

Lemon

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Scientific Name and Introduction: Lemons (*Citrus limon* L. Burman f.) are grown year-round in California, the major producer. Arizona, and to a lesser extent Florida, also produce a significant portion of the lemon crop. The primary varieties are Eureka and Lisbon. Both have firm, smooth skins, juicy flesh and few seeds. The exact origin of the lemon is unknown, but some have linked it to northwestern India.

Quality Characteristics and Criteria: The primary quality characteristics are intensity and uniformity of yellow color, size, shape, smoothness, firmness, freedom from decay and defects including freezing damage, drying, mechanical damage, rind stains, red blotch, shriveling, and discoloration. Lemons should have smooth thin skins and be firm. Ripe lemons should have a pleasant citrus fragrance. Lemons with discolored, bruised or wrinkled skins should be avoided.

Horticultural Maturity Indices: The generally accepted standard is a minimum juice content of 28 to 30% by volume depending on the grade.

Grades, Sizes and Packaging: The common packaging specifications are 40 lb (18.2 kg) cartons, 10 lb (4.6 kg) mini-pack cartons, 8 lb (3.6 kg) consumer cartons, as well as 2, 3 and 5 lb (0.9, 1.4 and 2.3 kg) bags. Grading includes U.S. No.1, U.S. Export No. 1, U.S. Combination and U.S. No. 2. Sizes include 75, 95, 115, 140, 165, 200 and 235 count.

Pre-cooling Conditions: Most packinghouses do not pre-cool lemons because the anticipated benefit is too modest, or they may need to degreen the fruit with ethylene which necessitates 20 °C pulp temperatures.

Optimum Storage Conditions: Yellow lemons harvested when dark-green have a much longer postharvest life than those picked yellow, which must be marketed more rapidly due their shorter shelf-life. Lemons should be stored between 7 to 12 °C (45 to 54 °F) depending on the maturity-ripeness stage at harvest, season of harvest, storage time and production area. They can be stored for up to 6 mo under the right conditions. The optimum RH is 85 to 95%. Because lemons are chilling sensitive, they should not be stored for prolonged periods below 10 °C (50 °F), although 3 to 4 weeks storage at 3 to 5 °C (37 to 41 °F), which is typical for some receivers, is usually tolerated without harm. Removal of ethylene from storage rooms can reduce senescence and incidence of fungal decay. It is generally recognized that proper storage of lemons improves quality, ie., juice content, flavor and color.

Adequate ventilation must be maintained during storage. Cartons should be kept off of the floor to help prevent cartons becoming wet from condensation. Lemons should be stored away from produce with a strong odor. Also, decay can occur from skin cuts or scratches caused by rough handling. Handle lemons with care, and be sure not to drop shipping containers on the floor. Any affected product should be removed immediately to prevent mold from spreading.

Controlled Atmosphere (CA) Considerations: Controlled atmosphere conditions of 7.5 to 10% O₂ + up to 10% CO₂ can delay senescence, including loss of green color, but the risk of injury to the fruit is high and it is only rarely used. Levels of CO₂ sufficient to inhibit fungal growth (> 10%) are not used because high CO₂ induces non-persistent but objectionable off-flavors due to the accumulation of volatiles from fermentation. Also, levels of O₂ sufficient to control fungi (< 1%) are not used because when O₂ < 5% is used, persistent off-flavors can develop.

Retail Outlet Display Considerations: Lemons should not receive a water sprinkle or top ice.

Chilling Sensitivity: Chilling injury can be a major disorder of lemon, and it is therefore important not to store lemons below 10 °C (50 °F). Symptoms include pitting of the skin (termed peteca), interior discoloration, red blotch and loss of juice. Chilling injury severity depends upon cultivar, production area, harvest time, maturity-ripeness stage at harvest, and time-temperature of postharvest handling operations. Moderate to severe chilling injury is usually followed by decay.

