Grape (Table)

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Scientific Name and Introduction

The table grape (*Vitis vinifera* L.) is a nonclimacteric fruit with a relatively low rate of physiological activity. It is subject to serious water loss following harvest, which can result in stem drying and browning, berry shattering, and even wilting and shriveling of berries. Gray mold, caused by the fungus *Botrytis cinerea*, requires constant attention and treatment during storage and handling. In California, the major cultivars are 'Thompson Seedless' (Sultanina) and 'Flame Seedless,' marketed mostly during the summer months up to 8 to 10 weeks after harvest. Present interest centers on other introduced seedless 'Fantasy' cultivars such as 'Ruby Seedless' and 'Crimson.' Seeded 'Red Globe' is becoming important late in the season.

Quality Characteristics and Criteria

High consumer acceptance is attained for fruit with high soluble solids content (SSC) or a high ratio of SSC to total acidity (TA)—that is, SSC/TA ratio. Berry firmness is also an important factor for consumer acceptance as are lack of defects such as decay, cracked berries, stem browning, shriveling, sunburned, dried berries, and insect damage.

Horticultural Maturity Indices

In California, harvest date is determined by SSC of 14 to 17.5%, depending on cultivar and production area. In early- production areas, an SSC/TA ratio of 20 or higher is used to determine minimum maturity for cultivars that meet a low minimum SSC. For red- and black-colored cultivars, there is also a minimum color requirement.

Grades, Sizes, and Packaging

Most California table grapes are packed in the field. In contrast to South Africa and Chile, few grapes are shed-packed in the United States. The most common field-packing system is the "avenue pack." Fruit are picked and placed into picking lugs. Usually, the picker also trims the cluster. The picking lug is then transferred a short distance to the packer, who works at a small, portable stand in the avenue between vineyard blocks.

Shed-packed fruit are harvested by pickers and placed in field lugs without trimming. The fruit are then placed in the shade of the vines to await transport to the shed. At the packing shed, the field lugs are distributed to packers who select, trim, and pack the fruit. Often two different grades are packed simultaneously by each packer to facilitate quality selection. In some operations, trimming, color sorting, and a first quality sorting may occur in the field. In all of the systems, grapes are nearly always packed on a scale to facilitate packing to a precise net weight,

whether field- or shed-packed. In general, mid- and late-season grapes are packed in plastic bags or wrapped in paper. For early-season grapes, bulk pack is mainly used. In all cases, packed lugs are subject to quality inspection and check weighing.

After packing and lidding, grapes are palletized on disposable or recycled pallets. Some strapping in the field before loading is necessary in grapes packed in shoebox boxes. Often, loaded pallets coming from the field pass through a "pallet squeeze," a device that straightens and tightens the stacks of containers. These pallet loads are unitized, usually by strapping or netting. Some palletizing glue is used in shed-packing operations. This glue bonds the corrugated containers vertically on the pallet so that only horizontal strapping is required.

Precooling Conditions

Cooling must start as soon as possible, and SO_2 applied, within 12 h of harvest. Many forced-air coolers for grapes in California are designed to achieve seven-eighths cooling in 6 h or less. After cooling is complete, pallets are moved to a storage room to await transport.

Optimum Storage Conditions

Ideally, storage rooms should operate at -1 to 0 ºC (30 to 32 ºF) with 90 to 95% RH and a moderate airflow of 20 to 40 $ft^3\ min^{-1}\ ton^{-1}$ (0.63 to 1.25 kL min^{-1} metric ton^{-1}) of stored grapes. The constant low temperature, high RH, and moderate airflow are important to limit water loss from fruit stems. Fruit should be stored at a pulp temperature of -0.5 to 0 ºC (31 to 32 ºC) throughout their postharvest life.

Optimum Temperature

A storage temperature of -1 to 0 ºC (30 to 32 ºF) is recommended for mature fruit. Freezing damage may occur in less mature grapes. The highest freezing point for berries is -3.0 ºC (27 ºF), but the freezing point varies depending on SSC. A -2 ºC (28 ºF) freezing point for stems has been reported for wine grapes. New table grape cultivars are more sensitive to stem freezing damage. An RH of 90 to 95% and an air velocity of approximately 20 to 40 $ft^3\ min^{-1}$ (0.63 to 1.25 kL min^{-1}) is suggested during storage.

Controlled Atmosphere (CA) Considerations

CA of 2 to 5% O_2 combined with 1 to 5% CO_2 during storage or shipment is not currently recommended for table grapes, because it is only slightly beneficial. SO_2 is used for decay control. CO_2 at 10 to 15% in air can be used to control grey mold for 2 to 4 weeks depending on cultivar.

Retail Outlet Display Considerations

Use of a cold table for display is recommended.

Chilling Sensitivity

Table grapes are not chilling sensitive.

Rates of Ethylene Production and Sensitivity

Table grapes produce less than 0.1 µL kg^{-1} h^{-1} at 20 ºC (68 ºF) ethylene. They are not very sensitive to ethylene.

