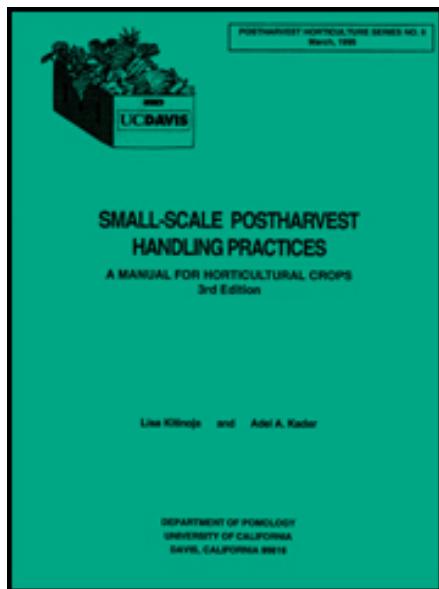
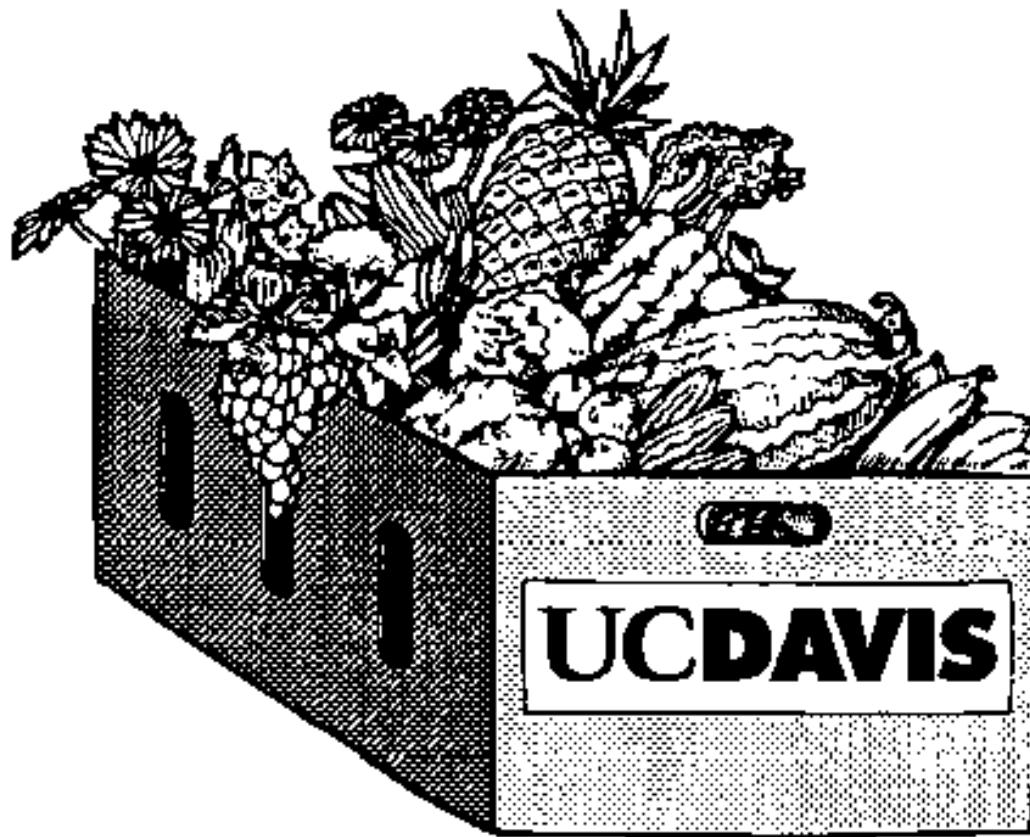


Small-scale postharvest handling practices - A manual for horticultural crops - 3rd edition



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POSTHARVEST HORTICULTURE SERIES NO. 8 -
March, 1995



Lisa Kitinoja and Adel A. Kader

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Appendix A: Manufacturers and suppliers of postharvest technology materials and equipment for small-scale horticultural handlers

Appendix B: Addresses, telephone and fax numbers of manufacturers and suppliers



Acknowledgments

The development of this manual was supported, in part, by USAID funds via USDA grant number 58319R-3-004, the National Agricultural Research Project, Ministry of Agriculture, Egypt. The first edition (published in June 1993) and second edition (January 1994) were much in demand and encouraged our efforts to update the manual and quickly produce a third edition.

This edition includes all the practices for postharvest handling discussed in the original edition, while providing information on additional practices for handling and food processing of horticultural commodities. The second edition of the manual is now also available in Arabic (published in January 1994) and the third edition will soon be available in Spanish (April 1995).

We thank Robert Kasmire, Extension Specialist Emeritus (Department of Vegetable Crops at U C Davis) and special consultant to the Postharvest Outreach Program for his careful review and suggestions for revision of the 3rd edition. We also thank Pam Moyer, in the Department of Pomology at UC Davis, for her work on new illustrations and formatting the text, and for proofreading the manual before reproduction. We also thank Don Thomas at the Postharvest Institute for Perishables (University of Idaho) for his aid in locating and providing some of the more obscure documents on postharvest handling and food processing; the University of California postharvest specialists for digging through their files and providing materials for the manual. And thanks are due to Marita Cantwell in the Department of Vegetable Crops for her helpful review of the various drafts of the first edition.

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March 28, 1995

Users' Feedback Solicited

The authors welcome suggestions for additions to this manual and for changes in the materials included in this edition and will include such changes in the next edition. Please send your correspondence to:

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Thank you for your cooperation and assistance.





Introduction the manual

[Postharvest handling steps for a typical commodity](#)

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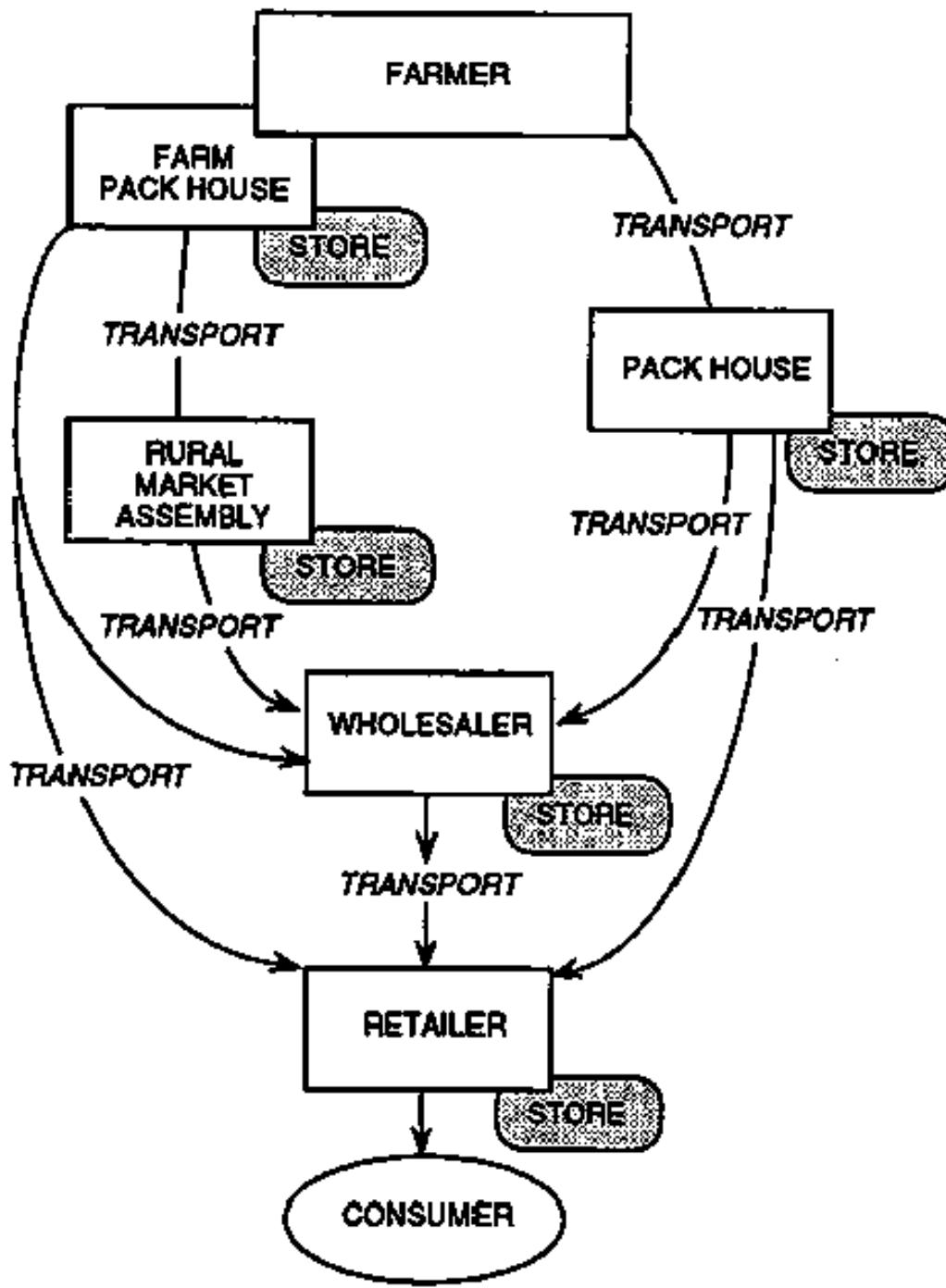
The two main objectives of applying postharvest technology to harvested fruits and vegetables are to maintain quality (appearance, texture, flavor, nutritive value and safety) and to reduce losses between harvest and consumption. Effective management during the postharvest period, rather than the level of sophistication of any given technology, is the key in reaching the desired objectives. While large scale operations may benefit from investing in costly handling machinery and high-tech postharvest treatments, often these options are not available to small-scale handlers for the simple reason of economies of scale. Instead, simple, low cost technologies can be more appropriate for small volume, limited resource commercial operations, farmers involved in direct marketing, for home gardeners, as well as for handlers in developing countries.

Many recent innovations in postharvest technology in developed countries have been in response to the desire to avoid the use of costly labor and the desire for cosmetically "perfect" produce. These methods may not be sustainable over the long term, due to socioeconomic, cultural and/or environmental concerns. For example, the use of postharvest pesticides can be costly both in terms of money and environmental consequences. Local conditions for small-scale handlers may include labor surpluses, lack of credit for investments in postharvest technology, unreliable electric power supply, lack of transport, storage facilities and/or packaging materials, as well as a host of other constraints. Fortunately, there is a wide range of simple postharvest technologies from which to choose, and many have the potential of meeting the special needs of small-scale food handlers and marketers. Many of the practices included in the manual have been successfully used in various parts of the world for handling horticultural crops for many years.

There are many interacting steps involved in any postharvest system. Produce is often handled, transported and stored repeatedly between harvest and consumption (Figure 1; FAO, 1986). While particular practices and the sequence of operations will vary for each crop, there is a general series of steps in postharvest handling systems that will be followed for the purposes of the manual.

Postharvest handling steps for a typical commodity

FIGURE 1: Postharvest Handling Steps for a Typical Commodity



Section 1 presents some harvesting practices and methods of preparation for market. Section 2 provides selected examples of how to cure root, tuber and bulb crops before further handling or storage. Section 3 illustrates simple technologies that can be used in the packinghouse, be it a simple shed in the field or a separate structure with cooling and storage facilities.

Section 4 presents a variety of packing methods and packaging materials that can help to maintain product quality and reduce mechanical damage during handling and storage. Section 5 describes pest control methods and offers suggestions for alternatives to chemical treatments for insect and disease control.

The most common causes of postharvest losses in developing countries include rough handling and inadequate cooling and temperature maintenance (Table 1). The lack of sorting to eliminate defects before storage and the use of inadequate packaging materials further add to the problem. In

general, minimizing rough handling, sorting to remove damaged and diseased produce and effective temperature management will help considerably toward maintaining a quality product and reducing storage losses. If the temperature during the postharvest period is kept as close to the optimum as feasible for a given commodity, storage life will be enhanced. Simple methods for cooling are described in Section 6. Storage structures, methods for ensuring adequate ventilation, and simple technologies for modified atmosphere storage are presented in Section 7. Transport practices that can reduce losses are described in Section 8, and methods for handling at destination (wholesale or retail markets) are illustrated in Section 9. Finally, Section 10 presents some simple methods for processing fresh produce such as drying, canning and juice extraction.

Principal causes of postharvest losses and poor quality

Table 1: Principal Causes of Postharvest Losses and Poor Quality for Various Groups of Fruits and Vegetables

GROUP	EXAMPLES	PRINCIPAL CAUSES OF POSTHARVEST LOSSES AND POOR QUALITY (IN ORDER OF IMPORTANCE)
Root vegetables	Carrots	Mechanical injuries
	Beets	Improper curing
	Onions	Sprouting and roving
	Garlic	Water loss (shriveling)
	Potato	Decay
	Sweet Potato	Chilling injury (subtropical and tropical root crops)
Leafy vegetables	Lettuce	Water loss (wining)
	Chard	Loss of green color (yellowing)
	Spinach	Mechanical injuries
	Cabbage	Relatively high respiration rates
	Green onions	Decay
Flower vegetables	Artichokes	Mechanical injuries
	Broccoli	Yellowing and other discolorations
	Cauliflower	Abscission of florets
Immature-fruit vegetables	Cucumbers	Decay
	Squash	Overmaturity at harvest
	Eggplant	Water loss (shriveling)
	Peppers	Bruising and other mechanical injuries
	Okra	Chilling injury
	Snap beans	Decay
Mature-fruit vegetables and fruits	Tomato	Bruising
	Melons	Over-ripeness and excessive softening at harvest
	Citrus	Water loss
	Bananas	Chilling injury (chilling sensitive fruits)
	Mangoes	Compositional changes
	Apples	Decay

Grapes	
Stone fruits	

Each of the practices presented in the manual are briefly described and illustrated. For further information on any particular practice, users can refer to the source listed or write directly to the authors of the manual. The practices described in this manual are not meant to be a comprehensive list of postharvest handling practices, but a starting point for low-input and/or small-scale handlers of horticultural commodities. It is hoped that users of the manual will send to the authors any information about simple, low cost technologies currently in use which were not covered in this edition. Such information would be very useful since we plan to update the manual on an annual basis.

Appendix A contains a list of manufacturers and suppliers of appropriate postharvest technologies, and handlers can contact these businesses directly. Suggestions for additions to this list are welcomed by the authors. We believe that application of some of the practices illustrated in the manual will enable small-scale handlers to reduce produce losses and help maintain quality of fruits vegetables and ornamental crops.

Resources for quality assurance and export marketing

For handlers who desire more detailed information on requirements for export, the Natural Resources Institute (1994) has published a comprehensive Manual for Horticultural Export Quality Assurance. NRI's manual provides practical guidelines for the total quality management of the postharvest process, including inspections, hygiene, pesticide residue analysis, standardization of instruments for temperature checking, and records maintenance. This manual is highly recommended to anyone involved in the business of exporting horticultural commodities to countries of the European Union. (Available for sale from NRI, Central Avenue, Chatham Maritime, Kent ME4 4TB, UK).

Standards for U. S. Grades are available for a wide range of fruits and vegetables for fresh market or processing. For a single free copy of U.S. Grades for a particular commodity, write to Fresh Products Branch, USDA-AMS, FV, Room 2056-S, Washington, D.C., 20250. U.S. Inspection Instructions are also available at a small fee from this address.

The Organization of Economic Cooperation and Development (OECD) publishes booklets on "International Standards of Fruits and Vegetables". In North America, write to: OECD Publications and Information Center, 2001 L Street, N.W., Suite 700, Washington, D.C., 20036-4910. From countries outside North America, contact OECD Publications Service, 2 Rue André-Pascal, 75775 PARIS Cedex 16, France.

