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Postharvest Handling
Technical Bulletin

TOMATO

Postharvest Care and Market Preparation

Technical Bulletin No. 9

October 2003

POSTHARVEST HANDLING TECHNICAL SERIES

TOMATO

Postharvest Care and Market Preparation

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

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Table of Contents

Preface 1

Introduction 2

Harvest Maturity Indices 2

Harvest Methods 4

Preparation for Market 5

A. Cleaning 5

B. Waxing 7

C. Grading 7

D. Packing 9

E. Ripening 10

Temperature Control 10

Relative Humidity Control 11

Principal Postharvest Diseases 11

A. Bacterial Soft Rot 12

B. Bacterial Sour Rot 12

C. Alternaria Rot 12

D. Rhizopus Rot 13

E. Buckeye Rot 13

F. Sour Rot 14

G. Sclerotium Rot 14

H. Anthracnose 15

Physiological Disorders 15

A. Chilling Injury 15

ANNEX I: Publications in the Postharvest Handling Technical Bulletin Series 16

Preface

This publication is part of a series of technical bulletins that seeks to provide specific recommendations for improvements in postharvest care 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 post harvest handling problems, to packaging and transportation, to final market.

Introduction

Tomatoes are one of the leading vegetable crops grown in Guyana. Production is year-round and nearly the entire volume is marketed domestically, with only small volumes exported to Barbados. The most common tomato types grown in Guyana have a round to slightly flattened shape, or are elongated. They typically have a thick fruit wall in order to withstand the rigors of handling and transport. Postharvest care recommendations are similar for all tomato cultivars. Tomatoes have a very short market life if harvested fully ripe. Mature-green or breaker stage fruit may last for several weeks. Tomato fruit are very delicate and can quickly be injured by rough harvesting and handling practices. The fruit is also damaged by holding at either too low or too high a temperature. Proper postharvest handling and storage methods are essential for maintaining acceptable quality and extending the market life.

Harvest Maturity Indices

The average time from transplanting to harvest of large-fruited cultivars ranges from 60 to 70 days for early cultivars, 70 to 80 days for mid-season cultivars, and more than 80 days for late cultivars.

There are several reliable external and internal indices of tomato fruit maturity. The external fruit maturity index is based on skin colour, while the internal indices are based on seed development and locular gel formation. Also, location of the fruit on the plant and fruit size may be used as rough guides in determining where to look for mature fruit. However, by themselves they are not reliable indicators of maturity.

The most widely used index of tomato maturity is skin colour. Distinct changes in external colour occur in tomato fruit which can be used to determine harvest maturity. Skin colour remains green during fruit development on the plant. As the fruit becomes mature, the blossom end changes to a light green or whitish colour. One or more distinct white streaks usually form at the blossom end, typically in the shape of a star. At this stage, the fruit is mature and ready for harvest and is referred to as being 'mature-green'. The fruit will continue to change colour, regardless if it is attached or detached from the plant. Tomato fruit colouration follows a typical sequence with ripening. With red-skinned cultivars, after the mature-green stage the tip of the blossom end will change to a pinkish-yellow colour, which is commonly referred to as the 'breaker stage'. The breaker stage usually occurs within a day after the mature-green stage. The entire fruit then turns colour to pink, followed by light red, and finally deep red. The ripening stages of mature tomato fruit are categorized as green, breaker, turning, pink,

Figure 1. Ripening stages of mature tomato fruit; from left to right: green, breaker, turning, pink, light red, red.

light red, and red (Figure 1) and are described in Table 1. For maximal market life, tomatoes should be picked at the mature-green stage. They will be able to tolerate the stresses of handling and transport much better at this stage. Properly handled mature-green tomatoes develop flavor to the same extent as fruit left on the vine another day, until the 'breaker' stage. However, if immature green stage fruit are inadvertently picked, eating quality is reduced. Immature green tomatoes will ripen poorly and be of low quality. The problem is when pickers are unable to determine the difference between immature green and mature-green fruit in the field. A tomato picked at the breaker stage will be indistinguishable in quality from one that has ripened to a full red colour on the vine. However, fruit allowed to ripen to a full red colour before picking will have a significantly shorter market life. Red fruit will be much more susceptible to bruising and injury during harvest and postharvest handling. This will result in more deterioration and postharvest decay.

Table 1. Terminology used to describe tomato colour as an indication of ripeness stage.

Colour	Description
Green	The surface of the tomato is completely green. The shade of green may vary from light to dark.
Breaker	There is a definite break in the colour from green to yellow, with pink or red skin covering not more than 10 percent of the surface.
Turning	More than 10 percent but not more than 30 percent of the surface, shows a definite change in colour from green to yellow, pink, red, or a combination of these colours.
Pink	More than 30 percent but not more than 60 percent of the surface shows pinkish red or red colour.
Light Red	More than 60 percent but not more than 90 percent of the fruit surface shows pinkish red or red colour.
Red	More than 90 percent of the surface shows red colour.

