit per container should be established.

Figure 6. Mesh sacks used for export do not provide adequate protection to the fruit.

Export market destined fruit should be packed in strong, well-ventilated fiberboard cartons. The carton should have a minimum bursting strength of 275 lb/in^2. The most common size cartons used for exporting limes contain 4.5, 9, or 18 kg (10, 20, or 40 lb) of fruit (Figure 7). All fruit within the carton should have a uniform appearance. Diphenyl treated pads are commonly put in export cartons to inhibit mould growth.

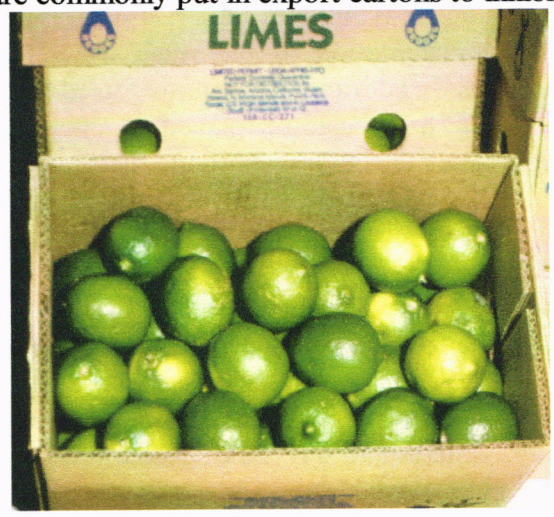

Figure 7. Two-piece fiberboard box of limes (without cover) filled with 4.5 kg of fruit.

Temperature Control

The West Indian lime loses its green peel colour and turns yellow if held at ambient temperature. The fruit also loses weight rapidly and begins to shrivel. In order to maximize market life and preserve fruit quality, limes should be cooled soon after harvest. The optimum storage temperature for limes is 9°C (48°F). At this temperature, limes will have a potential storage life of 6 to 8 weeks. Some loss of green colour will occur after 3 to 4 weeks and the peel is often yellow-green after 8 weeks. Holding limes at temperatures below 9°C should be avoided, as the fruit is susceptible to low temperature injury (chilling injury).

Relative Humidity

Limes are high in moisture content and susceptible to peel shrivel after harvest. In order to minimize water loss and preserve postharvest quality, limes should be held at their optimum relative humidity (RH) of 90% to 95%. At a low RH (i.e. < 70%) the peel will dry and cause the fruit to shrivel, adversely affecting the appearance and market quality of the fruit.

Principal Postharvest Diseases

Limes are susceptible to a number of different postharvest pathogens. Some of these microorganisms attack the fruit prior to harvest, but exist in a resting or dormant state until the conditions are right for infection. Others are problematic only after harvest. Limes should be harvested and handled gently to avoid bruising and skin injury, which

greatly accelerates postharvest microbial decay. In addition, adequate ventilation during storage is necessary to remove ethylene and other volatiles which may increase the incidence of decay.

Control of postharvest decay is obtained by a combination of treatments, including careful harvesting and handling to avoid skin injury, use of appropriate pre-harvest and postharvest fungicides, proper sanitation of the wash water, and appropriate storage temperature and RH conditions. In addition, pads impregnated with the fungistat diphenyl (at the rate of 4.7 gm/23 kg fruit) can be placed in shipping cartons to limit the development of postharvest decay during transport and distribution to market.

Green Mould

Green mould, caused by the fungus *Penicillium digitatum*, is a common postharvest disease of limes. It attacks injured areas of the peel and first appears as a soft, watery, de-colourized spot on the rind. Soon afterwards, an olive-green mould growth begins, surrounded by a broad zone of white mycelium. The fungus is a prolific spore producer, and airborne spores easily contaminate the packing area and storage environment. The decay spreads very little in packed cartons, but masses of spores produced on one infected fruit can soil surfaces of healthy fruit with green-coloured spores.