Protrade advises and promotes businesses in Latin America, Africa, Asia and Eastern Europe by providing marketing expertise for products that are competitive in European markets. Handbooks on general trade and marketing are available for fresh fruit and dried fruit. Export manuals (in English and Spanish) are available for asparagus, mangoes, avocados, papaya and pineapple. These publications are available from Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), GmbH Protrade, P.O. Box 5180, D-65726 Eschborn, Germany.

Publications on the harvesting, postharvest handling and marketing of banana, mango, rambutan, papaya and durian are available from the ASEAN Food Handling Bureau, as a part of its series on "Fruit Development, Postharvest Physiology, Handling and Marketing in ASEAN". Each book is available for sale from ASEAN Food Handling Bureau, Level 3, G14/G15, Pusat Bandar

Damansara, 50490 Kuala Lumpur, Malaysia.





Section 1: Harvesting and preparation for market

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 - [Harvesting practices](#)
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 - [Harvesting tools](#)
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-

Mechanical damage during harvest can become a serious problem, as injuries predispose produce to decay, increased water loss and increased respiratory and ethylene production rates leading to quick deterioration. In general, harvesting by machine will cause more damage than harvesting by hand, although some root crops can be severely damaged by careless hand digging. The containers used by pickers in the field should be clean, have smooth inside surfaces and be free of rough edges. Stackable plastic crates, while initially expensive, are durable, reusable and easily cleaned (FAO, 1989). If baskets are used, they should be woven "inside out" with the stubs of the beginning and end of each cane on the outside of the basket (Grierson, 1987).

Manual harvesters should be well trained in the proper way to harvest the crop to minimize damage and waste, and should be able to recognize the proper maturity stage for the produce they are handling. Pickers should harvest with care, by snapping, cutting or pulling the fruit or vegetable from the plant in the least damaging manner. The tips of knives should be rounded to minimize inadvertent gouges and excess damage to perennial plants. Knives and clippers should always be well sharpened. Pickers should be trained to empty their picking bags and/or baskets with care, never dumping or throwing produce into field containers. If harvesters pick directly into large bulk bins, produce can be protected from bruising by the use of a deaccelerating chute fashioned from canvas. Vented, stackable field containers should be kept clean and smooth.

Exposure to the sun should be avoided as much as possible during and after harvest, as produce left out in the sun will gain heat and may become sun-burned. Field bins should be placed in the shade or loosely covered (for example with light colored canvas, leafy plant materials, straw or an inverted empty container) if delays are expected in removing them from the field. Night or early morning harvest is sometimes an option for harvesting produce when internal temperatures are relatively low, reducing the energy needed for subsequent cooling. Latex flow is often lower later in the morning than it is at dawn for crops such as mango and citrus

(Pantastico, 1980), so harvesting as late in the morning as possible can also reduce later efforts required to clean the produce before packing.

Directly following harvest, when produce is prepared for marketing, cooling is essential. Cooling (also known as "pre-cooling") is the removal of field heat directly after harvest, before any further handling. Any delays in cooling will shorten postharvest life and reduce quality. Even produce undergoing repeated cooling and warming deteriorates at a slower rate than produce that has not been cooled (Mitchell et al, 1972).

Rough handling during preparation for market will increase bruising and mechanical damage and limit the benefits of cooling. Roads between the field and the packinghouse should be graded and free from large ruts, bumps and holes. Field boxes must be well-secured during transport and, if stacked, not overfilled. Transport speeds must be suited to the quality and conditions of the roads, and truck and/or trailer suspensions kept in good repair. Reduced tire air pressure on transport vehicles will reduce the amount of motion transmitted to the produce (Mitchell in Kader, 1992).

Any practice that reduces the number of times the produce is handled will help reduce losses. Field packing (selection, sorting, trimming and packaging of produce at the time of harvest) can greatly reduce the number of handling steps the produce must undergo before marketing. Small, mobile field packing stations can be designed to be moved along with the packers and to provide shade for packing operations.

Maturity standards

Maturity standards have been determined for many fruit, vegetable and floral crops. Harvesting crops at the proper maturity allows handlers to begin their work with the best possible quality produce. Produce harvested too early may lack flavor and may not ripen properly, while produce harvested too late may be fibrous or overripe. Pickers can be trained in methods of identifying produce that is ready for harvest. The following table, from Reid (in Kader, 1992) provides some examples of maturity indices.

Index	Examples
Elapsed days from full bloom to harvest	Apples, pears
Mean heat units during development	Peas, apples, sweet corn
Development of abscission layer	Some melons, apples, feijoas
Surface morphology and structure	Cuticle formation on grapes, tomatoes Netting of some melons Gloss of some fruits (development of wax)
Size	All fruits and many vegetables
Specific gravity	Cherries, watermelons, potatoes
Shape	Angularity of banana fingers Full cheeks of mangos Compactness of broccoli and cauliflower
Solidity	Lettuce, cabbage, brussels sprouts

Textural properties	
Firmness	Apples, pears, stone fruits
Tenderness	Peas
Color, external	All fruits and most vegetables
Internal color and structure	Formation of jelly-like material in tomato fruits Flesh color of some fruits
Compositional factors	
Starch content	Apples, pears
Sugar content	Apples, pears, stone fruits, grapes
Acid content, sugar/acid ratio	Pomegranates, citrus, papaya, melons, kiwifruit
Juice content	Citrus fruits
Oil content	Avocados
Astringency (tannin content)	Persimmons, dates
Internal ethylene concentration	Apples, pears

Source: Kader, A. A. 1983. Postharvest Quality Maintenance of Fruits and Vegetables in Developing Countries. In: Lieberman, M., Post-Harvest Physiology and Crop Preservation. Plenum Publishing Corporation. p.455-469.

Vegetables are harvested over a wide range of maturities, depending upon the part of the plant used as food. The following table provides some examples of maturity indices of vegetable crops.

Crop	Index
Root, bulb and tuber crops	
Radish and carrot	Large enough and crispy (overmature if pithy)
Potato, onion, and garlic	Tops beginning to dry out and topple down
Yam bean and ginger	Large enough (overmature if tough and fibrous)
Green onion	Leaves at their broadest and longest
Fruit vegetables	
Cowpea, yard-long bean, snap bean, batao, sweet pea, and winged bean	Well-filled pods that snap readily
Lima bean and pigeon pea	Well-filled pods that are beginning to lose their greenness
Okra	Desirable size reached and the tips of which can be snapped readily
Upo, snake gourd, and dishrag gourd	Desirable size reached and thumbnail can still penetrate flesh readily (overmature if thumbnail cannot penetrate flesh readily)

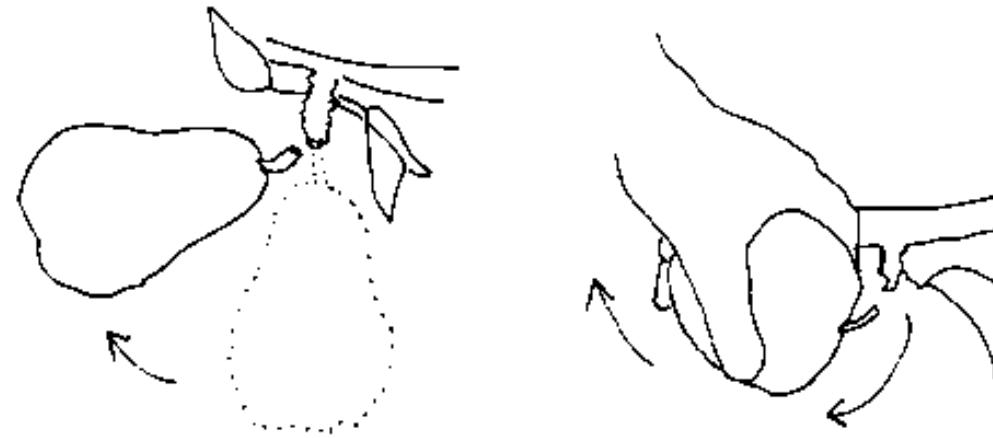
Eggplant, bitter gourd, chayote or slicing cucumber	Desirable size reached but still tender (overmature if color dulls or changes and seeds are tough)
Sweet corn	Exudes milky sap when thumbnail penetrates kernel
Tomato	Seeds slipping when fruit is cut, or green color turning pink
Sweet pepper	Deep green color turning dull or red
Muskmelon	Easily separated from vine with a slight twist leaving clean cavity
Honeydew melon	Change in fruit color from a slight greenish white to cream; aroma noticeable
Watermelon	Color of lower part turning creamy yellow, dull hollow sound when thumped
Flower vegetables	
Cauliflower	Curd compact (overmature if flower cluster elongates and become loose)
Broccoli	Bud cluster compact (overmature if loose)
Leafy vegetables	
Lettuce	Big enough before flowering
Cabbage	Head compact (overmature if head cracks)
Celery	Big enough before it becomes pithy

Source: Bautista, O.K. and Mabesa, R.C. (Eds). 1977. Vegetable Production. University of the Philippines at Los Banos.

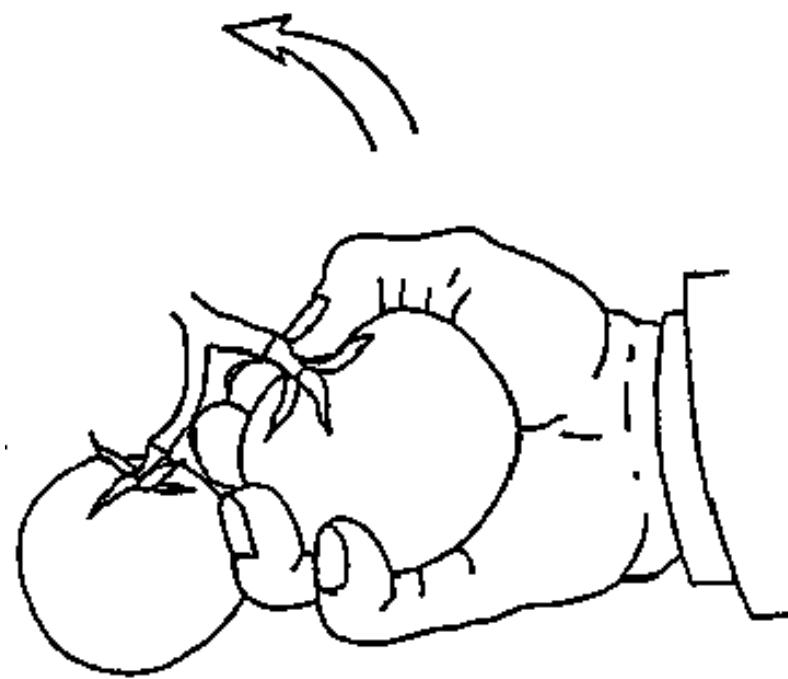
Harvesting practices

Harvesting practices should cause as little mechanical damage to produce as possible. Gentle digging, picking and handling will help reduce crop losses.

Pick carefully to avoid damage:



For some crops, a natural break point forms at the junction of the stem and the stalk when produce is mature. Harvesters should grasp the product firmly but gently and pull upward as illustrated below. Wearing cotton gloves, trimming fingernails, and removing jewelry such as rings and bracelets can help reduce mechanical damage during harvest.



Source: FAO. 1989. Prevention of Post-Harvest Food Losses: Fruits, Vegetables and Root Crops. A Training Manual. Rome: UNFAO. 157 pp.

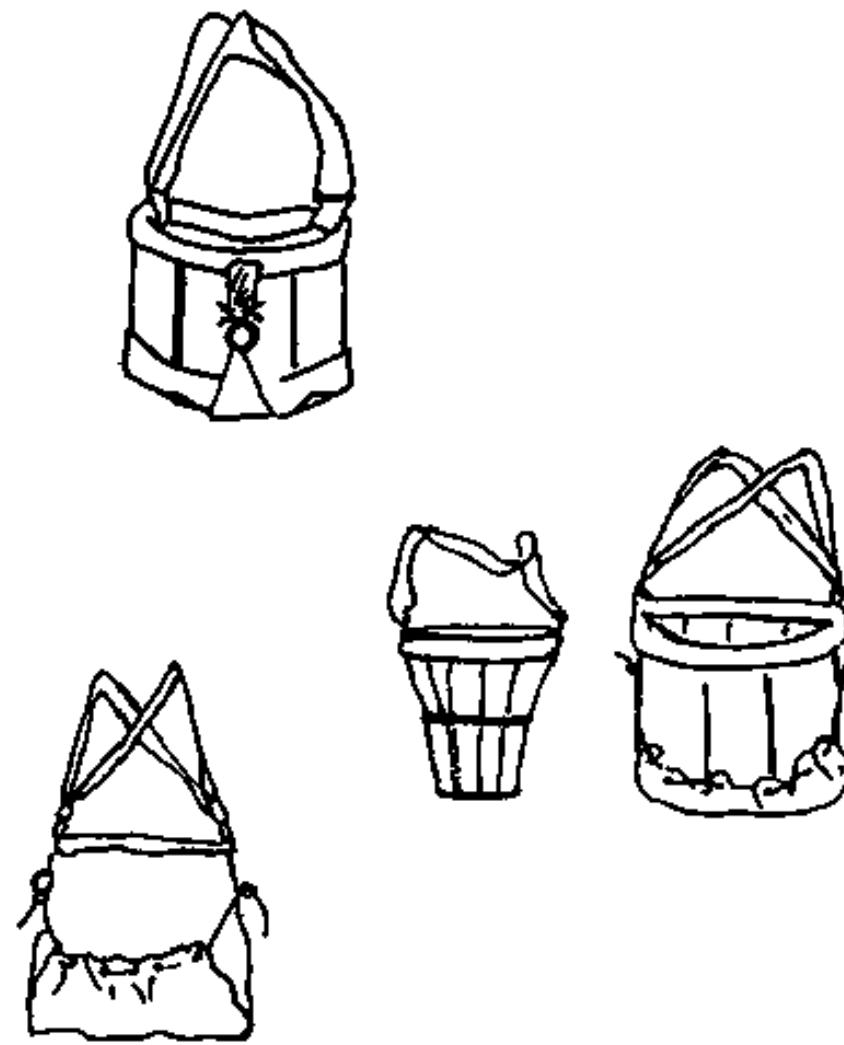
If a small amount of leafy vegetables are being harvested for home use or for sale at a nearby roadside or farmers' market, a small tub of cold water can be useful for cooling the produce. The tub can be brought directly to the field and used by the picker as a field container. Clean water should be used with each lot of produce. Chilling leafy vegetables by using cold water at harvest will help maintain quality and prevent wilting.



Source: Minnich, J. 1983. Gardening for Maximum Nutrition. Emmaus, Pa: Rodale Press.

Harvesting containers

Picking baskets, bags and buckets come in many sizes and shapes. These harvesting containers can be made by sewing bags with openings on both ends, fitting fabric over the open bottom of ready-made baskets, fitting bags with adjustable harnesses, or by simply adding some carrying straps to a small basket. Several examples are illustrated below.



Source: Friend Manufacturing Corporation, Prospect Street, P.O. Box 385, Gasport, New York 14067

Plastic crates are relatively expensive but are durable, reusable and easy to clean. When empty, they can be nested to save space in storage or transport. When filled they can be stacked if every other crate is turned in the direction opposite to the one below.

Stackable, reusable plastic crates:

Source: FAO. 1989. Prevention of Post-Harvest Food Losses: Fruits, Vegetables and Root Crops. A Training Manual. Rome: UNFAO. 157 Pp.

Harvesting tools

Some fruits need to be clipped or cut from the parent plant. Clippers or knives should be kept well sharpened. Penduncles, woody stems or spurs should be trimmed as close as possible to prevent fruit from damaging neighboring fruits during transport.

