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Pre-Harvest and Post-Harvest Factors Affecting Citrus Fruit and Post-Harvest Treatments

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Abstract

The review paper was aimed to assess major pre harvest and post-harvest factors affecting citrus fruit and their post-harvest treatments. Pre harvest factors such as climatic conditions, especially relative humidity, rain, temperature, cultivation practices, tree health, stage of fruit maturity, and fruit type and Post-harvest practices such as harvesting, handling, treatments, packaging, and marketing are found to be issues that greatly influence high fruit losses. Diverse treatments of pre harvest and post-harvest disorders of citrus fruit are reviewed to overcome citrus fruits disorder. According to this review, pre harvest factors are major causes of post-harvest loss.

INTRODUCTION

Citrus is claimed to have originated in south China and the Cathaysian ancient continent including Sichuan, Kangdian, south of the Yangtze River, and Indo-China peninsula, then dispersed into India, Africa, and Australia according to theories of continental drift and ecological and geological vicissitudes (Zhou 1990).

Agro meteorologically, citrus is grown under tropical and subtropical arid or humid climates representing 248 to 388F at either side of the equator with hot days/cool nights and little exposure to prolonged freezing temperature or relatively free from frost. Globally, most production 278 A. K. SRIVASTAVA, S. SINGH, AND L. G. ALBRIGO comes from citrus growing in soil represented by the orders Alfisol,Oxisol, Ultisol, Entisol, and Inceptisol (Srivastava and Singh 2003).

Citrus fruits are a rich source of minerals and vitamins. The manifestations of scurvy disease are prevented by its regular intake. In addition, citrus fruits have a high potassium level and relatively low nitrogen concentration (Gallasch et al. 1984). The exceedingly favorable ratio of potassium to nitrogen imparts therapeutic utility to citrus juice (McHard et al. 1980). Sweet orange juice is a much better supplier of the requirement for copper than for zinc. From the levels of vitamin C, B, and folic acid, it is obvious that the inclusion of citrus fruits and products in the diet is greatly beneficial in meeting recommended daily allowances and preventing even the subclinical signs of their deficiencies (Breeling 1971).

Losses in citrus are influenced by pre- and postharvest factors. Preharvest factors include climatic conditions, especially relative humidity, rain, temperature, cultivation practices, tree health, stage of fruit maturity, and fruit type. Post-harvest practices such as harvesting, handling, treatments, packaging, and marketing greatly infl uence fruit losses. Losses take place at various stages of handling, from harvesting until fruit reaches consumers. Usually higher losses are encountered in mechanically harvested citrus (Recham and Grierson, 1971).

Physiological disorders are the result of dysfunction or malfunction of the physiological processes of the fruit tissues due to abiotic stresses (temperature, RH, moisture/water stress, chemicals, and nutrient excesses and deficiencies) and are therefore distinct from disorders caused by biotic factors such as disease-causing pathogens and insect-pests (Eckert and Eaks,1989).

DISORDERS CAUSED BY POSTHARVEST FACTORS

Chilling Injury

Chilling injury develops mainly in tropical and subtropical fruits when held below 10–15ºC for certain period of time. In citrus fruits, which are also tropical, the critical temperature at which injury develops varies with species and varieties and even within same variety grown under different climatic conditions. In general limes, lemons, and grapefruits are more susceptible than mandarins and oranges. Chilling is a result of the time–temperature relationship. Chilling is different than freezing: there is no hardening or ice crystals in the tissues in former, though there can be some resemblance in symptom development. Frozen tissues collapse completely after thawing, and freezing takes place at a much lower temperature than chilling. At chilling temperature, tissues actually take a long time to develop injury symptoms, and symptoms usually develop very quickly when fruit is taken to warmer temperatures, while freezing takes place at freezing temperatures. One common chilling-injury symptom in citrus fruit is a pitting of the peel. Cell collapse creates irregular areas that are sunken and brown. The blemishes, although superficial, render the fruit esthetically undesirable, resulting in loss of revenue.Chilling-injury development can be caused by (1) changes in physical properties of cell membrane as a result of the physical state of cell-membrane lipids and (2) changes in structural proteins such as tubulin and enzymes, resulting in changes in enzyme kinetics. The chilling injury could be due to either or both of these factors. Membrane lipid characteristics were found to change at a characteristic temperature range of 7–15ºC, which is also the critical temperature range below which most tropical and subtropical plant tissues show chilling symptoms. About 10 percent or less of the membrane lipids undergo a physical change, which is probably a phase separation (Wills et al., 1998).

