VII. Postharvest Disorders and Their Controls

Three groups of disorders affect citrus fruit or become apparent during the course of their journey from the tree to the consumer's table: rots and molds caused by fungi, physiological disorders, and insect invasions. Pentzer (1955) mentioned fully a fifth of the nation's produce is never consumed but is lost through waste and spoilage. Much of this is preventable through careful handling. Many if not most of the various types of rind breakdown, including stem-end rind breakdown, oleocellosis, gas burn of 'Temple', tangerines and tangelos, zebra-skin of tangerines, peteca of lemons, and stylar-end breakdown of limes, among others, result from rough or improper handling. Leaving fruit in the sun, picking fruit when they are wet, too low humidity during degreening, condensation of moisture inside bags or cartons, too low temperatures, and the like exacerbate or in some cases cause rind breakdowns of various sorts. Comparatively few pathogens will penetrate the uninjured peel of a citrus fruit but all plus many which are normally saprophytic will readily enter even a minute wound. The notable sensitivity of citrus peel to abrasion, most often caused by coming in contact with grains of sand, cuts, nicks and similar types of injury makes prevention of these minor wounds most difficult; nevertheless control of postharvest disorders relies upon careful handling as the first line of defense.

Research on postharvest disorders and their controls on citrus in Florida has been carried on for over 60 years. Ramsey emphasized during his study of refrigeration as a means of reducing stem-end rot and "blue" mold on oranges back in 1915 that cooling fruit could not be expected to overcome the effects of rough handling. Most of the emphasis in the early years was placed on disorders and conditions after the fruit was harvested although Winston (U.S. Dept. Agr.) was with E. A. Wolf the day he found the perfect stage of *Diaporthe* (*Phomopsis*) *citri* on dead twigs under a tree in a grove near Ocoee, exactly where he said it should overwinter. Winston himself recognized the role of the calyx in harboring stem-end rot when he recommended pulling as a means of accelerating picking rates back in 1942, but it fell to Brown (Fla. Dept. Citrus) some 25 years later to ascertain when the spores entered the calyx. Both Wolf's discovery and Winston's should have alerted pathologists and horticulturists working on problems of fresh fruit handling to the fact the previous history of a citrus fruit is of vital importance in its behavior subsequent to harvest. Winston, who had introduced borax as the first effective fungicide against stem-end rots and green mold carried out the initial studies on o-phenyl phenol. Hopkins and Loucks at Lake Alfred, perfected the process whereby this potent fungicide was made usable through the addition of hexamine (hexamethyl tetramine) and palmolive soap to the sodium salt. Thus came into being the familiar Na-o-phenyl phenate (2%)-hexamine (1%)(Dowicide A-hexamine, SOPP), for which the discoverers obtained a public service patent in 1949.

Winston, "Mr. Packinghouse," retired in the mid-1950's after over 40 years of service with the U.S. Dept. of Agriculture, mostly at Orlando. About this same time, the multidiscipline, multiagency team, later designated the Harvesting and Handling Section, at the Lake Alfred station was gathering momentum under the aegis of Grierson. This group, unlike the scientists at Orlando, have not had the formal constraint of working solely on postharvest problems but were free to go as far back as necessary in the search for solutions. This "womb to tomb" approach has disclosed that events taking place at the time of flowering and the complex interaction of factors comprising the tree and fruit's environment during fruit development do have a profound, often unpredictable influence on postharvest behavior. Certain factors, such as increased levels of fertilization, particularly of nitrogen, irrigation and other practices designed to increase yields definitely have an adverse effect upon sensitivity of fruit to conditions conducive to rind breakdowns and decays. Many of the present disorders have been known for many years but the general acceleration in both production and packinghouse practices to keep costs within bounds together with increasingly more quality conscious consumers and the greater interference of regulatory agencies in all of these matters, have resulted in higher incidences of certain disorders and placed more severe constraints in combatting them. The occasional appearance of mutant strains of fungi resistant to traditional treatments, complexities of differing residue tolerances for various fungicides, the greater importance of certain disorders relative to others, e.g., chilling injury, as result of increased export shipments of grapefruit, the never-ending quest for packages which meet consumer demands and yet give the fruit the environment they need to stay sound and appealing in both appearance and taste with conventional handling--these problems and others mentioned in previous sentences are some of the ones which require a unified approach to acquire however laboriously the necessary knowledge for their solution. "Citrus fruit die from pathological causes" is the linchpin of postharvest handling from the time flowers open on the tree and fruit set until one savors his freshly squeezed glass of orange juice, grapefruit half or dish of cut up fruit many months later.