The two internal fruit characteristics commonly used to determine harvest maturity of green fruit are seed development and locular jelly formation. Mature-green fruit have fully developed tan-coloured seeds which will not be cut when the fruit is sliced with a sharp knife. The seeds in immature green fruit are white and not sufficiently formed, and are cut through when the fruit is sliced open with a knife. The fruit cavity of mature-green fruit is completely filled with jelly in each of the locules. Immature green fruit have one or more locules without jelly. Internal characteristics are used for determining harvest maturity of randomly selected green fruit of different sizes. It is then assumed that all green fruit of similar size from the same location on the plant will be of the same maturity. On this basis, mature-green fruit can be harvested according to size. Pickers should be trained on how to determine harvest maturity in order to avoid picking immature green fruit. The quality and flavor of immature green harvested fruit will be inferior and picking these fruit should be avoided.

The harvest maturity stage depends on the intended market destination and the time needed to market the fruit. Tomatoes for local markets can be harvested at the mature-

green stage if they will be held for a week or more, or they can be allowed to develop more colour before picking, according to buyer preferences. Tomatoes intended for export should be harvested at the mature-green stage, or the breaker stage if they will be marketed as 'vine-ripe. Fruits harvested at the breaker stage can be handled and shipped with less damage than those with more colour. The fruit from new 'long-shelf life' tomato cultivars stay firm for several weeks, even when picked at the breaker stage.

Vine-ripe tomatoes must be harvested every other day to avoid having too many red fruit. Mature-green tomatoes are normally harvested only four or five times during the season.

Harvest Methods

Tomatoes should be removed from the plant by gently twisting or rotating them in order to cleanly remove the stem from the fruit. The stems in most field-type tomato cultivars release at the point of attachment to the fruit (termed 'jointless'). However in some cultivars, a natural abscission layer or break point forms at the junction of the stem and the stalk when the fruit is mature (termed 'jointed'). With these cultivars, pickers should grasp the fruit firmly but gently and pull upward with the thumb and forefinger pressed against the stem (Figure 2). The stem should then be carefully removed prior to putting the fruit in the harvest container to prevent puncture wounds of adjacent fruit.

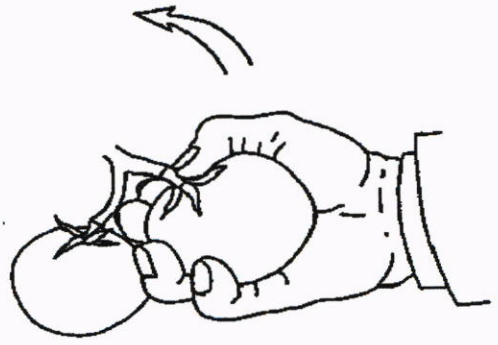

Figure 2. Harvest procedure for removing 'jointed' tomato fruit from the plant.

Workers should wear cotton gloves during picking to minimize harvest damage and to protect the skin of the fingers. If gloves are not worn, all fingernails should be trimmed short to avoid puncturing the skin. Jewelry such as rings and bracelets should also be removed to reduce mechanical damage to the fruit during harvest. Harvested fruits should not be thrown or dropped into the picking container, as they are very susceptible to bruise damage. The picking container should have smooth inner walls to prevent abrasion of the fruit (Figure 3). Ideally, picking containers should be wide, shallow, and stackable to avoid excessive weight and bruising of tomatoes at the bottom of the container. A well-ventilated plastic crate is ideal. It is recommended not to fill the container with more than 10 kg of fruit. Tomatoes may suffer compression injury if piled too high in the picking container. This is especially problematic if the fruit are picked in the afternoon with a high pulp temperature.

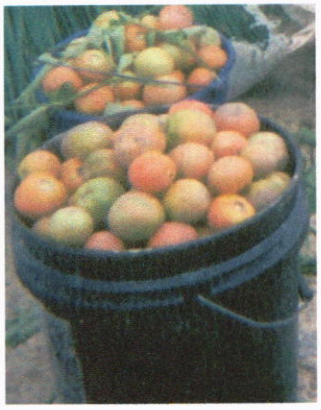

Figure 3. A smooth-lined plastic pail is an appropriate tomato harvest container.

