UNIVERSITY OF ILLINOIS EXTENSION

GROWING A NEW GENERATION OF ILLINOIS FRUIT AND VEGETABLE FARMERS

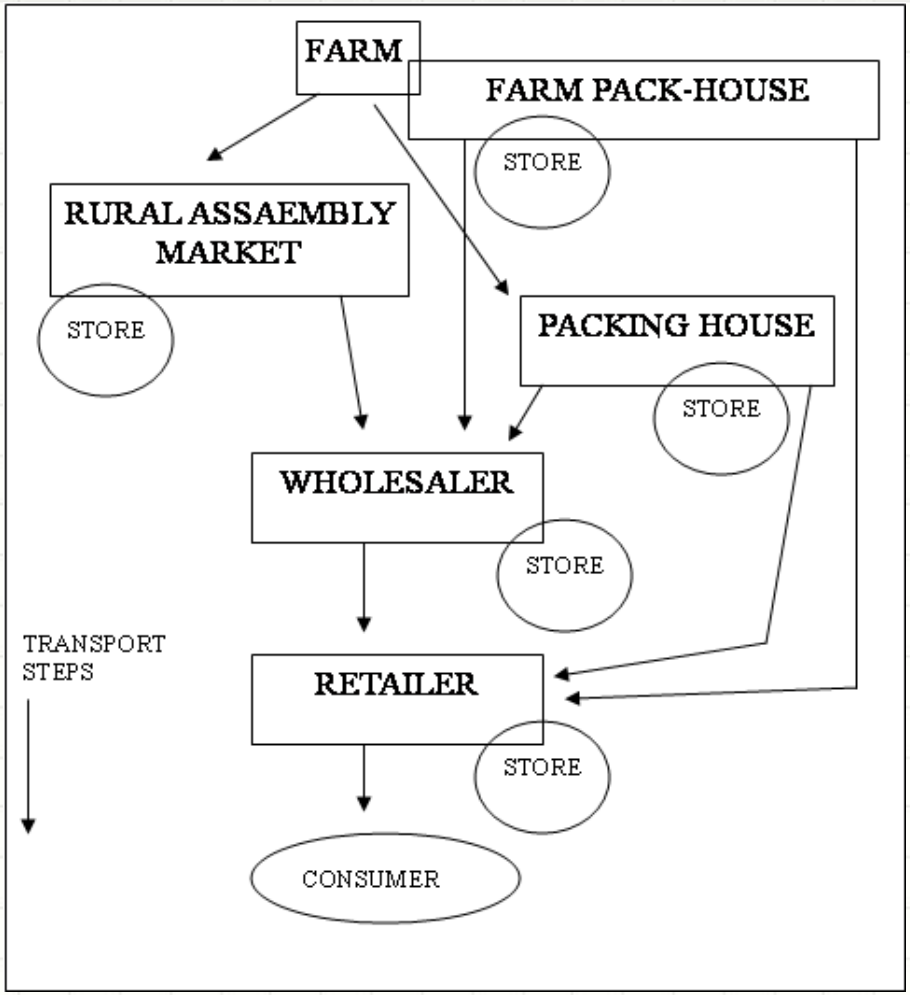
USDA NIFA Beginning Farmer and Rancher Development Program
Grant # 2012-49400-19565

POST-HARVEST HANDLING AND TRANSPORTATION METHODS THAT ALLOW SMALL-SCALE GROWERS TO DELIVER TOP-QUALITY PRODUCE

new ILLINOIS fruit & vegetable FARMERS

Why are good post harvest practices important?

High-quality, disease free produce with a good shelf life is a result of good production practices, proper handling during harvest, and appropriate post harvest handling and storage. ---- ATTRA, Post harvest handling of fruits and vegetables

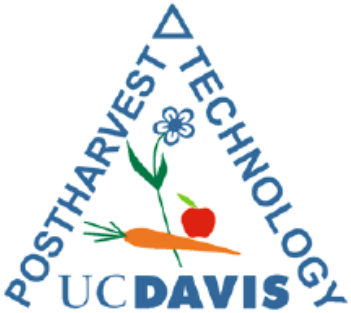


Maintain Quality

- Appearance
- Texture
- Flavor
- Nutritive value

Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th Edition)

Lisa Kitinoja and Adel A. Kader



University of California, Davis
Postharvest Technology Research and Information Center

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Immature-fruit vegetables	Cucumbers Squash Eggplant Peppers Okra Snap beans	Over-maturity at harvest
		Water loss (shriveling)
		Bruising and other mechanical injuries
		Chilling injury
		Decay
Mature-fruit vegetables and fruits	Tomato Melons Citrus Bananas Mangoes Apples Grapes Stone fruits	Bruising
		Over-ripeness and excessive softening at harvest
		Water loss
		Chilling injury (chilling sensitive fruits)
		Compositional changes
		Decay

RELATIVE PERISHABILITY	POTENTIAL STORAGE LIFE (WEEKS)	COMMODITIES
Very high	<2	Apricot, blackberry, blueberry, cherry, fig, raspberry, strawberry; asparagus, bean sprouts, broccoli, cauliflower, green onion, leaf lettuce, mushroom, muskmelon, pea, spinach, sweet corn, tomato (ripe); most cut flowers and foliage; minimally processed fruits and vegetables.

High	2-4	Avocado, banana, grape (without SO_2 treatment), guava, loquat, mandarin, mango, melons (honeydew, crenshaw, Persian), nectarine, papaya, peach, plum; artichoke, green beans, Brussels sprouts, cabbage, celery, eggplant, head lettuce, okra, pepper, summer squash, tomato (partially ripe).

Moderate	4- 8	Apple and pear (some cultivars), grape (SO_2-treated), orange, grapefruit, lime, kiwifruit, persimmon, pomegranate; table beet, carrot, radish, potato (immature).
Low	8-16	Apple and pear (some cultivars), lemon; potato (mature), dry onion, garlic, pumpkin, winter squash, sweet potato, taro, yam; bulbs and other propagules of ornamental plants.