The more important disorders in Florida are illustrated in "glorious technicolor" in Fig. 38 (courtesy of A. A. McCornack).

A. Pathological Disorders

Historically, the most problems affecting citrus fruit in Florida have been stem-end rots and green mold. (Blue mold, *Penicillium italicum*, is mentioned frequently especially in the early literature but accounts for less than 1% of the losses from penicillium. Blue mold is, however, a serious disease in California and occasionally seen on stored fruit in Florida.) Brown rot, alternaria rot and anthracnose have been of sporadic or localized importance or have been limited mainly to certain varieties, e.g., alternaria rot on lemons and anthracnose on 'Robinson' tangerines. Certain other disorders, notably sour rot (a soil-borne fungus), have become increasingly important, however, with the deterioration of picking care in recent years. Bacterial diseases, such as citrus canker, black spot and others which are serious in certain other countries, are unknown in Florida (or in the case of citrus canker have been eradicated)

Citrus Maturity and Packinghouse Procedures
Postharvest Disorders and Their Controls (cont.)

1. Stem-end rots:

Several organisms can cause stem-end rot. The 2 most important and common ones are *Diplodia natalensis* and *Diaporthe* (*Phomopsis*) *citri*. The former also causes twig dieback (and a type of foot rot in 'Persian' limes) and the latter melanose. Water-borne spores invade calyx tissues during the period of petal fall or later, spores germinate to form fungal mycelia which remain quiescent until the fruit is picked when evolution of ethylene causes them to penetrate tissues of the fruit proper. (As mentioned earlier, Winston recognized the role of the calyx in harboring stem-end rot when he recommended pulling as a means of accelerating picking rates back in 1942.)

The earliest fruit symptom of both stem-end rots is a slight softening and leathery appearance of the rind in the vicinity of the calyx The rots can not be distinguished visually at this stage, although time of year and prevailing temperatures often serve as to which one is likely to be present.

Diplodia stem-end rot is most prevalent during the warm months early in the fall or in the spring, since its optimum temperature for growth is 86°F (30°C). This stem-end rot grows more rapidly than phomopsis, the rind becomes increasingly dark brown as the fruit is invaded but remains leathery and pliable. Fingers of decay often follow the centers of segments in advance of the main decay. The decay advances rapidly down the central axis and discoloration begins at the stylar end before the entire rind surface has been visibly invaded. The color gradually darkens to an olive or blackish brown and infected fruits have a rather distinctive penetrating sour aroma.

Phomopsis stem-end rot is found during the cooler part of the season and has an optimum temperature of about 75°F (24°C). Phomopsis stem-end rot not only grows more slowly but is light brown, often tan, in color. It seldom shows fingers in advance of the general decay front, which usually has a slight shoulder where the affected part has shrunk. It also rarely penetrates to the stylar end before the entire fruit is invaded; and has a much less pronounced foul odor.

Citrus Maturity and Packinghouse Procedures
Postharvest Disorders and Their Controls (cont.)

Both rots enter readily through wounds anywhere on the fruit, in which case invasion is much more rapid. Mixtures of the 2 rots can occur, the prevailing temperature generally determining which one will predominate (usually diplodia). Diplodia stem-end rot is of particular concern because degreening room conditions are optimal for its growth. Fortunately, immature fruit are more resistant to attack than mature or overmature ones.

2. Blue and green molds:

Blue contact mold (*Penicillium italicum*) and green mold (*P. digitatum*) are primarily wound pathogens spread by air-borne spores, although the former can attack uninjured rind. Blue mold is rarely seen in Florida, except occasionally on stored fruit, but is much more prevalent and a serious disorder in California. Green mold is ubiquitous, being frequently encountered even in the grove.

Both organisms appear first as soft, watery spots about 1/4 to 1/2 inch (0.6-1.2 cm) in diameter and detectable mainly by feel as there is little discoloration at this stage. The lesion can occur anywhere on the fruit and may or may not show the wound through which the spores entered. Development of the spots is rapid, mycelium appearing on the surface in 2 days or less.

