Wholesale Distribution Center Storage

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Most produce is shipped from the point of production to regional or local distributors, such as terminal markets, independent wholesalers or chain store distribution centers. Produce orders are assembled at these sites and then shipped to retail stores, restaurants, or institutions such as schools or hospitals. Produce and floral items lose quality during these marketing steps, and the amount of quality loss accumulates at each step. The consumer will receive good quality produce only if each operation in the handling chain minimizes abuse caused by mechanical damage, improper temperature and RH, moisture loss, ethylene damage, odor contamination, and excessive storage time.

Large wholesale distribution facilities, whether independently owned or integrated with a retail chain, strive to receive only the amount of produce that can be shipped the following day. A few fruits such as mature-green avocados, bananas, mangos, and tomatoes are ripened before shipment to retail stores and may be held in special ripening rooms for several days.

Products should be received at their proper long-term storage temperature and then stored at that temperature. Fruits and vegetables can be divided into three categories according to their optimum temperature requirements (Table 1). The RH of the storage atmosphere should be 85 to 95%, however, for vegetables stored at low temperatures it should be 90 to 98%. The lowest temperature range of 0 to 2 °C (32 to 35.6 °F) should be used for the majority of the green, non-fruit vegetables and temperate fruits and melons. If there is enough capacity in the facility, the fruits should be stored separately from the vegetables. This allows installing equipment to maintain higher RH (90 to 98%) for the vegetables as many of them are quite subject to water loss and wilting. Table 2 shows cut flowers and nursery items divided into the recommended three categories. If handled with produce, the floral items in category No. 1 should be in the 1A vegetable room to minimize exposure to ethylene produced by many fruits.

The two warmer temperature ranges in Tables 1 and 2 are for chilling-sensitive produce (Groups 2 and 3). The highest temperature room can also be used to ripen fruit that only require a warm environment to ripen. If refrigerated space is limited, low temperature fruits, vegetables and flowers can be mixed in a room; air-conditioned space at 20 to 25 °C (68 to 77 °F) can be used for highest temperature products (Group 3).

Many green vegetables and most floral products are quite sensitive to ethylene damage. Ethylene must be kept away from these products. Minimize ethylene from near by banana ripening rooms by 1) using ethylene levels of 100 $\mu L\ L^{-1}$ in the ripening rooms instead of the higher levels often used in commercial operations, 2) venting ripening rooms to the outside after the exposure period is complete and before rooms are opened, 3) at least once per day, ventilate the area around ripening rooms or install an ethylene scrubber, and 4) use battery-powered forklifts instead of internal combustion driven units, eg., propane powered.

Floral products are particularly sensitive to ethylene and some distribution facilities have found that the previously described precautions are inadequate to prevent damage to flowers. They have chosen to handle flowers with dairy or meat products, where ethylene is low or they require that all floral products are chemically treated to resist ethylene damage.

Weak fiberboard containers are usually the cause of mechanical damage to produce between packing and retail display. If product arrives at the distribution facility in crushed boxes, store buyers must work with suppliers to use stronger boxes or insure packed boxes are correctly stacked and palletized.

The distribution center assembles pallets of mixed products to be shipped to retail outlets. Product can easily be damaged when boxes with different foot-prints are stacked and heavy bags of product are placed on weak boxes. Placing only strong containers on the bottom layers of a pallet load can minimize some of this damage. Plastic foam and returnable plastic containers are often stronger than typical fiberboard boxes

and they can reduce mechanical damage.

Most distribution facilities have special ripening rooms or areas reserved for fruit ripening. Ripening rooms are used extensively for bananas and may also be used to ripen avocados, kiwifruit, mangoes, tomatoes, nectarines, peaches, plums, and European pears. Pressurized or forced-air ripening rooms allow better control of ripening compared with older methods of space-stacking boxes in a warm room. The new designs force temperature-controlled air through the boxes to maintain fairly uniform product temperature. Ethylene gas (100 to 150 $\mu L\ L^{-1}$) is added to the atmosphere on a schedule appropriate for each product, and CO_2 levels are kept below 1% by ventilating the rooms with outside air. Ripening is done with air temperature in the range of 15 to 25 °C (59 to 77 °F), and water vapor is added to the air to keep RH above 85 to 95% in order to reduce moisture loss. The ripening of some products, like stone fruit and pears that were treated with ethylene at the packing operation, can be promoted by warming them to 13 to 18 °C (55.4 to 64.4 °F).

References:

Anon. 1987. Professional produce manager's manual. National-American Wholesale Grocers' Assn. and Produce Marketing Assn., Newark, DE

Anon. 1994. Refrigerated warehouse design (Chap. 24) and Retail food store refrigeration equipment (Chap. 46). ASHRAE Handbook, Amer. Soc. Heat. Refrig. Air Cond. Eng., Atlanta GA.

Thompson, J., A.A. Kader, and K. Sylva. 1996. Compatibility chart for fruits and vegetables in short-term transport and storage. Oakland, Univ. Calif. Div. Agric. Nat. Res. Pub. No. 21560.

Table 1. Compatible fresh fruits and vegetables during 7-day storage. Ethylene should be kept below 1 μL L^{-1} (1 ppm) in the storage area. From Thompson et al. (1996).