Oleocellosis (Rind-Oil Spot)

Oleocellosis is found in all citrus fruits; and early-harvested, green-colored fruits are more prone to this disorder. Early-morning harvesting of limes, lemons, mandarins, and Navel oranges followed by immediate transport can cause oil spotting. When released, phytotoxic oils (terpenes) cause injury to surrounding living cells, resulting in oleocellosis. This is mainly due to bruises at harvest and rough handling. Rupture of the oil glands results in necrosis of the adjacent epidermis, inducing the formation of irregularly shaped yellow, green, or brown spots in which the oil glands of the skin stand out prominently because of a slight sinking of the tissues between them. Oleocellosis appears while the temperature is high. Biochemical and physiological characteristics have been studied as they relate to the occurrence of oleocellosis in citrus. The level of antioxidant compounds seems to be related to the development of oleocellosis. In *Citrus junos*, flavedo with natural rind spot had less anti oxidative activity than sound fl avedo. Total tocopherol contents comprising about 8.2 mg/100 g α-tocopherol and 1.0 mg/100 g γ-tocopherol were lower in fl avedo with rind spot than in sound fl avedo, which had 7.2 and 4.5 mg/100 g, respectively (Sawamura et al., 1988)

Rind Staining

As a result of slight abrasion during harvesting, packing, and transportation, citrus fruits develop a brown or reddish-brown discoloration on the damaged areas.To control rind staining, careful handling of the soft mature fruit is necessary. Rind staining increases in matured peel, and GA3 applications may prove helpful in reducing this disorder.

Kohansho

Low temperatures are responsible for Kohansho in Navel orange fruits. Reducing light intensity by shading decreases the incidence in stored Navel orange fruits. An annual fl uctuation in the incidence of the disorder during storage in fruits taken from the same groves has also been observed. Lighter crop loads tended to increase the incidence on the tree. Spots were mostly found on the stylar-ends of fruit. Even fruits harvested in October and November that had not been exposed to low temperatures developed the injury symptoms during storage at 10ºC (Chikaizumi et al., 1999).

Peteca

The symptoms of Peteca are rind pitting, sinking rind, and darkening oil glands.Peteca is common in lemons. Increased brushing time induces the incidence of this disorder. Polyethylene-based waxes induce more Peteca than carnauba wax emulsion.Peteca develops at very high humidity. Nutritional imbalance has also been shown to cause this disorder. Control of as many factors as possible can reduce the incidence.The Peteca disorder of lemons in Lebanon is reportedly caused by high oxalate levels in the leaves. Increasing levels of N and, to a lesser degree, moisture stress contributed to high oxalic acid levels in the leaves. High Ca and low available P levels in the soil further contribute to this disorder (Khalidy and Nayyal, 1974).

Red Blotch or Red-Colored Lesions

Superficial wounds on fl avedo with a reddish color in the lesion and the surrounding peel have been reported in degreened Florida citrus (Grierson, 1986). With wound healing, lignin formation takes place and colored polyphenolic compounds are considered responsible. A similar physiological disorder in degreened lemons has been reported from Israel (Cohen, 1991).

Stem-End Rind Breakdown (SERB)

SERB is also referred to as aging and occurs in most citrus fruits. The rind around the stem wilts and dries down in sunken, brown, irregular areas during storage. In overripe fruit it may appear in the orchard itself. Nutritional imbalance of N and K in the orchard may also render fruit susceptible to this disorder (Grierson, 1986).

DISORDERS CAUSED BY PREHARVEST FACTORS

Freeze Injury

This is a common problem in areas where citrus is grown above 30ºN and 30º South latitudes or higher. Freezes have even damaged entire citrus plants. In India, in areas of Punjab and Rajasthan where temperatures fall below 0ºC during winter for considerable periods of time, Kinnow fruit damages have occurred. In the Mediterranean region, the U.S., Latin America, China, and Japan, citrus-growing areas suffer damages from freezes. The frozen fruits contain distorted intercarpellary membranes and white hesperidin crystals between segments can be seen.
Desiccated areas appear at the stem end, where moisture loss has taken place through damaged membranes (Grierson and Hayward, 1959).

Granulation

As per the available literature, granulation was fi rst reported by Bartholomew et al. (1935) in Valencia oranges.

In granulated fruits of oranges, tangerines, and tangerine hybrids, extractable juice is severely decreased because of gel formation with in the juice vesicles.