Green mold has an indefinite (poorly defined) band of softened rind at the edges of the decay, behind which is a broad zone of white mycelium with very numerous olive-green spores in the older portion. The fruit surface where invaded is wrinkled, spores appear only on the rind (except where there is an open wound into the interior), and affected fruits adhere to anything which touches them. Optimum temperature is about 75°F (24°C).

Blue mold differs in having the decayed area more sharply defined, a narrow band of pasty or velvety-appearing mycelium, blue spores which appear not only on the surface but also inside the fruit, and fruit do not adhere to other fruit, container walls, etc. Optimum temperature is the same as for green mold, according to Fawcett (1936). It is a general observation, however, that blue mold will grow at low temperatures inhibitory to green mold.

Citrus Maturity and Packinghouse Procedures

Postharvest Disorders and Their Controls (cont.)

3. Brown rot:

Several species of Phytophthora are causal agents of brown rot, notably *P. parasitica* in Florida and *P. citrophthora* (and others) in California. *Phytophthora* is related to slime molds. Spores live in the soil and are splashed by rain or irrigation water onto low-hanging fruit, where they germinate and cause infection only if the moisture remains for a long period. Conditions suitable for fruit infection occur mainly in the Indian River and Hardee-DeSoto County areas in Florida. Three to 10 days elapse between infection and appearance of a slight olive-drab or brownish discoloration, later becoming dark greenish-brown. Affected areas are firm and leathery until secondary organisms invade and cause decomposition

4 Alternaria rot:

A black rot of oranges, grapefruit and tangerines and a stem-end rot of lemons are caused by *Alternaria citri*. The former is largely an internal type of decay which invades the fruit through the calyx or stem end, stylar end, or wounds in the rind. Infected fruit may color prematurely and drop but more often appear sound except for slight premature coloration around the stylar end or rarely, the stem end. Infections through wounds usually show a dark brown or black spot on the surface.

Most alternaria infections in lemons occur at the stem end, since spores enter calyx tissues when the fruit are very young (probably they come in at the time of petal fall as in the case of phomopsis stem-end rot) but remain quiescent until after harvest. The infection develops in the calyx tissues, causing them to turn brown, after which the fungus produces a pinkish to light brown discoloration in the central axis as it moves down the vascular bundles and finally grows through the fruit interior to the surface where the color of the decayed area becomes lead brown.

Anthracnose:

This disease, caused by Colletotrichum gloeosporioides, attacks nearly all fruits, including citrus, as a secondary invader. Spores are ubiquitous on the peel of citrus fruit, usually embedded in the wax, but seldom does harm except in the case of 'Robinson' tangerines degreened for over 36 hours. Anthracnose enters through any wound, large or small, or weak unhealthy tissue. Initially, spots are brown to black and up to half an inch or more in diameter, which typically are covered with pink spores. Eventually, the fungus will penetrate deep into the flesh and produce an actual rot which is gray to blackish in color shading to pink. Overripe fruit or fruit subjected to long periods of degreening, particularly tangerines, tangelos and 'Temple',are most susceptible.

6. Sour rot:

The causal organism of sour rot (Goetrichum candidum, formerly Öospora or Oidium citra-aurantii) is endemic in the soil of citrus groves in Florida and elsewhere. Sour rot, which looks very much like green mold in its early stage of development on a fruit, has been known for a long time in the state but largely stayed in the soil until the advent of modern pickers (human and mechanized) and consequent rough handling of fruit. Infected spots are water-soaked, soft and buff to yellow-colored. They enlarge rapidly as the fungus invades interior tissues and turns them into a sour foul smelling, decomposing watery mess which collapses in a few days and infects adjacent fruit in a container. Sour rot not only has a distinctive evil odor which lingers around affected fruit and those contaminated with juice from the former but also is resistant to all of the currently legal fungicides once spores have invaded a wound. Sour rot has become a serious problem in packinghouses and gifthouses alike and will remain so until pickers are educated not to drop fruit on the ground or kick sand into the pallet boxes.

(Physoderma citri is an innocuous commensal fungus, a harmless little beastie, ubiquitous inside citrus tissues. Brown and Oberbacher. Phytopathology 59(2):241-242, 1969.)

B. Physiological Disorders

There are 3 main groups, rind breakdowns, in which damage is more or less confined to the flavedo and albedo, internal breakdowns, in which damage occurs in the segments and central axis portions of the fruit, and shriveling, the overall loss of moisture from the fruit to the extent that the rind becomes wrinkled. No pathogen is involved here but it must be clear that physiological disorders have numerous causes, many of which are either completely unknown or poorly understood.

