Lemons, Fresh, Concentrate, and Lemonade

Revised 2018

Thermal Properties

	English	Metric
Moisture, %	87.40	--
Protein, %	1.20	--
Fat, %	0.30	--
Carbohydrate, %	10.70	--
Fiber, %	4.70	--
Ash, %	0.40	--
Specific Heat Above Freezing	0.94 Btu/lb*°F	3.94 kJ/(kg*K)
Specific Heat Below Freezing	0.48 Btu/lb*°F	2.02 kJ/(kg*K)
Latent Heat of Fusion	126 Btu/lb	292 kJ/kg

Storage Conditions

	Fresh	Frozen Concentrate	For Lemonade
Temperature	45-50°F (7-10°C)	0 to -10°F (-18 to -23°C)	0 to -10°F (-18 to -23°C)
Storage Period	2-3 weeks	12 months	1 year and longer
Relative Humidity	85-95%	Gas tight packaging	

Lemons grown in coastal areas in California are usually picked when the rind is green after they have attained proper size. While in storage, the green lemons develop the characteristic yellow color, increase in juice content, and improve in flavor. Also, the rind of the fruits becomes thinner and physiological changes cause the fruits to become more susceptible to injury and decay. Once they attain the desirable yellow color, the lemons are removed from storage, washed, waxed, and prepared for shipment. Lemons from other areas that are picked yellow from the trees are washed, waxed, and shipped without storage and should not be held for long at terminal markets since yellow lemons cannot be held as long as can green lemons.

Storage of lemons for prolonged periods is usually not necessary, since lemon fruits are available fresh throughout most of the year. Most of the US fresh lemons for domestic consumption and export are produced in the California-Arizona region, although some fresh lemons are available from Florida. In the

coastal and foothill areas of California, lemons are picked throughout the year, the yellow fruit being marketed immediately and the green fruit put into storage to cure and change color slowly. In the desert areas fruit are all picked from September through March. San Joaquin Valley lemons are marketed from November through February, March, or April, depending on yearly variations. Most of the early-season green lemons from the desert and San Joaquin Valley producing areas are de-greened with ethylene so that they may be marketed rapidly without the long curing period in storage. This is done by holding the fruit for 5-10 days, depending on the greenness of the fruit, at 72-78°F (22-25°C) and 85-90% relative humidity and adding 5-10 ppm ethylene gas to the storage atmosphere. De-greened fruit, no matter from what geographic area, are usually weaker than fruit which are not de-greened, and therefore, long storage is not recommended for this fruit.

Storage of Lemons in Terminal Markets

There are times when short-term storage in terminal markets is advantageous, and small quantities of lemons may be stored there for as long as 2, 3, or 4 months. However, storage of lemons in terminal markets can be very risky since little of the handling and storage history of the fruit is known, nor are fruit washing and repacking facilities available there, should excessive numbers of decaying fruit develop that would require removal before further marketing.

Knowledge of field and packing history is very valuable. Early-season, green, or light-green lemons that have not received an ethylene treatment may be held satisfactorily at terminal markets for 1-3 months at 55-58°F (13-14°C). However, such fruit are rarely shipped to terminal markets in this green condition. Late-season, silver, or yellow lemons or lemons that have been de-greened with ethylene cannot be stored well at any temperature. If lemons are to be stored for not more than 2-3 weeks, 45-48°F (7-9°C) is a satisfactory temperature range, but if they are to be stored for longer periods, these temperatures may increase the likelihood of undesirable physiological changes, such as chilling injury (CI) and membranous stain. Such injuries generally result in increased decay after lemons are removed from refrigerated storage. Lemons should never be stored at 32-35°F (0-2°C) because of the possibility of CI. One of the quarantine treatments approved by regulatory agencies for control of certain Tephritid fruit flies, including the Mediterranean fruit fly, Caribbean fruit fly, Mexican fruit fly, and others, on citrus fruit is to hold fruit at 32-36°F (0-2.2°C) for 10-21 days, depending on the temperature used and the fruit fly species involved. Should this cold treatment be necessary, it can be used on lemons harvested in cool or cold weather without causing chilling injury to the lemons. However, if lemons are harvested in summer from hot desert areas, the likelihood of chilling injury to fruit is great. Curing or holding the fruit for several days at 59°F (15°C) before cold treatment will reduce fruit susceptibility to chilling injury.

A relative humidity of 85-95% is generally considered satisfactory for lemon storage. Higher humidity prevents proper curing of lemons, encourages mold growth on walls and containers, and encourage decay of the fruit. Low humidity causes excessive weight loss that result in fruit shrinkage and shriveling.

Proper ventilation in lemon storage is needed to avoid buildup of carbon dioxide over 0.1% and to prevent accumulation of ethylene.

In the event forced-air ventilation is used, extra precautions are necessary to maintain high humidity in order to retard fruit weight loss.

Controlled atmosphere (CA) storage containing less than 5% oxygen is NOT recommended because off-flavors develop in the fruit and brown spots appear on the peel and fruit is very susceptible to decay after it is removed from CA storage.

