Cabbage

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Scientific Name and Introduction

Brassica oleracea L. var. *capitata* L. is red, green (domestic or Danish-type), and oxheart (conical or pointed-head type) cabbage; *B. oleracea* var. *sabauda* L. is savoy cabbage. All are biennials of the Brassicaceae (Cruciferae) family (Munro and Small 1997, Pritchard and Becker 1989). The edible portion includes the leaf blades, stalks, and core (stem) inside the head. Cabbage is grown in most major temperate vegetable-growing areas and is available year-round in most markets. The major cabbage-producing countries, in order of production, are China, the Russian Federation, India, Japan, and South Korea (Ghosh and Madhavi 1998). In the United States, the major fresh-cabbage-producing States are New York, California, and Texas; and the major sauerkraut-producing States are New York and Wisconsin. (NASS 2005).

Quality Characteristics and Criteria

Cabbage leaves should be green, dark purple, or crinkly, depending on the cultivar (Ryall and Lipton 1979, Pritchard and Becker 1989). The head should be firm and heavy for its size. The heads are crisp and fresh if they squeak when rubbed together (Ryall and Lipton 1979, Boyette et al. 2008a, Cantwell and Suslow 2008). The presence of a waxy bloom on the leaves is desirable. Yellow leaves on green cultivars suggest extensive trimming of the outer leaves. The presence of a seedstalk is undesirable.

Horticultural Maturity Indices

Determination of maturity in brassicas is not simple and no one index of maturity is reliable (Ludford and Isenberg 1987) At maturity, a cabbage head should be firm and weigh 0.5 to 3 kg (1 to 6.6 lb), depending on cabbage type and cultivar. The optimum head density of green cabbage destined for storage should range between 0.72 and 0.80 kg L^{-1} (Pritchard and Becker 1989). Immature heads, besides being smaller and softer, have an excessive tendency to wilt and a less characteristic odor (Pritchard and Becker 1989). Overmature heads are more susceptible to splitting, pathogens, physiological disorders, and seed stalk formation (IOS 1991, Pritchard and Becker 1989, Boyette et al. 2008a, Cantwell and Suslow 2008).

Grades, Sizes, and Packaging

Grades include U.S. No. 1 and U.S. Commercial, based on defects (physical and decay), excessive wrapper leaves, and off-size heads (AMS 1997). Size classification is optional. For the pointed-head-type (oxheart) cabbage, small is less than 0.7 kg (1.5 lb), medium is 0.7 to 1.4 kg (1.5 to 3 lb), and large is over 1.4 kg (3 lb). For domestic and Danish-type (green) cabbage, small is less than 0.9 kg (2 lb), medium is 0.9 to 2.3 kg (2 to 5 lb), and large is over 2.3 kg (5 lb). Cabbage heads are shipped in sacks, wax-coated corrugated cardboard cartons, and wire-bound crates of various sizes up to 22.7 kg (50 lb). Some cabbage is shipped in heavy fiberboard bulk pallet bins holding 227 to 455 kg (500 to 1,000 lb) (Boyette et al. 2008b).

Precooling Conditions

Cabbage should be cooled as soon as possible after harvest to preserve quality and reduce wilting. If cabbage is harvested under cool conditions, it can be placed in storage and cooled without precooling. Hydrocooling before storage or forced air-cooling in storage can be used to rapidly remove field heat (Boyette et al. 2008a).

Optimum Storage Conditions

Cabbage should be stored at 0 °C (32 °F) with 98 to 100% RH. Storage at -1 °C (31 °F) may cause freezing, while storage at 1 °C (34 °F) may promote senescence-related storage losses, especially if held in long-term storage—for example, 6 mo (R. Prange, unpublished data). High RH minimizes decay and trimming losses (van den Berg 1987). The presence of light in the storage room reduces physiological disorders such as leaf yellowing and weight loss (Prange and Lidster 1991). Cabbage is stored in bins or in bulk (IOS 1991). Only three to six wrapper leaves should be left on the head (Hardenberg et al. 1986). All loose leaves should be trimmed before storage because they will interfere with air circulation between heads. Air circulation in the storage should be sufficient to maintain constant and uniform temperature and RH around all cabbage heads. Bulk-stored cabbage should be ventilated in a vertical direction and the depth should not exceed 3 m (9.8 ft). Bin-stored cabbage should be arranged to maximize uniform air flow around each bin. Storage life depends on cultivar (for example, early-maturing cultivars tend to have shorter storage life than late-maturing cultivars), quality (for example, freedom from decay), and storage conditions (Pritchard and Becker 1989, IOS 1991, Boyette et al. 2008a). The end of storage life is signaled by increased respiration rate, core elongation, and sometimes rootlet development on the core butt (Guffy and Hicks 1985, Pritchard and Becker 1989).

