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, and freedom from decay and defects including freezing damage, drying, mechanical damage, rind stains, red blotch, shriveling, and discoloration. Lemons should be firm and have smooth, thin skins. 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

Grading includes U.S. No. 1, U.S. Export No. 1, U.S. Combination, and U.S. No. 2. 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, and 2-, 3-, and 5-lb (0.9-, 1.4-, and 2.3-kg) bags. Sizes include 75, 95, 115, 140, 165, 200, and 235 count.

Precooling Conditions

Most packing houses do not precool lemons because the anticipated benefit is too modest, or they may need to degreen the fruit with ethylene, which requires 20 °C (68 °F) 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 and 12 °C (45 and 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. Optimum RH is 85 to 95%. Because lemons are chilling sensitive, they should not be stored for prolonged periods below 10 °C (50 °F), though 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 fungal decay. It is generally recognized that proper storage of lemons improves quality (juice content, flavor, and color).

Adequate ventilation must be maintained during storage. Cartons should be kept off the floor to prevent them becoming wet from condensation. Lemons should be stored away from produce having a strong odor. Also, decay can occur from skin cuts or scratches caused by rough handling. Lemons must be handled with care, and shipping containers should not be dropped 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% O_2 and up to 10% CO_2 can delay senescence, including loss of green color, but the risk of injury to the fruit is high and CA is only rarely used. Levels of CO_2 sufficient to inhibit fungal growth (>10%) are not used because high CO_2 induces nonpersistent but objectionable off flavors due to the accumulation of volatiles from fermentation. Also, levels of O_2 sufficient to control fungi (<1%) are not used because when O_2 is <5%, 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 on 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 μL kg^{-1} h^{-1} at 20 °C (68 °F). If degreening is desired, lemons can be treated with 1 to 10 μL 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

Data from Arpaia and Kader (2001).

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

Several disorders of lemon fruit are significant. Oleocellosis or oil spotting, a rind blemish that involves the breaking of oil cells due to physical stress on turgid fruits, results in the release of oil that damages surrounding tissues. Not harvesting lemons when they are turgid and careful handling reduce the severity of this disorder. Peteca, another rind disorder, begins in white portion of peel and develops sunken brown pits. It is favored by low temperatures before or after harvest, 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 in which 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 mycelia, 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. Fungicides thiabendazole, imazalil, and sodium ortho-phenyl phenate are 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 is digested by the pathogens, which spread rapidly from fruit to fruit. Sour rot is associated with cool, wet growing conditions. Partial control can be obtained by immersing fruit in soda ash, sodium bicarbonate, or sodium ortho-phenyl phenate after harvest and using minimal storage temperatures.

Other pathogens are occasionally troublesome in lemon storage, including *Alternaria citri* and the stem-end rot fungi *Diplodia natalensis*, as well as *Phomopsis citri*, *Botrytis cinerea*, *Trichoderma* spp., *Sclerotinia sclerotiorum*, and *Phytopthora* spp. Additional strategies to

minimize postharvest decay include prompt cooling to the proper temperature range, maintaining optimum ranges of temperature and RH; excluding ethylene during transport and storage; using gibberelic acid before harvest to delay senescence of the fruit after harvest; and providing 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 in North America.

Suitability as Fresh-Cut Product

Lemon sections, prepared by both manual and automatic processors, are distributed for use in the food service industry.

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