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Postharvest Handling Systems: Subtropical Fruits

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Subtropical fruits include avocado, carob, cherimoya, citrus fruits (orange, grapefruit, lemon, lime, pummelo, tangerine and mandarin, and kumquat), date, fig, jujube, kiwifruit (chapter 29), loquat, lychee (litchi), olive, persimmon, and pomegranate. Some of these fruits are also grown in tropical and temperate zones. Subtropical fruits are diverse in morphological and compositional characteristics and in postharvest requirements. Subtropical fruits can be grouped according to their relative perishability as follows:

- Highly perishable: fresh fig, loquat, lychee
- Moderately perishable: avocado, cherimoya, olive, persimmon
- Less perishable: citrus fruits, carob (dry), dried fig, date, jujube (Chinese date), kiwifruit, pomegranate

This chapter relates the general characteristics of subtropical fruits to their postharvest biology and handling requirements. The emphasis is on avocado and citrus fruits, the fruits that are most important commercially. Commercial production of citrus fruits in the United States is limited to Arizona, California, Florida, and Texas. The United States produces about 30% of the world's production of lemons and 40% of its oranges. Florida is the leading U.S. producer of citrus fruits, most of which (greater than 80%) is processed. Most California citrus fruits are marketed fresh. California accounts for almost all U.S. production of dates, figs, kiwifruit, olives, persimmons, and pomegranates.

Three strains of cultivated avocados are Mexican (e.g., Bacon), Guatemalan (e.g., Hass, Reed), West Indian (e.g., Pallock, Waldin), and their hybrids (e.g., Fuerte). Fresh avocados from Florida (West Indian cultivars) are available from July through February; California avocados (Mexican, Guatemalan, and Mexican-Guatemalan hybrid cultivars) are available year-round. California produces more than 80% of U.S. avocados.

MORPHOLOGICAL AND COMPOSITIONAL CHARACTERISTICS

Avocados are one-seeded berries. Cultivars vary in size. Usually pear shaped, avocados can also be round or oval. The flesh has more energy value than meat of equal weight and is a good source of niacin and thiamine. Of all tree fruits, avocados and olives are the highest in protein and fat content. In California, minimum maturity of the avocado is defined in terms of dry weight, which is highly correlated with oil content of the flesh. The minimum dry weight required before harvesting can begin varies with cultivar from 19 to 25%. Florida-grown cultivars have lower oil content and are harvested on the basis of a calendar date (days after full bloom).

Citrus fruits rank first in their contribution of vitamin C to human nutrition in the United States. Botanically, citrus fruits are classified as a hesperidium, a specialized berry. The rind has two components: the pigmented part, called the *flavedo* (epidermis and several subepidermal layers), and the whitish part, called the *albedo*. The juicy part consists of segments filled with juice sacs. Minimum maturity requirements of citrus fruits are based on juice content (lemon and lime) or soluble solids content, titratable acidity, and the ratio of the two (orange, grapefruit, and tangerine).

POSTHARVEST PHYSIOLOGY

Avocados have a relatively high respiration and ethylene production rate, and both rates exhibit a climacteric pattern. Citrus fruits are nonclimacteric and have low respiration and ethylene production rates. Postharvest compositional changes in citrus fruits are minimal, whereas avocados undergo many changes in composition, texture, and flavor associated with ripening.

Avocados do not ripen on the tree. The exact nature of the ripening inhibitor is not known, but it continues to exert its effect for about 24 hours after harvest. Avocado ripening can be hastened by exposure to 10 ppm ethylene at 15°C to 18°C (59° to 65°F) and 85 to 90% RH for 12 to 48 hours; temperatures up to 25°C (77°F) can be used if faster ripening is desired. On the other hand, removal or exclusion of ethylene from the storage environment helps extend the storage life of avocados by delaying softening, onset of chilling injury, and decay incidence.

Cold nights followed by warm days, are necessary for loss of green color and appearance of yellow or orange color in citrus fruits. This is why citrus fruits remain green after attaining full maturity and good eating quality in tropical areas. Occasionally, re-greening of Valencia oranges occurs in certain production areas after they have reached full orange color.

Degreening of citrus fruits essentially results in removal of chlorophyll from the flavedo but does not influence composition of the fruits' edible portion. The need for and duration of de-greening treatments depend on the cultivar and the fruit's condition at harvest—the amount of chlorophyll to be removed. Lemons are usually de-greened at 16°C (60.8°F) with or without added ethylene; higher temperatures may be used for faster de-greening. Recommended conditions for de-greening California oranges and grapefruits are:

- Temperature: 20° to 25°C (68° to 77°F)
- Relative humidity: 90%
- Ethylene concentration: 5 to 10 ppm
- Air circulation: One room volume per minute
- Ventilation: One to two air changes per hour, or sufficient changes to keep CO_2 below 0.1%

In Florida, a temperature of 27° to 29°C (80.6° to 84.2°F) and an ethylene concentration of 1 to 5 ppm are recommended.