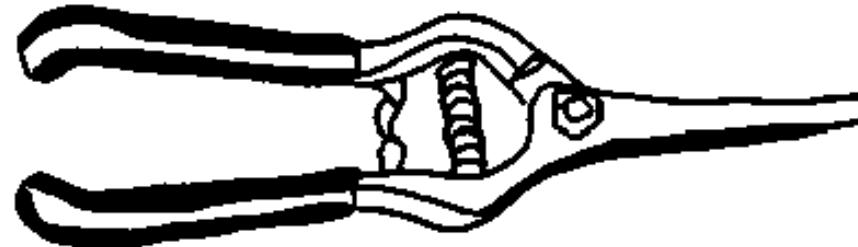


Pruning shears are often used for harvesting fruits, some vegetables, and cut flowers. A variety of styles are available as hand held or pole models, including shears that cut and hold onto the stem of the cut product. This feature allows the picker to harvest without a catching bag and without dropping fruits.

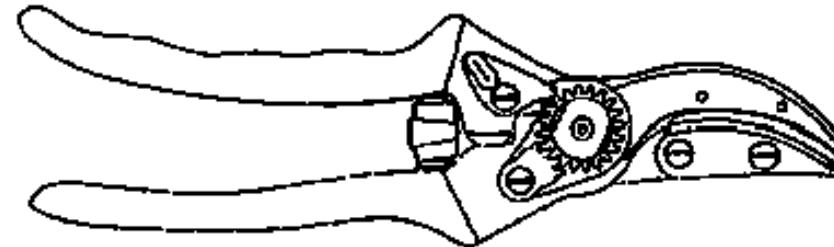
Straight bladed hand shears for fruits and flowers:



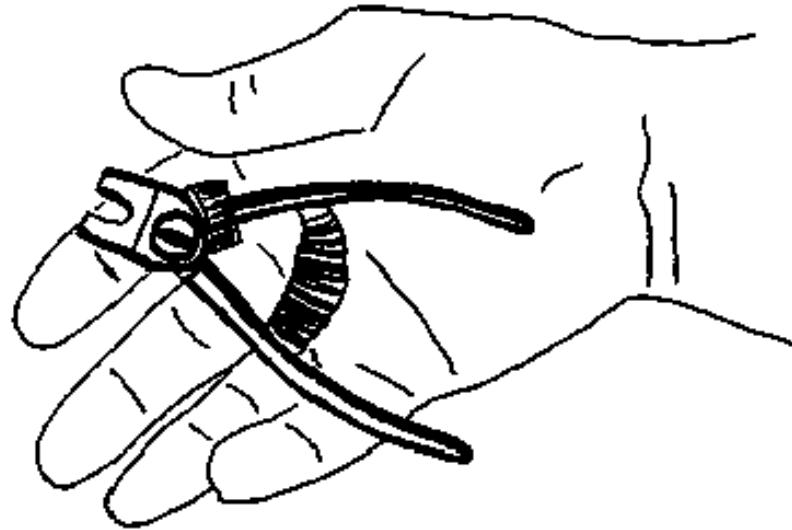
Thin curved blade for grapes and fruits:



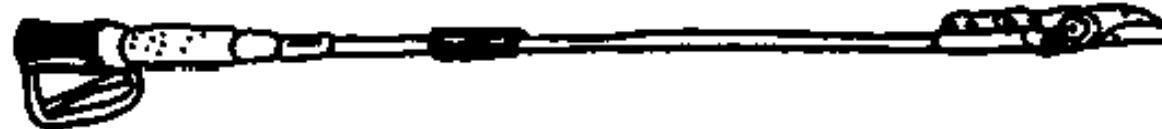
Cut and hold hand shears:



Clipper for citrus fruits:



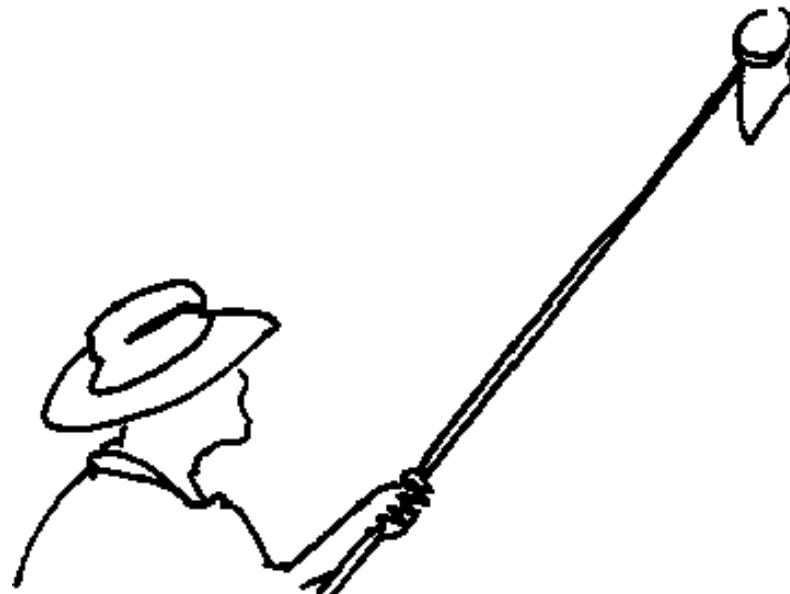
Pole mounted cut and hold picking shears:



Sources: See Appendix A for suppliers of harvesting tools.

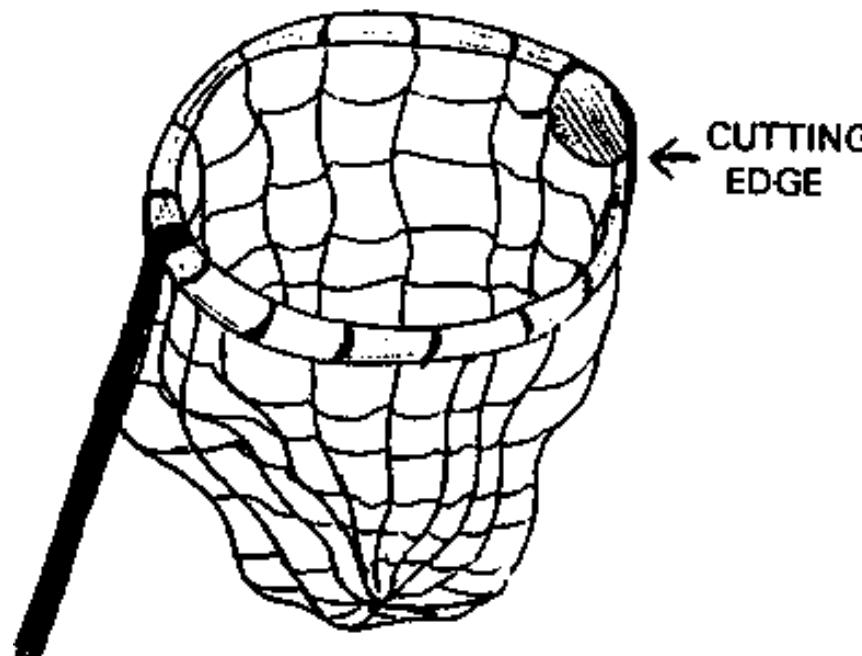
Using a cutting tool attached to a long pole can aid picking of crops such as mangoes and avocados when the fruit is difficult to reach. Cutting edges should be kept sharpened and the catching bag should be relatively small. The angle of the cutting edge and the shape of the catching bag can affect the quality of the fruit harvested, so it is important to check performance carefully before using any new tools.

Using a picking pole:

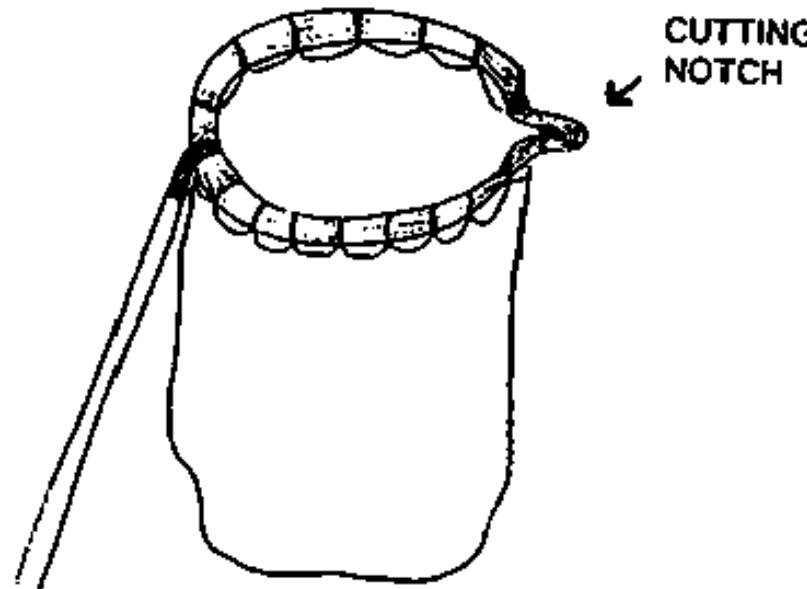


Picking poles and catching sacks can be made by hand or purchased from horticultural supply companies. The collection bags illustrated below were hand woven from strong cord or sewn from canvas. The hoop used as the basket rim and cutting edges can be fashioned from sheet metal, steel tubing or recycled scrap metal.

Hand woven collection bag



Canvas collection sack



Fruit trees are sometimes quite tall and letting fruit fall to the ground when it is cut from the tree will cause severe bruising. If two pickers work together, one can clip or cut the fruit from the tree, and the other can use a sack to break its fall. The catcher supports the bag with his hands and one foot, catches the falling fruit, then lowers the far end of the bag to allow the fruit to roll safely to the ground.



Source: FAO. 1989. Prevention of Post-Harvest Food Losses: Fruits, Vegetables and Root Crops. A Training Manual. Rome: UNFAO. 157 pp.

Unlike most nut crops, pistachio nuts should not be knocked to the ground during harvest because of their open shells and relatively high moisture content. The harvesting practice illustrated below can be used with pistachios and olives with good results. Plastic sheeting or canvas tarpaulins are spread below the tree being harvested, and trees are mechanically shaken or hand knocked (the branches hit with mauls) until the nuts drop. In the illustration below, two harvesters are gathering a sheet covered with produce.

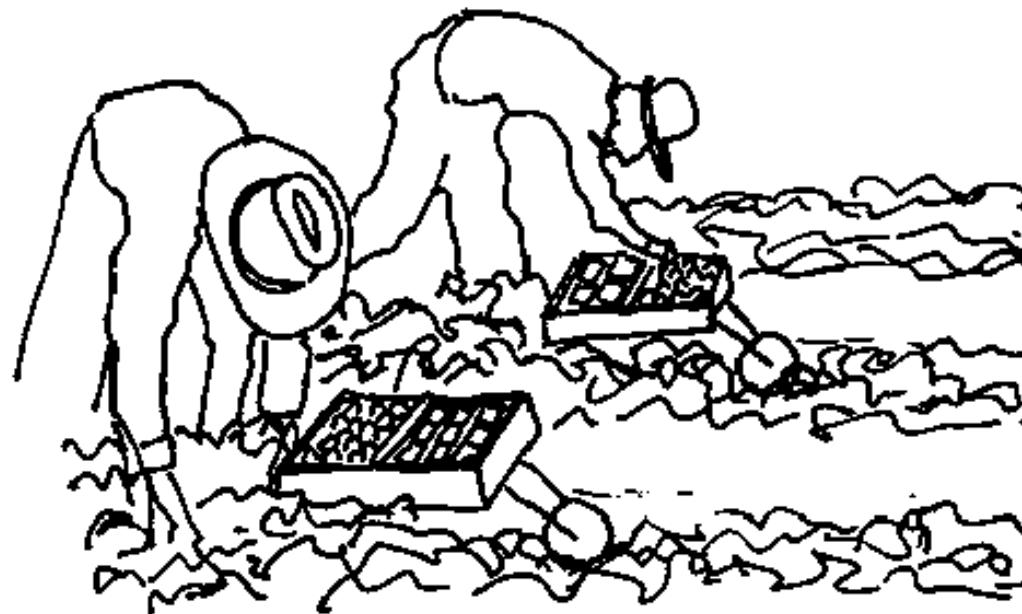


Field packing

When crops are field packed the picker harvests and then immediately packs the produce after minimal handling. Strawberries are generally field packed, since even a small amount of handling will damage these soft fruits. When lettuce is field packed, several wrapper leaves are left on the head to help cushion the produce during transport.

A small cart can help reduce the amount of bending and lifting the picker has to do during harvest. The carts shown below have a single wheel in front, and can be pushed along the row ahead the e picker.

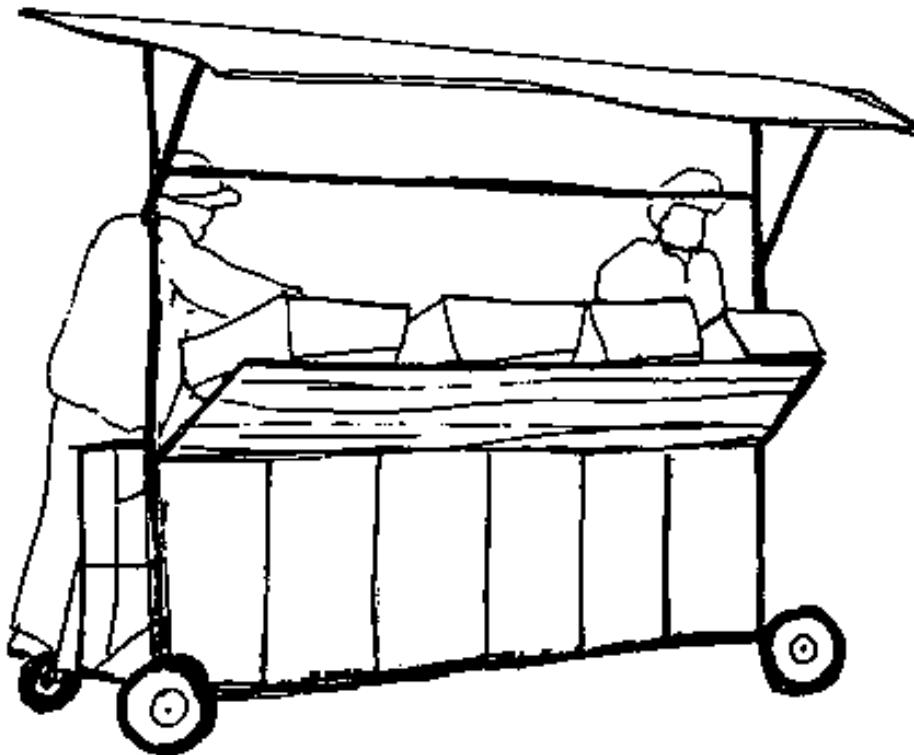
Field packing strawberries:



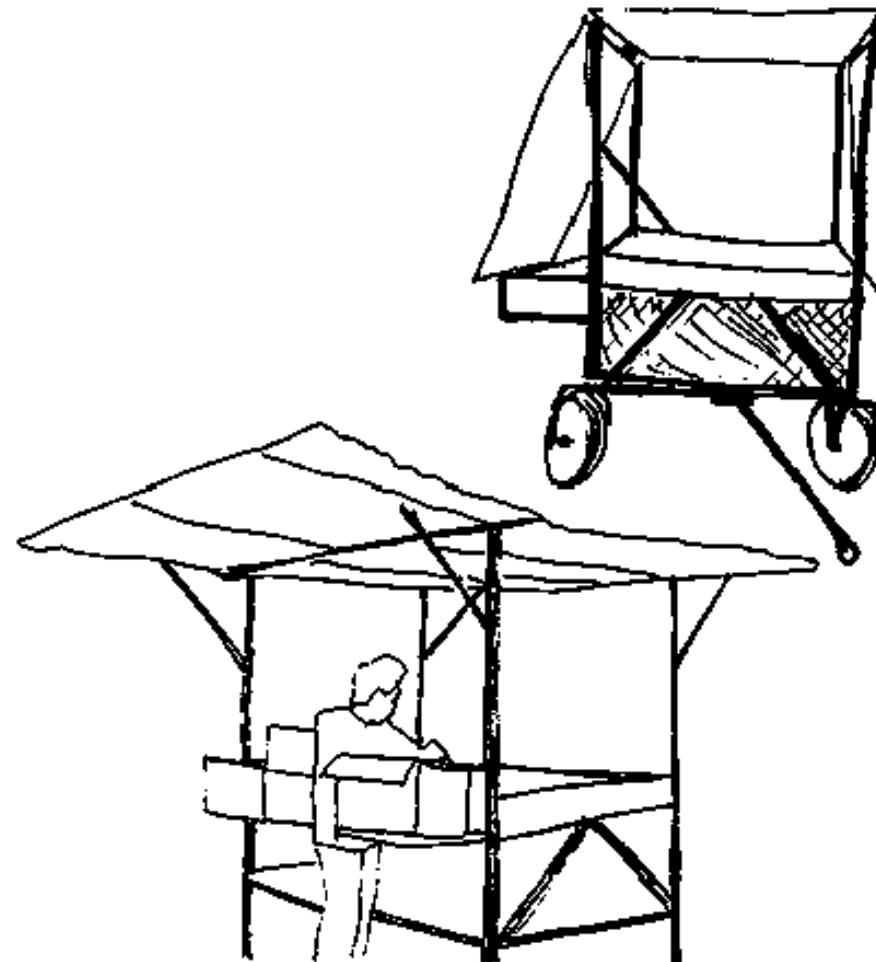
Field packing lettuce:



A simple aid for field packers is a movable cart with a rack for boxes and a roof to provide shade. This cart is designed to be pushed along the outer edge of the small field where harvest is taking place.



