Grapefruit

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Scientific Name and Introduction

Citrus paradisi Macf., a member of the Rutaceae family, originated in the Caribbean and was introduced in Florida in the early 19th century (Gmitter 1995). The grapefruit is classified as a hesperidium, a kind of berry with a leathery rind that is divided into segments. Each segment contains hundreds of individual juice vesicles that compose the majority of the edible portion of the fruit. Florida is the largest producer of grapefruit in the United States, followed by Texas, California, and Arizona. White- and red-pigmented cultivars are grown. 'Marsh' is the dominant white cultivar. 'Ruby Red,' 'Star Ruby,' 'Henderson,' 'Ray Ruby,' and 'Flame' are the most popular red-pigmented cultivars (Saunt 2000).

Quality Characteristics

A high-quality fresh-market grapefruit will have a turgid, smooth peel and be relatively blemish-free. The fruit should be elliptical and firm. SSC:TA balance within the edible portion should be appropriate, and bitterness should be at a minimum.

Horticultural Maturity Indices

In markets that emphasize processing, grapefruit must achieve a minimum juice content and SSC:TA ratio before harvest.

Grades, Sizes, and Packaging

Marketable fresh grapefruit generally range from size 23 (23 fruit/carton) to 56 (56 fruit/carton). Grade standards for fresh grapefruit rely on color-break, texture, peel blemishes, shape, and firmness. Grapefruit are commonly packed, stored, and shipped in $^4/_5$-bushel cardboard cartons (Soule and Grierson 1986).

Optimum Storage Conditions

Grapefruit are typically stored at 12 to 15 °C (54 to 59 °F) with 95% RH. Coatings are applied in the packinghouse to reduce water loss from the peel. However, to minimize postharvest pitting, grapefruit should be cooled immediately to <10 °C (50 °F) with 95% RH after harvest and maintained at 5 to 8 °C (41 to 46 °F) during transit and storage until distribution at retail outlets. High-shine water waxes will minimize chilling injury, and incorporated fungicides should control decay at these temperatures. At optimum storage temperatures, fruit respiration rates will be reduced and quality will be maintained up to 6 weeks (ASHRAE 1998).

Controlled Atmosphere (CA) Considerations

Though some benefit of increased firmness and delayed senescence can be gained from CA storage, commercial use of CA storage for grapefruit is very limited or nonexistent (Arpaia and Kader 2000).

Chilling Sensitivity

Chilling injury can occur with low-temperature storage, typically 5 °C (41 °F) or below. Chilling injury is characterized by peel pitting. Pitting associated with postharvest pitting is targeted to areas of the peel surrounding oil glands, whereas pitting associated with chilling injury is not targeted to oil glands (Petracek et al. 1995). Coating grapefruit with high-shine water waxes reduces the incidence of chilling injury. Conditioning fruit by intermittent warming or stepwise lowering of temperature can also reduce chilling injury.

Ethylene Production and Sensitivity

The grapefruit is a nonclimacteric fruit and does not exhibit a classic ripening pattern of increased respiration and ethylene production. The rate of ethylene production is typically <0.1 $\mu L\ kg^{-1}\ h^{-1}$ at 20 °C.

Degreening is necessary for marketing early-season fresh grapefruit in areas where night temperatures remain high. In these cases, 1 to 5 $\mu L\ L^{-1}$ ethylene for periods of 12 h to 3 days is used to cause the destruction of peel chlorophyll. The recommended temperature for degreening is 28 to 29 °C (82 to 84 °F) in Florida and 21 to 22 °C (70 to 72 °F) in California, each reflecting the physiological state of the fruit grown under different climactic conditions. High RH of 90 to 95% must be maintained to avoid softening and accentuation of existing peel injuries or blemishes. One complete air change per hour should enter the degreening room to avoid unnecessary buildup of CO_2 and to assist in uniform temperature and ethylene distribution (Wardowski 1996).

Respiration Rates

Respiration rates at optimum storage temperature are generally <10 mg $CO_2\ kg^{-1}\ h^{-1}$ (Arpaia and Kader 2000).

Physiological Disorders

Granulation, or section-drying, affects late-season grapefruit dominantly on the stem or stylar end of the segment. Granulation can be severe in larger fruit stored for extended durations (Burns and Albrigo 1998). Granulation can be avoided by harvesting large fruit early in the season.

Oleocellosis can occur during harvest when excessive squeezing force is used to remove fruit from the stem. Grapefruit harvested in the morning, when RH is high, are most susceptible because oil glands are easily broken in turgid peel. Symptoms of oleocellosis appear in the packinghouse or in storage, and can be exacerbated by degreening.

Stem-end rind breakdown (SERB) is characterized by collapse and sinking of the peel in irregularly shaped regions near the stem end. SERB is closely associated with excessive water loss. Late-season grapefruit are most susceptible to SERB.