1. Rind breakdowns:

a. Stem-end rind breakdown (SERB): Oranges subjected to too low humidity, an alternation of wetting and drying, too long exposure to degreening conditions, too long exposure to color-add solution, excessive brushing in a drier-polisher, and the like frequently develop a characteristic breakdown of rind cells in a partial or complete ring around the stem end. Tissues immediately adjacent to the stem are generally not affected. Spots are irregular in shape and brown in color indicating death of cells. Stem-end rind breakdown is more prevalent on thin-skinned and on smaller sized fruits but varies greatly with variety, 'Pineapple' oranges and tangerine types being highly susceptible, with seasons and with growing conditions. Overmature fruit, those slightly frozen and those picked too soon after a heavy rain are notably prone to breakdown, the extent of injury being markedly affected by drying conditions during the time between picking and waxing. Stem-end rind breakdown has many synonyms, such as brown stem, burnt stem, stem-end peel injury, aging and gas burn. The last, of course, is incorrect in the case of oranges or grapefruit, since ethylene does not cause a burn on those fruit. (Additional details, including means of reducing or eliminating SERB are given in McCornack and Grierson. Fla. Agr. Ext. Serv. Circ. 286, 1965.)

The susceptibility to SERB is associated with nutrition, particularly high nitrogen and low potash plus other undetermined complicating factors. This relationship is well exhibited in Fig. 26 in Chapter VI.

Citrus Maturity and Packinghouse Procedures

Postharvest Disorders and Their Controls (cont.)

b. Ageing: This disorder is similar in appearance to stem-end rind breakdown and often included in it but is separated here because it develops on fruits held in storage. Fruit showing typical ageing usually also have a stale, old or "tired" (Winston's graphic phrase for their taste) flavor and little aroma, indicating that they have been stored beyond their palatable life.

c. Pitting: Grapefruit or oranges sometimes develop abruptly sunken spots on the rind, usually on the upper half of the fruit at some distance from the stem end. Pits are 1/8 to 1/4 inch (0.3-0.6 cm) in diameter and not or only slightly discolored when they first appear. They become pinkish, tan or brown and coalescing into larger areas later. Pitting is typically a disorder of stored fruit, particularly of those susceptible to chilling injury described below, but may be seen occasionally in the field where fruits have been exposed to extended periods of cold weather (intermingled perhaps with light freezes).

d. Chilling injury: Most tropical and some subtropical fruit including grapefruit, lemons, limes, tangerines and 'Pineapple' oranges (possibly also 'Temple' and tangelos but not 'Murcott') among citrus, are sensitive to prolonged exposure to low temperatures well above freezing. Two general types of damage occur, pitting and scald as on grapefruit or lemons (e.g., peteca) and a general surface breakdown as on limes which have been brushed. Pits may be small or large, depending upon the variety, crop and conditions of storage. Fruit with pitting may also show scald, a superficial browning of the rind, or occasionally may show scald but no or little pitting. Either pitting or scale can occur on all temperature-sensitive fruits. Limes also develop a wide tan or brown colored water-soaked band around the fruits where they have been brushed.

Chilling injury may be induced when grapefruit or limes are stored at any temperature below about 50°F (10°C) and lemons, below about 50 to 55°F (10°-12.8°C) for more than 10 days to 2 weeks. Damage on limes is greatly increased by waxing and pits can be induced with acetaldehyde applied to the rind. The sensitivity of grapefruit (and others) varies widely in the length of storage required for chilling injury to develop. Susceptibility of grapefruit to chilling injury is maximal in early fall, minimal in mid-winter and increases again in the spring. It is greater in cool, damp seasons than in warmer, drier seasons.

The biochemical pathways leading to chilling injury are still unknown but respiration and evolution of ethylene are increased. The ratio of ATP to ADP in affected cells is also altered, an indication there is interference in the energy transfer systems. Preliminary study of endogenous growth regulators in grapefruit indicates levels of gibberellins are high in the fall, drop during the winter dormant period and rise again as growth is resumed, thus paralleling changes in susceptibility to chilling injury noted above.

