Garlic

Marita Cantwell
Cantwell is with the Department of Vegetable Crops, University of California, Davis, CA.

Scientific Name and Introduction

Garlic, *Allium sativum* L., is a member of the onion family (Alliaceae). It is a bulb comprised of cloves (thickened storage leaves) individually wrapped in dried leaf sheaths or skins attached to a compressed stem plate. The whole bulb is also wrapped in several layers of dried leaf sheaths. In the United States, garlic is grown mostly in California and neighboring States. Garlic is imported principally from Argentina, Chile, China, and Mexico. Garlic is produced as an annual crop for seed, fresh market, and processed (dried) products.

Quality Characteristics and Criteria

High-quality garlic bulbs are clean, white (or other color typical of the variety), and well-cured (dried neck and outer skins). The cloves should be firm to the touch. Cloves from mature bulbs should have a high dry weight and soluble solids content (SSC)—more than 35% in both cases.

Horticultural Maturity Indices

Garlic can be harvested at different stages of development for specialty markets, but most garlic is harvested when the bulbs are mature. Harvest occurs after the tops have fallen and are dried.

Grades, Sizes, and Packaging

Grades include U.S. No. 1 and unclassified and are based primarily on external appearance and freedom from defects. Minimum diameter for fresh market is 38.1 mm (1.5 in). Garlic is usually packed loose in 2.3-, 4.6-, 10-, and 13.6-kg (5-, 10-, 22-, and 30-lb) cartons and may also be packed in smaller-weight net bags or trays for retail.

Cooling

Well-cured garlic has a very low respiration rate and it is typically cooled when placed in storage. High initial airflow may be used to bring pulp temperature down rapidly to storage temperature.

Optimum Storage Conditions

The variety of garlic affects potential storage life, and the recommended conditions for commercial storage depend on the expected storage period. Garlic can be kept in good condition for 1 to 2 mo at ambient temperatures of 20 to 30 °C (68 to 86 °F) under 75% RH (Hardenburg et al. 1986). However, under these conditions, bulbs will eventually become soft, spongy, and shriveled due to water loss. Garlic can be stored for more than 9 mo at -1 to 0 °C (30 to 32 °F) with 60 to 70% RH. Good airflow throughout the vented bins or other storage containers is necessary to prevent any moisture accumulation. Garlic can also be held in common storage for 3

to 4 mo if temperatures are kept cool (cool night air ventilation) with good airflow and low RH. Garlic will eventually lose dormancy, signaled by internal development of the sprout. This occurs most rapidly at intermediate storage temperatures of 5 to 18 °C (41 to 64 °F) (Mann and Lewis 1956, Hardenburg et al. 1986). For long-term storage, garlic should have minimal or no internal sprout growth and should be well cured (see *Special Considerations*).

To control sprout development and lengthen the storage period, garlic may be treated with preharvest applications of sprout inhibitors, such as maleic hydrazide, or be irradiated after harvest (Hardenburg et al. 1986). Garlic odor is easily transferred to other products, so garlic should be stored separately. High RH in storage will favor mold growth and rooting. Mold growth can also be problematic if garlic has not been well cured before storing.

Controlled Atmosphere (CA) Considerations

Atmospheres with high CO_2 (5 to 15%) are beneficial in retarding sprout development and decay during storage at 0 to 5 °C (32 to 41 °F). Low O_2 (0.5%) alone does not retard sprout development of 'California Late' stored up to 6 mo at 0 °C (32 °F). Atmospheres with 15% CO_2 may produce a yellow, translucent discoloration on some cloves after about 6 mo (Cantwell 2006).

Retail Outlet Display Considerations

Garlic should be kept cool and dry.

Chilling Sensitivity

Garlic is not chilling sensitive, and the optimum storage temperature of -1 °C (30 °F) is just above the freezing point of garlic.

Ethylene Production and Sensitivity

Garlic produces very low amounts of ethylene and is not particularly sensitive to ethylene exposure.

Respiration Rates

Temperature	Intact bulbs	Fresh-peeled cloves
	----------mg CO_2 kg^{-1} h^{-1}----------	
0 °C	4 to 12	24
5 °C	8 to 24	30 to 40
10 °C	12 to 36	70 to 100
15 °C	14 to 30	
20 °C	14 to 26	

Data modified from Hardenburg et al. (1986) with data for intact and fresh-peeled cloves from Cantwell (2006).

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. Respiration rates increase when sprouting begins.