Tomatoes should be picked during the coolest part of the day, such as early morning or late afternoon. If they are picked in the morning, harvest should be delayed until the moisture has dried off the fruit surface. Tomatoes should never be picked in the rain or when they are wet. Harvesting wet fruit encourages the spread of decay. It is also important to avoid picking the fruit when it has a pulp temperature over 25°C (77°F). Fruit with higher pulp temperatures is very susceptible to pressure bruising when squeezed too hard during the picking process. Fruit should never be allowed to remain in the sun for extended periods. Tomatoes held in the sun for an hour on a hot, sunny day can be 10°C (50°F) hotter than fruit kept in the shade.

Fruit which are injured, diseased, or unmarketable should be removed from the plant and not mixed in the same harvest container as the marketable fruit. The culled fruit should be removed from the field to avoid the buildup of insect pests and diseases.

Preparation for Market

The harvested tomatoes should be taken to the packing area soon after picking to begin the process of cleaning, grading, and packing. During all operations, from harvest through packing, the fruit should be handled carefully to avoid bruising and injury to the tissue. Bruises can affect ripening and cuts or injuries to the skin and predispose the fruit to invasion of decay-causing organisms. The fruit should be kept in a well-ventilated shaded area during market preparation.

Cleaning

The initial step in preparing tomatoes for market is to clean the surface of the fruit and remove any dirt, surface stains, or adhering leaf tissue. Depending on the volume of fruit to be cleaned, the process can be done manually or automatically. Small scale operations usually choose to clean the individual fruit by wiping them with a damp cloth just prior to grading. Larger volume operations may choose to use a water dump tank or overhead spray wash system to clean the fruit. In order to avoid the spread of disease, the wash water should be clean and regularly sanitized by maintaining a 150 ppm sodium hypochlorite concentration (2.4 pints of 5.25% household chlorine bleach to 100 gallons of water) and a water pH of 6.5. The chlorine level and pH of the wash water should be checked at least hourly during the day with paper test strips or portable meters. If a conductivity meter is used to check the sanitizing potential of the water, the oxidation-reduction potential (ORP) should be at least 650 millivolts mV to kill the soft rot and sour rot bacteria freely suspended in the water. However, water chlorination may not eliminate the more tolerant fungal pathogens such as *Rhizopus* and *Botrytis*.

The sanitizing effect of chlorine is greater at higher water temperatures and the wash tank water temperature should range between 16°C to 27°C (60°F to 80°F) for effective sanitation. The temperature of municipal or well water in Guyana should fall within this range. Use of cool water relative to the tomato fruit temperature can be a problem. When

tomatoes are submerged in water of a lower temperature, the air inside the fruit contracts and water is drawn in through the stem scar or any openings in the skin. If the water is contaminated with microorganisms they will also enter the fruit through the stem scar, growth cracks, or damaged areas of the cuticle. Water will not be drawn into the fruit if the water temperature is higher than the tomato temperature. Ideally, it is recommended to heat the wash water temperature about 5°C (10°F) higher than the fruit temperature. At the least, the water temperature should not be less than the pulp temperature of the tomato. Therefore, it is very important to check both the water and fruit temperatures prior to cleaning and maintain a slightly warmer wash water temperature. The tomato fruit temperature at the time of harvest generally ranges from 22°C to 32°C, depending on the time of day and whether it was exposed to full sun or shaded. Keeping harvested tomatoes in the shade is highly recommended to minimize an increase in pulp temperature and avoid the necessity and cost of heating water.

The immersion depth of the tomato fruit in the water tank should not exceed 60 cm (2 feet). Pressure from deeper submersion forces pathogen-containing water through the stem scar into the fruit. In addition, the length of submergence time should not exceed 2 minutes. At the recommended 150 ppm concentration of hypochlorous acid and water pH of 6.5, the fruit should be sufficiently sanitized after about 30 seconds (Figure 4).

The other method to clean the fruit prior to grading is to move the tomatoes under a series of high pressure (> 60 psi) spray nozzles as they move over a set of soft brush rolls (Figure 5). The water remaining on the fruit surface should be removed by air drying, fans, or sponge-rollers prior to packing the fruit.

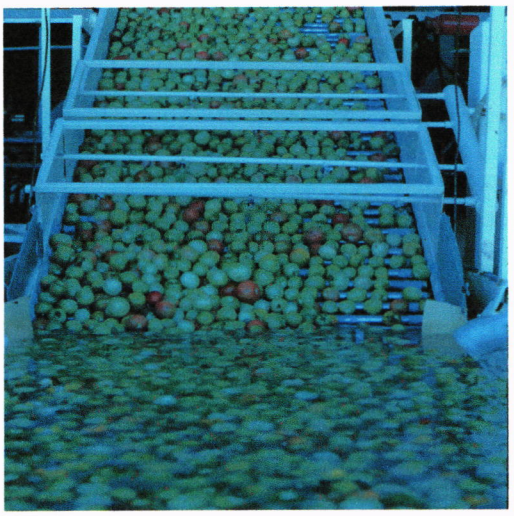

Figure 4. A properly sanitized wash tank is essential to minimize postharvest decay.