Fruit Splitting or Cracking

Citrus fruits, especially acid limes and mandarins, develop cracks in the rind or even in the pulp and become unmarketable. Wide fl uctuations in water content of soil and consequently plant tissues could be one possible reasons. In India, this problem occurs more in developing fruits of acid limes and oranges during May, June,and July when atmospheric humidity and soil moisture status changes abruptly with the onset of monsoon rains. Abrupt heavy irrigation or a sudden heavy downpour of rain can cause fruit splitting. Mature fruits are more susceptible and hence

such fruits should be harvested before the commencement of monsoon rains. In the Valencia orange-growing areas of South Africa, as much as 20 percent of the crop is lost before picking, and losses further increase as a result of postharvest bursting of fruit and decay (Bower et al., 1997).

Puffiness

Ponkan and Satsuma mandarins (*Citrus reticulata* Blanco and *C. unshiu*) are very prone to puffi ng, and fruits of advanced maturity develop puffi ness in the orchard itself. The rind becomes thick and separates from the pulp (segments) creating an air gap between peel and segments. In stored fruit, puffiness develops because of high humidity as the storage period is extended. Puffi ng is rare in sweet oranges,limes, and lemons. Pre storage curing of the fruit can reduce the incidence of puffiness (Murata, 1981).

Creasing

Creasing is also called albedo rind breakdown. A defi nite cause is not yet known but in general factors such as heavy cropping, old trees, low N and K with high P, or water stress that result in reduction of peel thickness may have potential in increasing susceptibility to creasing (Sneath, 1987).

POST-HARVEST DECAY OF CITRUS AND ITS MANAGEMENT

Green Mold

Green mold identification and biology

Green mold is caused by a fungal pathogen *Penicillium digitatum* (Pers.:Fr) Sacc.It is identified by the mass of olive-green spores produced on infected fruit and their prolific production ensures that this fungus is found wherever fruit is present, including field, packinghouses, equipment, degreening and storage rooms, transit containers and in the marketplace. Infection takes place only through wounds where nutrients are available to stimulate spore germination and fruit decay begins at these infected injury sites. The early infection area appears as a soft watery spot. As the lesion progresses, white mycelia develop and these produce the green spores. The white mycelium develops into a broad zone surrounding this sporulating area. Within a few days the entire fruit can be covered with green spores. Spoilage of fruit, caused by the spread of spores from diseased fruit onto adjacent fruit, can occur within the shipping container, but green mold spores will only infect damaged fruit in packed cartons.

Green Mold

Green mold control

1). Careful harvesting and handling of fruit to minimize fruit injuries;

2). drench fruit with chlorinated thiabendazole (TBZ), fludioxonil (Graduate) or imazalil if fruit can not be packed within 24 hours after harvesting;

3). apply a stringent daily sanitization with effective disinfectants (such as chlorine and quaternary ammonium) to the wet line through the wax brushes, and fruit bins after dumping;

4). wash fruit with sodium orthophenylphenate (SOPP, 2%) and applying TBZ and/or imazalil on packingline in aqueous or wax treatments;

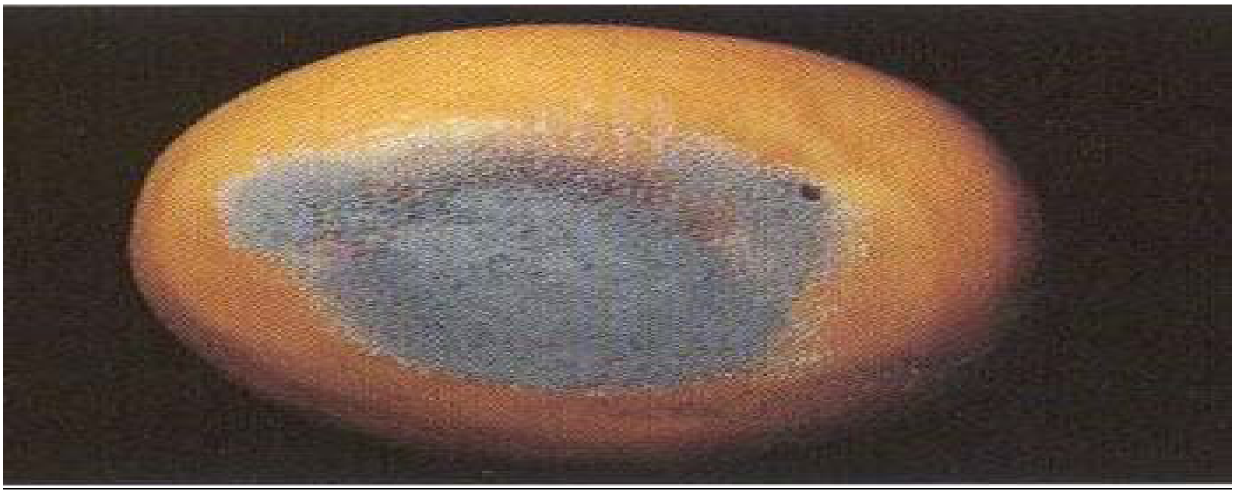
5). prompt removal of any infected fruit from the packinghouse, and no repacking of packed cartons with fungicide-treated sporulating fruit in the packinghouse facility; and