Protect Food Safety

- Maintain good sanitation
- Avoid introduction of pathogens
- Keep from spoilage

Reduce Losses Between Harvest and Consumption

- Improves efficiency
- Improves profitability

Process begins the moment produce is harvested

- Avoid rough handling
  - Train workers – what and how
- Use appropriate harvesting container
- Try to avoid harvest in excessive heat
- Keep product as cool as possible while awaiting transport to the packing shed
  - Shade
  - Get to the shed

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Packing Methods

- None ????
- Field packing
- Packing shed

Field packing

- Picking into final package
  - Reduced handling and associated damage
  - Reduces labor cost
  - Strawberries and peaches
- Self propelled field packing systems
  - Peppers and snap beans

Trip from field to packing shed

- Slow down ---- smooth ride
- Keep shaded if long trip or will sit out at shed before being packed

Packing Shed

Packing Shed

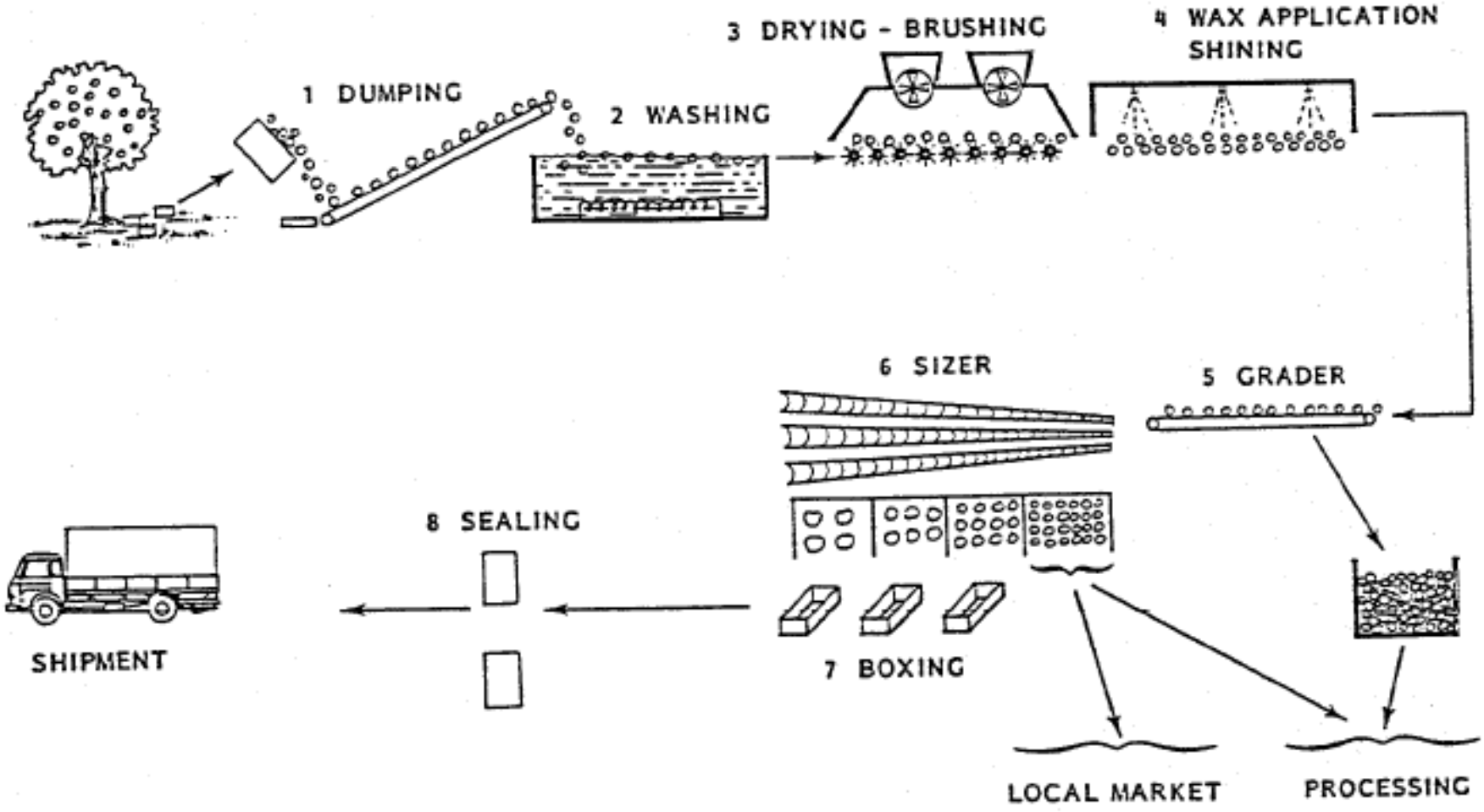
- Roof with or without sides
- Packing line
- Cold storage area
- Loading dock

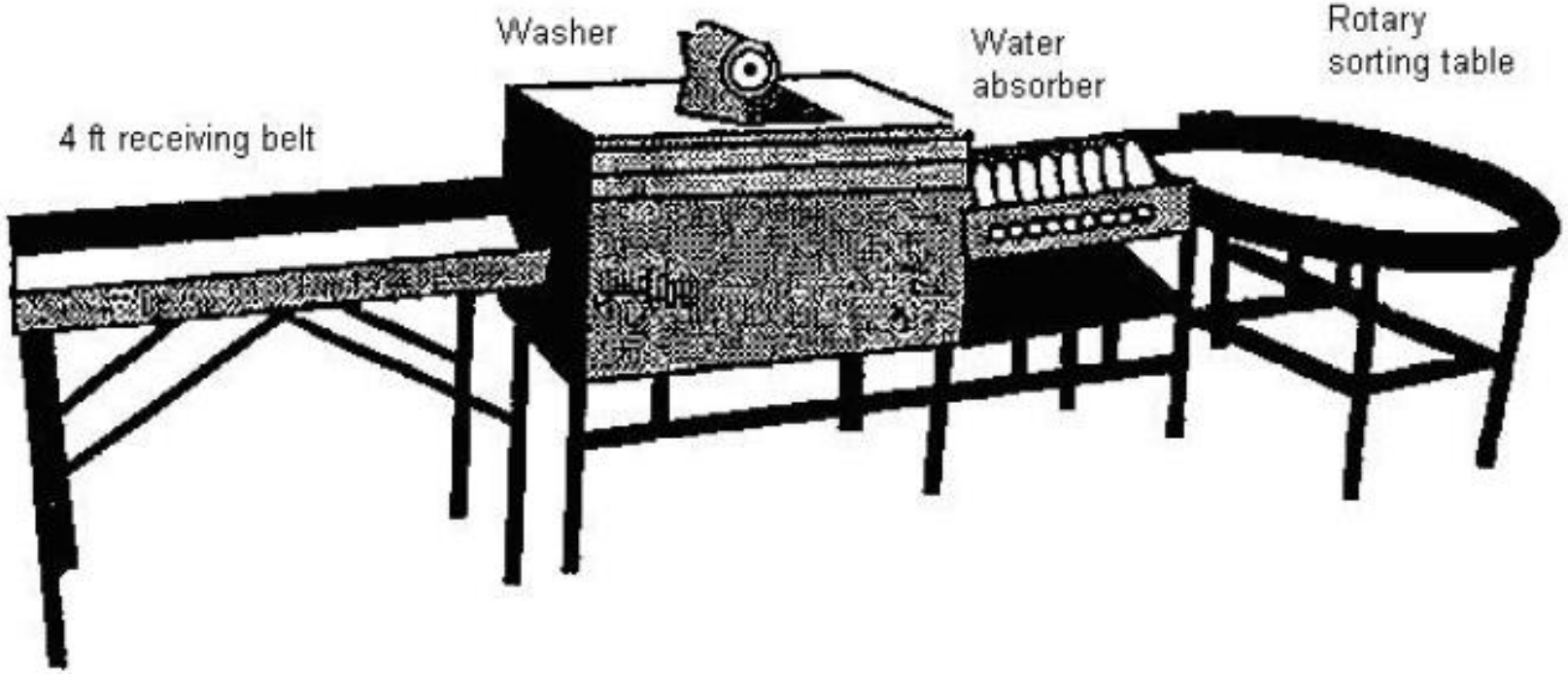
Packing line

- Should be appropriate for size of your operation
- Should be designed to work with commodity you grow
- Vary widely by producer