Table 30.1. Chilling injury symptoms on avocados and selected citrus fruits

	Minimum safe temperature*		
Fruit	°C	°F	Symptoms
Avocado	5–10	41–50	Skin pitting, scalding, and blackening are the main external symptoms. Internal symptoms include grayish-brown discoloration of flesh, discoloration of the vascular tissue, softening, and development of off-flavors.
Grapefruit	10–13	50–55	Pitting, scald, watery breakdown.
Lemon	10–13	50–55	Pitting, membranous stain, red blotch.
Lime	10–13	50–55	Pitting, accelerated decay.
Mandarin	5–8	41–46	Pitting, brown discoloration.
Orange	3–5	37–41	Pitting, brown stain.

Note: *Varies with cultivar, maturity-ripeness stage, and duration of storage.

PHYSIOLOGICAL DISORDERS

CHILLING INJURY

Susceptibility to chilling injury varies in subtropical fruits according to species and cultivar. For example, grapefruit, lemon, and lime are much more susceptible to chilling injury than orange and mandarin. Orange cultivars grown in Florida are reportedly less sensitive to chilling injury than those grown in California and Arizona. Date, fig, kiwifruit, and Hachiya persimmon are not sensitive to chilling injury. Fuyu persimmon, pomegranate, olive, and other subtropical fruits are chilling sensitive. Ripe avocado fruit tolerate lower temperatures than unripe fruit, without danger of chilling injury. Symptoms of chilling injury on selected subtropical fruits are summarized in table 30.1 and illustrated in figures 30.1 and 30.2 for orange and grapefruit, respectively.

OTHER DISORDERS

Fruits exposed to temperatures below their freezing point before or after harvest can suffer serious injuries; for example, injured citrus fruits become dry and useless and have to be separated in the packinghouse by flotation or X-ray techniques. High-temperature disorders resulting from preharvest exposure

Figure 30.1

Chilling injury symptoms on oranges. Darker areas are brown.

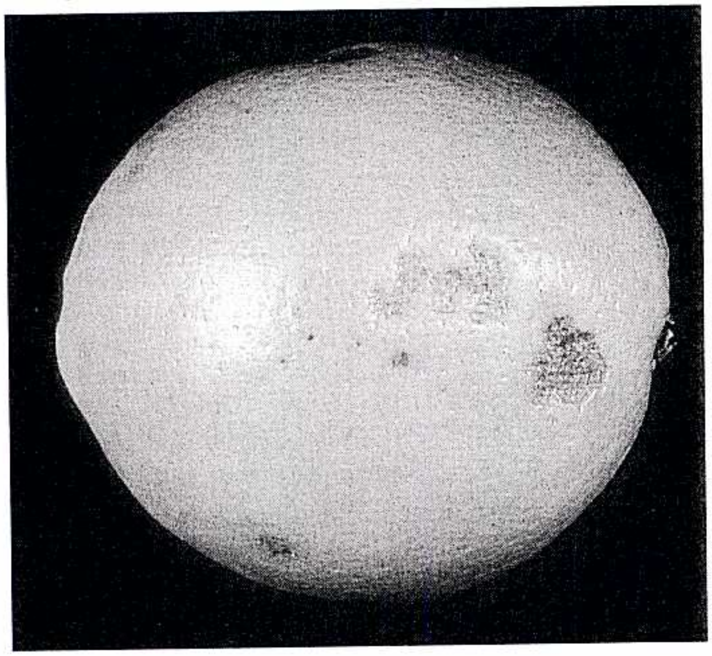
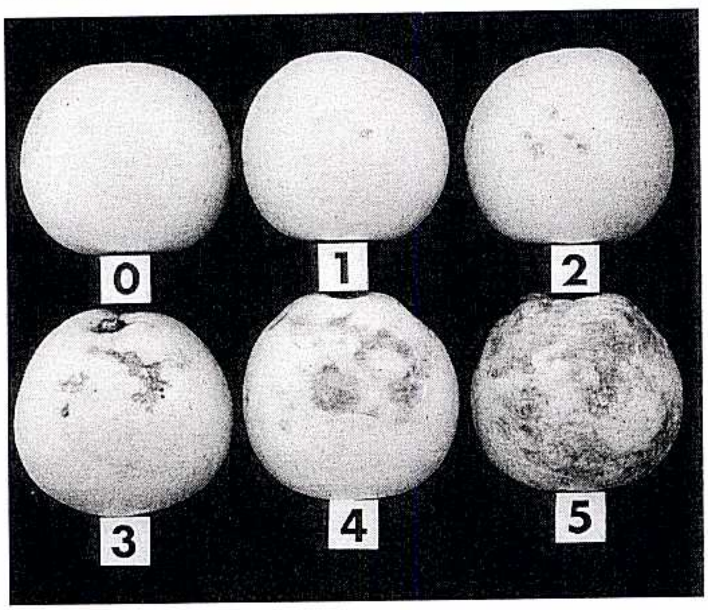


Figure 30.2

Scoring system for severity of chilling injury on grapefruit. Darker areas are brown.



to sun can result in sunburned avocado and citrus fruits. Exposure of avocado to temperatures above 25°C (77°F) may cause uneven softening, skin discoloration, flesh darkening, and off-flavors.