Green mould develops rapidly on non-refrigerated limes, and can be minimized by careful harvesting and handling practices, and postharvest use of benzimidazole fungicides (i.e. 500 ppm benomyl, or 1000 ppm thiabendazole or imazalil). Storage of the fruit at 9°C (48°F) will slow, but not eliminate, the growth of green mould. The fungus has the potential to develop resistance to postharvest fungicides due to its ability to produce large masses of spores.

Blue Mould

Blue mould, caused by the fungus *Penicillium italicum*, is a frequently observed postharvest disease of limes during storage. It attacks injured areas of the peel and first appears as soft, watery, de-colourized spots on the rind. Soon afterwards, a blue mould growth begins, surrounded by a zone of white mycelium. A pronounced halo of water-soaked, faded tissue surrounds the lesion between the fringe of fungal growth and the sound tissue. The blue spores covering the fruit may become brownish-olive with age. Adequate ventilation of the storage room is important because high concentrations of ethylene will increase the incidence of blue mould. Recommendations for control of blue mould are similar to the ones used for green mould. Unlike green mould, blue mould spreads in packed containers and results in nests or pockets of diseased fruit.

Stem-end Rot

Limes are susceptible to two different kinds of stem-end rot, caused by the fungi *Diplodia natalensis* and *Phomopsis citri*. Fungal spores lodge beneath the calyx at the time of flowering and remain dormant until the fruits are harvested. The fungus becomes

active at the stem end of the fruit and symptoms appear within several weeks after harvest at ambient temperature. Symptoms include the formation of water-soaked spots near the stem end of the fruit, which turn light or dark brown. In the case of Diplodia stem-end rot, the decay proceeds unevenly down the rind, producing finger-like projections of brown tissue. Fungal growth progresses rapidly through the spongy central axis of the fruit. Decayed tissue is initially firm, but later becomes wet and mushy. In the case of Phomopsis stem-end rot, the decay spreads evenly down the fruit surface. The infected tissue shrinks and shows a clear line of separation between diseased and healthy rind tissue. Stem-end rot decay usually does not spread from infected to healthy fruit in packed containers. Control of stem-end rot is obtained by pre-harvest fungicide sprays, postharvest application of imazalil (1000 ppm), and storage of the fruit at 9°C (48°F).

Postharvest Disorders

Chilling Injury

Limes are very susceptible to low temperature injury, commonly known as chilling injury (CI). It is a physiological disorder that adversely affects the appearance and quality of the limes and occurs at temperatures below 9°C (48°F). Different cultivars of limes have different thresholds of susceptibility to CI. In addition, growing location influences the susceptibility of the fruit to CI. Fruit symptoms include pitting, the formation of leathery brown sunken lesions on the peel surface, secondary decay, and off-flavor of the pulp. Damage is a function of temperature and time, with more CI incurred at lower temperatures and longer exposure durations. Maintaining a RH near 100% will reduce the amount of CI symptom development.

Oleocellosis

Oleocellosis, also known as oil spotting, is caused by the phytotoxic action of peel oil released onto the surface of the rind as a result of abrasion, rough handling, punctures, and other injuries. This results in necrosis of the adjacent epidermis and the formation of irregularly shaped yellow or brown spots in which the oil glands of the skin stand out prominently because of slight sinking of the tissues between them. The spots vary in size and shape. The fruit surface develops a pebbly texture along with the rind discolouration. Wet conditions at harvest accentuate this disorder by making the rind more swollen and subject to the rupturing of the oil glands. Fruit can be swollen and wet in the early morning and should not be harvested. The contact of wet fruit with sand in the field container during harvest is especially hazardous. Oil spotting normally does not show up until several days after harvest.

Oil spotting can be reduced by picking fruit in the afternoon of sunny days, delaying picking for several days after a rain or irrigation, using padded field containers, and having pickers use cotton gloves.