Components

- Dump
- Receiving line
- Washer (waxer)
- Inspection table
- Sizer (label applicator)
- Sorting tables
- Boxing
- Conveyors





Cold Storage

- Most important factor for maintaining quality
  - Removes field heat
  - Lowers respiration
  - Reduces water loss
  - Decreases sensitivity to ethylene

Even after picking, strawberries remain alive and produce heat as a natural consequence of respiration. The amount of heat they produce depends on the storage temperature. At 32 F a ton of strawberries will produce approximately 3,300 Btu per day, whereas at 80 F, a ton will produce 41,800 Btu!

Maintaining the Cold Chain for Perishables

Harvest

- Protect the product from the sun
- Transport quickly to the packinghouse

Cooling

- Minimize delays before cooling
- Cool the product thoroughly as soon as possible

Temporary Storage

- Store the product at optimum temperature
- Practice first in first out rotation
- Ship to market as soon as possible

Transport to Market

- Use refrigerated loading area
- Cool truck before loading
- Load pallets towards the center of the truck
- Put insulating plastic strips inside door of reefer if truck makes multiple stops
- Avoid delays during transport
- Monitor product temperature during transport

Handling at Destination

- Use a refrigerated unloading area
- Measure product temperature
- Move product quickly to the proper storage area
- Transport to retail markets or foodservice operations in refrigerated trucks
- Display at proper temperature range

Handling at home or foodservice outlet

- Store product at proper temperature
- Use the product as soon as possible

Why cool?

- Suppress enzymatic degradation and respiratory activity (softening)
- Slow or inhibit water loss (wilting)
- Slow or inhibit the growth of decay-producing microorganisms (molds and bacteria)
- Reduce production of ethylene (a ripening agent) or minimize the product's reaction to ethylene.

Lowest safe temperature

Commodity	Approximate lowest safe temperature		Character of injury when stored between 0°C and safe temperature[1]
	°C	°F	
Apples (Jonathan, McIntosh, Yellow Newton)	2-3	36-38	Internal browning, brown core, soggy breakdown, soft scald
Asparagus	0-2	32-36	Dull, gray-green, and limp tips
Avocados	4.5-13	40-55	Grayish-brown discoloration of flesh
Bananas, green or ripe	11.5-13	53-56	Dull color when ripened
Beans (lima)	1-4.5	34-40	Rusty brown specks, spots, or areas
Beans (snap)	7	45	Pitting and russeting
Cranberries	2	36	Rubbery texture, red flesh
Cucumbers	7	45	Pitting, water-soaked spots, decay
Eggplants	7	45	Surface scald, alternaria rot, blackening of seeds

Melons			
Cantaloupe	2-5	36-41	Pitting, surface decay
Honey Dew	7-10	45-50	Reddish-tan discoloration, pitting, surface decay, failure to ripen
Casaba	7-10	45-50	Same as above but no discoloration
Crenshaw and Persian	7-10	45-50	Same as above but no discoloration
Watermelons	4.5	40	Pitting, objectionable flavor
Okra	7	45	Discoloration, water-soaked areas, pitting, decay
Olives, fresh	7	45	Internal browning
Oranges, California and Arizona	3	38	Pitting, brown stain
Papayas	7	45	Pitting, failure to ripen, off flavor, decay
Peppers, sweet	7	45	Sheet pitting, alternaria rot on pods and calyxes, darkening of seed
Pineapples	7-10	45-50	Dull green when ripened
Pomegranates	4.5	40	Pitting, external and internal browning
Potatoes	3	38	Mahogany browning (Chippewa and Sebago), sweetening[2]
Pumpkins and hard-shell squashes	10	50	Decay, especially alternaria rot
Sweetpotatoes	13	55	Decay, pitting, internal discoloration; hardcore when cooked
Tamarillos	3-4	37-40	Surface pitting, discoloration
Tomatoes			
Ripe	7-10	45-50	Water-soaking and softening, decay
Mature-green	13	55	Poor color when ripe, alternaria rot

Cantaloupes (3/4-slip)	2-5	36-41	95	15 days
Cantaloupes (full-slip)	0-2	32-36	95	5-14 days
Carambola	9-10	48-50	85-90	3-4 weeks
Carrots, bunched	0	32	95-100	2 weeks
Carrots, mature	0	32	98-100	7-9 months
Carrots, immature	0	32	98-100	4-6 weeks
Cashew apple	0-2	32-36	85-90	5 weeks
Cauliflower	0	32	95-98	34 weeks
Celeriac	0	32	97-99	6-8 months
Celery	0	32	98-100	2-3 months
Chard	0	32	95-100	10-14 days
Chayote squash	7	45	85-90	4-6 weeks
Cherimoya	13	55	90-95	2-4 weeks
Cherries, sour	0	32	90-95	3-7 days
Cherries, sweet	-1 to -0.5	30-31	90-95	2-3 weeks
Chinese broccoli	0	32	95-100	10-14 days
Chinese cabbage	0	32	95-100	2-3 months
Chinese long bean	4-7	40-45	90-95	7-10 days
Clementine	4	40	90-95	24 weeks
Coconuts	0-1.5	32-35	80-85	1-2 months
Collards	0	32	95-100	10-14 days
Corn, sweet	0	32	95-98	5-8 days
Cranberries	2-4	36-40	90-95	24 months
Cucumbers	10-13	50-55	95	10-14 days