Figure 5. Over-head spray of high pressure water for cleaning mature green tomato fruit.

Waxing

A thin water-wax emulsion spray coating can also be applied to the fruit as the final step in the cleaning process. Waxing the fruit will enhance its appearance and make it more glossy. Waxing can reduce fruit shriveling and increase market life. Waxing also provides lubrication to the fruit surface which reduces rubbing injury during transit. Care should be taken to prevent heavy waxing of the stem scar because ripening will be adversely affected. Tomato waxes must be food-grade and are often made from plant extracts (i.e. candellila) or insect extracts (i.e. shellac, beeswax).

Grading

All tomatoes must be sorted and graded before packing for market. The main fruit characteristics used to grade tomatoes are size, colour, shape, appearance, and firmness.

Tomatoes should be separated into small, medium, and large sizes. If it is a round-type cultivar, this is typically based on fruit diameter. Size generally does not influence flavor, but does affect market demand and price. This holds true whether the fruit are sold domestically or exported. An example of the size classification used for tomatoes exported to North America is shown below in Table 2.

Table 2. Size classification of tomatoes intended for export to North America.

Size	Minimum Diameter	Maximum Diameter
Small	5.40 cm (2.13 in)	5.72 cm (2.25 in)
Medium	5.79 cm (2.23 in)	6.35 cm (2.5 in)
Large	6.43 cm (2.5 in)	7.30 cm (2.87 in)
Extra Large	7.30 cm (2.87 in)	

In small-scale operations, tomatoes are usually sized manually by one or more workers. Fruit is hand placed into the different market containers based on the acceptable pre-established size categories for the market. Larger-scale operations use various types of packinghouse equipment to speed up the grading and sizing process. Tomatoes may be sized by passing the fruit over a series of perforated belts with holes corresponding to the maximum allowable diameter for the particular size/class (Figure 6).

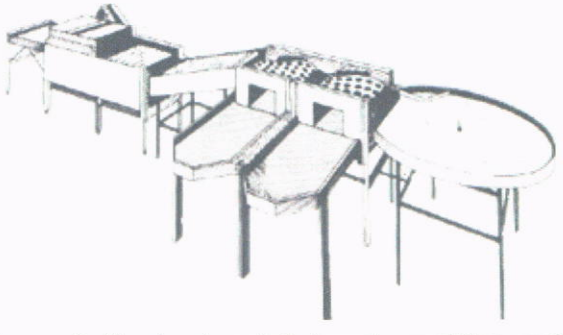

Figure 6. Semi-automated tomato washing and sizing equipment.

A rotating bar-sizer may also be used, constructed out of a series of PVC tubes of gradually increasing opening width (Figure 7). It is very important that the drop height be minimized and all impact surfaces be well padded. A layer of 1.5 cm (.6 inches) closed-cell foam with a

smooth, washable outer surface should be adequate. A daily cleaning with a strong chlorine solution (1/2 pint or .24 liters of 5.25% hypochlorous acid (bleach) per gallon or 3.79 liters of water) followed by a clean water rinse will help prevent the buildup of decay organisms on packing equipment.

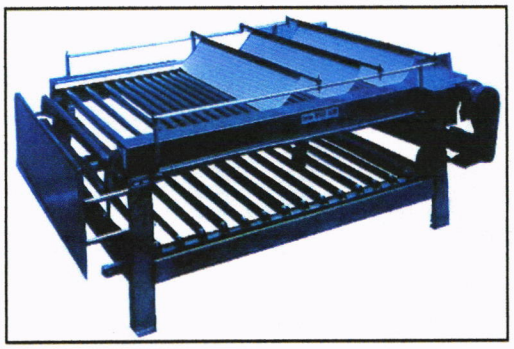

Figure 7. Rotating bar-sizer for categorizing tomato fruit.

Tomatoes of uniform colour should be packed into each container. Buyers do not like a mixture of ripeness stages and fruit colours within the same container (Figure 8). When marketing ripe fruit in the domestic market, the fruit should be as free of yellow shoulder as possible. This is a quality defect characteristic of certain cultivars and accentuated by low potassium fertility that negatively affects external appearance as well as internal eating quality (Figure 9).

Figure 8. Fruit of mixed ripeness stages should be separated and packed into different cartons.

Figure 9. Yellow shoulder is a common ripening disorder of certain cultivars.