Citrus fruit peel disorders, other than chilling injury, include

- oil spotting, or oleocellosis (breaking of oil cells, causing the oil to extrude and damage surrounding tissue) (fig. 30.3)
- rind staining of navel orange (an indication of peel overmaturity that can be controlled by preharvest application of gibberellin)
- stem-end rind breakdown of orange
- stylar-end breakdown of lime
- shriveling and peel injury around the stem end indicating aging

PATHOLOGICAL BREAKDOWN

AVOCADO

Avocado fruit can be affected by one or more pathogens. *Dothiorella gregaria* (probably the asexual state of *Botryosphaeria ribis*) is a postharvest rot of California avocados. Anthracnose occurs particularly in humid areas such as Florida. Neither organism is usually a serious problem in California unless the weather has been unusually wet at or near harvest time. Stem-end rots (*Diplodia natalesis, Phomopsis citri*) can also be serious in Florida and other humid growing areas.

Control methods include good orchard sanitation, effective preharvest fungicide application, careful handling to minimize physical injuries, prompt cooling to optimal temperature for the cultivar, and maintaining that temperature during marketing.

CITRUS FRUITS

Postharvest diseases also limit the postharvest life of citrus fruits. Blue mold (*Penicillium italicum*) and green mold (*Penicillium digitatum*) occur in citrus fruits in all production areas. In humid areas, stem-end rots (*Diplodia* spp. and *Phomopsis* spp.) and anthracnose (*Colletotrichum gloeosporioides*) are common. Sour rot (*Geotrichum candidum*) affects lemons during long-term storage, especially during wet seasons. Phytophthora brown rot occurs in California following cool, wet weather, and can be controlled by heat treatment. Alternaria stem-end rot (*Alternaria citri*) usually follows senescence of the calyx of the fruit.

Citrus diseases can be controlled by the following procedures:

Reduce the pathogen population in the environment. Use an effective preharvest disease control program to reduce postharvest incidence of stem-end rots and anthracnose. Use chlorine (e.g., sodium hypochlorite) in wash water. Regularly disinfest field

Figure 30.3

Scoring system for severity of oil spotting on lemons. Darker areas are green.

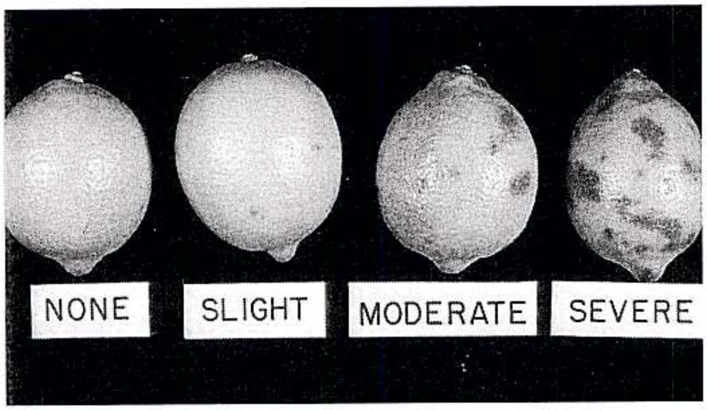
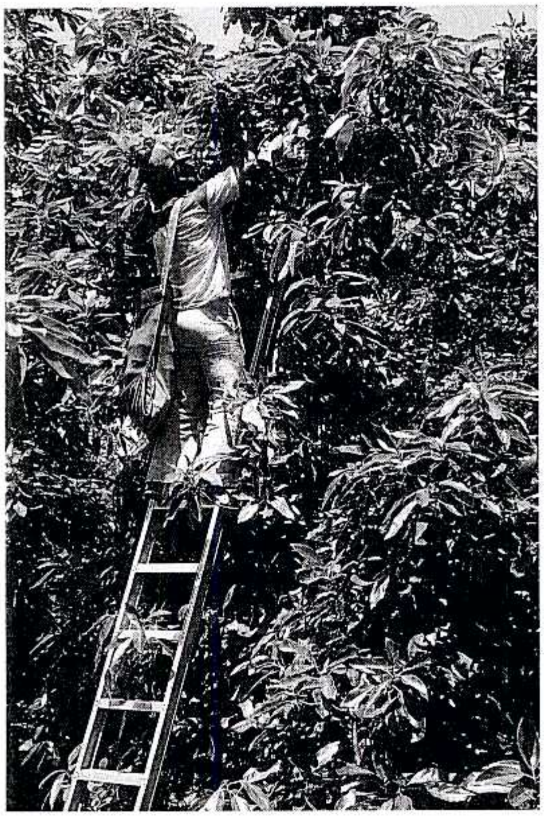