6). use low temperature to retard pathogen infection and disease development by immediately pre-cooling or storing fruit after packing at 10°C or less.

Blue Mold

Blue mold identification and biology

Blue mold is caused by a fungal pathogen *Penicillium italicum* Wehmer. *P. italicum* infects citrus fruit via injuries to cause blue mold. Blue mold is recognized by the mass of blue spores produced in decayed fruit. Initial lesions are similar to the lesions of green mold, but the spores are blue in color and are surrounded by a narrow band of white mycelium encompassed by water-soaked rind. Blue mold develops less rapidly than green mold under ambient conditions so that the green mold is often observed in mixed infections. Blue mold is more common in fruit held in cold storage for summer, and it can spread in packed cartons more readily than green mold. It occurs in all citrus-producing regions of the world, although it is not as prevalent as green mold under Florida conditions.



Blue mold

Blue mold control:

1). Careful harvesting and handling to minimize injuries;
2). stringent daily sanitization with approved sanitizers for packing line, equipment, fruit bins. Degreening and storage rooms should be sanitized when sporulating fruit are observed, and water in drenchers and soak tanks should be continuously chlorinated;
3). prompt removal of any infected fruit in the packinghouse, and no repacking of packed cartons with fungicide-treated sporulating fruit in the packinghouse facility;
4). monitoring of spore population in the packinghouse for concentration and resistance to post-harvest fungicides;
5). spaying thiophanate-methyl (Topsin-M) pre-harvest, washing fruit with SOPP and/or applying TBZ and/or imazalil on packingline in aqueous or wax treatments; and
6). immediately pre-cooling or storing fruit after packing at 10oC or below.

Sour Rot

Sour rot identification and biology

Sour rot is caused by a fungal pathogen *Geotrichum citri-aurantii* (Feraris) Butler.

It has been reported in most areas where citrus is grown, and it occurs on all cultivars, but it is particularly troublesome on fruits that are stored for long durations. The fungus only infects fruit through injuries and in particular deep injuries that involve the albedo tissue. Sour rot develops more frequently on mature to over-mature fruit with high peel moisture. The initial symptoms are water-soaked lesions, light to dark yellow and slightly raising with the cuticle being more easily removed from the epidermis than lesions caused by green or blue mold. Decayed fruit tissue has a sour odor that attracts fruit flies and these can spread the fungus to other injured fruit during storage. The fungus is present in soil and can reach the fruit surface from wind-blown or splash-dispersed soil and by fruit-soil contact. Fruits on the lower portion of the citrus tree contain higher populations of the fungus and soil from the field or from diseased fruit can contaminate drenching equipment, soak tanks, pallet bins, washer brushes, belts and conveyors. Packed infected fruits allow the disease to spread to sound fruit in the container. The disease develops rapidly at warm temperatures, with an optimum at 27oC.

Sour rot

Sour rot control:

1). Carefully harvesting and handling of fruit to minimize the fruit injuries;
2). preventing fruit from contacting soil;
3). equipment, rooms and fruit containers should be sanitized routinely;
4). continuous treatment of drenchers or soak tankers with chlorine;
5). removal of rotten fruit after dumping on packinghouse line to minimize equipment contamination, particularly washer brushes;
6). using sodium ortho-phenylphenate (SOPP), which is applied in a foam, spray or drench during washing;
7). immediately storage of packed fruit at 10oC or less delays disease development.

Diplodia Stem-end Rot

Diplodia stem-end rot identification and biology:

Diplodia stem-end rot is caused by a fungal pathogen *Diplodia natalensis* Pole-Evans (Syns. *Lasiodiplodia theobromae* (Pat) Griffon & Maubl., and *Botryodiplodia theobromae* Pat; teleomorph: *Botryosphaeria rhodina* (Cooke) Arx).