This cart for field packing is designed to be pulled by a small tractor into the field when the crop is harvested. This type of cart can be used for field packing many types of crops. The roof folds down for easy transport, and opens up to provide a wide area of shade for the packers and the commodity. The cart design can be modified as needed to suit various products and different operations.



A self-propelled field pack system allows field workers to cut, trim, tie-wrap and pack *in the field*, thus eliminating the expense of operating a packing shed. In the illustration below, a flat bed truck is moving along-side the field pack system, and packed produce is being loaded for transport.

SELF PROPELLED FIELD PACK SYSTEM

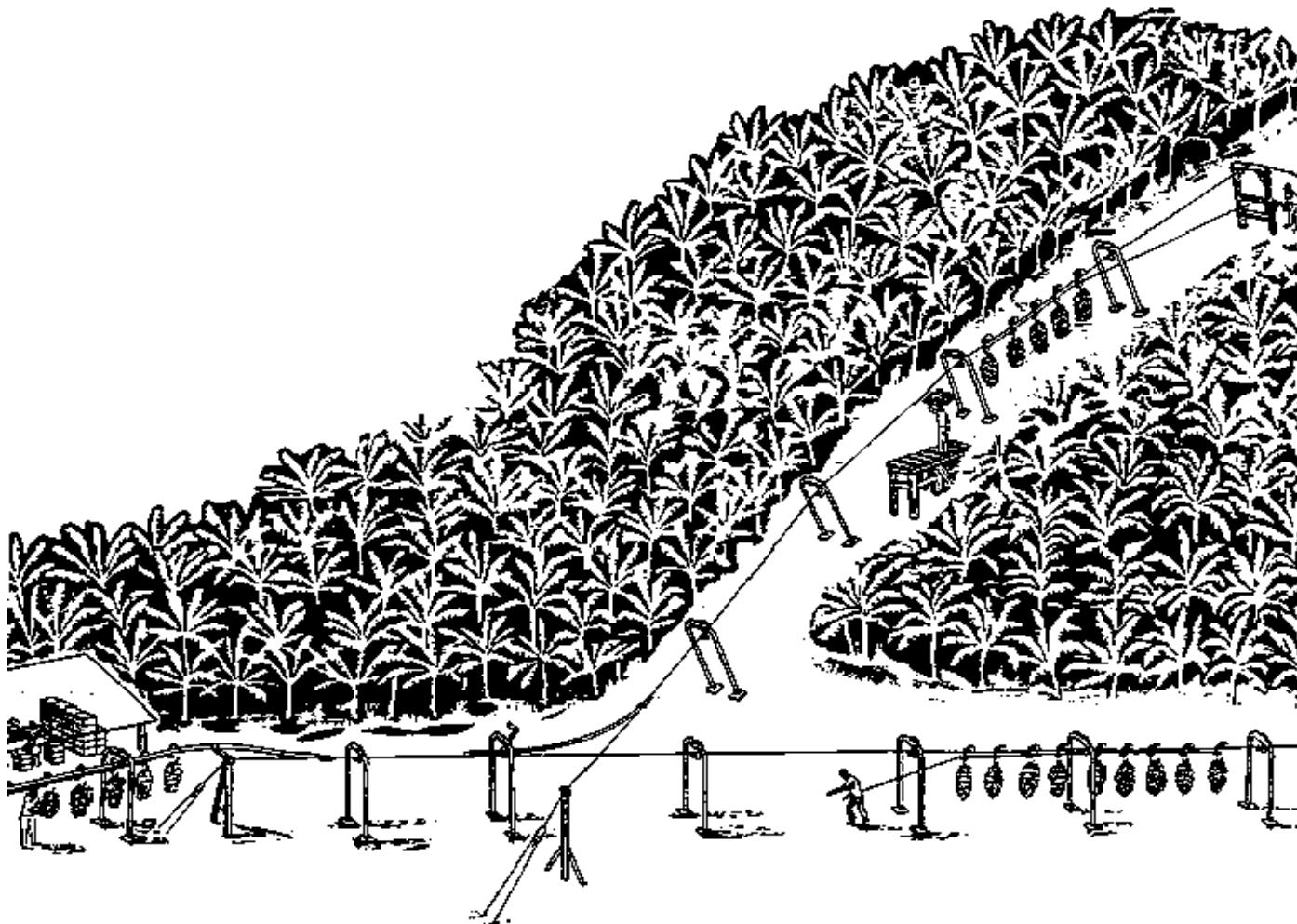
OPTIONS:

- Number of Worker positions per side. Row Spacing
- Ground Clearance
- Can Harvest front, rear, or both

Source: Highlander Ramsay Welding Machine Promotional Brochure. 1993.

Transport to the packinghouse

When crops are harvested at some distance from the packinghouse, the produce must be transported before packing. The gravity driven conveyor system for bananas illustrated below provides an example of how handling can be minimized during preparation for market. Harvested bananas are carried to the platforms set up along the conveyor route, then lifted and hung from hooks attached to the wire. Transport speed is controlled by workers who lead the produce to the packinghouse at the bottom of the hill.



Source: NIAE. 1977. Banana Conveyor. Tropical Agricultural Engineering Information O.D. Bulletin No. 7. National Institute of Agricultural Engineering, Silsoe, Bedfordshire, England. 15 pp.





Section 2: Curing root, tuber and bulb crops

[Field curing](#)

[Curing with heated air](#)

[Bulk systems for curing onions](#)

[Emergency curing](#)

Curing root and tuber crops such as sweetpotatoes, potatoes, cassava and yams is an important practice if these crops are to be stored for any length of time. Curing is accomplished by holding the produce at high temperature and high relative humidity for several days while harvesting wounds heal and a new, protective layer of cells form. While curing can be initially costly, the long extension of storage life makes the practice economically worthwhile.

The best conditions for curing vary among crops as shown in the following table:

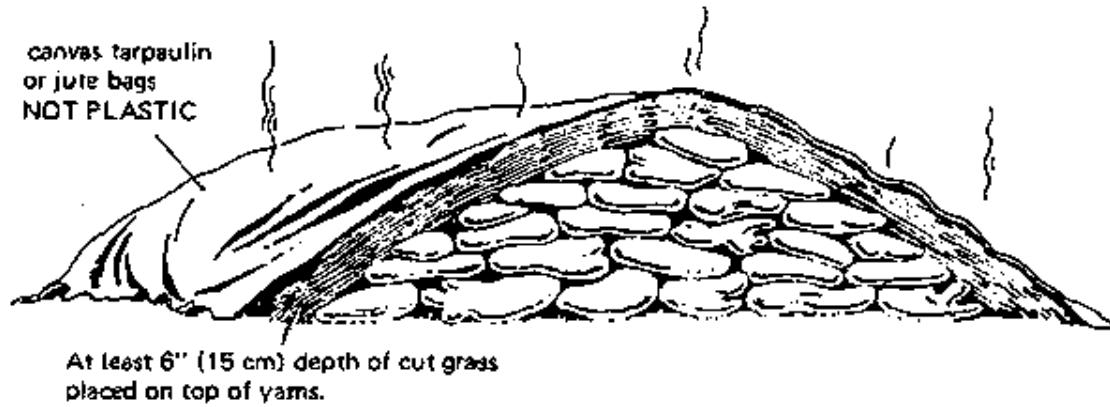
Commodity	Temperature		Relative Humidity (%)	Days
	C	F		
Potato	15-20	59-68	90-95	5-10
Sweetpotato	30-32	86-90	85-90	4-7
Yams	32-40	90-104	90-100	1-4
Cassava	30-40	86-104	90-95	2-5

Curing, when used for onions, garlic and flowering bulbs refers to the practice directly following harvest, of allowing the external layers of skin and neck tissue to dry out prior to handling and storage. If local weather conditions permit, these crops can be undercut in the field, windrowed and left there to dry for five to ten days. The dried tops of the plants can be arranged to cover and shade the bulbs during the curing process, protecting the produce from excess heat and sunburn. If forced heated air is used for curing onions and other bulbs, one day or less at 35 to 45 C (95 to 113 F) and 60 to 75% relative humidity is recommended. The dried layers of skin then protect the produce from further water loss during storage.

Field curing

Yams and other tropical root and tuber crops can be cured outdoors if piled in a partially shaded area. Cut grasses or straw can be used as insulating materials and the pile should be covered with canvas, burlap or woven grass mats. Curing requires high temperature and high relative humidity, and this covering will trap self-generated heat and moisture. The stack should be left for about four days.

Cut-away view of yam curing

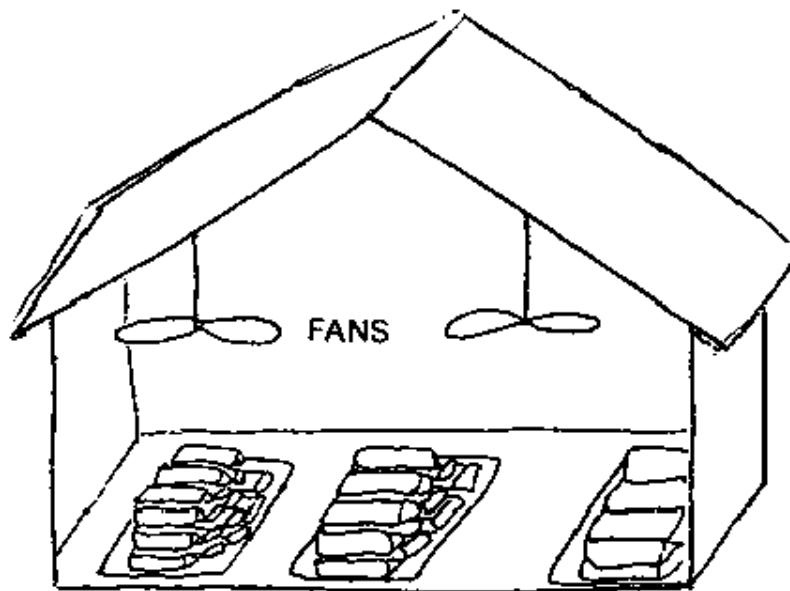


Source: Wilson, J. No date. Careful Storage of Yams: Some Basic Principles to Reduce Losses. London: Commonwealth Secretariat/International Institute of Tropical Agriculture. (IITA, Ibadan, Nigeria.)

Onions and garlic can be cured in the field in regions where harvest coincides with the dry season. The crops can be cured either in windrows or after packing into large fiber or net sacks. The produce can be left in the field for five days, then checked daily until the outer skin and neck tissues are properly dried. Curing may take up to ten days, depending on weather conditions.

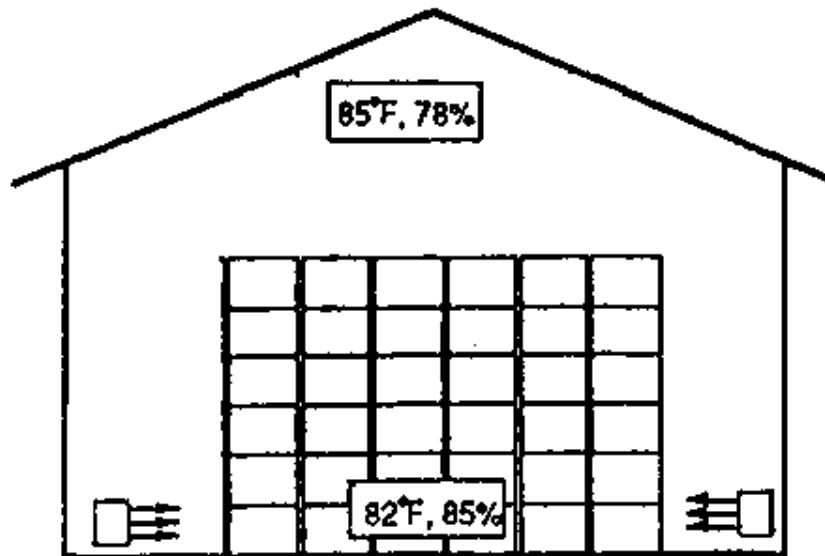
Curing can be assisted by the use of ventilated sheds in regions where solar radiation and/or relative humidity is high or natural air movement is low. Produce in sacks can be stacked in the shade on canvas tarpaulins under one or more ceiling fans.

Curing assisted by shade and ventilation:

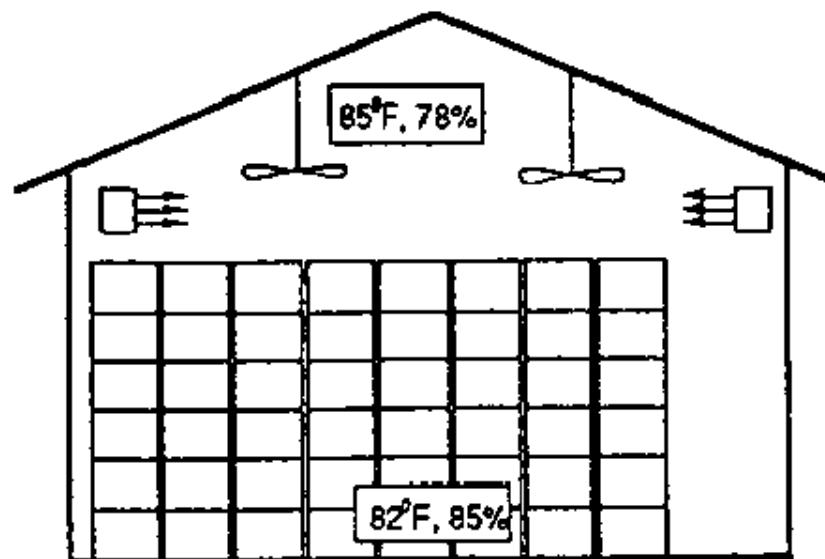


Curing with heated air

The most uniform distribution of heat is obtained when heat is introduced near the floor level of a curing structure. Heaters can be placed on the floor near the bins of produce, or heat can be ducted in from outside the curing room. A high relative humidity can be obtained by wetting the floor or by using an evaporative cooler in the room without introducing outside air.



If heaters are located near the ceiling, then ceiling fans can be used to help redistribute the heat down into the room of produce. Bulk bins must be stacked to allow a gap of 10 to 15 cm (4 to 6 inches) between rows for adequate air circulation.

