Orange

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Scientific Name and Introduction

The sweet orange (*Citrus sinensis* L. Osbeck) is a dicotyledonous, perennial evergreen of the Rutaceae family that leads other *Citrus* species in both production area and value. Fruit vary from spherical to oblong and are seedless (0 to 6 seeds) to seeded (>6 seeds). Peel color at maturity ranges from light to deep orange but may remain green under warm conditions. Late season 'Valencia' oranges may turn from orange to green ("regreen") under warm conditions.

Sweet oranges are generally classified into one of four groups: (1) round oranges such as 'Valencia,' 'Hamlin,' 'Pineapple,' and 'Shamouti'; (2) navel oranges such as 'Washington Navel'; (3) blood or pigmented oranges such as 'Moro' and 'Tarocco'; and (4) acidless oranges such as 'Succari.' In the United States, the leading orange-growing States are Florida, California, Texas, and Arizona. Of these, Florida is the largest producer of oranges; over 90% go for processing. California is the largest producer of oranges for the fresh market. Like other citrus fruits, oranges are nonclimacteric with no postharvest ripening phase.

Quality Characteristics and Criteria

A high-quality orange is mature, with good color intensity that is uniformly distributed over the surface. Fruit must be firm with a fairly smooth texture and shape that is characteristic of the variety. Fruit should be free from decay, defects, and blemishes.

Horticultural Maturity Indices

Maturity indices are based on percentage color break, SSC, TA, SSC:TA, and juice content. Specific regulations are established for different growing regions.

Florida: Minimum maturity indices for fresh fruit shipments change according to harvest date and are based on SSC and SSC:TA:

Date	SSC Minimum	SSC:TA ratio Minimum
	------------------%-------------------	
Aug. 1 to Oct. 31	9.0	10.00
Nov. 1 to Nov. 15	8.7	10.15
Nov. 16 to July 31	8.5	10.25

Florida oranges also have minimum requirements for TA (0.4%) and juice content (4.5 gal per 1.6-bu box).

California and Arizona: For fruit with yellow-orange color on≥ 25% of the surface, SSC:TA must be 8 or higher; and for fruit with green-yellow color on≥ 25% of the surface, SSC:TA ratio must be 10 or higher.

Texas: To meet minimum maturity, fruit must have 8.5 to 8.9% SSC with a SSC:TA ratio of 10 or higher, or must have SSC of 9% or higher with a SSC:TA of 9 or higher. Texas oranges also have a minimum juice content of 4.5 gal per 1.6-bu box.

Grades, Sizes, and Packaging

U.S. grade standards for sweet oranges are based on maturity, color intensity and uniformity, firmness, shape, size, smoothness, and freedom from decay, as well as freedom from defects (bruises and abrasions), insects, fungal attack (for example, cake melanose), growth cracks, chemical burns, and physiological disorders. See http://www.ams.usda.gov/AMSv1.0/standards for more details on State-specific grade standards.

U.S. grades for Florida oranges (AMS 1997): U.S. Fancy, U.S. No. 1 Bright, U.S. No. 1, U.S. No. 1 Golden, U.S. No. 1 Bronze, U.S. No. 1 Russet, U.S. No. 2 Bright, U.S. No. 2, U.S. No. 2 Russet, U.S. No. 3. Standard packed sizes used in Florida include 64, 80, 100, 125, and 163 fruit per 28.2-L (4/5 bu) container (Florida Department of Citrus 1999).

U.S. grades for California and Arizona oranges (AMS 1999): U.S. Fancy, U.S. No. 1, U.S. Combination, U.S. No. 2. Standard packed sizes used in California include 24, 32, 36, 40, 48, 56, 72, 88, 113, 138, 163, 180, 210, 245, and 270 fruit per 28.5-L (4/5 bu) container (California Department of Food and Agriculture 1990).

U.S. grades for Texas and States other than Florida, California, or Arizona (AMS 1969): U.S. Fancy, U.S. No. 1, U.S. No. 1 Bright, U.S. No. 1 Bronze, U.S. Combination, U.S. No. 2, U.S. No. 2 Russet, U.S. No. 3. Standard packed sizes used in Texas and States other than Florida, California and Arizona include 48 or 50, 64, 80, 100, 125, 144, and 162 fruit per 24.7-liter (7/10-bushel) container (AMS 1969).

Well-vented polyethylene and plastic mesh bags of various sizes are also used to market oranges. Oranges may be individually seal-packaged (wrapped with various plastic films), but this practice has not been widely adopted.

Precooling Conditions

Rapid cooling is often neglected in many citrus packinghouses but should be seriously considered as a means of improving fruit quality at destination markets. Cooling reduces respiration, slows pathogen growth, reduces water loss, and increases shelf-life. Common cooling methods for oranges include room-cooling and forced-air cooling. Oranges can also be hydrocooled, but this practice is seldom used because of the increased risk of spreading decay organisms. For room-cooling and forced-air cooling, maintaining good airflow through cartons is important to rapidly remove heat from the product. To facilitate this, carton design should include at least 5% side venting, designed to line up with adjacent carton vents and allow airflow through the entire load.