Respiration Rates

For grape clusters; that is, berries and stems:

Temperature	mg CO_2 kg^{-1} h^{-1}
0 ºC	2 to 4
5 ºC	6 to 8
10 ºC	10 to 16
20 ºC	24 to 30

Stem respiration is approximately 15-fold higher than berry respiration.

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 per ton per day or by 61 to get kcal per tonne per day.

Physiological Disorders

Shatter is a loss of berries from the cap stem. In general, shatter increases in severity with increasing maturity (that is, the longer fruit remain on the vine). Berries of seedless cultivars are usually less well attached to the cap stem than seeded cultivars. Shatter varies considerably from season to season, and there is a large variation among varieties. Gibberellin applied at fruit set weakens berry attachment. Shatter is mainly due to rough handling during field packing with additional shatter occurring all the way to final retail sale. Shatter incidence can be reduced by controlling pack depth and packing density (in^3 lb^{-1}), using cluster bagging, practicing gentle handling, and maintaining recommended temperature and RH. Cane-girdling reduces shattering incidence.

Waterberry is associated with fruit ripening and most often begins to develop shortly after veraison (berry softening). The earliest symptom is the development of small (1- to 2-mm) dark spots on the cap stems (pedicles) and/or other parts of the cluster framework. These spots become necrotic and slightly sunken, and they expand to affect more areas. The affected berries become watery, soft, and flabby when ripe. In California, this disorder has been associated with a high-nitrogen-status vine, canopy shading, or cool weather during veraison and fruit ripening. Avoid overfertilization with nitrogen. Foliar nutrient sprays of nitrogen should be avoided in waterberry-prone vineyards. Removing affected berries during harvest and packing is a common, though labor-intensive, practice.

Postharvest Pathology

Gray mold. The most destructive of the postharvest diseases of table grapes is gray mold *(Botrytis cinerea),* primarily because it develops at temperatures as low as 31 ^{o}F (-0.5 ^{o}C) and grows from berry to berry. Gray mold first turns berries brown, then loosens the skin of the berry. Its white, threadlike hyphal filaments erupt through the berry surface, and finally masses of gray-colored spores develop. Wounds on the berry surface near harvest provide opportunities for infection, though no wound is required for infection under wet conditions. Removing desiccated, infected grapes from the previous season can reduce gray mold infection. Leaf-removal canopy management, preharvest fungicides, and trimming visibly infected, split, cracked, or otherwise damaged grapes before packing is recommended. Prompt cooling and fumigation with SO_2 (100 µL L^{-1} for 1 h) are essential to control gray mold during cold storage. Because of increased interest in the export market, there is a need to use SO_2-generating pads, especially for long-distance export marketing in which grapes are in ocean transport for extended periods. These pads have sodium metabisulfite incorporated into them that releases SO_2 during transit and marketing.

Other pathogens. Black rot, caused by *Aspergillus niger;* blue rot, caused by *Penicillium* spp.; and rhizopus rot, caused by *Rhizopus stolonifer* or *R. oryzae,* become important at warmer temperatures, and they commonly appear sometime during transport or marketing after grapes are removed from cold storage. They are at least partially controlled by SO_2 fumigation, though little research has been done to show this (Snowdon 1990).

Sulfur dioxide use. Botrytis rot of grapes is not sufficiently reduced by fast cooling alone. It is standard practice in California to fumigate with SO_2 immediately after packing and follow with lower-dose treatments weekly during storage. Formulas for calculating initial and subsequent weekly SO_2 fumigation dosages using the traditional system are available (Luvisi et al. 1995, Nelson 1985). Recently it has been demonstrated that the amount of SO_2 gas needed to kill *Botrytis* spores or to inactivate exposed mycelium depends on the concentration and length of time the fungus is exposed to the fumigant. A cumulative concentration, calculated as the product of concentration and time, called "CT product," describes the SO_2 exposure needed to kill the decay organism. A CT of at least 100 µL L^{-1} h^{-1} is the minimum required to kill spores and mycelia of *Botrytis* at 0 ^{o}C (32 ^{o}F). This finding was the basis for the development of the total utilization system (Luvisi et al. 1992). Total utilization often uses about half as much SO_2 as the traditional method and improves uniformity and effectiveness of SO_2 fumigant. In this total utilization system, the first fumigation is done in conjunction with forced-air cooling. The forced air flows through boxes and ensures good penetration of SO_2 even to the center boxes on a pallet. In most combinations of boxes and packs, this system produces over 80% penetration, measured as a percentage of the room air CT product. Storage fumigation is done every 7 to 10 days.

During ocean shipment for periods longer than 10 days or long retail handling in which SO_2 fumigation cannot be applied, the use of SO_2-generating pads in combination with a box liner is advised. These SO_2-generating pads have sodium metabisulfite incorporated into them to allow a constant and slow release of SO_2 during shipping and marketing. In California, a slow-release SO_2-generating pad, combined with a perforated polyethylene box liner with 1/4-in (6.4-mm) holes at 3- to 4-in (7.6- to 10.2-cm) center, reduces water loss and assures gray mold control without enhancing SO_2 phytotoxicity (Crisosto et al. 1994).