Diseases and Injuries

Chilling Injury	Occurs to fruit stored at temperatures below 40°F (4.4°C) and especially below 32-35°F (0-2°C), but above the actual freezing point of the fruit. Symptoms are varied and may be external or internal. Susceptibility of fruits is very unpredictable, and considerable variation occurs on fruit from different areas, different seasons, different maturities, and different holding (curing) temperatures before the low temperature storage. Usually, fruit harvested during cool or cold weather will tolerate 32-35°F (0-2°C) without injury, but lemons harvested during weather above 90°F (32.2°C) are very susceptible to CI. **Control:** Conditioning fruit at 59°F (15°C) for 3-4 days before cold treatment will reduce the degree of chilling injury. Store at ideal temperature.
Albedo Browning	A discoloration of the white, spongy inner tissues of the rind; externally there may be a slight pebbly brown-gray darkening of the rind. **Control:** Do not store fruit at low temperature, provide good ventilation, and avoid harvesting immature, dark-green fruit.
Brown Staining	Irregular tan-to-brown superficial discoloration of the peel. Pitting or surface tissue collapse may occur in severe cases. **Control:** Do not store fruit at 32-34°F (0-1°C). Staining may fade or disappear upon removal to room temperature.
Membranosis	A browning or darkening of membranes or carpellary walls between segments. Core and inner tissues of rind also may be affected. Does not affect fruit held at 32 or 60°F (0 or 15°C). **Control:** Avoid picking fruit in cool, damp weather; do not store green fruit at 40°F (4.4°C) for long periods.
Watery Breakdown	Soft, spongy frozen appearance; flesh and rind may be softened; carpels loosely attached to rind; watery substance oozes from albedo when rind is pressed; disagreeable fermentation odor, especially when fruit are warmed. **Control:** Do not store fruit below 40°F (4.4°C) for prolonged periods.

Non-Chilling Injuries

Freezing Injury	Freezing point of lemons is 27.9-28.5°F (-2°C). Flesh becomes mushy upon thawing, the membrane between segments is water-soaked, and the rind is watery-discolored, may be sunken, and is brownish or grayish color. Fruit frozen on the tree is soft, light, and has woody pulp or open spaces between the segments due to collapse and drying-out of some of the juice sacs. **Control:** Avoid freezing temperatures. Air discharged from refrigeration units, especially in transit vehicles, is often below freezing temperature and should be deflected so as not to hit fruit directly until the air has warmed up. A better procedure is to locate thermostats controlling air temperature in the discharge air stream rather than in the return air ducts. Use proper open stacking patterns during shipping or storage so all cartons are exposed to cool air supply. Use supplemental heat if necessary during winter shipping in cold or mountainous areas.
Internal Decline	Limited to California lemons harvested in summer-fall. Tissues break down and become pinkish or brownish near the tip end of the fruit. In advanced stages an exudate or gummy substance is deposited in or next to the peel near the cavities. **Control:** No warehouse controls known.
CA Injury	CA, especially the use of low O_2, leads to injury of citrus fruits. Improper or inadequate air circulation and ventilation during long shipments or during storage may also cause similar injuries. Sometimes fruit develop a scald, or a light brown pebbly appearance of the rind, accompanied by fermented odor and flavor. Normal-appearing fruit may be off-flavored. Off flavor may dissipate when fruit are returned to air storage. Fruit are more susceptible to decay after CA storage. **Control:** Avoid using CA storage, provide adequate ventilation.
Oil Spotting or Oleocellosis	Irregularly shaped yellow, green, or brown spots in which the oil glands of the skin stand out prominently from the sinking tissues between them. Especially likely on green lemons handled wet or turgid; a bruising injury caused by oil liberated from ruptured oil glands. **Control:** Avoid picking fruit when wet or turgid, and rough handling that would release oil, especially during early parts of the year.
Pitting	Abruptly sunken spots in the rind, light or dark brown or black later, caused by holding at 32-40°F (0-4.4°C). **Control:** Avoid prolonged storage under 40°F (4.4°C).

