

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 shape varies from spherical to oblong and ranges from 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 (re-green) under warm conditions. Sweet oranges are generally classified into one of four groups: 1) round oranges like 'Valencia,' 'Hamlin,' 'Pineapple' and 'Shamouti'; 2) navel oranges like 'Washington Navel'; 3) blood or pigmented oranges like 'Moro' and 'Tarocco'; and 4) acidless oranges like 'Succari.' In the U.S., the leading orange growing states are Florida, California, Texas and Arizona. Of these, Florida is the largest producer of oranges with over 90% going for processing. California is the largest producer of oranges for the fresh market. Like all other citrus fruits, oranges are non-climacteric 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/or juice content. Specific regulations are established for different growing regions.

Florida: Minimum maturity indices for fresh fruit shipments change depending on harvest date and are based on SSC and SSC:TA. Florida oranges also have minimum requirements for TA (0.4%) and juice content (4.5 gal per 1.6 bu box).

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

California and Arizona: For fruit with yellow-orange color on $\geq 25\%$ of the surface, SSC:TA must be 8 or higher, and on fruit with green-yellow color on $\geq 25\%$ 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, freedom from decay, as well as freedom from defects (bruises and abrasions), insects, fungal attack (eg., cake melanose), growth cracks, chemical burns, and physiological disorders. See <http://www.ams.usda.gov/standards/> for more details on State-specific grade standards.

U.S. grades for Florida oranges (USDA, 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 Dept. of Citrus, 1999).

U.S. grades for California and Arizona oranges (USDA, 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 container (California Dept. Food and Agric., 1990).

U.S. grades for Texas and states other than Florida, California, or Arizona (USDA, 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 (7/10th bushel) container (USDA, 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.

Pre-cooling 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 hydro-cooled, 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 placing into storage, fruit should be pre-cooled 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, pre-harvest conditions, and postharvest handling. Oranges begin to freeze in storage at about -1 °C (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% O₂ + 0 to 5% CO₂ may aid in quality retention of oranges. Decreased O₂ levels help maintain firmness and retard senescence, while greater CO₂ levels can inhibit the development of chilling injury. However, CA is not commonly used because tolerable O₂ and CO₂ levels do not significantly inhibit decay (Hatton and Cubbedge, 1977), which limits shelf-life the most. Addition of 5 to 10% carbon monoxide to CA may improve decay control, but is dangerous because it is lethal to humans. Maintaining low ethylene (< 1 µL 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 non-refrigerated 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 °C (37.4 to 41 °F). 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 pre-harvest and postharvest factors. Pre-harvest 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 through temperature conditioning before storage, use of high CO₂ atmospheres (eg., in CA or through the use of wax coatings or plastic film wraps), intermittent warming, and use of benzimidazole fungicides (eg., thiabendazole and benomyl). The best means of preventing chilling injury is by storing fruit at non-chilling temperatures.

Ethylene Production and Sensitivity: Citrus produce very little ethylene at < 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 (eg., SSC, TA, etc.). However, ethylene stimulates decay, such as anthracnose (Brown, 1992) and stem-end rot (Barmore and Brown, 1985), especially if > 10 µL kg⁻¹ h⁻¹. Ethylene also increases respiration in citrus. Conditions for degreening (Wardowski, 1996; Kader and Arpaia, 1992) are:

	Florida	California
Temperature	28 to 29 °C	20 to 25 °C
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 h	1 to 2 air changes per h
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 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 per ton per day or by 61 to get kcal per metric ton per day.

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 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 due to gel formation within juice vesicles that greatly reduces extractable juice content. It may occur primarily at the stem end (Valencia oranges), or extend through the center of the fruit (navel oranges). In the U.S., this is considered a pre-harvest disorder that appears more in fruit exposed to the sun, fruit from young or water-stressed trees, over-mature fruit, or fruit from vigorously-growing trees. In other parts of the world, the disorder also develops after harvest.

Oil spotting (Oleocellosis) 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 by 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 that can begin to develop 2 days after packing. Collapsed regions turn bronze/brown or brown/black over time. This disorder is associated with low O₂ levels in fruit following application of low O₂-permeable wax coating and holding at warm temperatures >10 °C (50 °F; Petracek et al., 1998).

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

Stem-end rind breakdown (SERB) is characterized by the irregular collapse and darkening of rind tissue around the stem end of citrus fruit. A narrow ring of unaffected tissue immediately around the stem (button) is a distinctive symptom of SERB. It has been correlated in some growing regions with a pre-harvest imbalance in nitrogen and potassium. Postharvest, SERB is primarily associated with drying conditions and fruit water loss, particularly between harvest and waxing. Postharvest practice that minimizes water loss such as maintaining high RH during degreening, rapid handling, avoiding excessive brushing, and prompt application of 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 (*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 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; optimum temperature and RH; and use of approved fungicides or biological control agents.

Quarantine Issues: Oranges are 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 pre-harvest 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 (determined based on negative trapping or bait sprays with negative trapping). 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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