The fruit should also have a well-formed uniform shape typical of the cultivar. Deformed or catfaced fruit should be culled out and not be packed for market, particularly if the fruit are intended for export (Figure 10). The fruit should have a smooth, shiny external appearance, with small blossom-end and stem-end scars. The fruit should be void of cracks, bruises, open wounds, sunscald, insect injury, and decay. Finally, the fruit should be firm enough to withstand transport and distribution to market. Soft and over-ripe fruits should not be packed for market, as they will bruise easily and not tolerate transport and handling

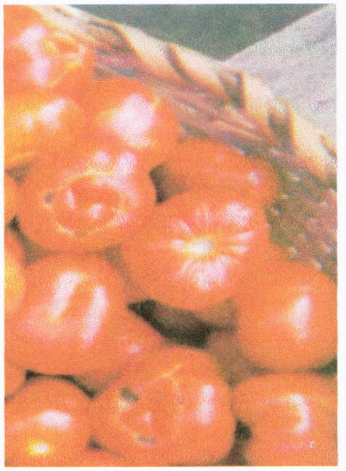

Figure 10. Irregular shaped catfaced fruit sold in Parika market, below export quality.

without suffering high amounts of postharvest losses. High quality fruit are firm, shiny, uniformly coloured, and free of mechanical injury, shriveling, and decay.

Packing

The fruit surface must be free of moisture before packing in order to reduce storage rots. The type of container used for packing tomatoes depends on the market destination. Tomatoes sold in the domestic market are packed in a diversity of container types. However, they should be well-ventilated, strong, and capable of being stacked without damaging the fruit. They should not be over-stuffed. Improper packaging can be a major source of postharvest loss (Figure 11).

Figure 11. Over-filled, inadequately ventilated wooden crates.

Figure 12. Well-ventilated fiberboard cartons used for exporting mature-green tomatoes.

Sized and graded mature-green tomatoes destined for export are typically packed loose in strong well-ventilated fiberboard cartons containing a net weight of 11 kg (25 lb). Carton dimensions are usually 30 x 40 x 24 cm (12 x 16 x 9.5 in) (W x L x H) The cartons should have a minimum test strength of 275 psi (Figure 12).

Vine-ripe fruit (i.e. breaker stage) are commonly packed in two-layer 9 kg (20 lb) cartons. The fruit is typically oriented with the stem scar facing down (Figure 13). In addition, the vine-ripe fruit may be wrapped in tissue to protect the fruit against abrasion damage during transit (Figure 14).

Figure 13. Vine-ripe tomatoes packed in 9 kg carton for export.

Figure 14. Vine-ripe tomatoes individually wrapped in tissue to protect against abrasion.

Roma-type tomatoes are normally packed in 11 kg cartons, while cherry and mini-pear tomatoes are typically packed in 227 to 454 g (8 to 16 oz) trays which are placed in larger fiberboard cartons containing 12 trays.

Ripening

Ripening of tomatoes is initiated by ethylene, a natural ripening hormone produced by the tomato fruit. Application of additional external ethylene may be used to promote faster and more uniform ripening of mature-green tomatoes. Fruit beyond the breaker stage do not benefit from supplemental ethylene because their ripening processes already have been initiated by their own ethylene.

The ethylene treatment consists of exposing mature-green fruit to 150 ppm ethylene for durations of 24 to 72 hours at temperatures ranging from 18°C to 21°C (65F° to 70°F) and 90% to 95% relative humidity. The length of exposure and temperature chosen depends on how soon red-coloured fruit is desired. The speed of the ripening process is increased with longer durations of exposure and higher temperatures. Mature-green tomatoes should start to develop red colour in 5 to 7 days at 19°C to 20°C.

Ethylene is applied in a fairly airtight room by using a commercially available catalytic generator or by using a flow-through system where the ethylene comes from a high pressure gas cylinder. The room should have good temperature control capability, good internal air circulation, and proper ventilation to prevent carbon dioxide (CO_2) from building up to more than 1%, which would retard the action of ethylene in stimulating ripening. The CO_2 comes from the respiring tomato fruit.

Temperature Control

The optimal storage temperature for tomatoes depends on the stage of ripeness. Fruit harvested at the mature-green stage should be held between 13°C to 20°C (56°F to 68°F), depending how long the fruit need to be stored. Holding the fruit at the lower end of the temperature range will maximize the storage life, which is up to 4 weeks with mature-green fruit. Holding mature-green tomatoes above 25°C (77°F) will result in soft fruit with a lighter red colour upon ripening. At temperatures above 35°C (95°F), mature-green fruit will not turn red (Figure 15).