Physiological Disorders

Waxy breakdown is a physiological disorder that affects garlic during later stages of growth and is often associated with periods of high temperature near harvest. Early symptoms are small, light-yellow areas in the clove flesh that darken to yellow or amber. Later, the clove becomes translucent, sticky, and waxy, but the outer dry skins are not usually affected. Waxy breakdown is commonly found in stored and shipped garlic, rarely in the field. In addition to its association with high preharvest temperatures and sunscald, low O_2 and inadequate ventilation during handling and storage may also be contributing factors.

Postharvest Pathology

Penicillium rots (*Pencillium corymbiferum* and other spp.) are common problems in stored garlic. Affected garlic bulbs may show little external evidence until decay is advanced. Affected bulbs are light in weight and individual cloves are soft, spongy, and powdery dry. In an advanced stage of decay, the cloves break down in a green or gray powdery mass. Low RH in storage retards rot development. Less common storage decay problems include fusarium basal rot *(Fusarium oxysporum cepae),* which infects the stem plate and causes cloves to shatter; dry rot due to *Botrytis allii;* and bacterial rots (*Erwinia* spp., *Pseudomonas* spp.).

Quarantine Issues

None.

Suitability as Fresh-Cut Product

Whole-peeled garlic cloves are a popular convenience product processed originally for foodservice but now found in retail food stores. Fresh-peeled garlic cloves are packed in rigid clear plastic containers or in plastic film liners in carton boxes. The mechanical peeling process results in broken and damaged pieces, and damage is the major factor leading to decay and quality loss during storage. Storage at 0 to 5 °C (32 to 41 °F) is imperative to maintain good quality. A 2- to 3-week storage life is expected if garlic is kept at 5 °C (41 °F) or below. Storage temperatures above 5 °C (41 °F) will result in pink and brown discoloration on the damaged areas and favor root and sprout development.

Special Considerations

Outer cloves of bulbs are easily damaged during mechanical harvest and these damaged areas discolor and decay during storage. Therefore, high-quality garlic for the fresh market is usually harvested manually (pulled and trimmed) to avoid mechanical damage.

Curing garlic is the process by which the outer leaf sheaths and neck tissues of the bulb are dried. Warm temperatures, low RH, and good airflow are conditions needed for efficient curing. Under favorable climatic conditions in California, garlic is usually cured in the field. After harvest and trimming, it may remain in bins in the field to cure further. Curing is essential to maximize storage life and minimize decay.

The characteristic odor and flavor of fresh garlic is due to the formation of organosulfur compounds when the main odorless precursor alliin is converted to allicin by the enzyme alliinase. The content of alliin decreases during storage, but the effect of time, storage temperature, and atmosphere has not been well documented. Production of allicin occurs at low rates unless the garlic cloves are crushed or damaged. Allicin is also an important compound since it decomposes into other sulfur-containing molecules that have purported human health benefits.

References

Cantwell, M. 2000. Garlic. Recommendations for maintaining postharvest quality. Perishables handling. *At* http://postharvest.ucdavis.edu/ produce_information.

Hardenburg, R.E., A.E. Watada, and C.Y. Wang. 1986. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. Agriculture Handbook 66, U.S. Department of Agriculture, Agricultural Research Service, Washington, DC.

Kwon, J.H., M.W. Byun, and H.O. Cho. 1985. Effects of gamma irradiation dose and timing of treatment after harvest on the storeability of garlic bulbs. J. Food Sci. 50:379-381.

Mann, L.K., and D.A. Lewis. 1956. Rest and dormancy in garlic. Hilgardia 26(3):161-189.

Shaffer, E., ed. 2000. Produce Availability and Merchandising Guide. *In* The Packer. Vance Pub. Corp., Lenexa, KS.

Snowdon, A.L. 1992. A Color Atlas of Postharvest Diseases and Disorders of Fruits and Vegetables, vol. 2, Vegetables, pp. 236-262. CRC Press, Boca Raton, FL.

Takagi, H. 1990. Garlic (*Allium sativum* L.). *In* J.L. Brewster and H.D. Rabinowitch, eds., Onions and Allied Crops, vol. 3, Biochemistry, Food Science and Minor Crops, pp. 109-158. CRC Press, Boca Raton, FL.

Yu, T.H., and C.T. Ho. 1993. Chemistry and stability of sulfur-containing compounds in the genus *Allium*. *In* G. Charalambous, ed., Shelf-life Studies of Food and Beverages. Chemical Biological and Nutritional Aspects, pp. 501-546. Elsevier Science, New York, NY.

The editors of this Handbook will appreciate your input for future editions of this publication. Please send your suggestions and comments to HB66.Comments@ars.usda.gov.