Optimum Storage Conditions

Under normal weather conditions, fruit store better on the tree than in cold storage. Cold storage should not be attempted if the fruit storage potential has been expended by prolonged tree storage. Once harvested, fruit quality will not improve. Before being placed into storage, fruit should be precooled to slow respiration and treated with an approved fungicide to reduce decay. Oranges can be stored for up to 12 weeks under optimum storage conditions. Ultimate storage life depends on cultivar, maturity, preharvest conditions, and postharvest handling. Oranges begin to freeze in storage at about -1 °C (30 °F) (Whiteman 1957). During storage, fruit should be inspected often for signs of decay or disorders. Such problems will advance rapidly once the fruit are removed from cold storage.

Recommended storage conditions are—

Growing Region	Temperature	Relative Humidity
Florida and Texas	0 to 1 °C	85 to 90%
California and Arizona	3 to 8 °C	90 to 95%

Controlled Atmosphere (CA) Considerations

CA of 5 to 10% O_2 and 0 to 5% CO_2 may aid in retaining quality of oranges. Decreased O_2 levels help maintain firmness and retard senescence, while high CO_2 levels can inhibit the development of chilling injury. However, CA is not commonly used because tolerable O_2 and CO_2 levels do not significantly inhibit decay (Hatton and Cubbedge 1977), which limits shelf-life the most. Addition of 5 to 10% CO to CA may improve decay control but is dangerous because it is lethal to humans. Maintaining low ethylene (<1 $\mu L\ L^{-1}$) during CA storage may improve flavor retention and reduce stem-end decay (McGlasson and Eaks 1972).

Retail Outlet Display Considerations

Oranges should be displayed on nonrefrigerated shelves and inspected often to remove damaged or decaying fruit.

Chilling Sensitivity

California and Arizona oranges may develop chilling injury when held at temperatures below about 3 to 5 ºC (37 to 41 ºF). Oranges produced in Florida or Texas rarely show chilling injury. Symptoms of chilling injury include pitting, brown staining, increased decay, internal discoloration, off flavors, and watery breakdown that may take 60 days to develop at 5 °C (41 °F) or become evident 1 to 2 days after moving to room temperature (about 72 °F). After removing fruit from chilling temperatures, respiration and ethylene production both increase.

The development and severity of chilling injury in citrus is influenced by both preharvest and postharvest factors. Preharvest factors include cultivar, weather conditions, and even location of fruit on the tree (sun-exposed fruit are more susceptible to chilling injury). Postharvest development of chilling injury symptoms can be reduced by temperature conditioning before storage, use of high-CO_2 atmospheres (for example, in CA or through the use of wax coatings or plastic film wraps), intermittent warming, and use of benzimidazole fungicides (such as thiabendazole and benomyl). The best means of preventing chilling injury is storing fruit at nonchilling temperatures.

Ethylene Production and Sensitivity

Citrus produce very little ethylene: <0.1 µL kg^{-1} h^{-1} at 20 °C (68 °F). Ethylene is used to degreen oranges, especially early in the season when natural degreening has been delayed because of warm night temperatures. Degreening usually takes 1 to 3 days to complete and does not affect internal quality (SSC, TA, etc.). However, ethylene stimulates decay, such as anthracnose (Brown 1992) and stem-end rot (Barmore and Brown 1985), especially at >10 µL kg^{-1} h^{-1}. Ethylene also increases respiration in citrus.

Conditions for degreening (Kader and Arpaia 1992, Wardowski 1996) are—

	Florida	California
Temperature	28 to 29 ºC	20 to 25 ºC
Ethylene	5 µL L^{-1}	5 to 10 µL L^{-1}
RH	90 to 96%	90%
Ventilation (<0.1% CO_2)	1 air change per hour	1 to 2 air changes per hour
Air Circulation	100 ft^3 min^{-1} per 900-lb bin	1 room volume per min

Respiration Rates

Temperature	mg CO_2 kg^{-1} h^{-1}
0 °C	2 to 6
5 °C	4 to 8
10 °C	6 to 10
15 °C	11 to 22
20 °C	20 to 31

To get mL CO_2 kg^{-1} h^{-1}, divide the mg kg^{-1} h^{-1} rate by 2.0 at 0 °C (32 °F), 1.9 at 10 °C (50 °F), and 1.8 at 20 °C (68 °F). To calculate heat production, multiply mg kg^{-1} h^{-1} by 220 to get BTU ton^{-1} day^{-1} or by 61 to get kcal $tonne^{-1}$ day^{-1}.