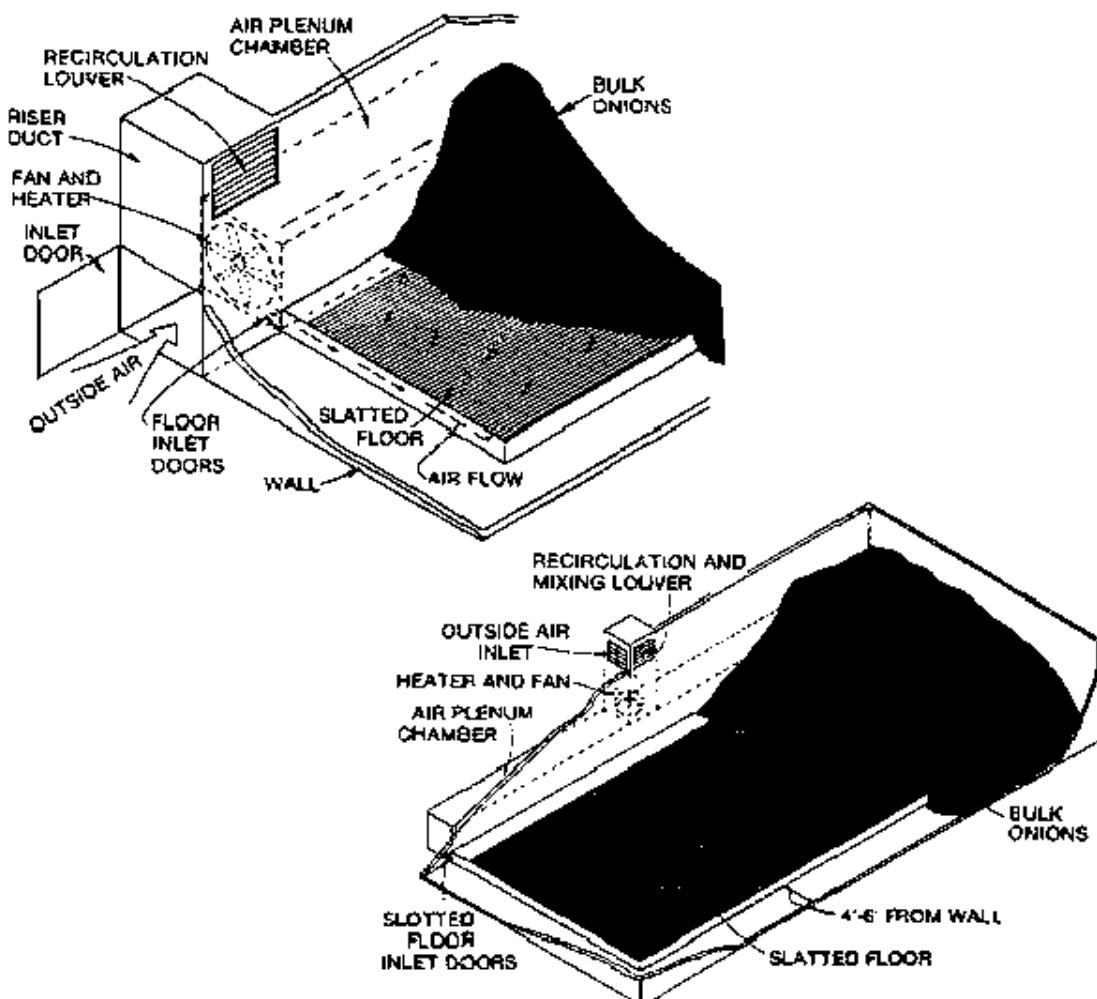


Source: Thompson, J. & Scheuerman, R.W. 1993. Curing and Storing California Sweetpotatoes. Merced County Cooperative Extension, Merced, California

Bulk systems for curing onions

Curing using a bulk system requires a fan, a heating unit and a slatted floor. The illustrations below shows how air can be brought in, heated and distributed through a load of bulk onions in the curing room An exhaust opening near the ceiling recirculates heated air.

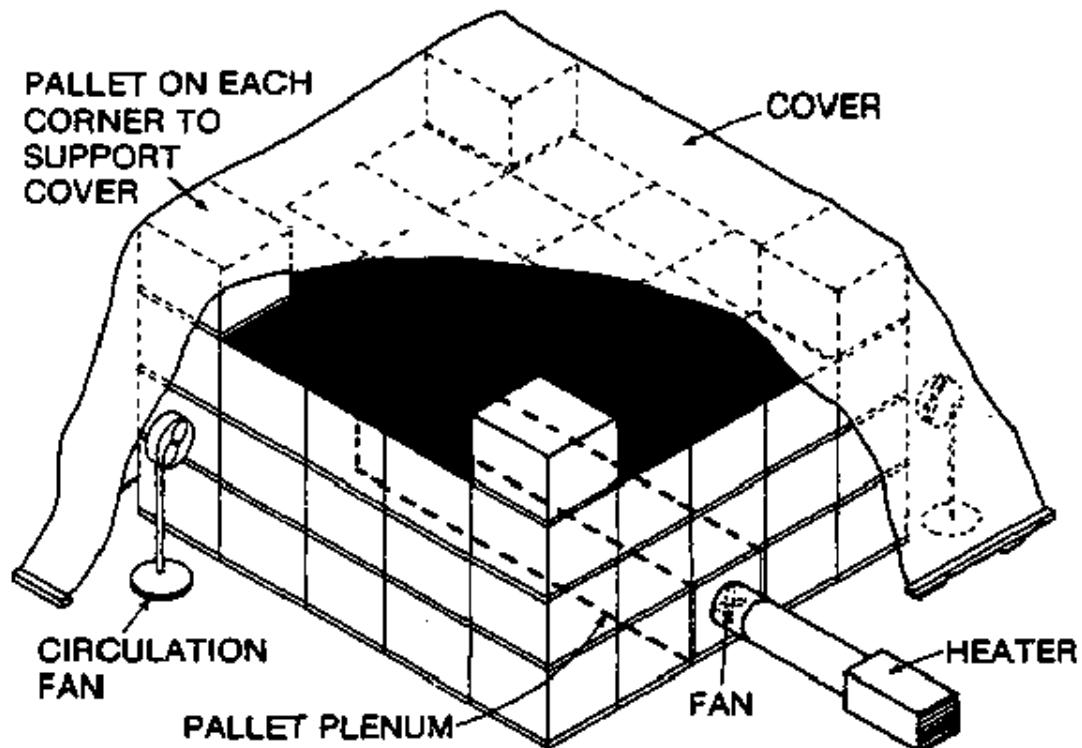
When using heated air it is easy to overdry the bulbs, leading to loss of external scales and exposure of the fleshy scales underneath. Curing onions should be checked regularly to avoid overdrying.



Source: Davis, H.R et al. No date. Storage Recommendations for Northern Grown Onions. Information Bulletin 148. Ithaca, NY: Cornell University Extension.

Emergency curing

If conditions such as rain or flooded fields do not permit field curing and curing facilities are not available, a temporary tent can be used for curing onions. In the example illustrated below, the tent is constructed from large tarps. Heated air is forced into a hollow area (known as a plenum) at the center of the bins of produce. Several fans are used to circulate the warm air through the onions while they are curing.



Source: Davis, H.R. et al. (No date). Storage Recommendations for Northern Grown Onions. Information Bulletin 148, Ithaca, New York Cornell University Extension.





Section 3: Packinghouse operations

[General operations](#)

[Dumping](#)

[Washing](#)

[Waxing](#)

[Sorting](#)

[Sizing](#)

[Fruit packing line](#)

Packinghouse operations can be as simple as moving produce from a field lug into a shipping container, or may include a variety of handling practices, from cleaning, waxing, sizing, and quality grading to color sorting. The provision of shade during the packing operations is extremely important. Shade can be created using palm leaf fronds, a plastic mesh or canvas sheet hung from temporary poles, or via a permanent roofed structure. When deciding upon where to locate a packinghouse, access to the field and market point, adequate space for vehicles to enter and leave the packinghouse and ease of access to labor will all be considerations (Proctor, 1985).

In the simplest packinghouse, produce is delivered in picking containers, immediately after harvest, directly to the packers. The packers then sort, grade, size and pack the produce directly into appropriate transport containers. In this case, each worker must be knowledgeable regarding produce defects, grade and size requirements, and packing methods.

As the size and complexity of the packinghouse increases, more operations and workers trained in specific tasks might be added.

Dumping

Produce must somehow be removed from the field bin or harvesting container and moved through the packinghouse. This first step is known as "dumping". Dumping must be done gently, whether using water assisted methods or dry dumping. Wet dumping can decrease bruising and abrasions by using moving, chlorinated (100-150 ppm) water to carry delicate produce. When using dry dumping, padded, sloped ramps or moving conveyor belts can decrease injuries to produce.

Pre-sorting

Pre-sorting produce is usually done to eliminate injured, decayed, or otherwise defective produce (culls) before cooling or additional handling. Pre-sorting will save energy in that culls will not be handled. Removing decaying produce items will limit the spread of infection to other units, especially if postharvest pesticides are not being used.

Cleaning

For some commodities, such as kiwifruits and avocados, dry brushing may be sufficient to clean the produce. Other commodities, however, such as bananas and carrots, require washing. The choice of brushing and/or washing will depend upon both the type of commodity and the type of contamination.

Sanitation is essential, both to control the spread of disease from one item to another, and to limit spore buildup in wash water or in the packinghouse air. Chlorine treatments (100 to 150 ppm Cl) can be used in wash water to help control pathogen buildup during packing operations (Moline, 1984). There is some variation in the strength of bleach available commercially in different countries, but a rule of thumb is to use 1 to 2 mls of chlorine bleach per liter (1 to 2 ounces of chlorine bleach per 8 gallons of clean water). Walls, floors and packing equipment can also be cleaned using quaternary ammonium compounds labelled as safe for food processing equipment (Kupferman, 1990).

Waxing

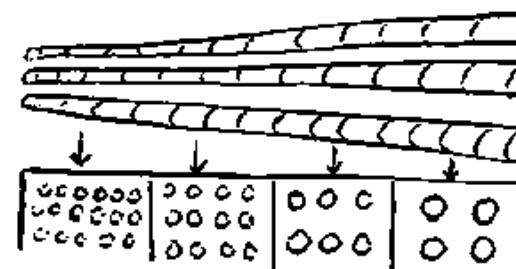
Waxing of immature fruit vegetables such as cucumbers and summer squash; mature fruit vegetables such as eggplant, peppers and tomatoes; and fruits such as apples and peaches is common. Food grade waxes are used to replace some of the natural waxes removed in washing and cleaning operations, and can help reduce water loss during handling and marketing. If produce is waxed, the wax coating must be allowed to dry thoroughly before further handling.

Sizing

Sizing produce is optional but may be worthwhile if certain size grades receive a higher price than others. In most low-input packinghouses, manual sizing is still commonly practiced. Operators should be trained in selecting the size desired and to either directly pack the items into containers or place the selected produce gently into a bin for packing further down the line. Sizing can be done subjectively (visually) with the use of standard size guages. Examples of the smallest and largest acceptable sizes for each product can be placed within view of the operator for easy reference. Hand held sizers are used for a variety of products.

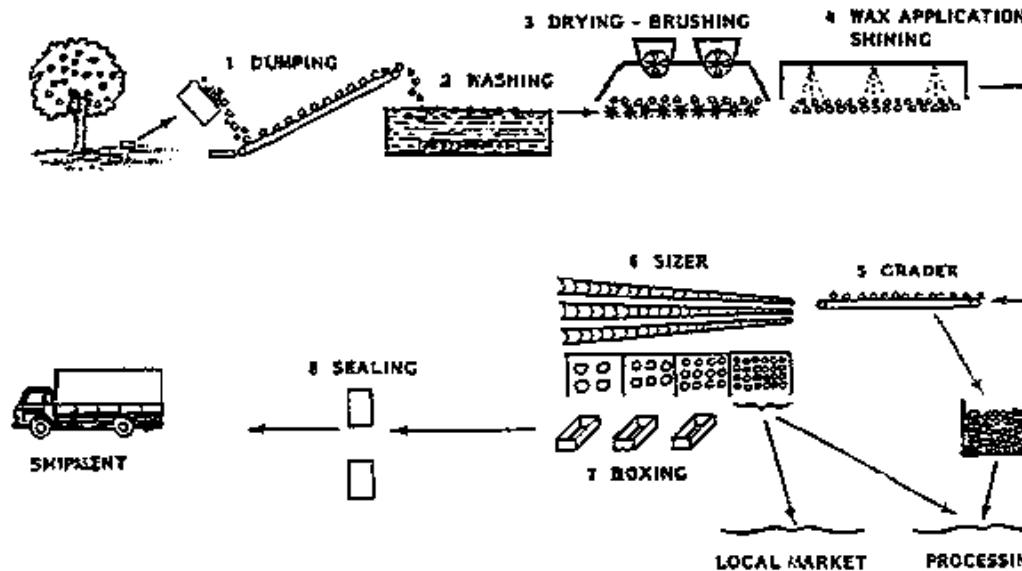
Several types of mechanical sizers are available for small scale operations. One type is composed of a long slanted tray with a series of openings which converge (largest at the top, smallest at the bottom). This type of sizer works best with round commodities. Other sizers are designed as conveyors fitted with chain or plastic belts with various sized openings, and are useful for sizing most commodities. Another simple method for mechanical sizing is to use a set of diverging bar rollers (see illustration below), where the smallest sized produce falls through the rollers first to a sorting belt or bin, and larger sized produce falls between successively more divergent rollers.