Experiments have indicated that a modified atmosphere with increased carbon dioxide or holding under partial vacuum may inhibit or at least slow the appearance of chilling injury symptoms. The effects are, however, unreliable for grapefruit picked after the bloom period, when interest in storage is greatest. Much remains to be learned about chilling injury but substantial progress is being made. This disorder is, of course, of great interest to anyone handling and marketing tropical fruits, since it is a principal limiting factor in their shelf life.

e. Gas burn of 'Temple', tangerines and tangelos: Exposure to ethylene gas for periods longer than 48 hours will cause a burn type of rind breakdown on 'Temple', tangerines and tangelos, damage occurring sooner and being more pronounced on poorly colored fruit and with too low relative humidity during or after degreening. Concentrations of ethylene above 1 to 2 ppm greatly increase damage.

f. "Gas burn" of oranges and grapefruit: True gas burn from exposure to the normal concentration range of ethylene used in degreening does not occur but rather damage results from residues on the rind, too low humidity, etc., as explained under stem-end rind breakdown.

g. Zebra skin of tangerines: This occurs when tangerine trees are allowed to get too dry and then receive a heavy rain or irrigation. Ground water then moves up through the tree and into the fruit so distending the peel cells that they rupture if the fruit is handled, starting about 3 days after the rain or irrigation. The condition gradually declines over a period of about a week. Fruit picked during this time are highly susceptible, the condition being greatly exacerbated by degreening and polishing. NEVER polish tangerines! (Additional information may be found in Fla. Coop. Ext. Serv. Circ. 285, 1965.)

h. Sloughing disease of grapefruit: Pink or red grapefruit picked from young trees early in the season (October or before) occasionally develop faintly colored lesions on the rind which gradually darken to chocolate brown color. Affected tissues are confined to the rind, which soon can be sloughed off with light finger pressure. The rind soon becomes a soft mush of disorganized albedo and flavedo but the flesh underneath is perfectly sound and edible (if anyone cares to). Sloughing apparently is caused by conditions in certain groves but why this should be so or what conditions induce the disorder are unknown. It is associated with an immature stage of peel development and has hardly been seen since the juice requirement early in the season was last raised.

i. Stylar-end breakdown of 'Persian' ('Tahiti') limes: Fruit often develop a breakdown of the rind at the stylar end during May to September when the weather is warm and rainy. Rind tissue around the apex becomes brown and translucent, hence the name "rot", although no pathogen is involved until after the lesion has spread over most of the surface. The disorder is physiological, being caused by rough handling, particularly banging of the apical end against a limb or box surface, when fruit are turgid. Anything which will cause rupture of an internal cell starts the process as the contents of a ruptured cell are toxic to the albedo tissue. The most common cause is rough handling of very turgid limes during harvesting (i.e., picking before the dew has dried off the trees). It is usually caused on the tree by excessive heat.

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Postharvest Disorders and Their Controls (cont.)

j. Oleocellosis (Oil spotting): This disorder was described earlier in the discussion on blemishes of fruit on the tree. It is a burn caused by peel oil from glands ruptured from mechanical injury killing adjacent cells of the flavedo or those on the surface of other nearby undamaged fruit. All varieties can suffer damage but those with numerous, prominent oil glands are particularly vulnerable. It is most severe in Florida on 'Parson Brown' and navel oranges, 'Temple', tangelos, lemons and limes. The color of the lesion depends upon when the damage occurs but can be green, yellow or brown. The principal cause is rough treatment of fruit during harvesting, particularly when fruit are wet and turgid, and subsequent handling. Holding fruit at high humidity following harvest is definitely recommended as a means of making oleocellosis less obvious. (Further details will be found in Fla. Coop. Ext. Serv. Cir. 410.)

k. Wood pocket of limes and lemons (lime blotch disease): This is a genetic disorder found in certain strains of 'Persian' ('Tahiti') lime and lemons. Affected fruits have longitudinal rows of necrotic (thus discolored) rind cells quite unlike any other disorder in appearance.

l. Albedo browning and red blotch of lemons: Browning of albedo cells and a reddish superficial discoloration often occurs in conjunction with peteca (small pits) in lemons stored for long periods or stored after being picked in a period of high humidity and low temperatures.