D. natalensis is a saprophyte that completes its life cycle on deadwood of citrus trees in grove. Water transmits fungal spores from deadwood to the surfaces of immature fruit where the fungus colonizes dead tissue of the button (calyx and disk). These fungal colonization remains latent and does not cause fruit decay before harvest. Infections develop after harvest especially under conditions of high temperature and relative humidity. The pathogen usually infects fruit from the button at the stem-end of the fruit. It proceeds through the core more quickly than the rind, leading to development of soft brown to black decay symptoms at both ends of the fruit. The pathogen usually develops unevenly in the rind, forming finger-like projections of black to brown discolorations at the lesion margin between the segments. Decay develops rapidly during and after excessive degreening and can be observed in fruit at the packinghouse. It is often observed at market arrival or shortly thereafter. This decay does not spread from infected fruit to healthy fruit in packed cartons. It is a serious post-harvest decay in humid subtropical and tropical areas.

Diplodia stem-end rot

Diplodia stem-end rot control:

1). Perform good cultural practices to minimize the amounts of deadwood in citrus trees;

2). delay harvest or spot pick for fruit with better natural color development;
3). drench fruit with TBZ or fludioxonil (1,000 ppm) before degreening. Heated imazalil solution may also be used for drenching the fruit before degreening treatment, but TBZ generally is more effective against stem-end rot;
4). minimize degreening treatment: time (< 36 hrs) and concentration of ethylene (no more than 5 ppm);
5). on the packingline, apply TBZ on fruit in aqueous (1,000 ppm) or in water wax (2,000 ppm) treatments. Imazalil might also be used in combination with TBZ to effectively control green and blue mold; and
6). pre-cool or store fruit immediately after packing at 10oC or below.

Phomopsis Stem-end Rot

Phomopsis stem-end rot identification and biology

Phomopsis stem-end rot is caused by a fungal pathogen, *Phomopsis citri* H. Fawc. Non Sacc. Traverso & Spessa (teleomorph: *Diaporthe citri* F. A. Wolf).

The fungus grows on tree deadwood, where it produces spores that spread by water to immature fruit during rainfall or irrigation. Infection of the young fruit produces small pustules. The fungus also becomes established in dead tissue of the button, where it lays dormant until harvest. As the button deteriorates during storage, the fungus grows from the surface into the base of the fruit through natural openings that occur in the abscission zone. Decay progresses evenly through the rind and core until the entire fruit is completely rotted, with no spread to adjacent fruit. This type of stem-end rot is dark to light brown in color and more prevalent in late-season non-degreened or cold storage fruit of all types. Ethylene degreening has no effect on *Phomopsis* stem-end rot. It is a serious post-harvest decay in humid subtropical and tropical areas.

Phomopsis stem-end rot

Phomopsis stem-end rot control

1). Using good cultural practice to produce trees with minimal amounts of deadwood;
2). applying TBZ, fludioxonil and/or imazalil on the packinghouse in aqueous or wax treatment; and
3). immediately pre-cooling or storing fruit after packing at temperature of 10oC or less.

Anthracnose

Anthracnose identification and biology

Anthracnose is caused by a fungal pathogen *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. *C. gloeosporioides* grows and sporulates in deadwood on the trees, with water transmitting spores to the immature fruit surface where the fungus forms infection structures known as appressoria. These appressoria remain latent and do not cause decay prior to harvest. The appressoria germinate and form infection hyphae when fruit is treated with ethylene during the degreening process. Anthracnose lesions are initially silvery gray and leathery, being similar in firmness and elevation to adjacent healthy rind tissue. The infected rind becomes brown to grayish black and softens as the rot progresses. Lesions vary in size and are irregular in shape. Pink spores may form on the lesion surface in humid environments. Decay may also develop on injured rind of any type of fruit, producing firm, sunken dry lesions.

Anthracnose only occurs in a few citrus growing regions (such as Florida) and is a major cause of decay in tangerines that are harvested early in the crop season when long periods of degreening are required to enhance fruit appearance. It is a minor problem on other citrus varieties.

Anthracnose

Anthracnose control

1). Good cultural practices to produce trees with minimal amounts of deadwood;
2). delaying harvesting or spot picking for better natural color development to minimize the amount time required for degreening treatment;
3). minimizing degreening time to less than 36 hours with less than 5 ppm of ethylene; and
4). pre-cooling or storing fruit immediately after packing at temperature of 10oC or below.