Figure 30.4

Harvesting avocados.



containers, packinghouse equipment, and storage facilities using a fog of 1% formaldehyde solution or quaternary ammonium products. Circulate *Penicillium* spore–laden air through filters in a special box-dumping room for stored lemons.

Maintain fruit resistance to infection. Minimize mechanical injuries during harvesting and postharvest handling. Use proper temperature and relative humidity management throughout postharvest handling. Use 2,4-D treatment (200 ppm) on lemon to maintain vitality of button tissue and reduce development of stem-end rots, or use gibberellic acid (50 ppm in the storage wax) as an alternative to 2,4-D; this treatment decreases the incidence of *Geotrichum* during storage. Use postharvest fungicides, such as sodium orthophenylphenol (SOPP), thiabendizole (TBZ), sec. butylamine, and imazalil. New fungicides are continually being evaluated. Choosing a fungicide depends upon whether it has been approved for use and whether it has been accepted by importing countries. Judicious use of fungicides is a valuable component of a disease control program, as resistance to fungicides can develop quickly.

ALTERNATIVES TO POSTHARVEST FUNGICIDES

Without the use of available postharvest fungicides or replacements, storage life of citrus fruits would be significantly reduced. Consequently, exports of fresh citrus fruits, other than air-shipped, would be curtailed, and postharvest losses would increase in both domestic and export marketing. Short-term and long-term options and alternatives to currently used postharvest fungicides are listed below.

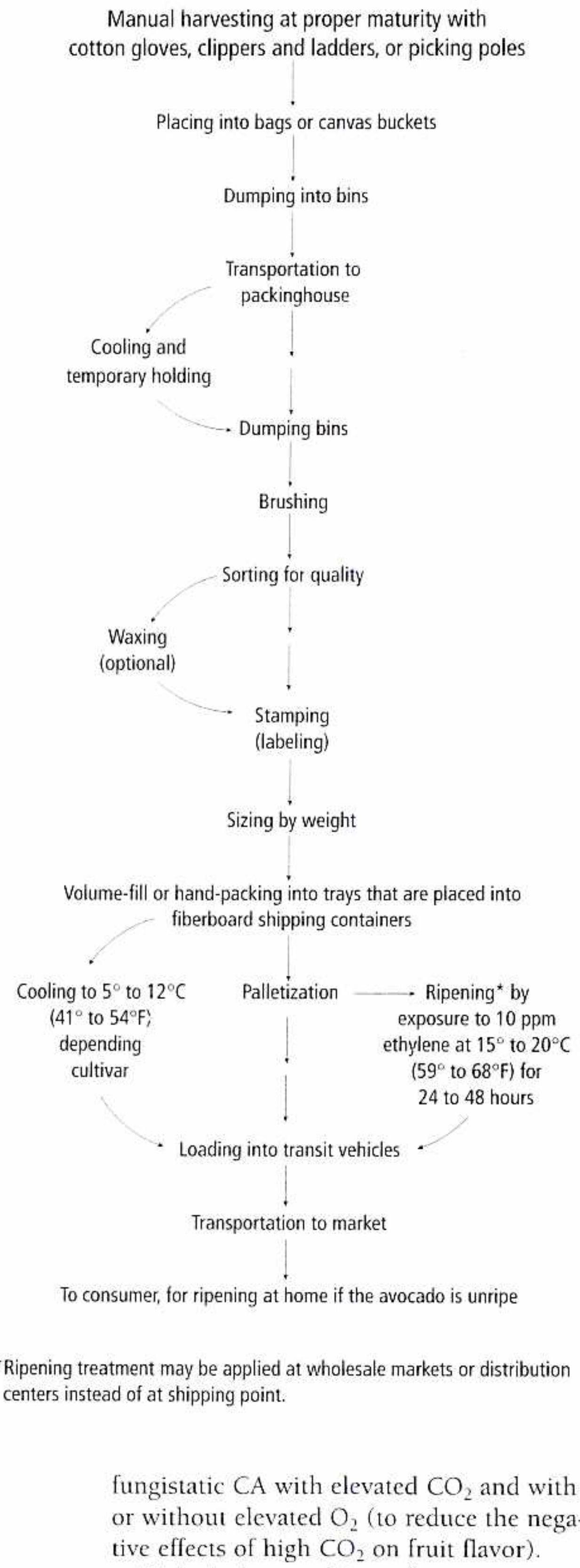
SHORT-TERM ALTERNATIVES

More careful handling during harvest and postharvest operations to reduce mechanical injuries will reduce fungal infection and losses due to decay. This, coupled with providing the optimal temperature and RH and expedited handling during all marketing steps, can extend the postharvest life of citrus fruits about 2 to 3 weeks, depending on the cultivar.