Fungus Diseases

Alternaria Rot	Occurs in lemons from all producing areas. Infection usually is through the button (calyx tissues) and usually in lemons of low vitality that have been in storage for some time. Weak or overripe fruit are especially vulnerable. Buttons turn brown first, and then rot develops along the central core. Later the fungus breaks down the outer rind to a slimy, lead-brown color, and eventually a gray-black fungus mycelial growth develops on the surface. **Control:** Treat lemons with 2, 4-dichlorophenoxy acetic acid (isopropyl ester) (2,4-D) during pre-storage wash. Buttons stay green longer and infection is delayed. The fungus develops slowly below 50°F (10°C).
Anthracnose	Brown or black spots usually at bruised or injured points; pink spores at first, turning to gray or black specks. Disease may penetrate deeply into fruit. **Control:** Careful handling; avoid weak fruit from unhealthy trees for storage. Proper cultural practices in field prevent orchard infections which carry over into storage.
Penicillium Rots	Commonest of all citrus rots; starts as soft, watery, slightly discolored spots which enlarge; a white fungus mycelial covering develops which soon is covered with dusty olive-green or blue spore masses. A soft water-soaked ring surrounding the white edge of the fungus colony is characteristic. **Control:** Careful handling at all times to avoid wounds; fungicides may be used in fruit washes, in wax, and incorporated into Kraft paper inserts in citrus cartons. Proper cooling is essential.
Botrytis	In early stages resembles Cottony Rot but decayed rind areas are darker, and later turn buff or dark brown. The fungus mycelium is gray rather than cottony white. **Control:** Prevent injuries, keep fruit from contact with soil or trash, wash fruit at 115-120°F (46-49°C), avoid excessive humidity in storage.
Brown Rot	Remarkably firm, leathery decay starting as a slight olive-drab or brownish-tan rind discoloration, later turning dark brown. Usually no fungus mycelium is apparent, except under very humid conditions when a white growth appears; distinctive aromatic or fermentative "cinnamon" odor. **Control:** Apply fungicide sprays in field prior to rainy or moist periods, wash fruit in 115-120°F (46-49°C) water. Usual fungicides for *Penicillium* mold control are ineffective.
Cottony Rot	Affects fruit slowly; leathery, pliable at first, color yellowish-brown or greenish-brown. In moist atmosphere a white, cottony mycelium develops rapidly in which black, cheesy large spores develop. Rapidly spreads by contact to surrounding fruit; nest of decaying fruit may develop. **Control:** Careful handling; packinghouse and field sanitation; wash fruit in hot water.
Sour Rot	At its worst, in combination with other decay organisms, this is one of the messiest and unpleasant of citrus decays. Similar in appearance to green and blue molds in early stages, with water-soaked areas which are eventually overgrown with a cream-colored, pasty, foul-smelling fungus which is very attractive to fruit flies.

	Control: Ordinary fungicides are ineffective. Avoid injuries and refrigerate fruit to below 40°F (4.4°C) if possible.
Stem End Rot	A common decay in all citrus fruit from Florida but rarely from California-Arizona. Stem end softening of rind, later turning tan, brown, or black. Infection progresses rapidly, down the spongy central axis to the stylar end, and then affects the surface rind. Little surface fungus growth. Occurs mostly on mature fruit. **Control:** Hot water wash fruit; fungicides in wash water, in wax, and on paper inserts.
Trichoderma Rot	Decaying fruit turn cocoa-brown; have a firm, pliable texture, and a coconut-like odor. In a moist, dark carton white fungus mycelia appear which, on exposure to light, turn yellow-green to dark-green. **Control:** Avoid injuries to fruit; keep wooden storage boxes clean.

Frozen Lemon Product

About 40% of the U.S. lemon crop is processed, primarily into juice and frozen lemonade concentrate. The commercial production of lemon products in the United States is confined almost exclusively to California, where the Eureka lemon, the principal variety grown, comprises approximately 88% of the total production. The lemon industry is unique in that the fruit is picked on the basis of size rather than maturity in order to avoid very large fruit, and then held under controlled storage conditions to change color from green to yellow instead of being left on the trees to color.

The lemons are inspected, washed, and sized. After the juice is extracted, it is screened to remove rag and seeds, and held in tanks to chill. If necessary, the juice can be de-aerated in tanks by applying a vacuum of 20-25 in. (51-63 cm) for about 30 minutes. Lemon juice is frozen as single strength juice, concentrate, or lemonade concentrate. For canned frozen single strength juice, the chilled juice is drawn from the cold holding tanks and further cooled to 30°F (-1°C) by passing through a heat exchanger. It is then filled into enamel-lined cans, sealed, frozen, cased, and stored at 0 to -10°F (-18 to -23°C). Lemon juice is concentrated in the same evaporation equipment used for oranges except that cut-back juice is not used and the lemon juice is concentrated to 43° Brix or approximately 5.75 to 1.

Frozen Concentrate for Lemonade: Frozen concentrate for lemonade is second only to orange juice concentrate in production in the US. This product is primarily single-strength lemon juice with sugar added. Approximately 10% of concentrated lemon juice is added to give the proper balance of sugar and citric acid.

A low storage temperature is more important for lemon juice than most citrus juice concentrate to maintain good flavor and color and high vitamin C retention. It is therefore suggested that lemon juice concentrate be stored frozen at 0 to -10°F (-18 to -23°C). At such temperatures the lemon juice concentrate will maintain satisfactory quality for up to 1 year. Lower temperatures will retard rates of deterioration, but unless the product is to be stored for periods longer than 1 year, lower temperatures than -10°F (-23°C) are not necessary.

Packaging

Modern packaging of purees and puree concentrates utilizes some form of aseptic totes. There are a number of different styles, including stainless steel totes that can be sterilized and reused; reusable plastic totes with disposable aseptic liners; or large (275 to 300 gallon) fiberboard disposable totes. It is important to note that none of these container types are designed for frozen use. Freezing and thawing destroys the integrity of the disposable fiberboard totes, and the plastics can become brittle and/or break. Stainless steel totes can burst with freezing due to internal gas pressure. As a result, containers should be stored in either ambient or refrigerated areas using similar storage length as drums under the same conditions. This limits their use to aseptic products. After opening, the items either need to be used immediately or transferred into another container for refreezing and storage.

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