Brown Rot

Brown rot identification and biology

Brwon rot is caused by fungal pathogens, *Phytophthora palmivora*, *P. citrophthora*, *P. nicotianae*, *P. hibernalis* and/or *P. syringae*, occurs in several citrus-growing regions. In Florida, brown rot is caused by *P. palmivora* or *P. nicotianae*.

Brown rot occurs in both pre-harvest and post-harvest stages. *Phytophthora* species persist in the soil and are spread through rain splashes to fruit hanging on the lower canopy of the trees thereby infecting the fruit. Most infections develop on the tree within 3 to 4 feet of the soil surface although they might be found in higher locations as a result of wind-driven rains. Initial infection shows as light discoloration on any area of the fruit surface. As the decay develops, the lesion becomes light brown, firm and leathery. Under humid conditions, decayed areas spread rapidly and white mycelia may form on infected areas. Fruits with brown rot have a characteristic rancid odor. Brown rot spreads in packed containers from infected to healthy fruit.

Brown rot

Brown rot control:

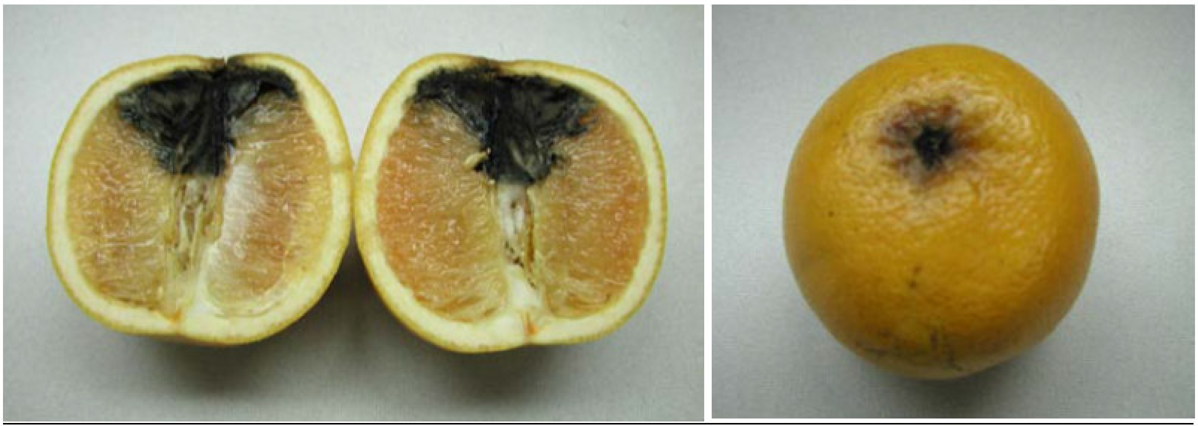
1). Using cultural practices to minimize long periods of fruit wetness by pruning to move low hanging branches, by proper irrigation and soil drainage management, and use of mowing and herbicide treatment to reduce ground vegetation;
2). avoiding harvest of fruit from poorly drained groves during rainy periods;

3). delaying harvest at least 2 weeks after infection in the absence of re-infection, to allow infected fruit to drop the ground;
4). applying sprays of copper or Aliette in August or early September to the tree canopy in blocks with a history of brown rot or at the occurrence of disease outbreaks; and
5). immediately pre-cooling or storing fruit after packing at temperature of 10oC or less.

Alternaria Stem-end Rot (Black Rot)

Alternaria stem-end rot identification and biology

Alternaria stem-end rot (black rot) is caused by a fungal pathogen, *Alternaria alternata* (Fr.:Fr.) Keissl. This disease occurs primarily as a stem-end rot on fruit stored for a long time. The decay can develop at the stylar end of the fruit, particularly in Navel oranges and cause premature fruit drop. The pathogen grows on dead citrus tissue or other substrates and produces airborne conidia. Latent infections are established in the button or the stylar end of the fruit. The disease can develop further when the button becomes senescent, as in over-mature fruit and during long-term storage. It is an important problem in commercial storage of lemons in California. *Alternaria* black rot can also be a problem for the processing industry by contaminating the juice. Black rot occurs throughout all citrus growing regions, but is rarely abundant enough to cause economic losses in Florida.