Product	Temperature		Relative Humidity (percent)	Approximate storage life
	°C	°F		
Potatoes, early crop	10-16	50-60	90-95	10-14 days
Potatoes, late crop	4.5-13	40-55	90-95	5-10 months
Pummelo	7-9	45-48	85-90	12 weeks
Pumpkins	10-13	50-55	50-70	2-3 months
Quinces	-0.5-0	31-32	90	2-3 months
Raddichio	0-1	32-34	95-100	2-3 weeks
Radishes, spring	0	32	95-100	34 weeks
Radishes, winter	0	32	95-100	24 months
Rambutan	12	54	90-95	1-3 weeks
Raspberries	-0.5-0	31-32	90-95	2-3 days
Rhubarb	0	32	95-100	24 weeks
Rutabagas	0	32	98-100	+6 months
Salsify	0	32	95-98	2-4 months
Santol	7-9	45-48	85-90	3 weeks
Sapodilla	16-20	60-68	85-90	2-3 weeks
Scorzonera	0-1	32-34	95-98	6 months
Seedless cucumbers	10-13	50-55	85-90	10-14 days
Snow peas	0-1	32-34	90-95	1-2 weeks
Soursop	13	55	85-90	1-2 weeks
Spinach	0	32	95-100	10-14 days
Squashes, summer	5-10	41-50	95	1-2 weeks
Squashes, winter	10	50	50-70	2-3 months
Strawberries	0	32	90-95	5-7 days
Sugar apples	7	45	85-90	4 weeks
Sweetpotatoes	13-15	55-60	85-90	4-7 months
Tamarillos	3-4	37-40	85-95	10 weeks
Tamarinds	7	45	90-95	3-4 weeks
Tangerines, mandarins, and related citrus fruits	4	40	90-95	24 weeks
Taro root	7-10	45-50	85-90	4-5 months
Tomatillos	13-15	55-60	85-90	3 weeks
Tomatoes, mature-green	18-22	65-72	90-95	1-3 weeks
Tomatoes, firm-ripe	13-15	55-60	90-95	4-7 days
Turnips	0	32	95	4-5 months
Turnip greens	0	32	95-100	10-14 days

Product	Temperature		Relative Humidity (percent)	Approximate storage life
	°C	°F		
Amaranth	0-2	32-36	95-100	10-14 days
Anise	0-2	32-36	90-95	2-3 weeks
Apples	-1-4	30-40	90-95	1-12 months
Apricots	-0.5-0	31-32	90-95	1-3 weeks
Artichokes, globe	0	32	95-100	2-3 weeks
Asian pear	1	34	90-95	5-6 months
Asparagus	0-2	32-35	95-100	2-3 weeks
Atemoya	13	55	85-90	4-6 weeks
Avocados, Fuerte, Hass	7	45	85-90	2 weeks
Avocados, Lula, Booth-1	4	40	90-95	4-8 weeks
Avocados, Fuchs, Pollock	13	55	85-90	2 weeks
Babaco	7	45	85-90	1-3 weeks
Bananas, green	13-14	56-58	90-95	14 weeks
Barbados cherry	0	32	85-90	7-8 weeks
Bean sprouts	0	32	95-100	7-9 days
Beans, dry	4-10	40-50	40-50	6-10 months
Beans, green or snap	4-7	40-45	95	7-10 days
Beans, lima, in pods	5-6	41-43	95	5 days
Beets, bunched	0	32	98-100	10-14 days
Beets, topped	0	32	98-100	4-6 months
Belgian endive	2-3	36-38	95-98	24 weeks
Bitter melon	12-13	53-55	85-90	2-3 weeks
Black sapote	13-15	55-60	85-90	2-3 weeks
Blackberries	-0.5-0	31-32	90-95	2-3 days
Blood orange	4-7	40-44	90-95	3-8 weeks
Blueberries	-0.5-0	31-32	90-95	2 weeks
Bok choy	0	32	95-100	3 weeks
Boniato	13-15	55-60	85-90	4-5 months
Breadfruit	13-15	55-60	85-90	2-6 weeks
Broccoli	0	32	95-100	10-14 days
Brussels sprouts	0	32	95-100	3-5 weeks
Cabbage, early	0	32	98-100	3-6 weeks

Cold storage compatibility

- Ethylene
  - Producer
  - Sensative
- Similar temperature
- Similar relative humidity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Group 1A – Vegetables

32-36°F, 0-2°C, 90-98% rh

Alfalfa Sprouts
Amaranth
Anise
Artichoke
Arugula*
Asparagus*
Beans: Fava, Lima
Brean Sprouts
Beet
Belgian Endive*
Bok Choy
Broccoli*
Broccoflower*
Brussels Sprouts
Cabbage*
Carrot*
Cauliflower*
Celeriac
Celery*
Chard*
Chinese Cabbage
Chinese Turnip
Collard*
Corn: Sweet, Baby
Cut Vegetables
Daikon*
Endive* - Chickory
Escarole*
Fennel
Garlic
Green onion*
Herbs* (not Basil)
Horseradish
Jerusalem Artichoke
Kailon
Kale
Kohlrabi
Leek*
Lettuce*
Mint
Mushroom
Mustard Greens*
Parsley*
Parsnip
Radicchio
Radish
Rutabaga
Rhubarb
Salsify
Scorzonera
Shallot
Snow Pea*
Spinach*
Sweet Pea*
Swiss Chard
Turnip
Turnip Greens*
Water Chestnut
Watercress*

Ethylene level should be kept below 1 ppm in storage area.
* products marked with an asterisk are sensitive to ethylene damage.

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Group 1B - Fresh Fruit

32-36°F, 0-2°C, 85-95% rh

Apple
Apricot
Avocado, ripe
Barabados Cherry
Blackberry
Blueberry
Boysenberry
Caimito
Cantaloupe
Cashew Apple
Cherry
Coconut
Currant
Cut fruits
Date
Dewberry
Elderberry
Fig
Goosebery
Grape
Kiwifruit*
Longan
Loganberry
Loquat
Lychee
Nectarine
Peach
Pear: Asian & European
Persimmon*
Plum
Plumcot
Pomegranate
Prune
Quince
Raspberry
Strawberry

Ethylene level should be kept below 1 ppm in storage area.
* products marked with an asterisk are sensitive to ethylene damage.

Group 2 – Vegetables

45-50°F, 7-10°C, 85-95% rh

Basil
Beans: Span, Green, Wax
Cactus Leaves (Nopales)
Calabasa
Chayote*
Cowpea (Southern Pea)
Cucumber*
Eggplant*
Kiwano (Horned Melon)
Long Bean
Malanga
Okra*
Pepper: Bell, Chili
Squash: Summer, Soft Rind*
Tomatillo
Winged Bean

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Group 2 – Fruits

45-50°F, 7-10°C, 85-95% rh

Avocado, unripe
Babaco
Cactus Pear, Tuna
Calamondin
Carambola
Cranberry
Custard Apple
Durian
Feijoa
Granadilla
Grapefruit*
Guava
Juan Canary Melon
Kumquat
Lemon*
Lime*
Limequat
Mandarin
Olive
Orange
Passion Fruit
Pepino
Pineapple
Pummelo
Sugar Apple
Tamarillo
Tamarind
Tangelo
Tangerine
Ugli Fruit
Watermelon

Ethylene level should be kept below 1 ppm in storage area.
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Group 3 – Vegetables