Controlled Atmosphere (CA) Considerations

Cabbage is the most common vegetable stored under CA (Saltveit 1997, Thompson 1998). Wide ranges of O_2 levels from 1.5 to 5% and CO_2 levels from 0 to 8% have been recommended. Therefore, the mid range of 2 to 3% O_2 and 4 to 5% CO_2 is probably a good general recommendation. Low O_2 reduces color and trimming loss and inhibits root growth, while elevated CO_2 reduces rot, decay, and sprouting (Saltveit 1997). Atmospheres with lower than 1.5 to 2% O_2 and/or higher than 8 to 10% CO_2 may injure stored cabbage. Low-O_2 and high-CO_2 injury is slow to appear and the extent of the injury depends on the cultivar and maturity (Masters and Hicks 1990). For example, low-O_2 injury does not occur in oxheart cabbage until after 35 days when held in 0% O_2 (100% N_2) at 0 to 4 °C (32 to 39 °F) (Schouten et al. 1997), and green cabbage does not show low-O_2 injury until after 2, 3, or 6 mo, if held at 0 °C (32 °F) in 0.5, 1.0 or 1.5% O_2, respectively (Masters and Hicks 1990, Menniti et al. 1997). Similarly, CO_2 injury is seen after 2 mo if held at 0 °C (32 °F) in 20% CO_2 or after 2.5 mo (Menniti et al. 1997) or 6 mo (Masters and Hicks 1990) in 10% CO_2. Symptoms of low-O_2 and high-CO_2 injury are off flavors and off odors as well as visible damage (Lougheed 1987, Ludford and Isenberg 1987, Masters and Hicks 1990, Menniti et al. 1997, Schouten et al. 1997). Both low O_2 and high CO_2

produce very similar visible damage beginning in the meristematic tissue located at the apex of the stem in the middle of the cabbage. Damage spreads to outer leaves and appears as black spots (low O_2) (Schouten et al. 1997) or bronzing (high CO_2) (Masters and Hicks 1990). Lougheed (1987) suggested there may be no interaction between low O_2 and high CO_2 in injury, but Kaji et al. (1993) showed that high CO_2 (5 to 15%) keeps shredded cabbage in good condition if O_2 is high (5 to 10%).

Retail Outlet Display Considerations

Damaged outer wrapper leaves should be trimmed. Trimming may expose lighter green inner leaves, but natural or artificial light can increase the chlorophyll content and green color (Perrin 1982). The greatest concern is loss of moisture, which can be prevented by wrapping each head in a clear plastic film, frequent water sprinkling, and/or displaying in a refrigerated cabinet.

Chilling Sensitivity

Cabbage is not chilling sensitive. The freezing point is -0.9 to -0.83 °C (30.4 to 30.5 °F) (Hardenburg et al. 1986, Pritchard and Becker 1989). Even though cabbage with core temperature of -1.1 °C (30 °F) before harvest can show no evidence of freeze damage (Pritchard and Becker 1989), storage at -1.0 °C (30.2 °F) is not advisable because it can produce freeze damage, especially on outer leaves (R. Prange, unpublished data). Temperature oscillations during cycling of mechanical refrigeration may expose tissue to freezing temperatures if the setpoint is too low or if the hystersis is too large.