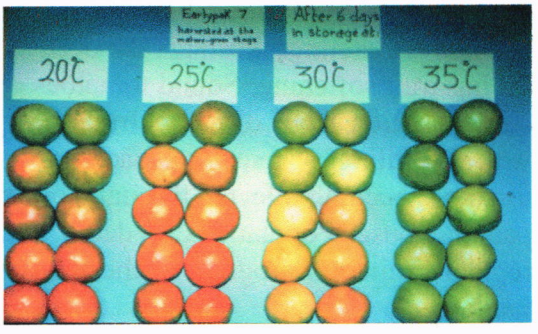

Figure 15. Red colouration is inhibited in mature-green fruit held at 35°C or higher

Fully red fruit can be stored at 10°C (50°F) for maximizing market life, which is about 7 to 10 days. However, tomatoes should never be held at temperatures below 10°C, as chilling injury will result and the fruit will not ripen properly.

Tomatoes destined for distant markets or tomatoes in the pink or light red stage should be cooled as soon as possible after harvest to avoid becoming overripe before reaching the consumer. Proper temperature control is critical to product quality and shelf life.

Relative Humidity Control

A high relative humidity (RH) is essential to maintain tomato quality and prevent fruit shrivel. The ideal storage RH for tomatoes is between 90% and 95%.

Tomato fruit are very high in water content and susceptible to shrinkage after harvest. Most of the water loss occurs through the stem scar or any cracks in the skin. Fruit shrivel may become evident with as little as 3% water loss (Figure 16). The amount of shrivel depends on the temperature, RH, and length of storage. Completely saturated atmospheres of 100% RH should be avoided, as moisture condensation on the fruit encourages the growth of surface molds and fungal decay in the stem scar area.

Figure 16. Storage of tomatoes at a low RH result in fruit shrivel.

Principal Postharvest Diseases

The major cause of postharvest loss in tomatoes is physical damage to the fruit which results in postharvest decay. Physical damage may be incurred during harvest, by rough handling, from improper packaging, or during transport. Wounds such as punctures, cuts, abrasions, and cracks as well as stem scars provide potential points of entry for decay organisms. Therefore, tomatoes with surface injuries should be separated promptly from sound fruit and discarded before decay can occur and spread. The fruit is very delicate and should always be handled carefully and gently. It is essential to devise methods of minimizing fruit injury to obtain adequate market life of the fruit.

Tomato fruit are susceptible to numerous bacterial and fungal decays, from the field through marketing. Postharvest decays often develop in wounds, bruised tissue and during fruit softening. Sound tomatoes can be inoculated by disease organisms via cross-contamination from diseased fruits, dirty harvest containers and from poorly sanitized water handling systems and packing line components. Devastating losses can occur if tomatoes become infected through absorption of contaminated water in dump tanks at the packinghouse. Populations of decay pathogens can be adequately controlled through a regular sanitation program in the field and during all the steps in preparing the fruit for market.

Bacterial Soft Rot

Bacterial soft rot is the main postharvest bacterial decay of tomatoes. It is caused by one of several bacterial pathogens, including *Erwinia carotovora*, *Xanthomonas campestris*, *Pseudomonas* species, and *Bacillus* species. Soft rot decay may develop at any injured site on the fruit surface. The bacteria can also enter the fruit through the stem scar of tomatoes in unheated wash water tanks. Lesions are initially soft and slightly depressed, appearing watersoaked near the margins (Figure 17). Rotting is rapid at ambient temperature and the skin may split, with leakage of infected juices. The soft, mushy tissues of decaying fruit also have a characteristic foul odour.

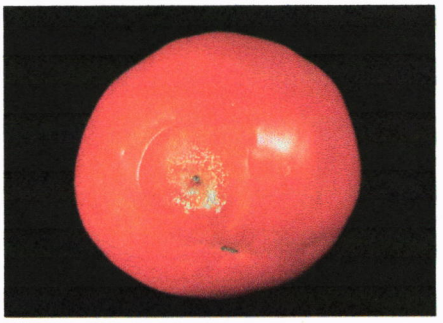

Figure 17. Bacterial soft rot developing around punctured area of tomato fruit.

Bacterial Sour Rot

Bacterial sour rot is the second most common postharvest bacterial disease of tomatoes. It is caused by several different bacteria, including *Lactobacillus* species and *Leuconostoc mesenteroides*. On green fruit, watery rot lesions have a dull, greasy, water-soaked to bleached appearance. Although the decay may originate at cracks, cuts, or skin punctures, it frequently is found starting at the edge of the stem scar. The affected tissues remain fairly firm until the decay is quite advanced (Figure 18). The fruit have a definite sour odour. Bacterial soft rot often follows sour rot.