Controlled or modified atmospheres (including carbon monoxide) can be used during transport and temporary storage. CO at 5 to 10%, added to 5% O_2, provides adequate fungistatic control of many fungi causing citrus postharvest diseases. Use of CO requires strict safety precautions to protect transport and storage facility workers. Also, the cost of maintaining such atmosphere is greater than the cost of treatments with postharvest fungicides. More research is needed, however, to evaluate the fruit tolerance to

Figure 30.5

Postharvest handling of avocados.



*Ripening treatment may be applied at wholesale markets or distribution centers instead of at shipping point.

fungistatic CA with elevated CO_2 and with or without elevated O_2 (to reduce the negative effects of high CO_2 on fruit flavor).

Biological control (use of antagonistic microorganisms) has been and continues to be investigated to identify the most effective agents. Some biocontrol products have been approved for use and are used either alone or in combination with postharvest fungicides (at lower concentrations) for effective decay control.

LONG-TERM ALTERNATIVES

Treatment with ionizing radiation for decay control has been suggested. However, the dose needed to effectively control decay is between 1.5 and 2.0 kGy (150 and 200 krad). Such doses can result in rind injuries and increase fruit softening. Furthermore, the currently approved upper limit for irradiating fresh fruit is 1 kGy (100 krad). Combining irradiation with heat treatments may reduce the dose required and consequently the resulting detrimental effects.

Heat treatments, such as dipping citrus fruits in 44°C (111°F) water for 2 to 4 minutes, have been tested as possible means to kill fungal spores on fruit surfaces and reduce decay. The limiting factor for heat treatments is the narrow margin between the time and temperature combinations that reduce decay and those that cause fruit injury.

Breeding new citrus cultivars whose fruit show resistance to decay-causing fungi is a long-term option.

POSTHARVEST HANDLING PROCEDURES

HARVESTING

Research into mechanical harvesting of citrus fruits (especially in Florida for processing fruit) has been extensive, but no satisfactory system is available. Chemicals that promote abscission will probably be part of any mechanical harvesting system. Several harvest aids, such as mobile ladders and picker platforms, have been tested, but few are in commercial use. California avocados (fig. 30.4) and citrus fruits are harvested with hand clippers. Some Florida citrus fruits are snap-picked (twist and pull method), but this may increase their susceptibility to decay. Some Florida processing oranges and grapefruit are picked and dropped on the ground. This practice is detrimental to the fruit even though they are processed within a day or two after harvest.

Figure 30.6

Dry-dumping of avocados at the packinghouse.

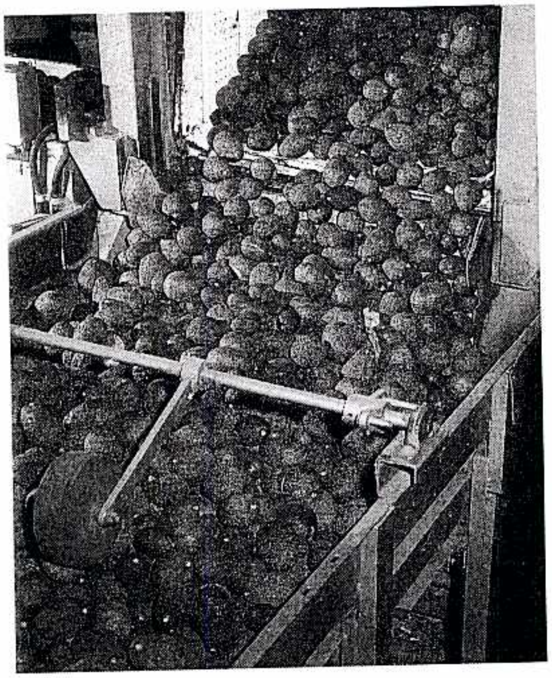
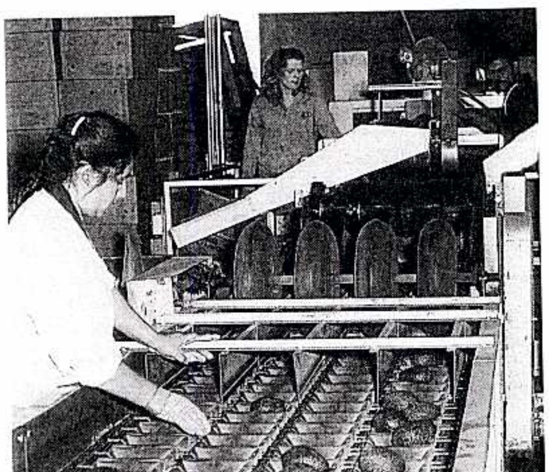


Figure 30.7

Sizing avocados by weight.