Stylar-end Breakdown

Tahiti limes are susceptible to a collapse of the rind at the blossom or stylar-end of the fruit. The initial symptom of stylar-end breakdown (SEB) is a water-soaked grayish or tan patch, especially near the blossom end of seedless limes (Figure 8). It progresses rapidly and may eventually cover up to half of the fruit surface. The affected area dries and becomes sunken. Postharvest decay commonly follows SEB. Fruit picked early in the morning, when the fruit can be swollen, are more susceptible to SEB. High temperatures at the time of picking and during transit increase the incidence of this disorder. Rough handling also accentuates SEB. Large sized fruit are the most susceptible to this disorder. Small fruit less than 3.5 cm in diameter show little incidence of SEB. This disorder can be minimized by holding the fruit at 9°C (48°F).

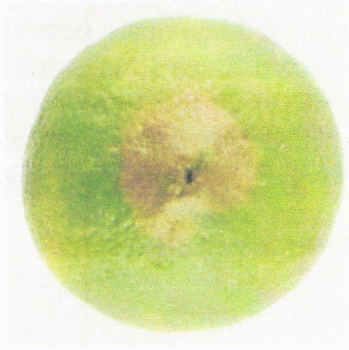

Figure 8. Stylar-end breakdown of Tahiti lime.

De-greening

In many markets, the preferred peel colour for limes is green. Therefore, it is desirable to inhibit the loss of chlorophyll so the fruit remains a uniform green colour as long as possible (Figure 9). Several treatments will significantly extend the time of green peel colouration. These include treating limes before harvest with gibberellic acid to delay senescence and dipping the fruit in hot water (50°C to 53°C; 120°F to 126°F) for 2 to 3 minutes prior to grading.

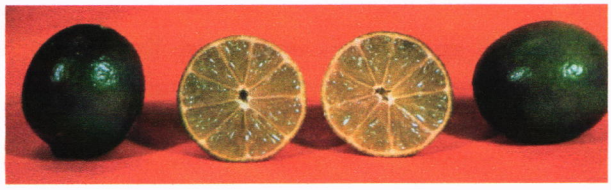

Figure 9. A uniform green peel colour is desirable in many export markets.

Exposure to ethylene causes limes to lose their green peel colour and slowly turn yellow. This is undesirable if the intended market prefers green-coloured limes. Removal of ethylene from the storage environment can be achieved by proper ventilation, removal of decaying fruit, and placement of potassium permanganate granules in the storage room to absorb ethylene. Also, limes should not be stored with other high ethylene emitting fruit like passion fruit, bananas or plantains.

ANNEX I

PUBLICATIONS IN THE POSTHARVEST HANDLING TECHNICAL BULLETIN SERIES

PH Bulletin No. 1	Pineapple: Postharvest Care and Market Preparation, November 2002.
PH Bulletin No. 2	Plantain: Postharvest Care and Market Preparation, June 2003.
PH Bulletin No. 3	Mango: Postharvest Care and Market Preparation, June 2003.
PH Bulletin No. 4	Bunch Covers for Improving Plantain and Banana Peel Quality, June 2003.
PH Bulletin No. 5	Papaya: Postharvest Care and Market Preparation, June 2003.
PH Bulletin No. 6	Watermelon: Postharvest Care and Market Preparation, October 2003.
PH Bulletin No. 7	Peppers: Postharvest Care and Market Preparation, October 2003.
PH Bulletin No. 8	Oranges: Postharvest Care and Market Preparation, October 2003.
PH Bulletin No. 9	Tomato: Postharvest Care and Market Preparation, October 2003.
PH Bulletin No. 10	Okra: Postharvest Care and Market Preparation, October 2003.
PH Bulletin No. 11	Pumpkin: Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 12	Lime: Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 13	Grapefruit: Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 14	Passion Fruit: Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 15	Green Onions: Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 16	Sweet Potato: Postharvest Care and Market Preparation, January 2004.

PLANNED PUBLICATIONS - 2004

Cassava: Postharvest Care and Market Preparation.

Eggplant (Boulanger): Postharvest Care and Market Preparation.

Yam: Postharvest Care and Market Preparation.

Ginger: Postharvest Care and Market Preparation.