Diverging bar rollers sizer:



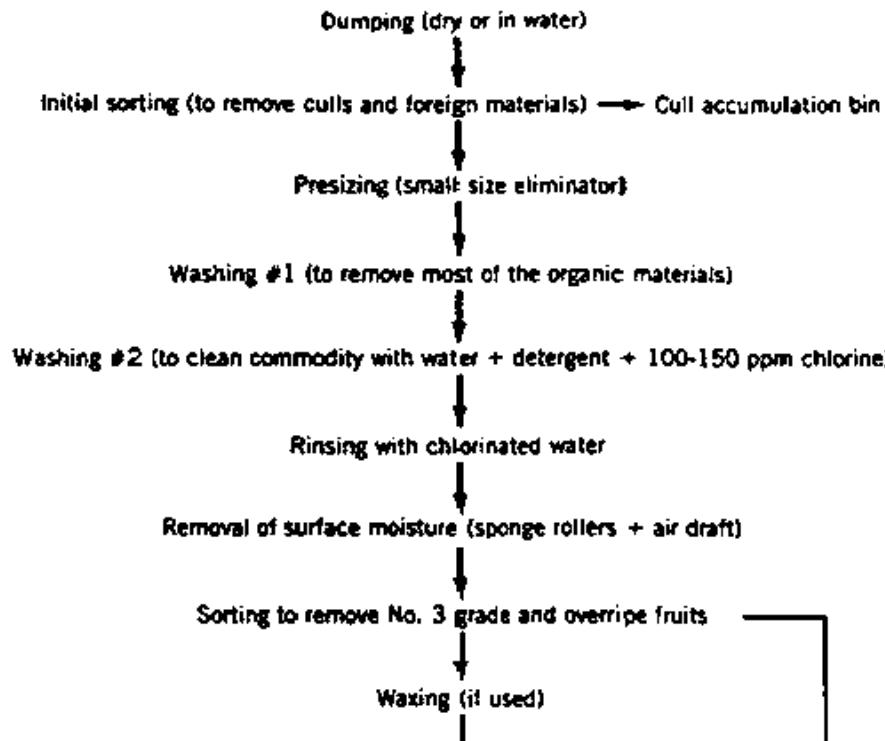
General operations

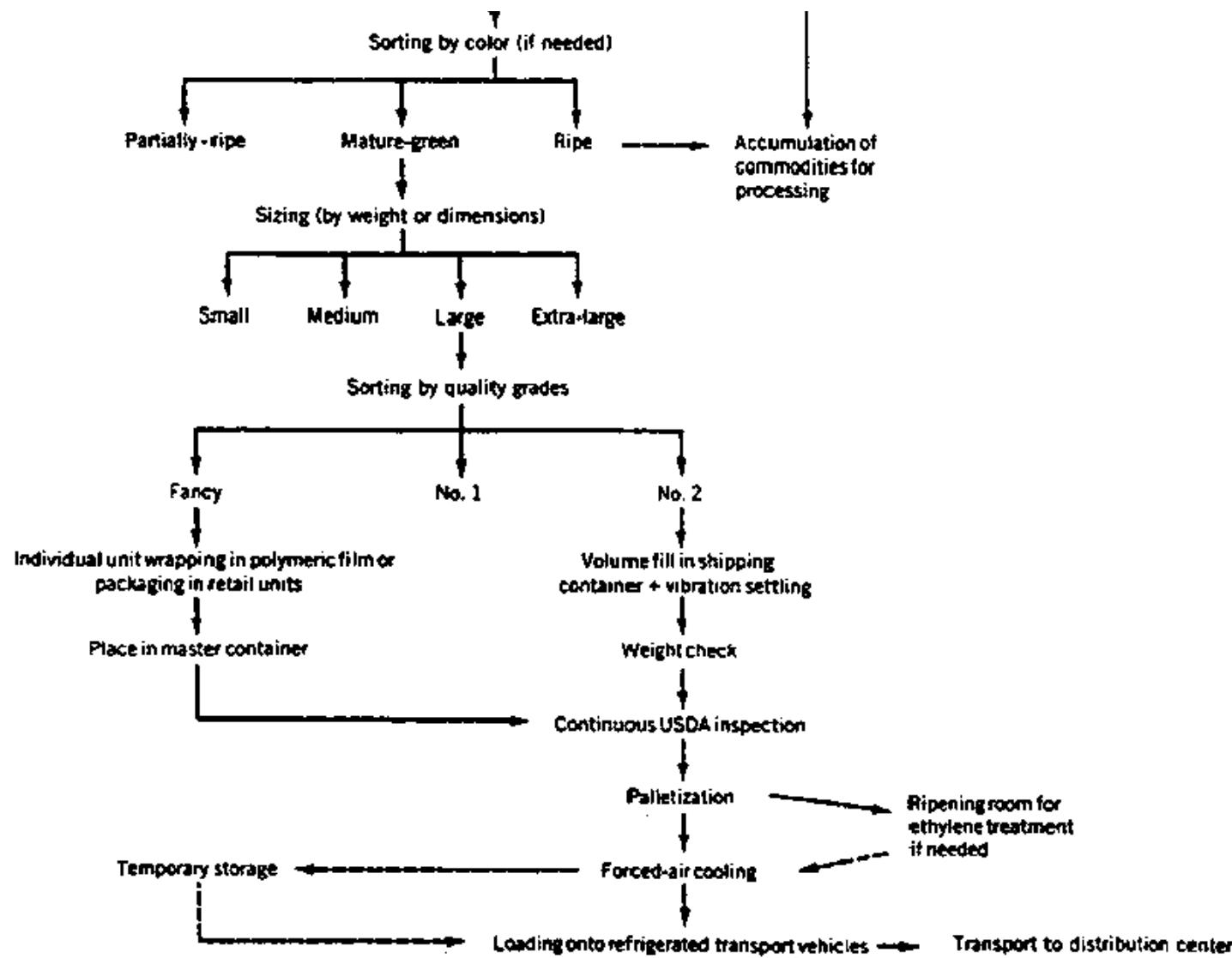
The typical series of operations in a packinghouse are illustrated below. Dumping can be done using either dry or water-assisted methods, depending upon the sort of produce being handled. Cleaning, as well, can be by washing with chlorinated water or dry brushing alone. Waxing, if practiced, occurs after washing and removal of surface moisture. Grading, as illustrated, separates the product into processing and fresh market categories. Sizing further separates the product, with the smallest size going to the local market or to processing. Typically, the best quality produce is packaged and marketed at the regional or national level.



FAO. 1986. *Improvement of Post-Harvest Fresh Fruits and Vegetables Handling - A Manual*. Bangkok: UNFAO Regional Office for Asia and the Pacific.

The following is a flow diagram of packinghouse operations. The number and size of packing lines will depend on the kinds and quantities of produce that are handled each day.



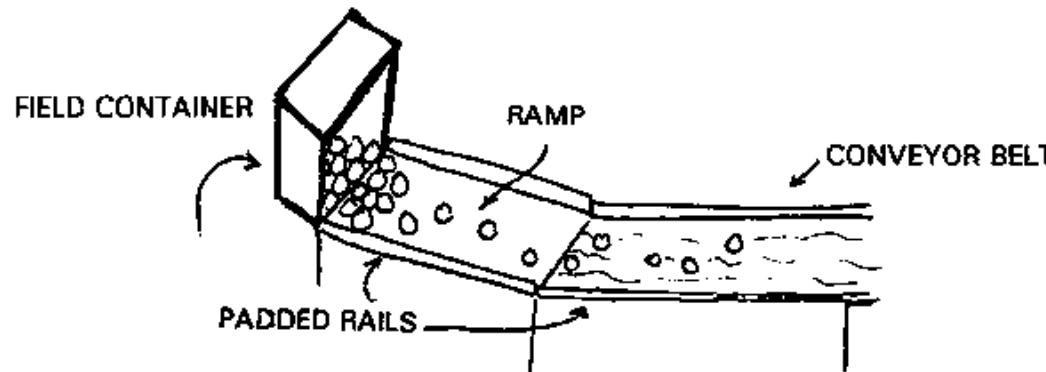


Source: Kader, A.A. 1993. Postharvest Handling. In: Preece, J.E. and P.E. Read, *The Biology of Horticulture - An Introductory Textbook*. New York: John Wiley & Sons, Inc. pp. 353-377

Dumping

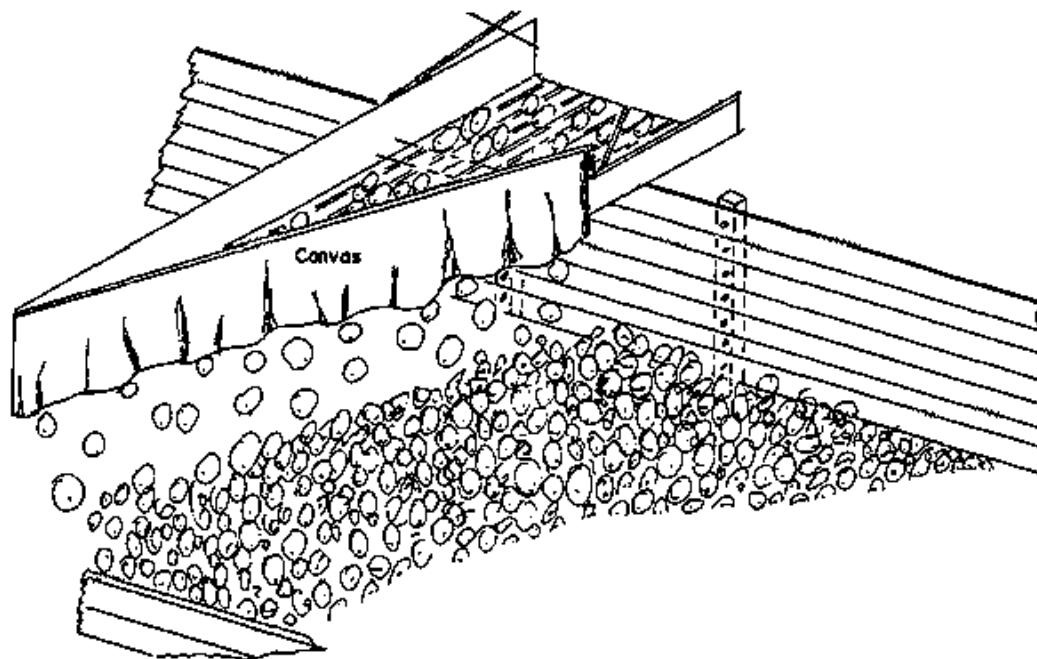
Any time produce is dumped from one container into another, care should be taken to reduce mechanical damage to the commodity. When dumping produce from field bins or from transport vehicles into the packinghouse, dry or wet dumping can be practiced. When using dry dumping practices, the filled container should be emptied slowly and gently onto a tilted ramp with padded edges. In the illustration below, a conveyor belt then carries the dry dumped produce into the packinghouse.

Dry dumping



Wet dumping is sometimes used to reduce mechanical damage, either by dumping into water rather than onto a dry ramp, or by immersion and floatation. If the specific density of the produce, such as apples, is lower than that of water the produce will float. For some produce, such as pears, salts (such as sodium lignin sulfonate, sodium silicate or sodium sulfate) must be added to the water to increase its specific density and assure fruit floatation.

The canvas curtain illustrated below is used to break the fall of fruit moving from a conveyor into a bulk bin.



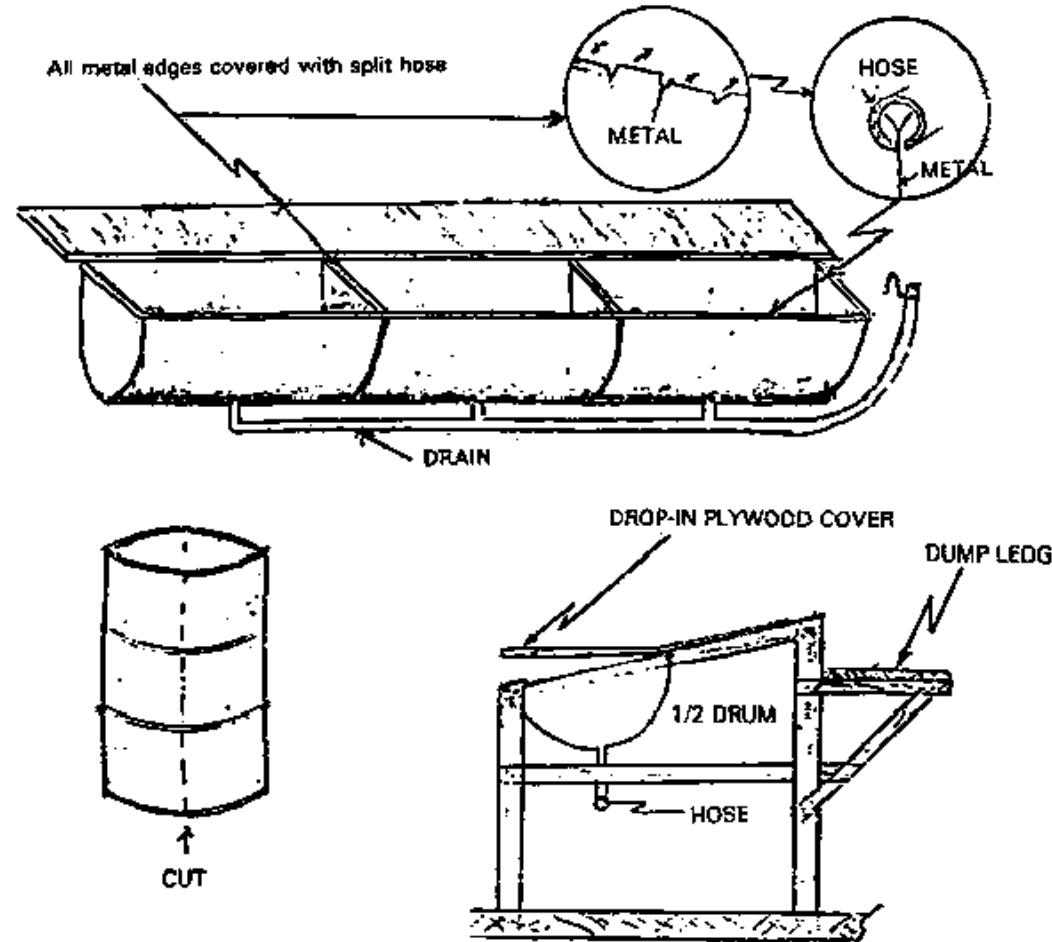
Source: USDA. No date. Modernising Handling Systems for Florida Citrus from Picking to Packing Line Agricultural Research Service, USDA Marketing Report No. 914.

Washing

Steel drums can be used to make a simple washing stand. The drums are cut in half fitted with drain holes and all the metal edges are covered with split rubber or plastic

hose. The drums are then set into a sloped wooden table. The table top is constructed from wooden slats and is used as a drying rack before packing.

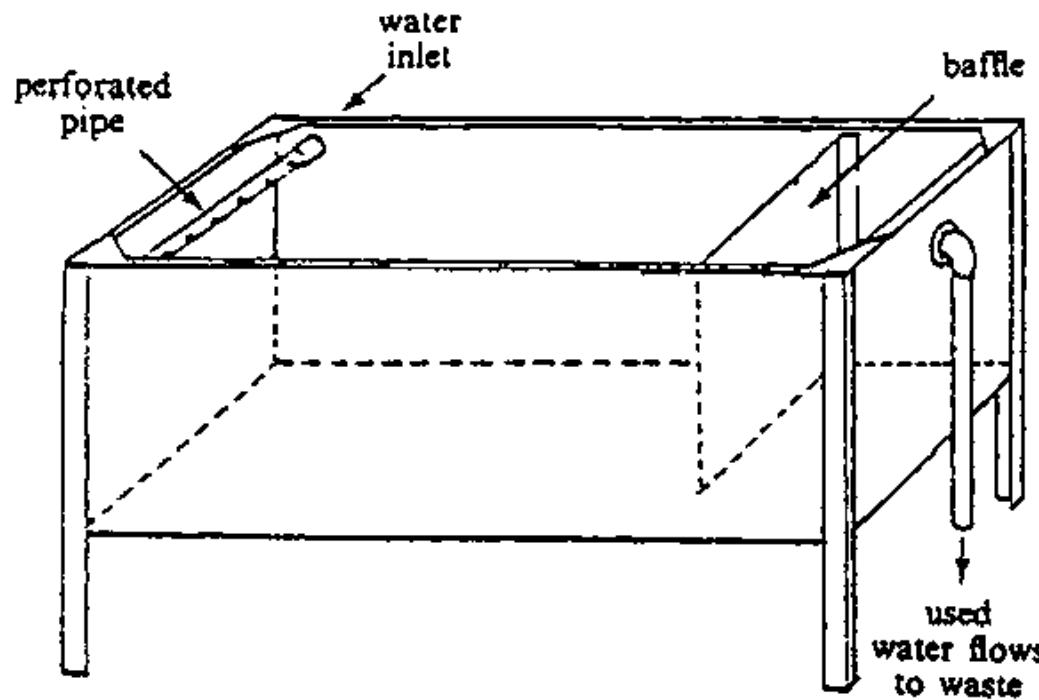
Because steel drums are often used to store petroleum and chemical products, they should be thoroughly cleaned before being used as a washing stand.



Source: Grierson, W. 1987. Postharvest Handling Manual. Commercialization of Alternative Crops Project. Belize Agribusiness Company/USAID/Chemonics International Consulting Division.

This tank for washing produce is made from galvanized sheet metal. A baffle made of perforated sheet metal is positioned near the drain pipe and helps to circulate water through the produce. Fresh water is added under pressure through a perforated pipe, which helps move floating produce toward the drain end of the tank for removal after cleaning.