PACKINGHOUSE OPERATIONS

A flow diagram of the postharvest handling system used for avocados in California is shown in figure 30.5. The dumping, sizing, and packing operations are illustrated in figures 30.6, 30.7, and 30.8, respectively.

The packinghouse operations for citrus fruits are summarized in figure 30.9. Figures 30.10 to 30.14 illustrate surface drying, quality sorting, hand-packing, pattern-packing, and packing in bags. Lemons are usually

Figure 30.8

Packing avocados from an accumulation bin.

sorted into four color classes (dark green, light green, silver, and yellow) by electronic sorters based on their light reflectance (fig. 30.15). Some orange and tangelo cultivars are colored with a certified food dye in Florida, but this treatment is not allowed in California. Cooling methods include hydrocooling, forced-air cooling, and room cooling. Attention to proper and fast cooling for citrus fruits is badly needed in most citrus-handling facilities.

Seal packaging (wrapping with various types of plastic film) of individual citrus fruit has been extensively tested and is currently used by a few shippers. The treatment reduces water loss and maintains the vitality of the peel because of the high RH maintained around the fruit. It also prevents the spread of decay from fruit to fruit. For decay control, fruit must be treated with fungicides before wrapping. While seal packaging of individual fruit may allow short-term holding of citrus fruits without refrigeration, it must be combined with refrigeration for long-term storage to maintain good quality and reduce losses.

Citrus fruits produced in certain areas must be treated for insect control before shipment to some markets. The main disinfestation method in use was once fumigation with ethylene dibromide (EDB) against fruit flies. Since EDB was completely withdrawn from the EPA's list of approved chemicals in 1987, cold treatments or fumigation with methyl bromide or phosphine have been used. These treatments result in some phytotoxicity. Losses due to phytotoxicity as a result of cold treatment can be mitigated by conditioning the fruit for 1 week at 16°C

Figure 30.9

Postharvest handling of citrus fruits.

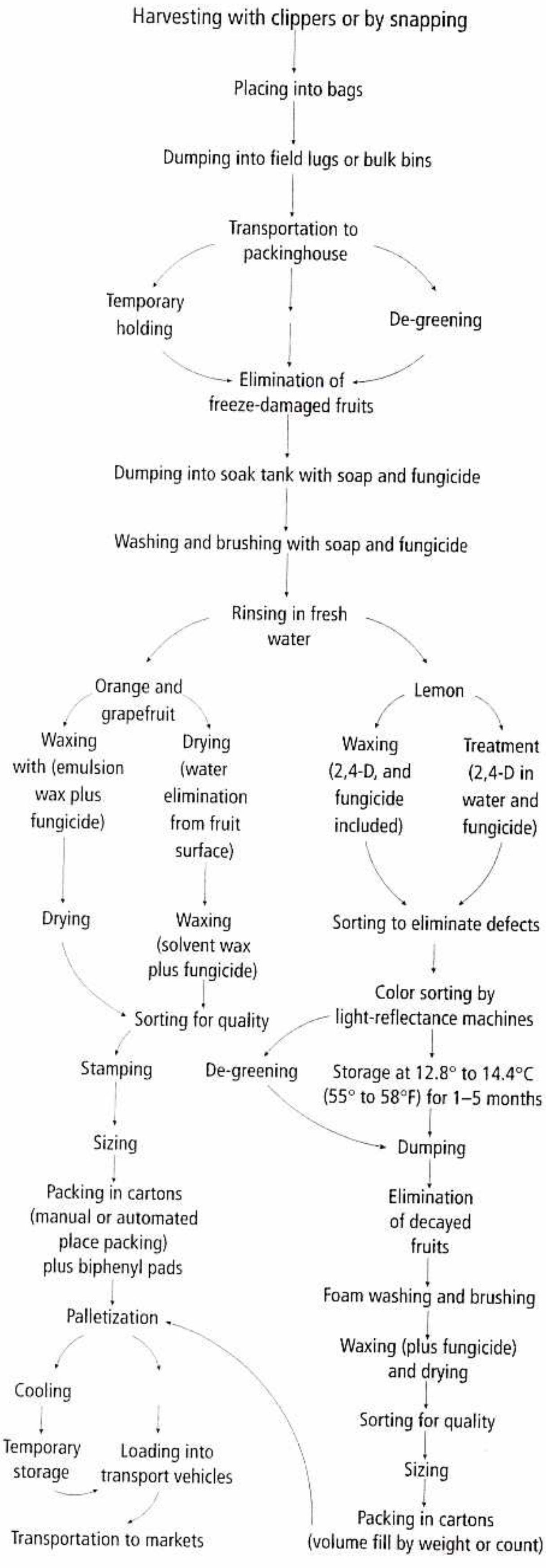


Figure 30.10

Drying citrus fruits with warm air to remove surface moisture.