Quarantine Issues

Issues associated with exotic pest quarantines, addressing either imported or exported table grapes, can change rapidly. Rules regarding import requirements are issued by USDA Animal and Plant Health Inspection Service (APHIS). This agency provides information to assist exporters in targeting markets and defining what entry requirements a particular country might have for table grapes. APHIS, in cooperation with State plant boards, developed a database called "Excerpt" to track the phytosanitary requirements for each country. APHIS also provides phytosanitary inspections and certifications declaring grapes are free of pests to facilitate compliance with foreign regulatory requirements.

Grapes imported into the United States are fumigated with methyl bromide, following treatment schedules issued by APHIS, to prevent entry of insect pests. Cold treatments are also accepted by APHIS for the control of fruit flies. Of primary concern are the vine moth, *Lobesia botrana;* the Mediterranean fruit fly, *Ceratitis capitata;* and miscellaneous external-feeding insects.

Grapes exported from the United States may harbor pests of concern elsewhere, but they rarely require treatment, though this situation can change rapidly. Black widow spiders are occasional hitchhikers within grape clusters or within grape boxes. SO_2 fumigation, alone or combined with CO_2, has been used successfully to kill spiders before export. Omnivorous leafroller, *Platnota stultana,* is found on grapes in California and has the potential to be a pest of regulatory concern on table grapes exported to counties where this pest is not found. Two methods of control are insecticidal CA treatment (Ahumada et al. 1996) and low-temperature storage combined with SO_2 slow-release generators (Yokoyama et al. 1999).

Suitability as Fresh-Cut Product

Grapes are well-adapted to a stemless packaging system.

Special Considerations

Market life varies among table grape cultivars grown in California and is also strongly affected by temperature management and decay susceptibility.

References

Ahumada, M.H., E.J. Mitcham, and D.G. Moore. 1996. Postharvest quality of 'Thompson Seedless' grapes after insecticidal controlled-atmosphere treatments. HortScience 31:833-836.

Cappellini, R.A., M.J. Ceponis, and G.W. Lightner. 1986. Disorders in table grape shipments to the New York market, 1972-1984. Plant Dis. 70:1075-1079.

Crisosto, C.H., J.L. Smilanick, N.K. Dokoozlian, and D.A. Luvisi. 1994. Maintaining table grape postharvest quality for long distant markets. *In* Proceedings of the International Symposium on Table Grape Production, Anaheim, California, June 28-29,1994, pp. 195-199. American Society

for Enology and Viticulture, Davis, CA.

Harvey, J.M., and W.T. Pentzer. 1960. Market Diseases of Grapes and Other Small Fruits. Agriculture Handbook 189, U.S. Department of Agriculture, Agricultural Marketing Service, Washington, DC.

Kanellis, A.K., and K.A. Roubelakis-Angelakis. 1993. Grape. *In* G.B. Seymour et al., eds., Biochemistry of Fruit Ripening, pp. 189-234. Chapman and Hall, London, U.K.

Lindsey, P.J., S.S. Briggs, K. Moulton, and A.A. Kader. 1989. Sulfites on grapes: issues and alternatives. Chemical Use in Food Processing and Postharvest Handling: Issues and Alternatives, pp. 5-19. University of California, Agricultural Issues Center, Davis, CA.

Luvisi, D.A., H. Shorey, J. Smilanick, et al. 1995. Packaging California Table Grapes. DANR Pub. no. 1934, University of California, Oakland, CA.

Luvisi, D.A., H.H. Shorey, J.L. Smilanick, et al. 1992. Sulfur Dioxide Fumigation of Table Grapes. DANR Pub. no. 1932, University of California, Oakland, CA.

Nelson, K.E. 1985. Harvesting and Handling California Table Grapes for Market. DANR Pub. no. 1913, University of California, Oakland, CA.

Nelson, K.E. 1978. Precooling—its significance to the market quality of table grapes. Int. J. Refrig. 1:207-215.

Ryall, A.L., and J.M. Harvey. 1959. The Cold Storage of Vinifera Table Grapes. Agriculture Handbook 159, U.S. Department of Agriculture, Agricultural Marketing Service, Washington, DC.

Snowdon, A.L. 1990. A Color Atlas of Postharvest Diseases and Disorders of Fruits and Vegetables, vol. 1, General Introduction and Fruits. CRC Press, Boca Raton, FL.

Yahia, E.M., K.E. Nelson, and A.A. Kader. 1983. Postharvest quality and storage-life of grapes as influenced by adding carbon monoxide to air or controlled atmospheres. J. Amer. Soc. Hort. Sci. 108:1067-1071.

Yokoyama, V.Y., G.T. Miller, and C.H. Crisosto. 1999. Low temperature storage combined with sulfur dioxide slow release pads for quarantine control of omnivorous leafroller *Platynota stultana* (Lepidoptera: Tortricidae). J. Econ. Entom. 92(1):235-238.

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