Carrot

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Scientific Name and Introduction: Carrots (*Daucus carata* L.) are biannuals of the *Apiaceae* (*Umbelliferae*) family. The edible portion is the storage taproot, which contains high levels of carbohydrates (sugars) and ß-carotene (pre-vitamin A). Most of the carrots in U.S. markets are produced in California complemented by limited production in Michigan, Texas, Colorado, Florida and Washington (Schaffer, 2000), and are available year round.

Quality Characteristics and Criteria: Quality criteria vary with the end usage. In general, high quality carrots are firm, straight from "shoulder" to "tip," smooth with little residual "hairiness," sweet with no bitter or harsh taste, and show no signs of cracking or sprouting (Suslow and Cantwell, 1998).

Horticultural Maturity Indices: Harvest maturity varies with the market outlet and the end usage. For fresh market, most carrots are harvested partially mature, when the roots are about 1.8 cm (0.75 in) or larger in diameter at the upper end (Kotecha et al., 1998). Late harvesting may improve storability by reducing decay during extended storage (Suojara, 1999). For fresh-cut processing, carrots are harvested immature to insure they are tender and sweet.

Grades, Sizes and Packaging: Carrots can be harvested either bunched or top trimmed; top trimmed is the dominant method. The common grades for bunched carrots are No. 1 and commercial grade. For topped carrots, the grades are extra No. 1, U.S. No. 1, No. 1 Jumbo, and No. 2. Topped carrots are typically packed in 0.5 to 2.25 kg (1 to 5 lb) consumer bags that are grouped in 11 or 22 to 22.7 kg (24 or 48 to 50 lb) cartons or master poly bags. Bunched carrots are packed loosely in 12 kg (26 lb) cartons.

Pre-cooling conditions: Prompt washing and hydro-cooling to < 5 °C (41 °F) is essential to maintain carrot freshness and crispness. Typically, carrots pass through several wash and flume steps that remove field heat and are then hydrocooled in chlorinated water before packing.

Optimum Storage Conditions: Storage temperature at 0 to 1 °C (32 to 33.8 °F) is essential to minimize decay and sprouting during storage. High RH is required to prevent desiccation and loss of crispness. The recommended conditions for commercial storage are 0 °C (32 °F) with 98 to 100% RH. Under this condition, mature topped carrots can be stored for 7 to 9 mo. However, commercial storage and distribution condition rarely achieve the optimum storage conditions and topped carrots can be stored for 5 to 6 mo at 0 °C (32 °F) to 5 °C (41 °F) with 90 to 95% RH. Common "Cello-pack" carrots are typically immature and may be stored successfully for 2 to 3 weeks at 3 to 5 °C (37.4 to 41 °F). Bunched carrots are highly perishable due to the presence of leaves and can be maintained for only 8 to 12 days. Bunched carrots are typically shipped and stored with shaved or flake-ice.

Controlled Atmosphere (CA) Considerations: CA generally does not extend storage-life of carrots beyond that in air with high RH (Leshuk and Saltveit, 1990). Low O_2 (1%) inhibited sprouting, but also promoted decay (Abdel-Rahman and Isenberg, 1974). CO_2 injury appears as soft brown spots upon exposure to air. CO_2 levels > 5% promote decay. Storage at < 3% O_2 can result in increased bacterial rot, off-flavors, and off-odors (Leshuk and Saltveit, 1990).

Retail Outlet Display Considerations: Carrots are often displayed loosely on a shelf with mist or in polyethylene consumer packages.

Chilling Sensitivity: Carrots are not chilling sensitive and should be stored as cold as possible without freezing. Their freezing point is -1.2 °C (29.8 °F).

Ethylene Production and Sensitivity: Carrots produce very low ethylene at < 0.1 μL kg^{-1} h^{-1} at 20 °C (68 °F). Exposure to exogenous ethylene (~ 0.2 μL L^{-1}) will induce development of isocoumarin and bitter flavor (Lafuente et al., 1996; Talcott and Howard, 1999). Induction and accumulation of isocoumarins is greatest on cut but not yet peeled carrot sections. Exposure of peeled carrot to ethylene does not result in development of bitterness. Thus, whole or sectioned carrots should not be mixed in storage with ethylene-producing commodities.

Respiration Rates:

Temperature	Topped	Bunched
	(mg CO_2 kg^{-1} h^{-1})	
0 °C	10 to 20	18 to 35
5 °C	13 to 26	25 to 51
10 °C	20 to 42	32 to 62
15 °C	26 to 54	55 to 106
20 °C	46 to 95	87 to 121

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 from Hardenburg et al. (1986).

Physiological Disorders: Bruising, shatter-cracks, longitudinal cracking, and tip-breakage are signs of excessively rough handling. Nantes-type carrots are particularly susceptible to mechanical damage (McGarry, 1993). The severity of shatter-cracking is partially related to varietal background. Wilting, shriveling, and rubberiness are signs of moisture loss. Sprouting may occur on topped carrots if the storage temperature is too high. Bitterness can develop in storage due to the accumulation of isocoumarin, caused by disease or exposure to ethylene. Harsh flavor may be caused by the high terpenoid content, generally from pre-harvest water stress. Surface browning or oxidative discoloration often develops during storage, especially on carrots harvested when immature.

Postharvest Pathology: The most prominent storage decays are bacteria soft rot (induced by *Pectobacterium carotovora* or *Pseudomonas marginalis*), gray mold rot (*Botrytis cinerea*), Rhizopus soft rot (*Rhizopus spp*.), watery soft rot (*Sclerotinia sclerotiorum*), and sour rot (*Geotrichum candidum*) (Snowden, 1992). Ozone is a fungistatic against *Botrytis* and *Sclerotinia*, but tissue damage and color loss occur after treatment (Liew and Prange, 1994). Good sanitation during packing and storing 0 °C (32 °F) are most important to minimize postharvest diseases.

Quarantine Issues: None

Suitability as Fresh-cut Product: A significant portion of fresh carrot production is used to produce fresh-cut products such as "baby carrots," carrot coins, shreds, and sticks. Carrots directed or consigned to fresh-cut processing are typically harvested at an immature stage for optimal texture and taste. Fresh-cut carrots typically have a shelf-life of 3 to 4 weeks at 0 °C (32 °F) and 2 to 3 weeks at 3 to 5 ºC (37 to 41 °F). "White blush" has remained a problem for processors and shippers of fresh-cut carrots. The superficial whiteness is caused by dehydration of the cut surface (Cisneros-Zevallos et al., 1995). Low storage

temperature and the presence of residual surface moisture significantly delays development of this disorder. Using sharp knives is important to reduce tissue damage and extend shelf-life (Barry-Ryan and O'Beirne, 1998).

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