2. Internal breakdowns:

a. Freeze injury: Tissues of citrus fruit will show more or less freeze injury, starting from the stem end, if subjected to temperatures below about 27° to 29°F (-3° to -2°C) on the tree or in storage for more than a few hours. Little or no internal injury may occur if segment and juice sac membranes remain intact. More or less severe injury results according to the amount of membrane damage and consequent disruption of cells. A fruit cut while still frozen or shortly after thawing may show little damage other than some distortion of membranes and the interior of the segments mushy rather than firm. Injured areas gradually dry out over a period of several weeks as moisture is lost through the rind which may show little or no damage. Fruit whose stems have been frozen will usually drop, while others may remain on the tree. Hesperidin crystals may be deposited between the segment membranes in frozen oranges. (Gravity separation of freeze injured fruit will be discussed later in the chapter on packinghouse operations. Additional details are given in Fla. Coop. Ext. Serv. Circ. 372, 1972.)

b. Granulation (sclerocystosis): This disorder is the gradual hardening of juice sacs, particularly at the stem end late in the shipping season. Juice sacs do not dry out or collapse but solidify into yellowish or grayish white masses while retaining their original size and shape. Fruit of varieties on rough lemon (or 'Rangpur' lime) are affected earlier in the season than those on sour orange, etc.

c. Watery breakdown: Grapefruit and occasionally other varieties sometimes collapse internally after several weeks of storage at 40°F or below to produce what is sometimes termed "leaky boxes." Affected fruit have a disagreeable fermented odor which is especially noticeable when they warm up upon removal from storage.

d. Membranous stain of lemons: Fruits which show peteca, or albedo browning or red blotch usually also have a reddish or brownish stain of the segmental membranes.

3. Shriveling: Unwashed citrus fruits and those that have been washed but not waxed will gradually lose moisture from the rind until the surface becomes wrinkled and hard. Shriveling is never seen under normal conditions of packinghouse handling.

Insects

The chief insects which have caused or cause a postharvest disorder of citrus fruit are Mediterranean fruit fly (*Ceratitis capitata*) and Caribbean fruit fly (*Anastrepha suspensa*). Both lay their eggs in peel tissues while the fruit are on the tree, the maggots which hatch later rendering the fruit unfit for human consumption. "Medfly" has been eradicated from Florida several times in the past 50 years at a cost of many millions of dollars and the state is currently (1978) free. Caribbean fruit fly, which has given considerable trouble to tropical fruit growers in Dade County during the last decade, has spread further north into the main citrus area, particularly the Indian River area, Caribbean fruit fly is not the serious menace that Medfly is whenever it appears, since citrus in general is not a favored host. It will, however, oviposit in very mature grapefruit. This has made postharvest fumigation necessary for all fruit exported to other citrus areas such as California and Japan.

D. Controls for Postharvest Disorders

Concern over losses from stem-end rots and penicillium molds was evident in research on citrus fruits as early as 1914 (Staubenrauch). Ramsey recommended 40°F as a suitable temperature for shipment of oranges in 1915, emphasizing that refrigeration could not be expected to overcome the effects of rough or careless handling. Most if not all physiological disorders can not be controlled once they appear. Rind breakdowns provide means of entry into otherwise sound fruit for a wide assortment of fungi.

Careful handling, proper operation of degreening rooms and proper use of refrigeration, including provision for adequate ventilation and humidity control, are the first lines of defense against pathological disorders. There are no chemicals in present or past use and legally cleared for use on citrus fruit which will actually kill decay organisms once they have entered tissues in the rind. Heat from hot water is used for brown rot control in California. Benlate is a systemic material that has shown great promise in control of stem-end rot. The sole function of other materials is to kill decay organisms on the surface and to prevent their spreading to other fruit. (Benlate is the first fungicide, aside from hot water, which has been found. All of the others are actually fungistats.) The following is a brief chronological survey of antiseptics in past or current use:

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Postharvest Disorders and Their Control (cont.

1. Hot water, or hot soapy water, at 115° to 120°F (42°-49°C) for a maximum of 3 to 4 minutes; used widely, especially in California for brown rot and molds. (Not used commercially in Florida.)

2. Borax or borax-boric acid (2 to 1) 5 to 8% at 115° to 120°F (42°-49°C) for 4 minutes; developed by Winston and coworkers in the early 1920's as the first fungicide (fungistat) used in commercial citrus packinghouses to control stem-end rots and blue and green molds; more effective against diplodia and green mold than phomopsis and blue mold; now obsolete (and no longer legal).