55-65°F, 13-18°C, 85-95% rh

Bitter Melon
Boniato
Cassava
Dry Onion
Ginger
Jicama
Potato
Pumpkin
Squash: Winter, Hard Rind*
Sweet Potato*
Taro (Dasheen)
Tomato: Ripe, Partially Ripe & Mature Green
Yam*

Ethylene level should be kept below 1 ppm in storage area.
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Group 3 - Fruits

55-65°F, 13-18°C, 85-95% rh

Atemoya
Banana
Breadfruit
Canistel
Casaba Melon
Cherimoya
Crenshaw Melon
Honeydew Melon
Jabolicaba
Jackfruit
Mamey Sapote
Mango
Mangosteen
Papaya
Persian Melon
Plantain
Rambutan
Sapodilla
Sapote
Soursop

Ethylene level should be kept below 1 ppm in storage area.
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Cold storage methods

- Mechanical Refrigeration
- Evaporative
- Ice
- Underground
- High altitude

Mechanical Refrigeration Cooling

- Forced Air

- Room Cooling

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CoolBot systems take LONGER to cool down
+CoolBot Systems recover SLOWER after you open the door
+Poor functionality below 36 F (2 C)
+You can't freeze things with a CoolBot
+Running through the winter
+Automatic Restart when you lose electricity

More things that don't work well with CoolBots
+Portable Air Conditioners
+Using the CoolBot to cool a room above 61 F (16 C)
+Room is too big *or* Airconditioner is too small for the room size
+Rooms that have less than industry standard Cold-Room insulation
+You have even small GAPS or HOLES in the room
+Air Conditioners without a DIGITAL DISPLAY

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If you want to be at 37F or above (2.8C) and you open the door less than 5 times/hour you will absolutely love us. We will save you thousands in up-front costs, but we'll save you MORE than that in electricity savings and repair bills!

If you need to keep things at 36F (2.2 C)(, and you open the door less often and you don't mind that it takes a few hours to get down to 36, you'll be really happy, too, but you won't save nearly as much electricity over a conventional system (yes, I know it's just a ONE degree F drop, but it's true!).

If you need to be under 34F (1.5 C) you aren't going to be happy with us unless you oversize the air conditioner and NEVER open the door. And you wont' save any money in electricity.

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Introduction to
Proper Postharvest Cooling and Handling Methods

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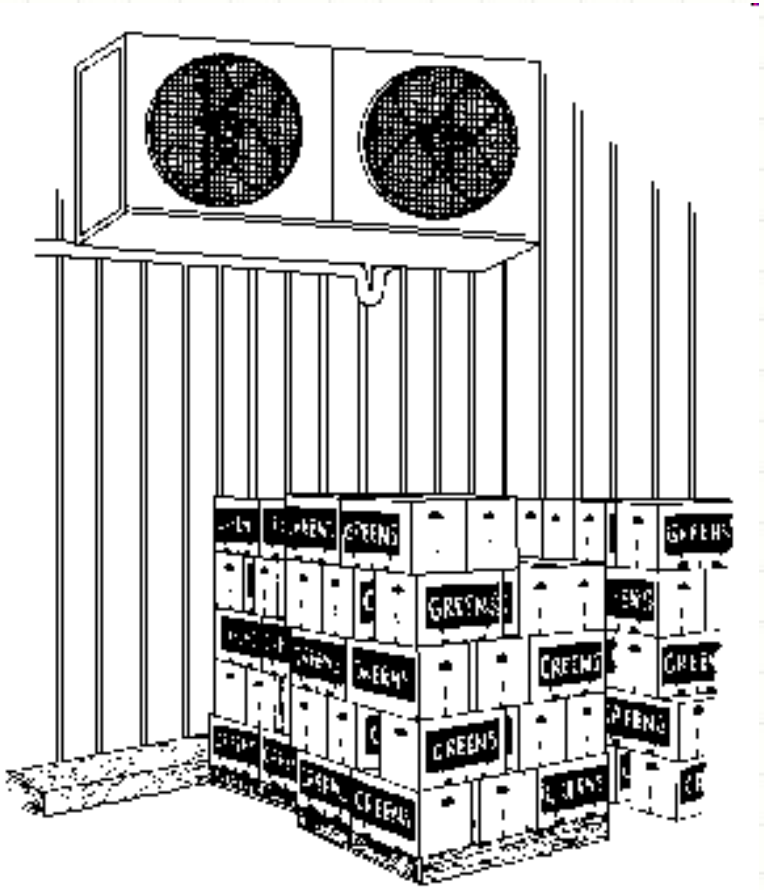
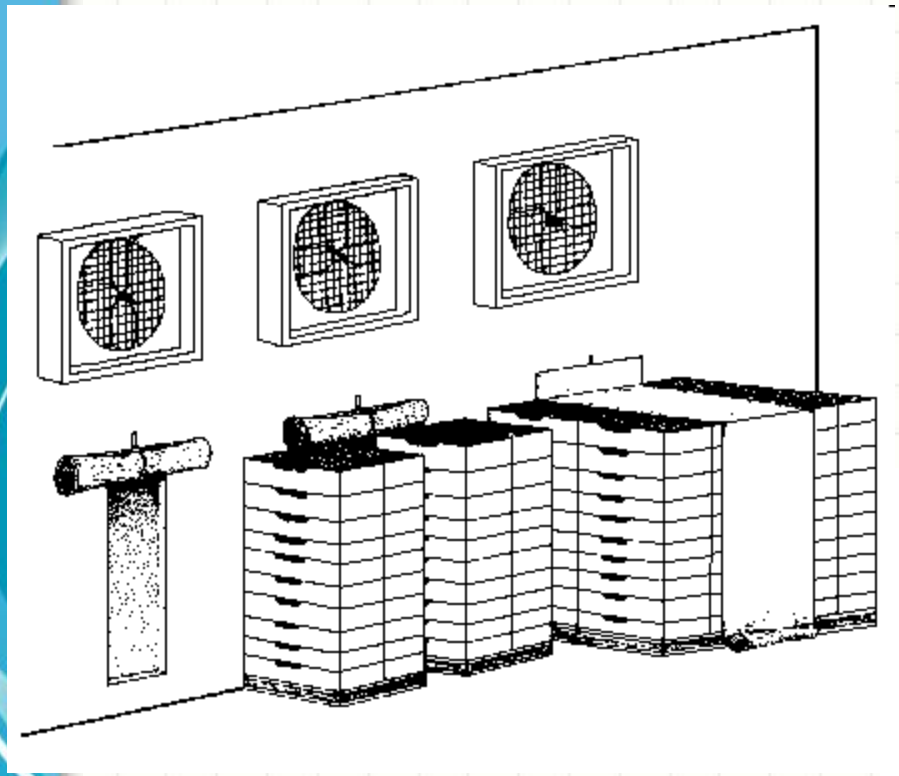
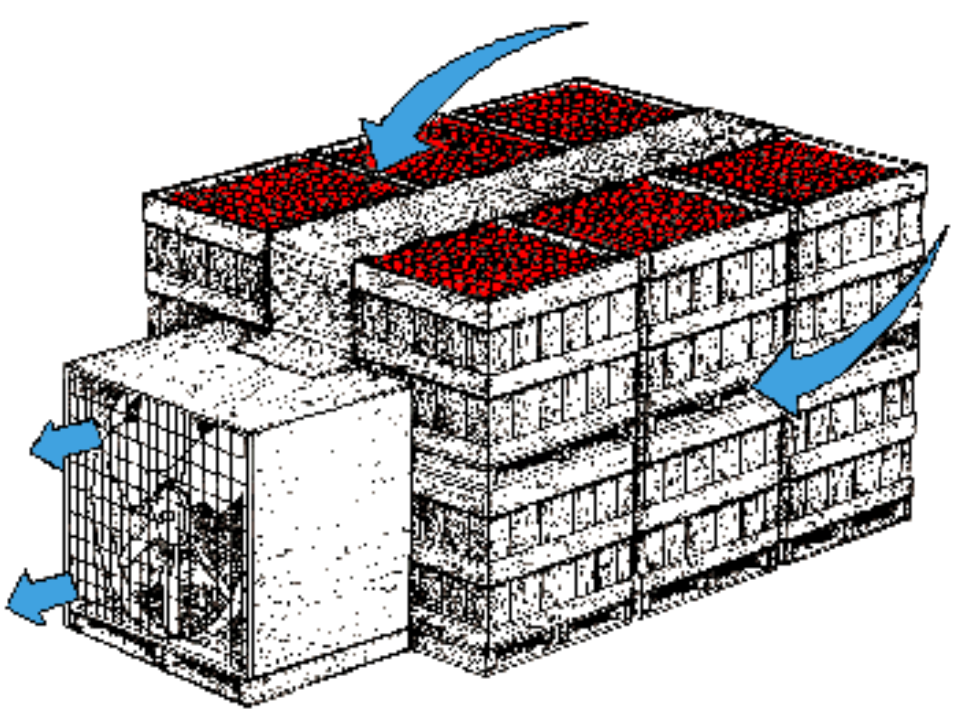
Sponsored by the Energy Division, North Carolina Department of Commerce, with petroleum violation escrow funds, in cooperation with the Agricultural Extension Service, North Carolina State University. Any opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not reflect the views of the Energy Division, North Carolina Department of Commerce.