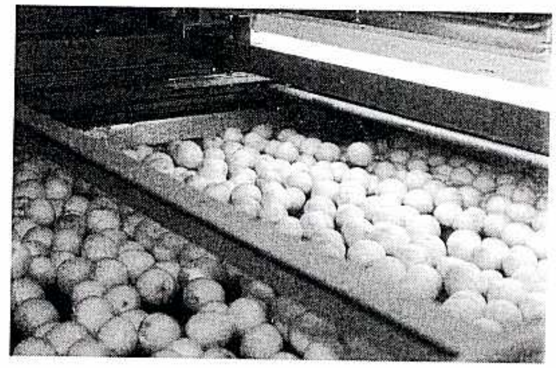
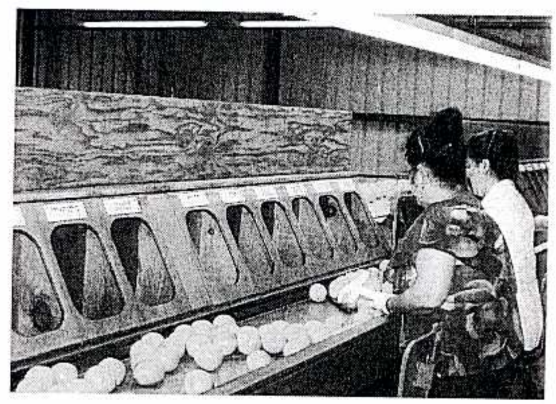


Figure 30.11

Quality sorting of citrus fruits.



(61°F). Other alternatives to chemical fumigation being evaluated include heat treatments, irradiation, and controlled atmospheres. The citrus cultivar and the stage of maturity at harvest influence the fruit's response to the quarantine treatment.

QUALITY AND STORAGE LIFE OF CITRUS FRUITS

The composition and quality of citrus fruits at harvest and the fruits' potential for storage are influenced by many pre- and postharvest factors. Preharvest factors include rootstock and cultivar, fruit maturity at harvest, harvesting season, tree condition (vigor), weather conditions (temperature, RH, rain), and cultural practices (fertilization, irrigation, pest control, growth regulators). Harvesting methods influence the uniformity among fruit and the extent of mechanical injuries due to rough handling.

Postharvest factors that influence the postharvest life span of citrus fruits include delays between harvest, packing, and cooling;

Figure 30.12

Rapid packing of citrus fruits.

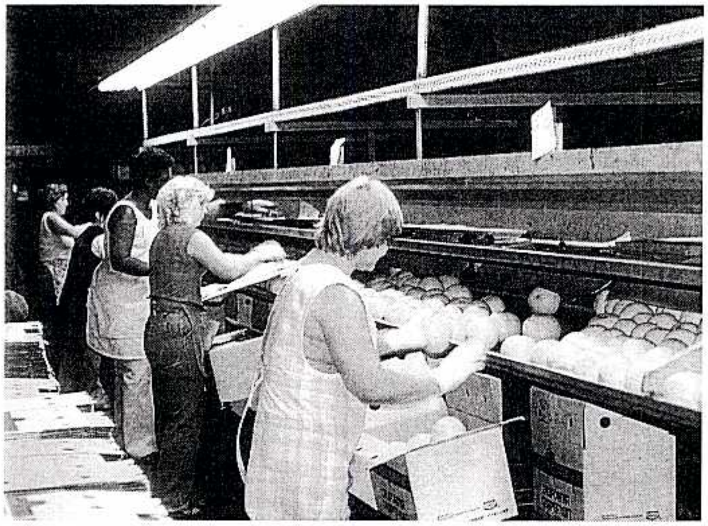


Figure 30.13

Automated pattern packing system for oranges.