Alternaria stem-end rot

Alternaria stem-end rot control:

1). Delaying harvest until fruit affected by stylar-end infections have dropped to the ground;
2). applying 2-4, dichlorophenoxyacetic acid (2-4, D) and/or imazalil on the packingline in aqueous or wax treatment; and
3). immediately pre-cooling or storing fruit after packing at temperature of 10oC or less.

POSTHARVEST TREATMENTS OF CITRUS

Curing

Water content of fruit peel is an important factor, determining turgidity of rind tissues that in turn determines the extent of injuries and disorders after harvest.When these fruits are harvested early in the morning or in wet weather, they tend to develop oleocellosis or brown spots on the rind with slight pressure or bruises.Curing is a pre-treatment and a conditioning of the fruit before running it on the packing line. Curing for few hours or days depending on variety or species removes slight moisture from the peel so that it becomes suitable for mechanical handling. This curing is achieved by just holding the fruit under shade in ambient conditions. Lemons are generally cured at 15–17ºC for 1–2 days in many countries so that rind physiological disorders are minimized. In Israel, fruit is cured at 36ºC for 72 h in vented plastic crates covered on top with non-vente HDPE. The fruit is then coated with water wax containing TBZ (2000 ppm). Temperature, relative humidity, and wrapping/lining in the box are the critical factors as far as water loss from citrus fruit is concerned.

Disinfection and Cleaning

Disinfection of water used in washers or for general cleaning purpose can be achieved by chlorination, ozone, and/or UV treatment. The most commonly used chemicals are sodium or calcium hypochloride for chlorination. Liquid soaps and detergents are also added to the wash water used for general sanitation of the packing house and for cleaning fruit. Fruit cleaners of various companies are available in the market. For example, FMC corporation, USA supplies fruit cleaner detergent (FMC fruit cleaner detergent 395) used as a foam application. The SOPP is commonly added to the water along with detergent before fruits are coated. Fruit cleaner, a biodegradable detergent, and FOMER (detergent _ 20 percent SOPP) are commercial products from the Fomesa Company of Spain.

Surface Coatings

Waxes and coatings for polishing and improving sheen and reducing water loss of citrus fruits are available in various forms such as solvent waxes, aqueous emulsions, and resin solutions. 'Wax' has become a generic term, and any type of coating – whether it contains wax or not – is called wax.

Wax Coatings

Initially (early twentieth century) waxing and polishing of citrus fruit was done using solid wax slabs. Slab waxing, though simple, was not considered satisfactory.The hot fog method is also no longer used, although it gives excellent results when carried out correctly. Solvent waxing was widely used in Australia during the 1950s and 1960s (Long and Leggo, 1959).

Edible Coatings

Edible coatings are developed from edible ingredients (carbohydrates, fats, and proteins) and therefore they have recently generated considerable interest. These coatings can be classifi ed in fi ve categories: lipid-based, polysaccharide-based, protein-based, composite, and bilayer coatings (Baldwin et al., 1995).

Several edible and eco-friendly (biodegradable) materials such as cellulosebased coatings, sucrose esters of fatty acids, and chitosan, have been used to extend the shelf life of citrus fruits. NO-carboxymethyl chitosan is a water-soluble derivative of chitin and reduces respiration to a large extent. Oranges treated with chitosan solution can be stored for 2 months without adverse effects on fruit appearance. Chitosan also reduces fungal growth (Li and Cao, 1997).

Plant-Growth Regulators

Plant-growth regulators (PGRs) control physiological processes at extremely low concentrations. Most of these compounds occur naturally and hence their use in postharvest citrus treatments is expected to receive consumer acceptance.Auxins, gibberellins (GA), cytokinins, abscissic acid (ABA), and ethylene are five important types of PGRs that occur naturally in fruits. The first three types of compounds are used to extend the vitality of fruit tissues while last two are known to promote aging and senescence processes. Synthetic compounds with auxin-like action (2,4-D) are also used. The jasmonates are also naturally occurring PGRs and known to regulate various aspects of plant development and responses to biotic and abiotic stresses.Gibberellic acid (GA3) and 2,4-dichloro phenoxy acetic acid (2,4-D) are the most widely and commercially used PGRs in citrus. Both these chemicals have pre-harvest and postharvest applications. As a preharvest application 2,4-D delays and reduces abscission of mature fruit and increases fruit size. As a postharvest application in lemons, 2,4-D delays button abscission by maintaining its vitality and thus reduces *Alternaria* rot. GA3 is primarily used as preharvest spray on navels and Minneola tangelos to delay peel senescence and fruit maturity in lemons while postharvest application in lemons is aimed at delaying coloration and reducing sour rot (Coggins, 1991). Gibberellin A3 is observed to be highly persistent in orange peel (half life _ 80 days). Ethylene causes a slight enhancement of GA3 metabolism in orange fruit (Shechter et al., 1989).