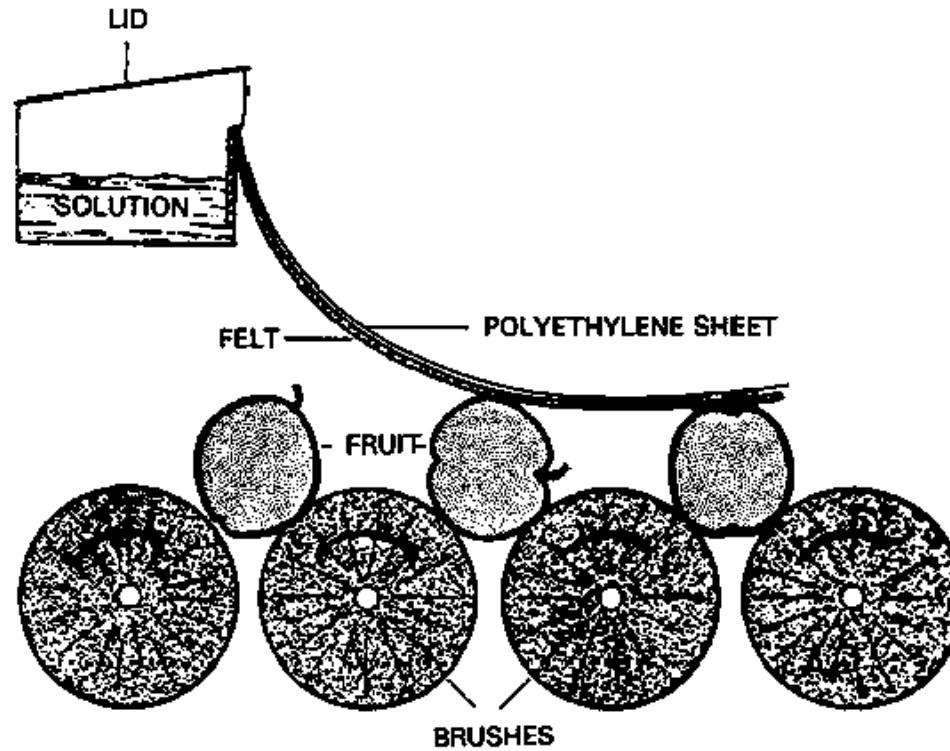
Improvements to the design shown below might include a removable trash screen in front of the baffle, and/or a recirculating system for the wash water (with the addition of chlorine).



FAO. 1989. Prevention of Postharvest Food Losses: Fruits Vegetables and Root Crops. A Training Manual. Rome: UNFAO. 157 pp.

Waxing

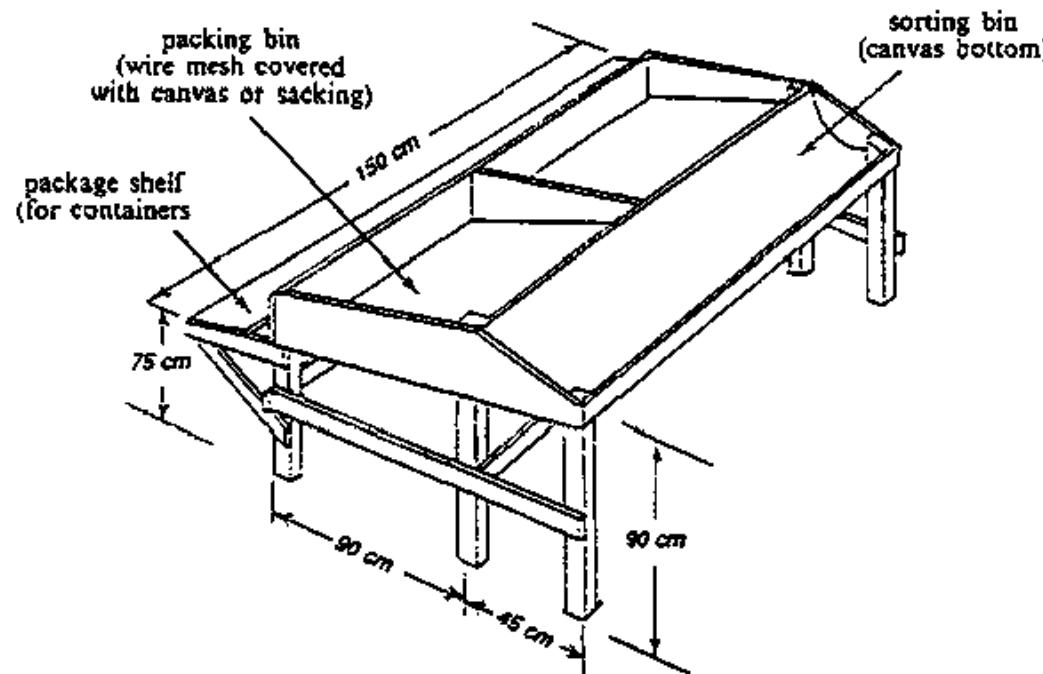
The waxing device illustrated here is designed to be used after a series of dry brushes on a conveyor line. Industrial wool felt is used to distribute the liquid wax to the fruits or vegetables from a trough made the same width as the belt. Evaporation of wax from the felt is reduced by covering the felt with a layer of heavy polyethylene sheeting.



Source: Martin, D and Miezitis, E.O. 1964. A wipe-on device for the application of materials to butts. Field Station Record Volume 3 No. 1 CSIRO Tasmanian Regional Laboratory, Hobart, Tasmania.

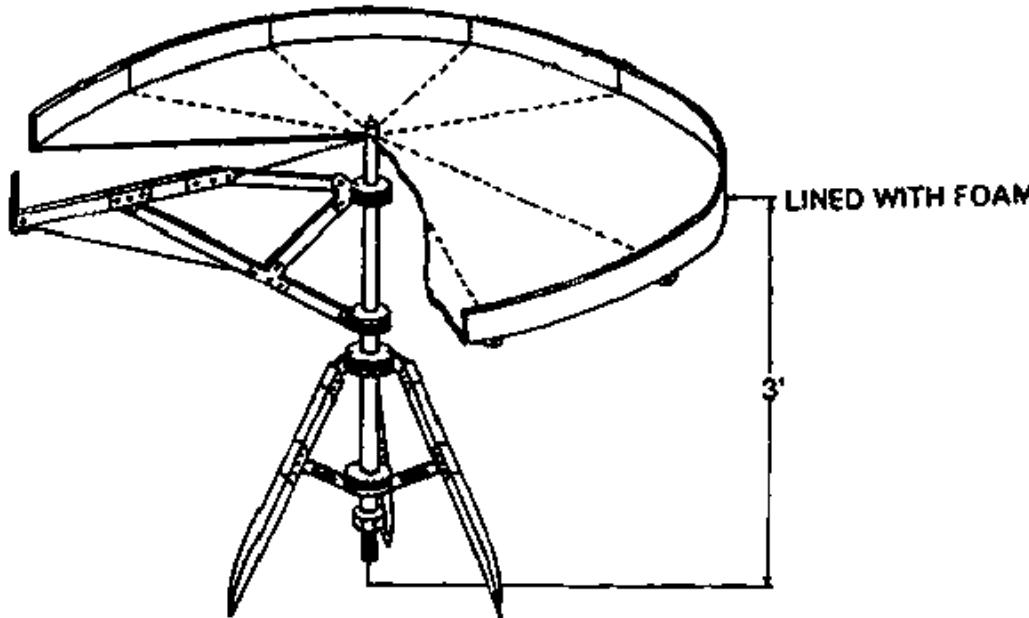
Sorting/Packing

The table illustrated below is a combination sorting and packing stand. Incoming produce is placed in the sorting bin, sorted by one worker into the packing bin, and finally packed by a second worker. If workers must stand to sort produce, a firm rubber pad for the floor can help reduce fatigue.



Source: FAO. 1986. *Improvement of Post-Harvest Fresh Fruits and Vegetables Handling- A Manual*. Bangkok: UNFAO Regional Office for Asia and the Pacific.

The surface of the portable sorting table illustrated below is constructed from canvas and has a radius of about 1 meter (about 3 feet). The edges are lined with a thin layer of foam to protect produce from bruising during sorting, and the slope from the center toward the sorter is set at 10 degrees. Produce can be dumped onto the table from a harvesting container, then sorted by size, color and/or grade, and packed directly into shipping containers. Up to 4 sorters/packers can work comfortably side by side.



Source: PHTRC. 1984. A portable sorting table. Appropriate Postharvest Technology 1(1):1-3. (Post-Harvest Training and Research Center, Department of Horticulture, University of the Philippines at Los Banos.)

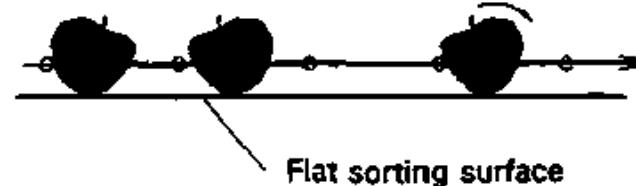
Sorting

The following illustrations represent three types of conveyors used to aid sorting of produce. The simplest is a belt conveyor, where the sorter must handle the produce manually in order to see all sides and inspect for damage. A push-bar conveyor causes the produce to rotate forward as it is pushed past the sorters. A roller conveyor rotates the product backwards as it moves past the sorter.

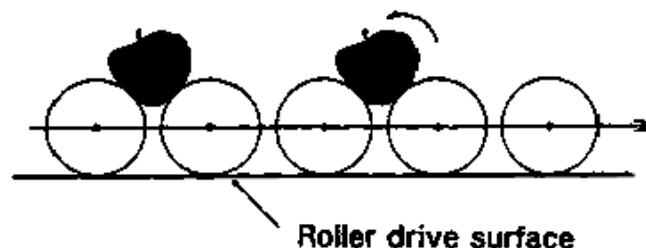
Belt conveyor:



Push-bar conveyor



Roller conveyor:

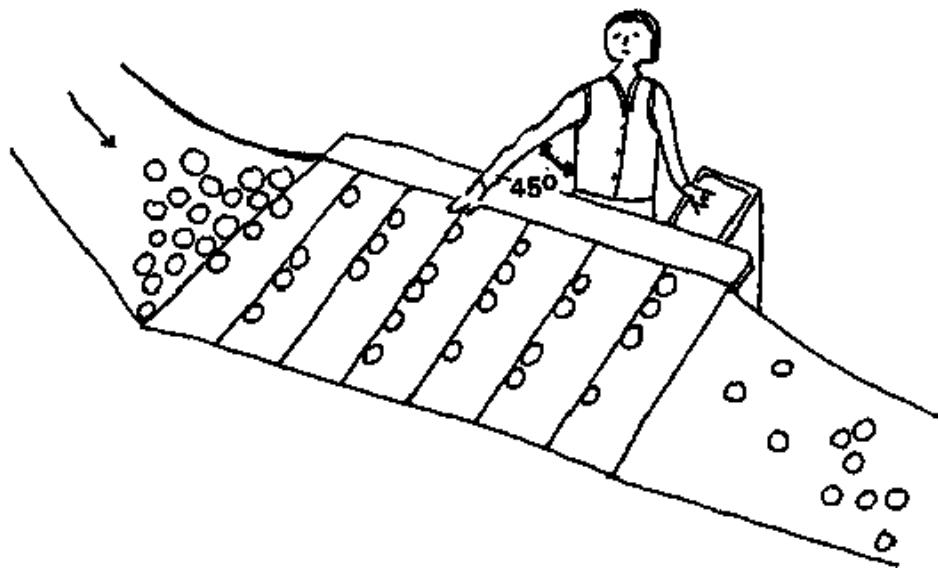


Source: Shewfelt, R.L. and Prussia, S.E. 1993. Postharvest Handling: A Systems Approach. San Diego: Academic Press Inc. 356 pp.

When sorting for rejects, and removing any product that is too small, decayed or damaged, the height of the sorting table should be set at a level comfortable for sorters. Stools, or a firm rubber pad on which to stand, can be provided to reduce fatigue. Locations of the table and the sorting bins should be chosen to minimize hand movements.

It is recommended that the workers' arms create a 45 degree angle when s/he reaches toward the table, and that the width of the table be less than 0.5 meter to reduce stretching. Good lighting will enhance the ability of the sorter to spot defects, and dark, dull belts or table tops can reduce eye strain.

If a conveyor system is in use, the product must not flow too fast for the sorters to do their work. The rotational speed of push-bar or roller conveyors should be adjusted to rotate the product twice within the immediate field of view of the worker.

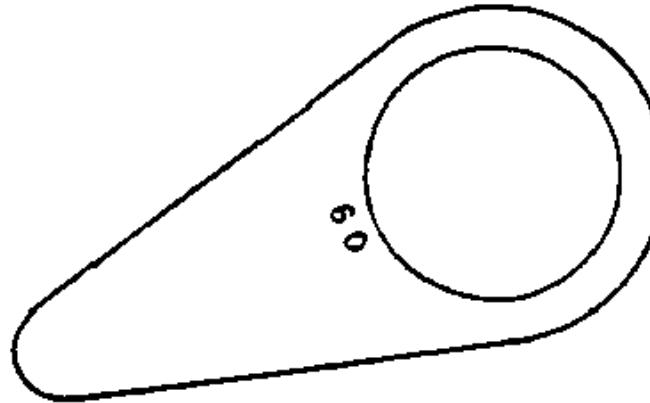


Source: Shewfelt R.L. and Prussia, S.E. 1993. *Postharvest Handling: A Systems Approach*. San Diego: Academic Press Inc. 356 pp.

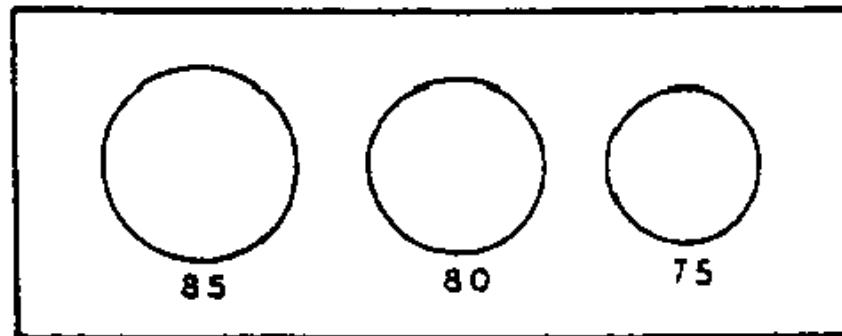
Sizing

Round produce units can be graded by using sizing rings. Rings can be fashioned from wood or purchased ready-made in a wide variety of sizes.

Single size hand held sizing ring:

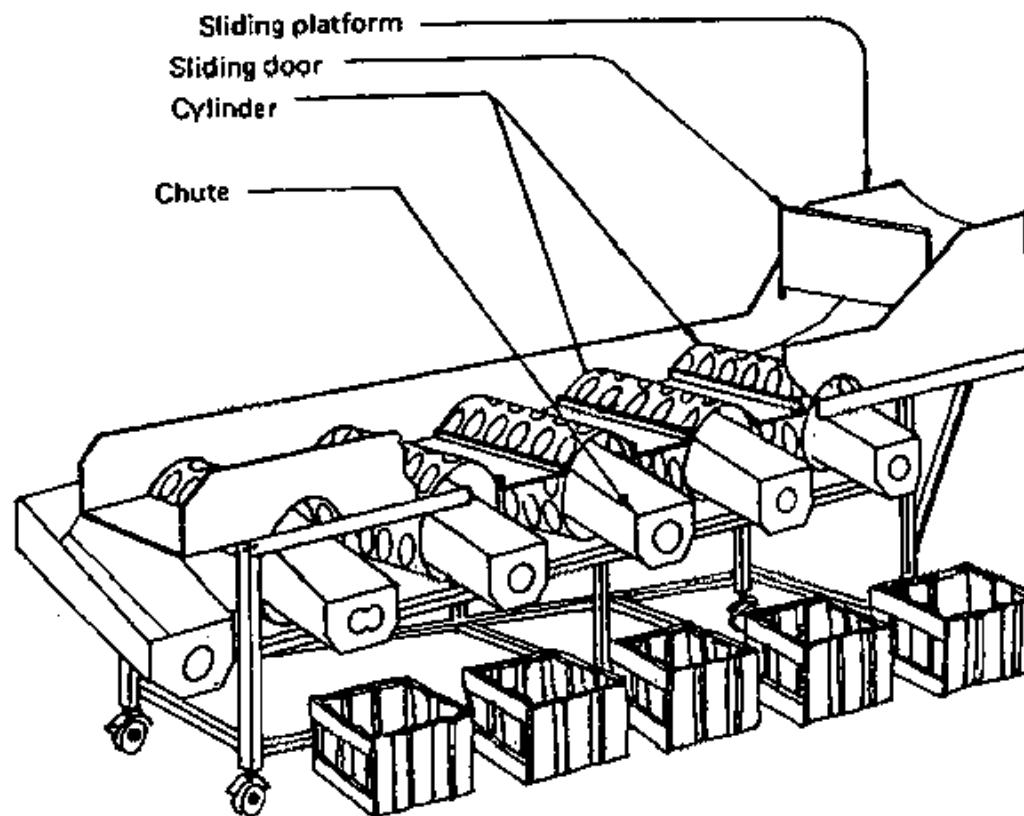


Multiple size rings:



Source: FAO. 1989. *Prevention of Postharvest Food Losses: Fruits, Vegetables and Root Crops. A Training Manual*. Rome: UNFAO. 157 pp.