3. Sodium hypochlorite or calcium hypochlorite (active chlorine 0.6%) under several trade names (e.g., clorox) is added to wash water for mold control in California.

4. Sodium carbonate 1-1/4% or sodium bicarbonate 2-1/2 to 3% is added to hot water for control of molds, alternaria rot and brown rot in California.

5. O-phenylphenol (Dowicide 1) or sodium-o-phenylphenate (SOPP, Dowicide A) showed great promise when used at concentrations of 3/4 to 1% but was not safe, since fruit burns would show up in 10 to 15 days; research workers at USDA Orlando and AREC Lake Alfred tested numerous compounds to lessen its phytotoxicity. (USDA suggested formaldehyde as an additive.)

6. Dowicide A-hexamine (2% sodium-o-phenylphenate + 1% hexamethyl-tetramine + 0.05% palmolive soap) was developed by Hopkins and Loucks at AREC Lake Alfred (a public service patent was obtained) and quickly became the standard fungicide (fungistat) for citrus in Florida. Sodium hydroxide was substituted for the soap, which was added to maintain pH from 11.5 to 11.7 (lower pH causes peel injury and excessive residue). Treatment time is 2 minutes at 90°F, with a tolerance of 10 ppm permitted on fruits (cost is about 1 to 2¢ per box). (Dowicide A alone at 0.1% and pH 11.5 to 11.7 is used in hydrocooling water where these are still in operation.)

Citrus Maturity and Packinghouse Procedures
Postharvest Disorders and Their Controls (cont

7. Diphenyl (biphenyl) was originally used in the eastern Mediterranean area in 1934 but did not become known in the United States until after World War II; 1/4 to 1/3 ounce is put into a container, usually as 2 impregnated papers containing 1.75 to 2.2 g of diphenyl each or carton liners. It is effective as long as the smell persists. It is recommended for use in conjunction with SOPP. Tolerances on citrus are 110 ppm in the U.S. and Canada and 70 ppm in Europe and Japan. Tangerines and their hybrids absorb excessive amounts of diphenyl necessitating use of only 50% as much as that on other types of citrus. Residues on immature grapefruit shipped export (e.g., to Japan) may also exceed legal tolerances.

8. Ammonia gas or gas released from ammonium carbonate was also used in the early 1930's in the eastern Mediterranean area but did not become known in this country until the late 1950's when interest in antiseptics with no residue became intense. Ammonia gas or ammonia released from moistened ammonium carbonate pellets was found to suppress molds effectively when used in degreening rooms within 4 to 5 hours after fruit were harvested under California conditions but was not effective when tested in Florida.

9. 2,4-Dichlorophenoxyacetic acid (2,4-D) is used at low concentration (5 to 50 ppm, usually 20) as a preharvest spray or at high concentration (100 to 1000 ppm) as a postharvest dip in California for retention of the calyx (button) on lemons. The tolerance is 5 ppm. An "IR-4 clearance" was obtained in 1977 for the postharvest use of the alkanolamine salt of 2,4-D on all citrus. This is on a "24(c) label" and so limited to use in Florida only.

10. Thiabendazole (TBZ) and benomyl (benlate), both benzamidazoles, are the latest decay controls released for use on citrus. Tolerances are 10 ppm in the U.S. and Australia and 6 ppm in western Europe (e.g., France, Italy, etc.). Benlate is a systemic which can be used preharvest.

11. 2-Aminobutane (2-AB) is utilized in California (usually as the phosphate or other salt form). The principal use is as an alternate when *Pencillium* mutants resistant to the benzamidazoles are a problem. It is not currently (1978) employed commercially in Florida.

E. Legal Aspects and Screening Tests

Federal (and state) Food, Drug and Cosmetic Act, as Amended, and other laws, rules and regulations spell out conditions of use, restrictions, permissible residues, labeling requirements, clearance procedures, compliance with pollution requirements, etc., for each decay control, plus all dyes, waxes, etc., used on fruit. Federal laws are administered by the Environmental Protection Agency (EPA), Food and Drug Administration (FDA), etc.; notices are published in the Federal Register. State laws are administered through state counterparts of federal agencies, particularly the Florida Dept. of Citrus and the Division of Fruit and Vegetable Inspection of the Florida Dept. of Agriculture & Consumer Services. It is a complicated situation which is becoming worse as times goes on. Costs of clearance procedures at the federal level now amount to several million dollars per chemical.