Ethylene Production and Sensitivity: Rates of ethylene production are generally $< 0.1 \mu\text{L kg}^{-1} \text{h}^{-1}$ at 20 °C (68 °F). If degreening is desired, lemons can be treated with 1 to 10 $\mu\text{L L}^{-1}$ ethylene for 1 to 3 days at 20 to 25 °C (68 to 77 °F). However, it should be noted that this exposure may accelerate deterioration and incidence of decay, since lemons are sensitive to ethylene exposure. They should not be stored together with ethylene-producing produce.

Respiration Rates:

Temperature	mg CO ₂ kg ⁻¹ h ⁻¹
10 °C	10 to 12
15 °C	14 to 24
20 °C	20 to 28

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. Data are from Arpaia and Kader, 2001.

Physiological Disorders: Several significant disorders of lemon fruit are:

Oleocellosis or oil spotting, a rind blemish which involves the breaking of oil cells due to physical stress on turgid fruits which results in the release of oil that damages surrounding tissues. Both the avoidance of harvesting of lemons when they are turgid and careful handling will reduce the severity of this disorder.

Peteca, another rind disorder, begins in white portion of peel initially and develops sunken brown pits. It is favored by low temperatures before or after harvest and oil applications in the grove and an imbalance of calcium and potassium in the peel. Some reduction in peteca is obtained by gibberelic acid applications to trees and by avoiding storage of susceptible lemons below 13 °C (55 °F).

Membrane stain, an internal disorder where the membranes between segments, or carpellary walls, show irregular brown or black areas. It is reduced by avoiding storage of lemons below 13 °C (55 °F) and improving ventilation in storage.

Postharvest Pathology: There are three main postharvest pathological diseases of lemon.

Green Mold and Blue Mold are caused by *Penicillium digitatum* and *P. italicum*, respectively. Spores of these pathogens access the fruit rind through wounds. Symptoms begin as water-soaked areas at the fruit surface followed by growth of colorless mycelium, and then sporulation. Blue Mold is more common when storage temperatures are low and it spreads from fruit to fruit more readily than Green Mold.

Thiabendazole, imazalil, and sodium ortho-phenyl phenate are fungicides used for these diseases, and partial control can be obtained with biological control agents and the immersion of fruit in soda ash or sodium bicarbonate. Incidence of these diseases is reduced by careful handling to minimize wounds.

Sour Rot is caused by *Geotrichum citri-aurantii* which enters lemons initially through wounds made by insects, then infected fruit are digested by the pathogens and it spreads rapidly from fruit. It is associated with cool, wet growing conditions. Partial control can be obtained by immersion of fruit in soda ash, sodium bicarbonate, or sodium ortho-phenyl phenate after harvest and using minimal storage temperatures.

Other pathogens including *Alternaria citri*, the stem-end rot fungi *Diplodia natalensis* as well as *Phomopsis citri*, *Botrytis cinerea*, *Trichoderma* spp., *Sclerotinia sclerotiorum* and *Phytophthora* spp. are occasionally troublesome in lemon storage. Additional strategies to minimize postharvest decay include: prompt cooling to the proper temperature range; maintaining optimum ranges of temperature and RH; exclusion of ethylene during transport and storage; the use of gibberelic acid before harvest to delay senescence of the fruit after harvest, and sanitation throughout the handling system.

Quarantine Issues: Most quarantine concerns for lemons address eliminating fruit flies, such as the Caribbean, Oriental, Mediterranean, and Mexican fruit flies. Heat, cold, and methyl bromide treatments are certified for this purpose, but they all pose risk of injury to lemons. Harvest and export of fruit from certified pest-free zones is another option to control fruit flies that eliminates risks of fruit injury, and this approach has also been employed against citrus black fly and Fuller rose beetle. Quarantine authorities are concerned that citrus black spot, an unsightly rind blemish caused by *Guignardia citricarpa* that occurs in South Africa and parts of Asia and South America, could potentially become established in Mediterranean countries and/or in North America.

Suitability as a Fresh-cut Product: Lemon sections, prepared by both manual and automatic processors, are distributed for use in the food service industry.

Special Considerations: None.

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