	Groups No. 1A and 1B 0 to 2 °C, 1A: 90 to 98% RH, 1B: 85 to 95% RH				Group No. 2 7 to 10 °C with 85 to 95% RH		Group No. 3 13 to 18 °C with 85 to 95% RH	
Vegetables	alfalfa sprouts	Chinese cabbage*	mint*	**1A**	basil*		bitter melon	
	amaranth*	Chinese turnip	mushroom		beans; snap, green, wax		boniato*	
	anise*	collard*	mustard greens*		cactus leaves (nopales)*		cassava	
	artichoke	corn;sweet, baby	parsley*		calabaza		dry onion	
	arugula*	cut vegetables	parsnip		chayote*		ginger	
	asparagus*	daikon*	radicchio		cowpea (Southern pea)		jicama	
	beans; fava, lima	endive*-chicory	radish		cucumber*		potato	
	bean sprouts	escarole*	rutabaga		eggplant*		pumpkin	
	beet	fennel*	rhubarb		kiwano (horned melon)		squash; Winter (hard rind)*	
	Belgian endive*	garlic	salsify		long bean		sweet potato*	
	bok choy*	green onion*	scorzonera		malanga*		taro (dasheen)	
	broccoli*	herbs* (not basil)	shallot*		okra*		tomato; ripe, partially ripe & mature green	
	broccoflower*	horseradish	snow pea*		pepper; bell, chili			
	brussels sprouts*	Jerusalem artichoke	spinach*		squash; Summer,(soft rind)*		yam*	
	cabbage *		sweet pea*		tomatillo			
	carrot*	kailon*	Swiss chard*		winged bean			
	cauliflower*	kale*	turnip					
	celeriac	kohlrabi	turnip greens*					
	celery*	leek*	waterchestnut					
	chard*	lettuce*	watercress*					
Fruits and Melons	apple[e]	elderberry	prune*	**1B**	avocado, unripe[e]	lime*	atemoya[e]	sapodilla[e]
	apricot[e]	fig	quince*		babaco	limequat	banana[e]	sapote[e]
	avocado, ripe[e]	gooseberry	raspberry		cactus pear, tuna	mandarin	breadfruit[e]	soursop[e]
	Barbados cherry	grape	strawberry		calamondin	mango, ripe[e]	canistel[e]	watermelon
	blackberry	kiwifruit*[e]			carambola	olive	casaba melon	
	blueberry	loganberry			cranberry	orange	cherimoya[e]	
	boysenberry	longan			custard apple[e]	passion fruit	crenshaw melon[e]	
	caimito	loquat			durian, ripe[e]	pepino	honeydew melon[e]	
	cantaloupe[e]	lychee			feijoa	pineapple	jaboticaba	
	cashew apple	nectarine			granadilla[e]	pummelo	jackfruit[e]	
	cherry	peach			grapefruit*	sugar apple	mamey[e]	
	coconut	pear (Asian & European)			guava[e]	tamarillo	mangosteen[e]	
	currant	persimmon*			Juan canary melon[e]	tamarind	papaya[e]	
	fresh-cut fruits[e]	plum, ripe*				tangelo	Persian melon[e]	
	date	plumcot, ripe*			kumquat	tangerine	plantain[e]	
	dewberry	pomegranate			lemon*	ugli fruit	rambutan	

* Sensitive to ethylene damage; [e] produce significant ethylene

Table 2. Compatible flowers, florist's foliage and nursery items during 7-day storage. (*) Can store with category 1A vegetables in a mixed produce storage. Ethylene should be kept below 1 μL L^{-1} (1 ppm) in the storage area.

	Group No. 1* 0 - 2 °C; 85 to 95% RH			Group No. 2 7 to 10 °C; 85 to 95% RH	Group No. 3 13 to 18°C; 85 to 95% RH
Flowers	Acacia	Gaillardia	Protea	Anemone	African violet
	Alstroemeria	Gardenia	Rannunculas	Bird of paradise	Anthurium
	Allium	Gerbera	Rose	Camellia	Ginger
	Aster	Gladiolus	Snapdragon	Eucharis	Heliconia
	Bouvardia	Gypsophlia	Snowdrop	Gloriosa	Orchid, cattleya,
	Buddleia	Heather	Squill	Godetia	vandal
	Calendula	Hyacinth	Statice	Sweet-william	Poinsettia
	Candytuft	Iris	Stephanotis		
	Carnation	Laceflower	Stevia		Bulbs, corms, rhizomes,
	Chrysanthemum	Lilac	Stock		tubers & roots
	Clarkia	Lily	Strawflower		
	Columbine	Lily-of-the-valley	Sweet pea		Nursery stock
	Coreopsis	Lupine	Tullip		
	Cornflower	Marigolds	Violet		
	Cosmos	Mignonette	Zinnia		
	Crocus	Narcissus			
	Dahlia	Orchid,			
	Daisy, English,	Cymbidium	Cuttings & sions		
	Marguerite,Shasta	Ornithogalum			
	Delphinium	Poppy			
	Feverfew	Peony			
	Forget-me-not	Phlox			
	Foxglove	Primrose			
	Freesia				
Florist's Foliage (Greens)	Adiantum (Maidenhair)	Gallax	Pittosporum	Chamaedorea	Dieffenbachia
	Asparagus	Ground pine	Rhododendron	Cordyline	Staghorn fern
		Hedera	Salal (lemon leaf)	Palm	
	(plumose)	Ilex (holly)	Scotch-broom	Podocarpus	
	Buxus (boxwood)	Juniper	Smilax		
	Camellia	Leatherleaf	Vaccinium		
	Cedar	Leucothoe	(huckelberry)		
	Croton	Magnolia	Woodwardia fern		
	Dracaena	Mistletoe			
	Fern, dagger,	Mountain-laurel			
	wood	Myrtus (myrtle)			
	Eucalyptus	Philodendron			