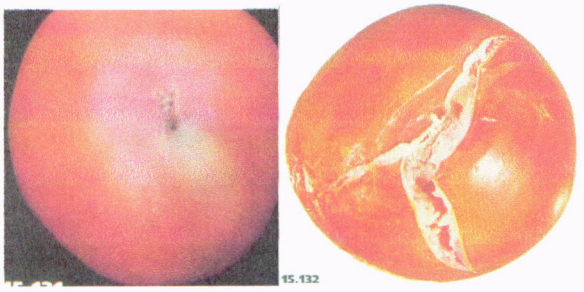

Figure 18. Early stage symptoms (left) and advanced stage symptoms (right) of sour rot.

Alternaria Rot

Alternaria rot, caused by the fungus *Alternaria alternata*, is a common soil-borne tomato disease, where it survives on plant debris. It does not usually attack sound fruits which have been grown under good conditions and stored correctly after harvest. However, infection can occur via insect injuries, cracks at the stem end, weakened tissue due to sunscald, chilling injury, or overmaturity. Lesions begin as sunken or slightly flattened areas, sometimes water-soaked in appearance. They may not have definite margins, and they extend

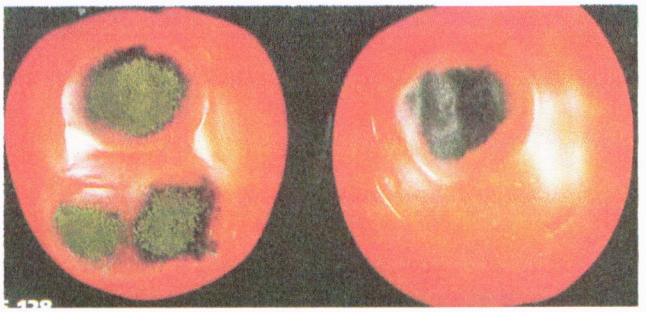

Figure 19. Tomato fruit infected with Alternaria rot.

into the fruit as a large mass. The exterior of the lesions soon becomes brown to black. The surface of lesions becomes covered with a dense, dark gray to black covering fungal growth (Figure 19). Most lesions are located on the shoulders or adjacent to the stem scar of the fruit, primarily because these tissues often have small cracks in the cuticle. Green fruit are quite resistant. However, lesions develop in chilled tomatoes or those damaged by sunscald or impact injury to the shoulders (black shoulder). In ripening fruit, Alternaria infects various breaks in the skin. The disease progresses most rapidly at 24°C to 28°C (75°F to 82°F), particularly in overripe fruit. Fruit-to-fruit spread occurs in tomatoes stored for long periods of time. Control of this disease is obtained by avoiding physical damage to the skin tissue and storage of the fruit between 10°C to 13°C (50°F to 55°F).

Rhizopus Rot

Rhizopus rot, caused by the fungus *Rhizopus stolonifer*, primarily attacks ripe fruit, although tomatoes at all stages of ripeness may be affected. Lesions begin as rapidly enlarging, water-soaked areas located adjacent to wounds, stem scars, or open stylar pores. Normally the affected area is not discoloured, but the lesions are soft and somewhat watery. Under high humidity, grayish white masses of mold structures develop over the surfaces of diseased fruit (Figure 20). In packed cartons of tomatoes, nests of fungal structures and decayed fruit will develop. The odour of fruit infected with Rhizopus rot is similar to that of fermentation. The optimum temperature for disease is 24°C to 27°C (75°F to 81°F). Little disease occurs at 10°C.

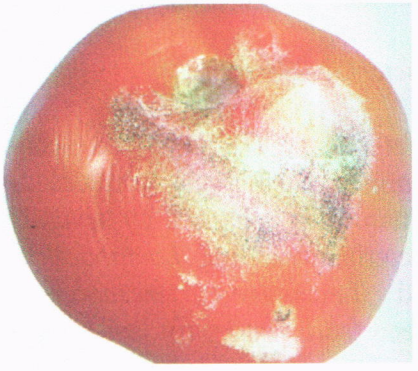

Figure 20. Rhizopus rot of tomato.

Buckeye Rot

Buckeye rot is caused by several different species of the fungus *Phytophthora.* Lesions on the fruit first appear as small, sunken, light-to dark-coloured, water-soaked areas adjacent to or associated with injuries and natural openings. Bacterial ooze may flow from wounds, breaks in the epidermis over lesions, or through the stem scar. Initial infection usually occurs via the stem scar or through open pores at the blossom end of the fruit. Early external symptoms of buckeye rot include softening of parts of the fruit surface, and a dark, water-soaked area adjacent to the stem scar or blossom end. Lesions begin as water-soaked spots, which later develop concentric rings of various shades of brown (Figure 21). A humid atmosphere allows for the formation of an off-white mold.

Figure 21. Buckeye rot of tomato.