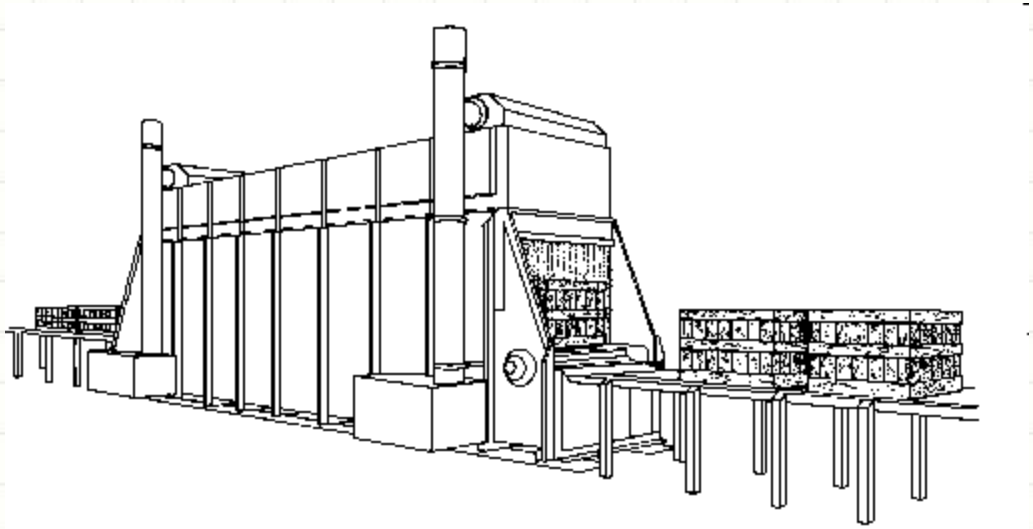
Room Cooling





Forced Air Cooling

COOL AND SHIP:
A LOW-COST, PORTABLE FORCED-AIR COOLING UNIT



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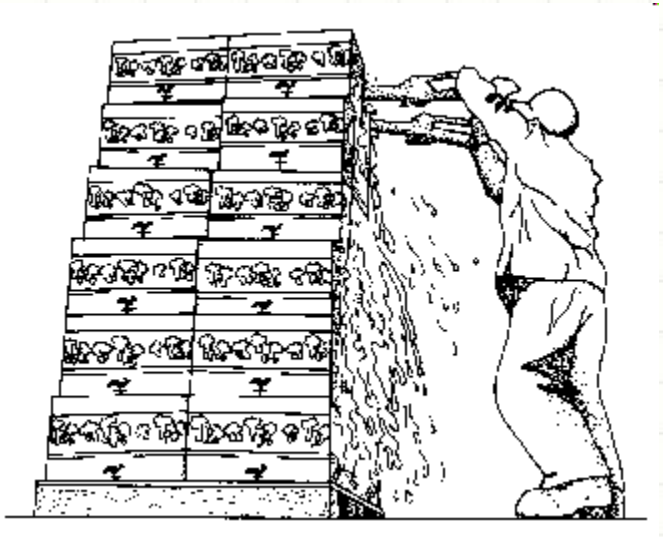
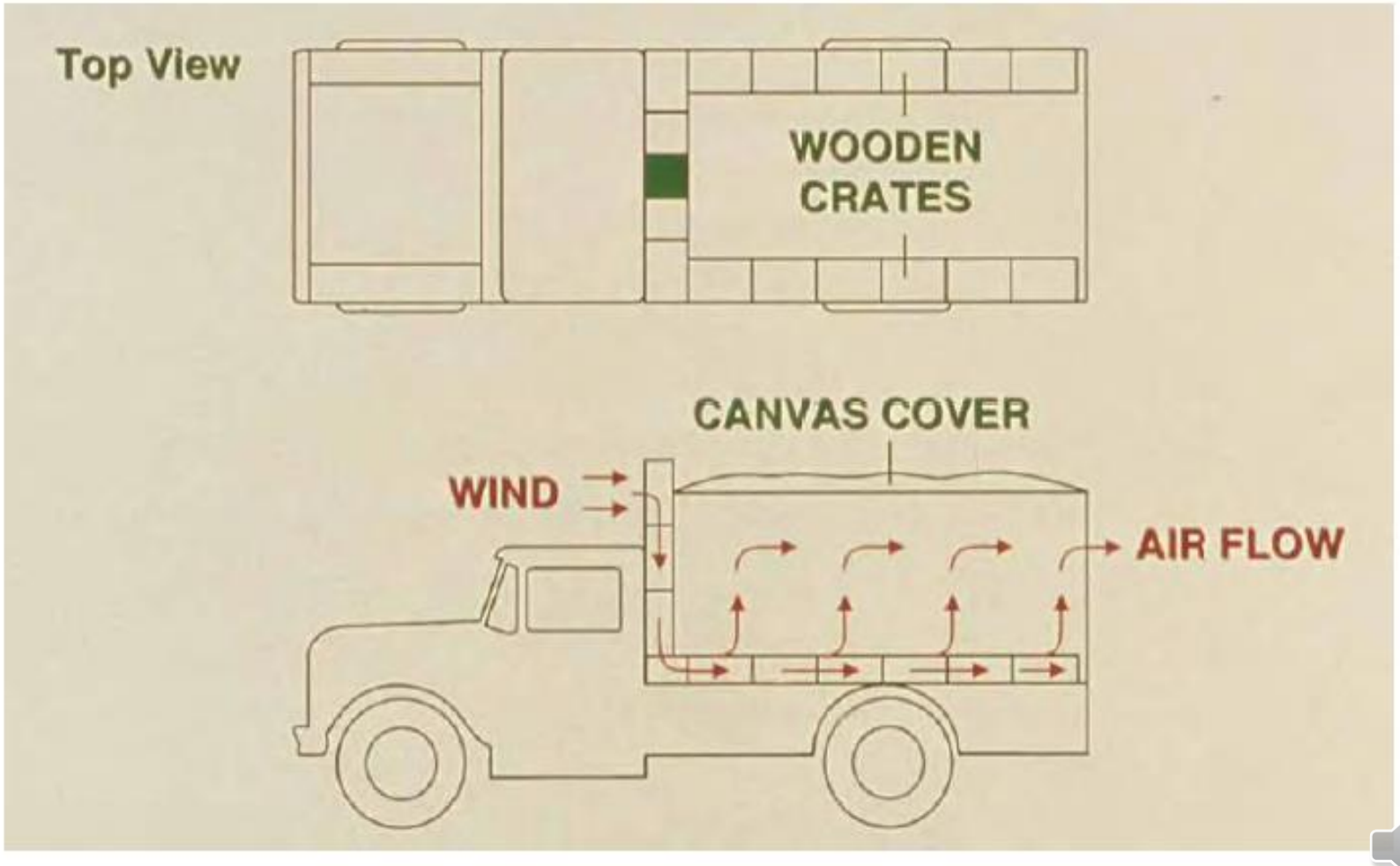
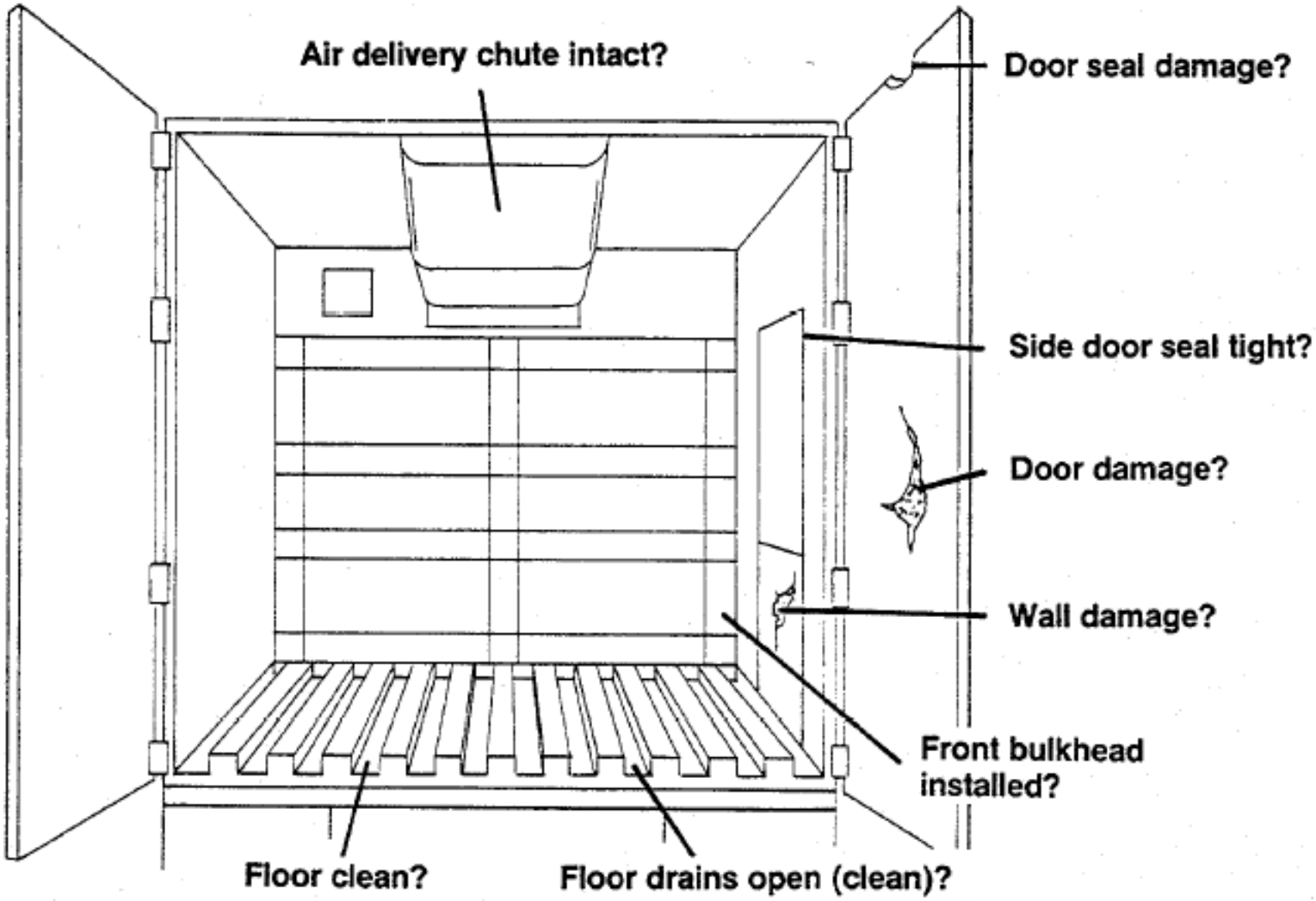


Should be Top-iced:	Can be Top-iced:
beets with tops	artichokes, globe
broccoli	beet greens
carrots with tops	beets topped
corn sweet	brussels sprouts
endive	cantaloupes
escarole	carrots, topped
green onions	celeriac
parsley	chard
radishes with tops	kohlrabi
radish greens	leeks
spinach	mustard greens
turnips	parsnips
turnips with tops	radishes
turnip greens	rutabagas
watercress	

Transportation Methods

- Open Vehicle
- Refrigerated Vehicle
  - Box Truck
  - Tractor Trailer


Top View
WOODEN
CRATES
CANVAS COVER
WIND
AIR FLOW



Inside width adequate for load?
Inside height adequate for load?
Door height adequate for load?