The Florida Citrus Code of 1949, as Amended (Chap. 601 Florida Statutes) stipulates that nothing (decay controls, soap, waxes, dyes, etc.) can be put on citrus fruit without first being registered with the Commissioner of Agriculture. All materials must be submitted to the Technical Section of (Dr. George F. Westbrook, Chief) of the Fruit & Vegetable Inspection Division for approval prior to registration. Official Rules of the Florida Department of Citrus stipulate all domestic (includes Canada and Mexico) and Japan fresh fruit shipments must have a fungicide on them. Details are spelled out in Chapter 20-33 (Table 18).

Chemical companies, U.S. Dept. of Agriculture and AREC Lake Alfred are continually searching for better decay controls, particularly ones which will kill pathogens inside fruit tissues. Attributes of new compounds are they must exert effective control (be at least as good or better than Dowicide A-hexamine), be nontoxic to man or animals, not have too unpleasant an odor, not be phytotoxic, be readily soluble in common solvents, preferably water, be long lasting, and not be too expensive. The number of new compounds being screened every year is decreasing as the harassment of chemical companies by EPA, OSHA, and the like proliferates.

CHAPTER 20-33

FUNGICIDE OR FUNGISTAT TREATMENT REQUIRED FOR FRESH CITRUS FRUIT

20-33.01 Application: Except as otherwise provided herein, all fresh citrus fruit shipped by a registered packing house shall be treated with one or more of the following fungicides or fungistats:

Thiabendazole, sodium o-phenylphenate and sec-butylamine (2-aminobutane) shall be applied with an aqueous solution or aqueous emulsion.

(2) Diphenyl (biphenyl) shall be applied through use of impregnated pads, wraps or liners.

(3) Benomyl shall be applied either in aqueous solution, aqueous emulsion or organic solvents.

General Authority: 601.10(1), (7), F.S. Law Implemented: 601.02(3), (4), 601.10(7), 601.11, F.S. History: Formerly 105-1.43 (1); revised 1/1/75; amended 1/12/78.

20-33.02 Minimum residues:

(1) The residue of fungicides or fungistats, applied as required in Sections 20-33.01 or 20-33.04, in the whole citrus fruit shall be not less than 0.5 ppm of sodium o-phenylphenate, expressed as o-phenylphenol, or 0.1 ppm of thiabendazole, or 0.1 ppm of benomyl, or 0.5 ppm of sec-butylamine (2-aminobutane). When diphenyl (biphenyl) is used, the total content shall be not less than 2 grams (1 pad or equivalent) per 4/5 bu. container or the equivalent in other sized containers. The total residue of any fungicide or fungistat shall not exceed the maximum tolerance established by the U. S. Food and Drug Administration.

(2) If two or more fungicides or fungistats are used, the above residue requirements shall apply to each and shall not be cumulative. However, if the minimum residue requirements are met by any one fungicide or fungistat, the treatment shall be considered to be in compliance without regard to the minimum amount of residue of the other fungicide or fungistat which may be present on the fruit.

General Authority: 601.10(1), (7), F.S. Law Implemented: 601.02(3), (4), 601.10(7), 601.11, F.S. History: Formerly 105-1.43(2); revised 1/1/75; amended 1/12/78.

20-33.03 **Exceptions:**

Fruit for export — Except as required by Section 20-33.04, this rule chapter shall not apply to shipments of fresh citrus fruit certified for export to foreign countries other than Canada, Mexico or Japan.

(2) Special purpose shipments — This rule chapter shall not apply to fresh citrus fruit comprising a Special Purpose Shipment under a valid Certificate of Privilege authorized by the provisions of Federal Marketing Orders regarding Florida citrus.

General Authority: 601.10(1), (7), F.S. Law Implemented: 601.10(7), 601.11, F.S. History: Formerly 105-1.43(3); revised 1/1/75; amended 1/12/78, 8/1/78.

20-33.04 Required fungistat treatment for fresh fruit certified for export to Japan: All fresh citrus fruit certified for export to Japan shall be treated, to comply with minimum residue levels of Section 20-33.02, with sodium o-phenylphenate in aqueous solution or emulsion, and the containers thereof shall be conspicuously so labeled.

General Authority. 601.10(1. (7), F.S. Law Implemented: 601.02(3), (4), 601.10(7), 601.11, F.S. History: New 1/12/78.

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