CITRUS PRODUCTS

Based on (www.stoltze@arc.agric.za),One of the many opportunities to grow markets, turnover and profits, is by adding value to farm produce through further processing. Most value-added food products available to consumers have been processed in some way or other, even if the processing is as simple as cleaning produce before it is packed in plasticor net bags. Two types of processing methods may be performed on raw materials:

Primary Processing: this type of processing includes the simplest of processes such as washing,peeling, chopping,ageing, the milling of wheat for flour production, and the processing of sugarcane;

Secondary Processing: this type of processing involves the conversion of primary processed products into more complex food products and includes procedures such as mixing, depositing, layering, extruding, drying, fortifying, fermentation, pasteurisation, clarification, heating etc.

Grapefruit Products

Canned grapefruit: Grapefruit is canned in segments or wedges in sugar syrup of various strengths or artificially sweetened liquor. The canned product is a convenience product that is used to replace the fresh product. It has a long shelf life and thus extends the availability of the seasonal fresh product. It is used as a breakfast food or is bakery products.

Grapefruit juice: Grapefruit juice was originally produced as a by-product from the drippings of grapefruit sections intended for canning. Today it is a popular breakfast beverage and acidulant for other beverages. The bitterness and astringency of grapefruit juice can be made more acceptable by the sweetening and blending with other fruit juices. The single-strength juice is preserved by pasteurisation, canning or refrigerated storage but has a relatively short shelf life, unless preserved by sulphite (www.stoltze@arc.agric.za).

Lemon Products

Cold pressed lemon oil: Cold pressed lemon oil has an extensive range of applications. The main demand for the oil is as flavouring in the food and beverage industry, but is also used in cosmetics, pharmaceuticals and household products.

Dried lemon peel: Dried lemon peel is usually a by-product from juice extraction or other processes and finds application in cereals, baked products, sauces, marmalade, spice mixtures and herbal teas.

Lemon juice: Lemon juice is a popular acidulant for other fruit juices, beverages and various food products. It is rich in vitamin C and can be used to substitute salt in food. Although it is seldom consumed as a beverage on its own, it can be made more acceptable by sweetening and the blending of various other juices or ingredients.

Lemon juice concentrate: Concentration and freezing are the best long-term preservation options for lemon juice.The concentrate thus serves as a semi-processed product that can be further processed into various beverages such as lemonade, juice blends etc. or purely an acidulate.

Lemon puree: Lemon puree is prepared from sound, whole fruits that have been sliced/crushed and pureed. The puree is a semi-processed product that is useful in the commercial preparation of baked foods, beverages and frozen desserts. It is preserved by freezing. The yield of puree is approximately 50 - 60 % of the whole fruit(www.stoltze@arc.agric.za).

Orange Products

Cold pressed orange oil: Orange oil is obtained from the peel of the orange by piercing or pressing the peel.Cold pressing is the primary method of extraction and can be performed as a separate operation or form part of the commercial juice extraction process

Dried orange peel: Dried orange peel is usually a by-product from juice extraction or other processes. The peel is preserved by drying and finds application in cereals, marmalades, spice mixtures, baked products,sauces and herbal teas

Frozen orange pulp: Orange pulp is a by-product of the juice extraction plant and mainly consists of the cells removed during the finishing/sieving process. Although nearly all citrus waste can be successfully converted into animal feed or fodder products, orange pulp is mainly used to improve the flavour and mouth-feel of orange juice concentrate upon dilution. The product is preserved by pasteurisation and freezing.Concentration of the pulp is optional

Orange puree: Orange puree is prepared from sound, whole fruits that have been sliced/crushed and pureed.The puree is a semi-processed product that is useful in the commercial preparation of baked foods, beverages and frozen desserts. It is preserved by freezing. The yield of puree is approximately 50 - 60 % of the whole fruit

Orange wine (Fermented beverage): Orange wine is an alcoholic beverage that is produced through the process of fermentation of orange juice in much the same way as grape juice is fermented to produce wine.The juice from Valencia oranges is used for the making of orange wine. The final product is sweet, with an alcohol content of 14.5 % and is served as an aperitif or dessert wine(www.stoltze@arc.agric.za).

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