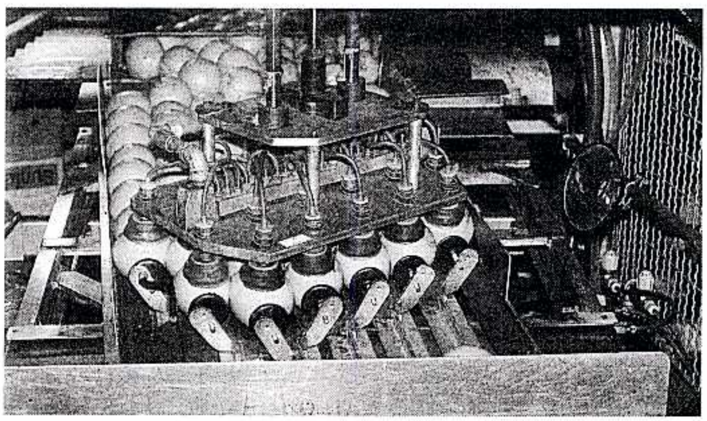
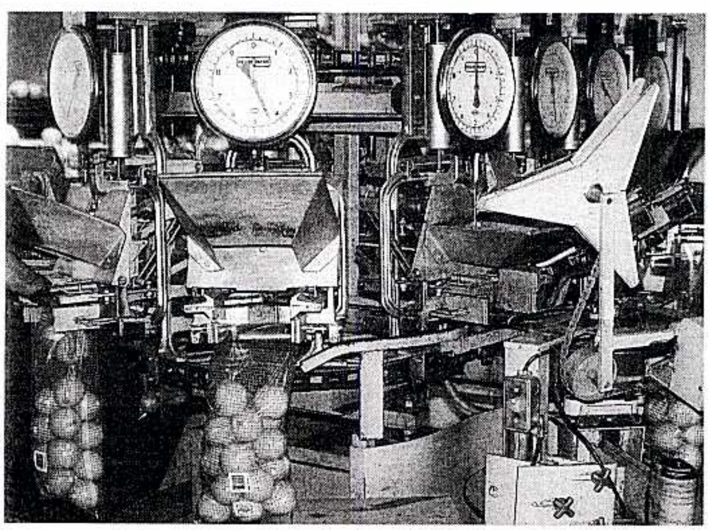


Figure 30.14

Packing citrus fruits into consumer packages.



de-greening conditions; fungicidal treatments; waxing; seal-packaging; growth-regulator treatments; temperature and RH management; and presence of ethylene and other volatiles in storage. Scrubbing ethylene from the storage environment can be useful in retarding fruit senescence and decay incidence.

STORAGE

Some citrus cultivars may be left on the tree for up to 5 months after attaining legal maturity. Depending on the cultivar, avocados will remain attached to the tree for 3 to 12 weeks after maturity before excessive abscission begins. The duration of "on-tree storage" depends on the cultivar. Quality of citrus fruits and avocado may, however, deteriorate during on-tree storage. For successful postharvest storage, maintain the conditions summarized in table 30.2. These recommendations also apply for optimal transport and temporary storage conditions.

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Figure 30.15

Light reflectance machine used for sorting lemons by color.

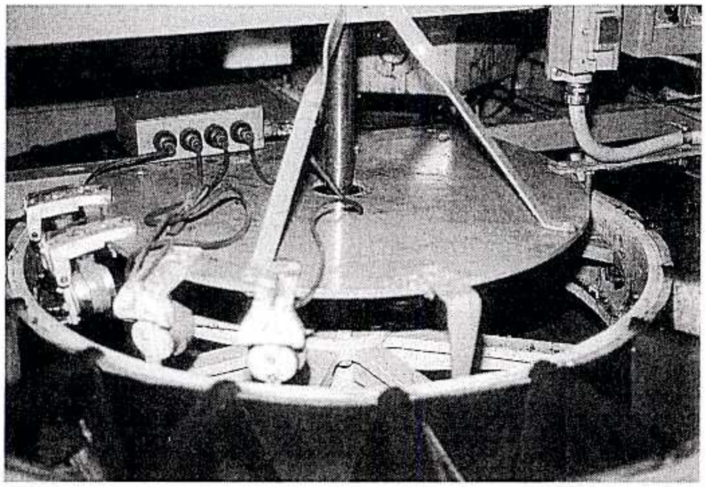

Table 30.2. Optimal storage conditions for avocado and selected citrus fruits

	Temperature		Approximate storage life*	Modified atmospheres if used†	
Commodity	**°C**	**°F**	**(weeks)**	**% O_2**	**% CO_2**
Avocado, unripe‡	5–12	41–54	2–4	2–5	3–10
Avocado, ripe‡	2–4	36–40	1–2	—	—
Grapefruit	12–14	54–57	4–8	3–10	5–10
Kumquat	4–8	39–46	2–4	5–10	0–5
Lemon§	12–14	54–57	16–24	5–10	0–10
Lime	10–12	50–54	6–8	5–10	0–10
Mandarin	5–8	41–46	2–4	5–10	0–5
Orange	4–8	39–46	4–8	5–10	0–5
Pummelo	8–10	46–50	8–12	5–10	5–10

Notes:

*Under optimal temperature and 90 to 95%RH.

†MA use on citrus is limited; 5 to 10% CO may be added to MA for decay control during transport to export markets.

‡Response to temperature and MA is dependent upon cultivar.

§Storage life for dark-green lemons; for other stages: light-green, 8–16 weeks; silver, 4–8 weeks; yellow, 3–4 weeks.

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