Blossom-end clearing is most commonly found in late harvested, thin-peeled red-pigmented grapefruit. The wet, translucent area that develops dominantly on the blossom end results from the leaking of juice from the segments to the peel. Blossom-end clearing can be reduced by reducing pulp temperatures to <21 °C (70 °F) after harvest and eliminated by avoiding high-impact handling procedures (Echeverria et al. 1999).

Green ring is a physiological disorder that has recently appeared on early-season grapefruit in Florida. The disorder is characterized by failure of the peel to degreen in circular areas around fruit-to-fruit contact points. The remaining green ring can become necrotic as fruit remain in storage. The incidence of green ring disappears as the fruit peel matures.

Recently, interest in long-term storage of grapefruit has developed for the purposes of extending market availability. Grapefruit stored longer than 6 weeks at 3 °C (37 °F) may develop physiological collapse of juice vesicles (Brown et al. 1998).

Postharvest Pathology

Postharvest pitting is a peel disorder that affects waxed grapefruit stored at higher temperatures. Postharvest pitting can be reduced or eliminated by reducing fruit pulp temperature to 10 °C (50 °F) or less and coating fruit with highly gas-permeable coatings (Petracek et al. 1995, Florida Department of Citrus 1996).

Postharvest decay can result in significant losses of grapefruit. Postharvest grapefruit decays generally fall into two categories: those that develop as a result of colonization or infection on the fruit before harvest (stem end rots, anthracnose, and brown rot) and those that develop by inoculations made through wounds made during harvest or subsequent handling (blue and green mold and sour rot). Stem end rots develop as latent infections on the fruit button (calyx and disc) and begin growth through the core after harvest. The decay develops unevenly at the stem and stylar ends resulting in wavy margins. Stem-end rots are a problem with grapefruit grown in warm humid climates such as Florida but are rare in Mediterranean climates.

Diplodia natalensis is prevalent in early-season fruit if temperatures are high and degreening is used. Development of *Phomopsis citri* is favored during the winter months when temperatures are low and degreening is no longer necessary. *Alternaria citri* is a less aggressive fungus that can be problematic in overmature grapefruit and those in extended storage. Often the symptoms of alternaria, internal black discoloration generally towards the stem end, are not visible until the fruit are cut.

Anthracnose, *Colletotrichum gloesporioides*, is a minor problem that can appear on late-season fruit. Brown rot, caused by *Phytophthora citrophthora*, appears more frequently in mature fruit and fruit stored for longer durations at low temperatures. Green and blue mold, caused by *Penicillium digitatum* and *italicum*, respectively, invade fruit through wounds made during harvest handling. Growth of *P. digitatum* is more favorable at temperatures above 10 °C (50 °F), whereas growth of *P. italicum* occurs more readily at lower temperatures. Immature fruit are resistant to sour rot *(Geotrichum candidum)* infection, but as the fruit mature, the disease can become a problem. Consequently, late-season grapefruit can become infected, especially since the disease develops more readily at temperatures above 15 °C (59 °F) (Eckert and Brown 1986, Whiteside 1988, Florida Department of Citrus 1996).

Drenching harvested grapefruit with thiabendazole (TBZ) before packinghouse arrival is recommended for *Diplodia*, *Phomopsis*, anthracnose, and *Penicillium* control. In addition, application of aqueous imazalil or TBZ in the wax treatment aids in control. Minimizing degreening time by delaying harvest will assist in controlling stem-end rot caused by *Diplodia* and anthracnose. Careful harvesting and handling can reduce injuries that allow wound pathogens to enter grapefruit. Good sanitation of packinghouse equipment and storage areas will help control diseases that have no effective chemical control, such as sour rot. Generally, precooling or storing fruit after packing at temperaturesof 10 °C (50 ºF) or below will help control growth of postharvest pathogens.

Quarantine Issues

In areas infested with tropical fruit flies, cold treatment is an approved quarantine treatment. However, grapefruit must first be preconditioned at 10 to 15 °C (50 to 59 °F) to increase resistance to chilling injury. After 1 week, temperatures can be reduced to 0.6 to 2.2 °C (33 to 36 °F) for 14 to 24 days. In areas of low fly infestation, a less stringent temperature-duration schedule can be used (Florida Department of Citrus 1996). The recent appearance of citrus canker (*Xanthomonas axonopodis* pv. citri) has restricted movement of grapefruit grown in affected areas in Florida. Compliance with the Citrus Canker Eradication Program (2000) is required for harvesting, packing, and shipping fruit from quarantined areas.

Suitability as Fresh-Cut Product

The potential for grapefruit as a fresh-cut product is great. Peeled and sectioned grapefruit packaged in hard plastic containers have recently appeared on refrigerated shelves of Southeastern U.S. retail markets. Technological developments have overcome various postharvest problems with fresh-cut citrus. However, further development of automated systems for efficient and economical peeling is essential (Pao et al. 1997).

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