Load bars used to secure load?
Trailer precooled before loading?
Refrigeration unit operates satisfactorily?

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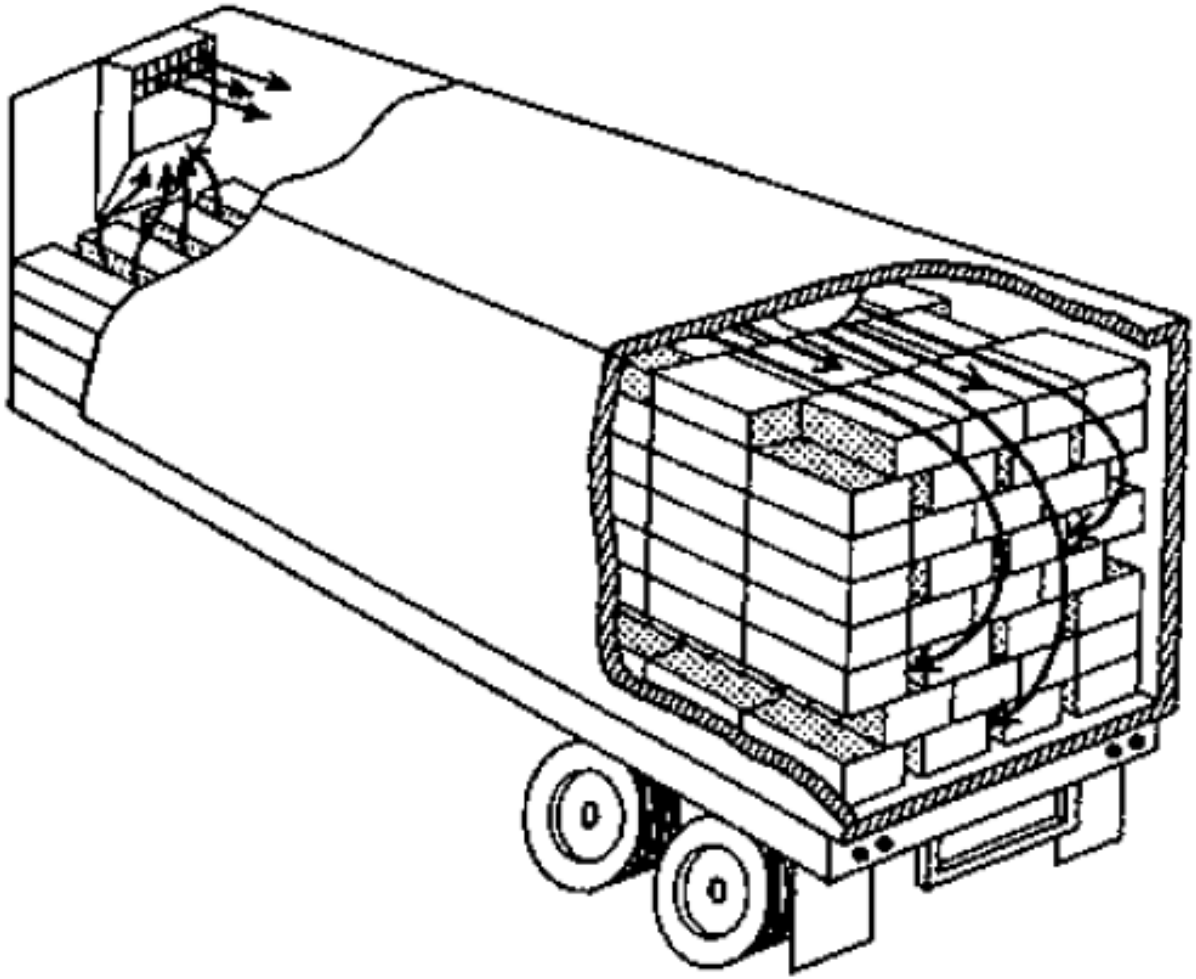

Resources


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fruit & vegetable
FARMERS

Grades and Standards, Phyto-Sanitary Regulations

http://www.ams.usda.gov
http://www.ams.usda.gov/fv (Fruit & Vegetable Programs)
http://www.ams.usda.gov/tmd (Transportation & Marketing Programs)
Agricultural Marketing Service at the U.S. Department of Agriculture
The Agricultural Marketing Service includes six commodity programs--Cotton, Dairy, Fruit and Vegetable, Livestock and Seed, Poultry, and Tobacco. The programs employ specialists who provide standardization, grading and market news services for those commodities. They enforce such Federal Laws as the Perishable Agricultural Commodities Act and the Federal Seed Act. AMS commodity programs also oversee marketing agreements and orders, administer research and promotion programs, and purchase commodities for Federal food programs.

http://www.ams.usda.gov/nop/ (The National Organic Program)
This site includes the national standards on organic agricultural production and handling.

http://www.aphis.usda.gov/ (Animal and Plant Health Inspection Service)
The mission of the Animal and Plant Health Inspection Service (APHIS) is to protect America's animal and plant resources by:

- Safeguarding resources from exotic invasive pests and diseases,
- Monitoring and managing agricultural pests and diseases existing in the United States,
- Resolving and managing trade issues related to animal or plant health, and
- Ensuring the humane care and treatment of animals.

http://postharvest.ucdavis.edu
At this University of California (UC) website you will find a wide range of fact sheets on individual fruits and vegetables, temperature recommendations for storage, links to suppliers of postharvest equipment and many reference articles on the postharvest handling of perishables.

http://www.uckac.edu/postharv/
This University of California, Kearney Agricultural Center Internet site includes information about postharvest handling of apricot, Asian pear, fig, kiwifruit, nectarine, olive, peach, persimmon, plum and fresh prune, and table grape.

www.fao.org/inpho/
This United Nations website includes a variety of FAO and other publications that users can browse on-line or download for their personal use. The UCDavis training publication. Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (3rd edition) provides cost-effective recommendations on improved handling of fruits and vegetables from the farm to the market. Other publications focus on packaging, storage, marketing or training and extension.

www.bae.ncsu.edu/programs/extension/publicat/postharv/
This website sponsored by North Carolina State University offers information on postharvest cooling and storage options for many commodities.

http://www.postharvest.tfrec.wsu.edu
This Washington State University Internet site includes information about postharvest handling of apple, pear, cherry, and stone fruits.