Ethylene Production and Sensitivity

Cabbage produces very little ethylene (<0.1 $\mu L\ kg^{-1}\ h^{-1}$ at 20 °C [68 °F]) (Kader 1992). Kubo et al. (1990) detected only a trace amount of ethylene from cabbage at 25 °C (77 °F). When heads are stored in the dark at 5 °C (41 °F) in sealed plastic bags, ethylene reaches only 1 $\mu L\ L^{-1}$, regardless of cultivar (Meinl and Bleiss 1986).

Cabbage should not be exposed to ethylene after harvest. Ethylene increases respiration (Inaba et al. 1989), and concentrations as low as 1 $\mu L\ L^{-1}$ accelerate senescence and quality loss (for example, leaf yellowing, wilting, and abscission more in air than in CA) (Hicks and Ludford 1980, Pritchard and Becker 1989). Reduced ethylene production and phenylalanine ammonia-lyase (PAL) activation is linked to less tissue browning in shredded cabbage (Takahashi et al. 1996)

Respiration Rates

Temperature	mg $CO_2\ kg^{-1}\ h^{-1}$
0 °C	4 to 6
4 to 5 °C	9 to 12
10 °C	17 to 19
15 to 16 °C	20 to 32
20 to 21 °C	28 to 49

25 to 27 °C	49 to 63

Data from Hardenburg et al. (1986).

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

The physiological cause is unknown for some disorders of stored cabbage (for example, black midrib, black speck of cabbage [pepper spot, spotted necrosis], gray speck, and necrotic spot) (Bérard 1994). The occurrence of these disorders is influenced by cultivar and cultural practices, especially mineral nutrition. Some storage disorders are clearly frost-induced (for example, black blotching, black spot, epidermal detachment, frost blemishing, and redheart). Bérard (1994) also describes storage disorders caused by dormancy, ethylene, and head maturity.

Postharvest Pathology

The major cause of postharvest decay in cabbages is the gray mold fungus *(Botrytis cinerea)* (Geeson 1983, Snowden 1991). Gray mold can be minimized by using resistant cultivars, using preharvest fungicides, practicing strict hygiene, avoiding mechanical or frost damage, rapid cooling to 0 °C (32 °F), and using CA storage (Snowden 1991). Alternaria rot, also known as dark, black, or gray leaf spot and caused by *Alternaria* spp., infects a wide range of cruciferous vegetables and can cause significant storage losses (Geeson 1983, Snowden 1991, Cerkauskas 1994). Since this disease is commonly transmitted through infected seed, it can be minimized by using disease-free seed, rotation with noncruciferous crops, applying preharvest fungicides, destruction of diseased material before storage, and using rapid cooling to 0 °C (32 °F). There are other fungi (such as ring spot), bacteria (bacterial rots and watery soft rot, for example), and a virus (tobacco mosaic virus) that cause significant losses (Dennis 1983, Ceponis et al. 1987, Snowden 1991).

Quarantine Issues

None.

Suitability as Fresh-Cut Product

Shredded cabbage is suitable as a fresh-cut product, packaged in air or MAP. Gorny (1997) indicates MA treatment efficacy as good in extending storage life of shredded cabbage and provides respiration rates at different temperatures, atmospheres, and varying amounts of shredding.

Temperature	Atmosphere	Degree of shredding	mg CO_2 kg^{-1} h^{-1}
2 °C (35 °F)	air	quarter head	8
		rough cut (1 × 3 cm)	16 to 18

		fine cut (0.5-1.5 cm)	18 to 24
5 °C (41 °F)	air	quarter head	10 to 12
		rough cut (1 × 3 cm)	22 to 34
		fine cut (0.5-1.5 cm)	26 to 40
5 °C (41 °F)	5 % O_2	quarter head	12 to 14
	+ 5 % CO_2	rough cut (1 × 3 cm)	26 to 30
		fine cut (0.5-1.5 cm)	30 to 40
10 °C (50 °F)	air	quarter head	19 to 23
		rough cut (1 × 3 cm)	42 to 48
		fine cut (0.5-1.5 cm)	51 to 57
23 °C (73 °F)	air	quarter head	54 to 63
		rough cut (1 × 3 cm)	117 to 153
		fine cut (0.5-1.5 cm)	153 to 171

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. Data from Gorny (1997).

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