Sour Rot

Sour rot is caused by the common soil-borne fungus *Geotrichum candidum*. Greasy, water-soaked lesions begin at wounds or at the edge of the stem scar. On mature-green fruit the lesions appear pale and dull, and have a definite sour odour. On ripe fruits, infected tissue is dark, soft, and watery. If the skin splits then a creamy white mold develops on the exposed flesh, producing sticky spores (Figure 22). In ripe fruit the disease progresses rapidly, particularly under warm conditions. The epidermis covering the lesions usually cracks, allowing the watery contents to spill out. Fruit may become contaminated with sour rot through contact with fruit flies and other insects, splashing rainfall, decaying vegetation, and pickers. The sour-rot fungi are considered wound pathogens and cannot penetrate the fruit epidermis directly. However, if infiltrated into tomato fruit, the fungi will cause disease. Green fruit are generally not attacked by sour rot; however, chilled green tomatoes are quite susceptible. The disease may advance rapidly through containers of ripe tomatoes. Fruit-to-fruit spread is facilitated by the watery contents of the lesions. The fungus thrives under conditions of poor ventilation, when the air is warm, moist, and low in oxygen. The optimal temperature for sour rot growth is 30°C (86°F). Care should be taken to minimize mechanical damage during harvesting, and to discard fruit with stem-scar cracks. It is also important to control the insects which spread the spores and puncture the fruit. Holding the tomatoes at 10°C (50°F) will also minimize the development of sour rot.

Figure 22. Sour rot of ripe tomato fruit.

Sclerotium Rot

The fungus *Sclerotium rolfsii* is widespread in Guyana and causes sclerotium rot of tomatoes. Fruits near the ground may become infected as a result of soil particles being splashed up during rain. If the infected fruits are kept at ambient temperatures after harvest, sclerotium rot develops rapidly and spreads to healthy fruit. Symptoms of decay include discoloured and sunken areas of the fruit, with the skin often splitting. A bright white silky mold develops, and spreads in a characteristic fan-like formation over the decayed tissue. Numerous spherical bodies about 1 to 2 mm (0.04 to 0.08 in) in diameter develop on the mold. These are white at first and later shrink

Figure 23. Advanced stages of Sclerotium rot on ripe tomato fruit.

slightly and turn brown (Figure 23). The optimal temperature for decay is about 30°C (86°F). Postharvest rotting can be minimized by holding the fruit at 10°C (50°F), since the fungus grows very slowly at this temperature.

Anthracnose

Anthracnose is a serious postharvest fungal disease caused by various species of *Colletotrichum*. The fungus persists in the soil on infected plant debris. Fruit may be infected when green and small, but do not show any marked lesions until they begin to ripen. The disease mostly affects only ripe fruit. At first, infected fruit show small, slightly sunken, water-soaked spots (Figure 24). These spots enlarge, become darker in colour, sunken, and have concentric rings. Masses of the pink fruiting fungus can be seen on the surface of the lesions in moist weather. Under warm and humid conditions, the fungus penetrates the fruit, completely destroying it. Control of this disease involves the use of disease-free seed, well-drained soil, crop rotation, a preventative fungicide program in the field, and avoidance of chilling injury after harvest.

Figure 24. Anthracnose decay of tomato.

Physiological Disorders

Chilling Injury

The tomato is a tropical fruit and is adversely affected by exposure to low temperature. Chilling injury (CI) occurs in ripe fruit at temperatures below 10°C and in mature-green fruit below 12.5°C (55°F). CI is cumulative and is a function of both temperature and exposure time. Tomatoes are damaged by CI if held at 5°C (41°F) for longer than 6 days. The negative consequences of chilling injury include irregular colour development (Figure 25), premature softening, surface pitting, water-soaked lesions, browning of seeds, off-flavor development, and increased postharvest decay.

Figure 25. Mature-green tomatoes held below 10°C (left) will not ripen to a normal red colour following removal from cold storage.

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, November 2002.
PH Bulletin No. 3	Mango: Postharvest Care and Market Preparation, November 2002.
PH Bulletin No. 4	Bunch Covers for Improving Plantain and Banana Peel Quality, November 2002.
PH Bulletin No. 5	Papaya: Postharvest Care and Market Preparation, November 2002.
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.

PLANNED PUBLICATIONS - 2004

Cassava: Postharvest Care and Market Preparation.

Eggplant (Boulanger): Postharvest Care and Market Preparation.

Lime: Postharvest Care and Market Preparation.

Sweet Potato: Postharvest Care and Market Preparation.

Yam: Postharvest Care and Market Preparation.

Ginger: Postharvest Care and Market Preparation.

Pumpkin: Postharvest Care and Market Preparation.