Physiological Disorders

Creasing (albedo breakdown) results from the irregular deterioration of albedo cells (white spongy tissue) and the collapse of the overlaying flavedo (colored portion of the rind) into irregular grooves over the fruit surface. Such areas are weaker and often split, providing entry for pathogenic fungi and subsequent decay. This disorder is usually more common on thin-skinned, fully mature fruit. Conditions giving rise to creasing are complex and not well understood, but appear to be related to cultivar, potassium nutrition deficiencies, high levels of nitrogen, rootstock, water status, and temperature during fruit expansion. Because the disorder is associated with advanced fruit maturity, earlier fruit harvesting may also reduce the problem.

Granulation is caused by gel formation within juice vesicles that greatly reduces extractable juice content. It may occur primarily at the stem end (in ‘Valencia’ oranges), or extend through the center of the fruit (in navel oranges). In the United States, this is considered a preharvest disorder that appears more in fruit exposed to the sun, fruit from young or water-stressed trees, overmature fruit, or fruit from vigorously growing trees. In other parts of the world, the disorder also develops after harvest.

Oil spotting (oeocellosis) arises when mechanical damage releases oil from the oil glands. When fruit are very turgid, even slight pressure from bumps and abrasions can result in oil release and spotting. The oil is toxic to surrounding tissue and will inhibit degreening of that tissue. Symptoms appear as irregularly shaped green, yellow, or brown spots that darken over time and make the glands more prominent. The most effective means of prevention is not harvesting turgid fruit early in the morning, when dew is present, during foggy conditions, or immediately after rain or irrigation (Wardowski et al. 1997).

Postharvest pitting is characterized by clusters of collapsed oil glands (often 5 to 20) scattered over the fruit surface. It can begin to develop 2 days after packing. Collapsed regions turn bronze-brown or brown-black over time. This disorder is associated with low O_2 levels in fruit following application of wax coating having low O_2 permeability and holding at warm temperatures >10 °C (50 °F; Petracek et al. 1998).

Rind staining is associated with physiologically overmature fruit that are easily injured by mechanical abrasions, particularly navel oranges. Brown or reddish-brown blemishes develop 12 to 24 h after washing and waxing (Eaks 1964). In California, fruit are sprayed with gibberellic acid to delay peel senescence and reduce incidence of this disorder.

Stem-end rind breakdown (SERB) is characterized by the irregular collapse and darkening of rind tissue around the stem end of the fruit. A narrow ring of unaffected tissue immediately around the stem (button) is a distinctive symptom of SERB. In some growing regions, SERB has been correlated with a preharvest imbalance in nitrogen and potassium. Postharvest, SERB is primarily associated with drying conditions and fruit water loss, particularly between harvest and waxing. Postharvest practices that minimize water loss, such as maintaining high RH during degreening, rapid handling, avoiding excessive brushing, and promptly applying an even coat of wax, are currently the best means of reducing SERB.

Postharvest Pathology

Postharvest decay is the most important factor limiting shelf-life of oranges. Oranges are susceptible to a wide variety of fungal diseases, including green mold *(Penicillium digitatum),* blue mold *(Penicillium italicum),* diplodia stem-end rot *(Diplodia natalensis),* phomopsis stem-end rot *(Phomopsis citri),* brown rot *(Phytophthora citrophthora),* sour rot *(Geotrichum candidum),* and anthracnose rot *(Colletotrichum gleosporioides).*

Factors such as growing region, production practices, cultivar, rootstock, and postharvest practices influence susceptibility to each of these pathogens. For example, stem-end rots are more prevalent under environmental conditions found in Florida and Texas. Green mold predominates in Florida, but blue mold does so in California. Postharvest decay can be reduced by harvesting at optimum maturity, gently handling fruit during harvest and postharvest operations, maintaining sanitary facilities and water handling systems, prompt cooling, storing at optimum temperature and RH, and using approved fungicides or biological control agents.

Quarantine Issues

Oranges are a fruit fly host, and when produced in areas where any fruit fly is found, must be treated for insect control before shipment to some markets. Approved disinfestation for oranges include methyl bromide fumigation, cold treatments, and vapor heat treatments. Use of methyl bromide is being phased out and will no longer be available by the year 2005. Cold treatments are commonly used but may result in chilling injury. Use of irradiation and controlled atmospheres are currently being evaluated as potential alternative disinfestation treatments.

All disinfestation treatments can result in phytotoxic injury to the fruit, with the degree of injury depending on preharvest factors such as cultivar and stage of maturity. As an alternative to disinfestation treatments, some production areas have established protocols that are accepted by receiving markets for certifying “fly-free” areas. Oranges grown in these areas do not have to be treated before shipment.

Suitability as Fresh-Cut Product

Consumers’ preference for peeled, sectioned, or cubed oranges that are ready to eat has driven research and development of new technologies and equipment to help meet this demand. Fresh-cut oranges can maintain quality for about 12 days, but mechanically removing the peel has been problematic. Though there are several different peeling technologies developed or under development, none is yet widely adopted.

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Some information included was taken from the University of California-Davis website “Fresh Produce Facts” at http://postharvest.ucdavis.edu/produce_information.

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