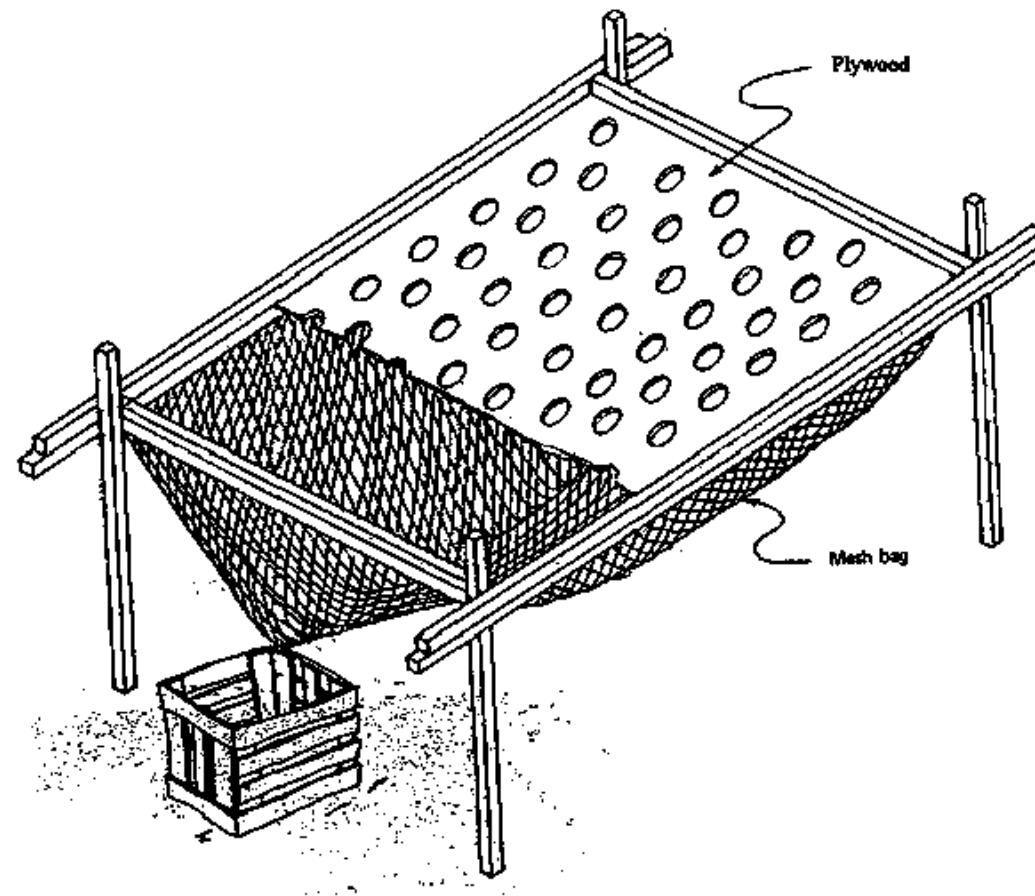
The rotary cylinder sizer illustrated below is composed of five hollow cylinders which rotate in a counterclockwise motion when driven by an electric motor. Each cylinder is perforated, with holes large enough to let fruits drop through. The first cylinder has the smallest diameter holes, and the fifth has the largest holes. When fruits fall through, they are caught on a slanted tray (the chute), and roll into the containers as shown. Take care that the distance of the drop is as short as possible to prevent bruising. Oversized fruits are accumulated at the end of the line. This equipment works best with round commodities.



Source: Reyes, M. U. (Ed.) 1988 Design Concept and Operation of ASEAN Packinghouse Equipment for Fruits and Vegetables. Postharvest Horticulture

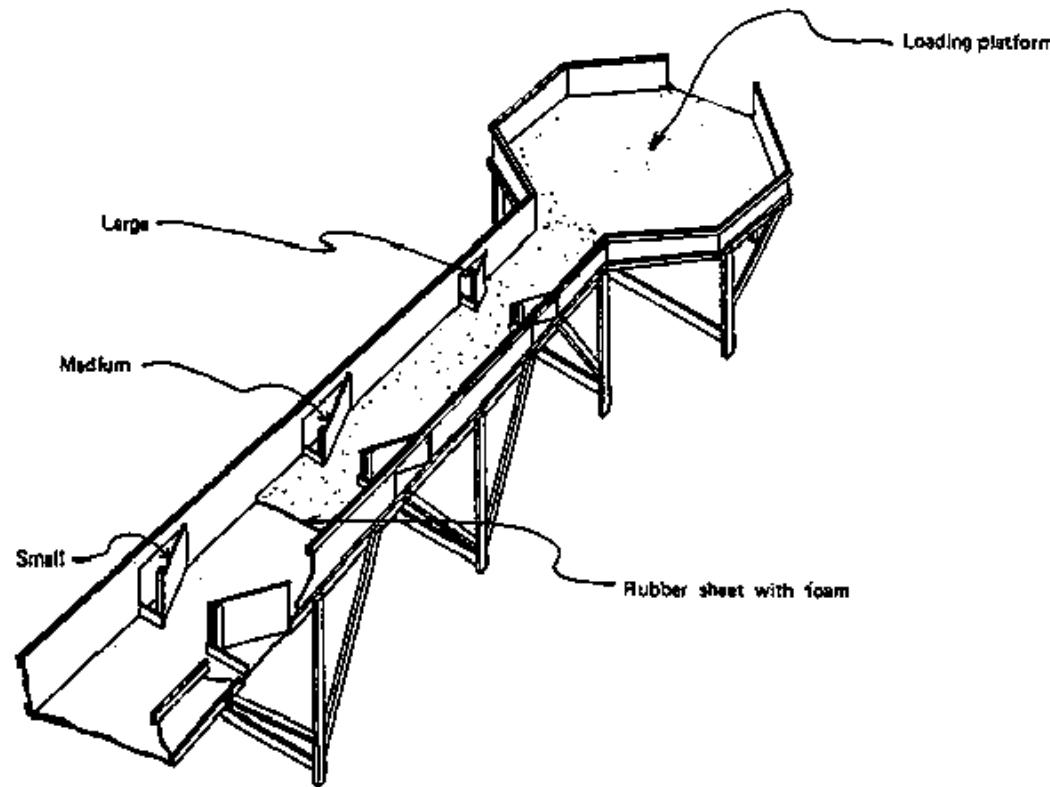
Training and Research Center, University of Los Baños, College of Agriculture, Laguna, Philippines.

The onion sizing table illustrated below is one of three (or more) tables used in a stairway fashion. Each table is made of plywood, and has been perforated with holes of a specific size. The uppermost table has the largest size holes, and the lowest table has the smallest holes. A layer of onions is dumped onto the uppermost table. Those that do not pass through are classified as "extra-large" in size. Those that pass through fall into a mesh bag and roll into a large container. This container of onions is dumped onto the second sizing table. The onions that do not pass through are classified as "large", and so on.



Source: Reyes, M. U. (Ed.) 1988. Design Concept and Operation of ASEAN Packinghouse Equipment for Fruits and Vegetables. Postharvest Horticulture Training and Research Center, University of Los Baños, College of Agriculture, Laguna, Philippines.

The pommelo sizer illustrated below is composed of a rectangular chute made of plywood, padded with foam to prevent bruising. The fruit is dumped into the octagonal platform at the top of the chute, then allowed to roll, one by one, down toward a series of constrictions. Large fruits are caught in the first constriction, medium in the second, and small in the last. Undersized fruit passes out the end of the chute directly into a container. Workers must manually remove each fruit and place it into the appropriate size container before the next fruit can pass through the chute. The sizing is fastest when five workers are stationed at the sizer.

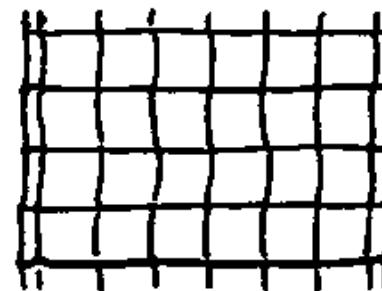


Source: Reyes, M. U. (Ed.) 1988. Design Concept and Operation of ASEAN Packinghouse Equipment for Fruits and Vegetables. Postharvest Horticulture Training and Research Center, University of Los Baños, College of Agriculture, Laguna, Philippines.

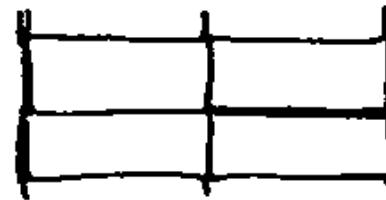
If a conveyor system is used in the packinghouse, a wide variety of sizing chains and belts are available for sorting produce. Sizing chains can be purchased in many widths and in any size opening.

Square openings are usually used for commodities such as apples, tomatoes and onions, while rectangular openings are used for peaches and peppers. Hexagonal openings are often used for potatoes and onions.

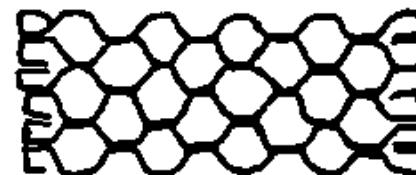
Square:



Rectangular:



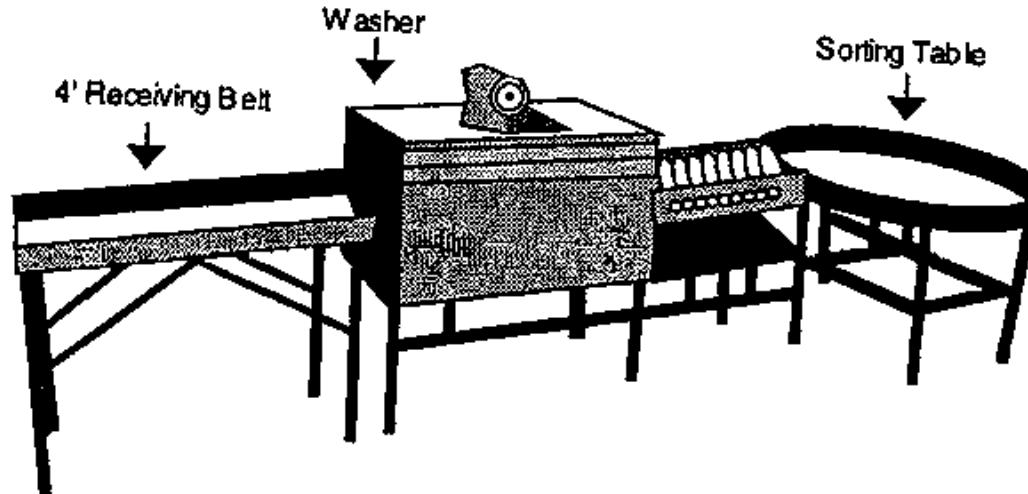
Hexagonal:



Source: 1994 Catalog of TEW Manufacturing Corporation, P.O. Box 87, Penfield, New York 14526 USA

Fruit packing line

Small scale equipment for packing produce is available from several manufacturers and suppliers. Illustrated below is a fruit packing line, available from TEW Manufacturing Corporation at a cost of less than US\$ 5000. This particular model includes a receiving belt, washer and sorting table.



Source: 1994 Catalog of TEW Manufacturing Corporation, P.O. Box 87, Penfield, NY 14526 USA





Section 4: Packing and packaging materials

[Packing practices](#)

[Packing containers](#)

[Packaging practices](#)

[Labeling](#)

[Modularization of containers](#)

[Modified atmosphere packaging \(MAP\)](#)

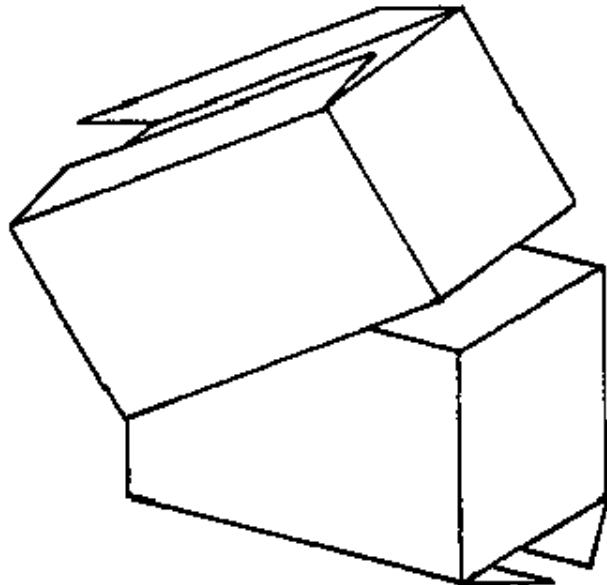
[Unit loads](#)

If produce is packed for ease of handling, heavily waxed cartons, wooden crates or rigid plastic containers are preferable to bags or open baskets, since bags and baskets provide no protection to the produce when stacked. Sometimes locally constructed containers can be strengthened or lined to provide added protection to produce. Waxed cartons, wooden crates and plastic containers, while more expensive, are reusable and can stand up to the high relative humidity found in the storage environment. Containers should not be filled either too loosely or too tightly for best results. Loose products may vibrate against others and cause bruising, while overpacking results in compression bruising. Shredded newspaper is an inexpensive and lightweight filler for shipping containers (Harvey et al, 1990).

For small-scale handlers interested in constructing their own cartons from corrugated fibreboard, Broustead and New (1986) provide detailed information. Many types of agricultural fibres are suitable for paper making (Hunsigi, 1989), and handlers may find it economically sensible to include these operations in their postharvest system.

Throughout the entire handling system, packaging can be both an aid and a hindrance to obtaining maximum storage life and quality. Packages need to be vented yet be sturdy enough to prevent collapse. Collapsed packages provide tattle or no protection, requiring the commodity inside to support all of the weight of the overhead load. Packing is meant to protect the commodity by immobilizing and cushioning it, but temperature management can be made more difficult if packing materials block ventilation holes. Packing materials can act as vapor barriers and can help maintain higher relative humidities within the package. In addition to protection, packaging allows quick handling throughout distribution and marketing and can minimize impacts of rough handling.

Produce can be hand-packed to create an attractive pack, often using a fixed count of uniformly sized units. Packaging materials such as trays, cups, wraps, liners and pads may be added to help immobilize the produce. Simple mechanical packing systems often use the volume-fill method or tight-fill method, in which sorted produce is delivered into boxes, then vibration settled. Most volume-filers are designed to use weight as an estimate of volume, and final adjustments are done by hand (Mitchell in Kader, 1992).



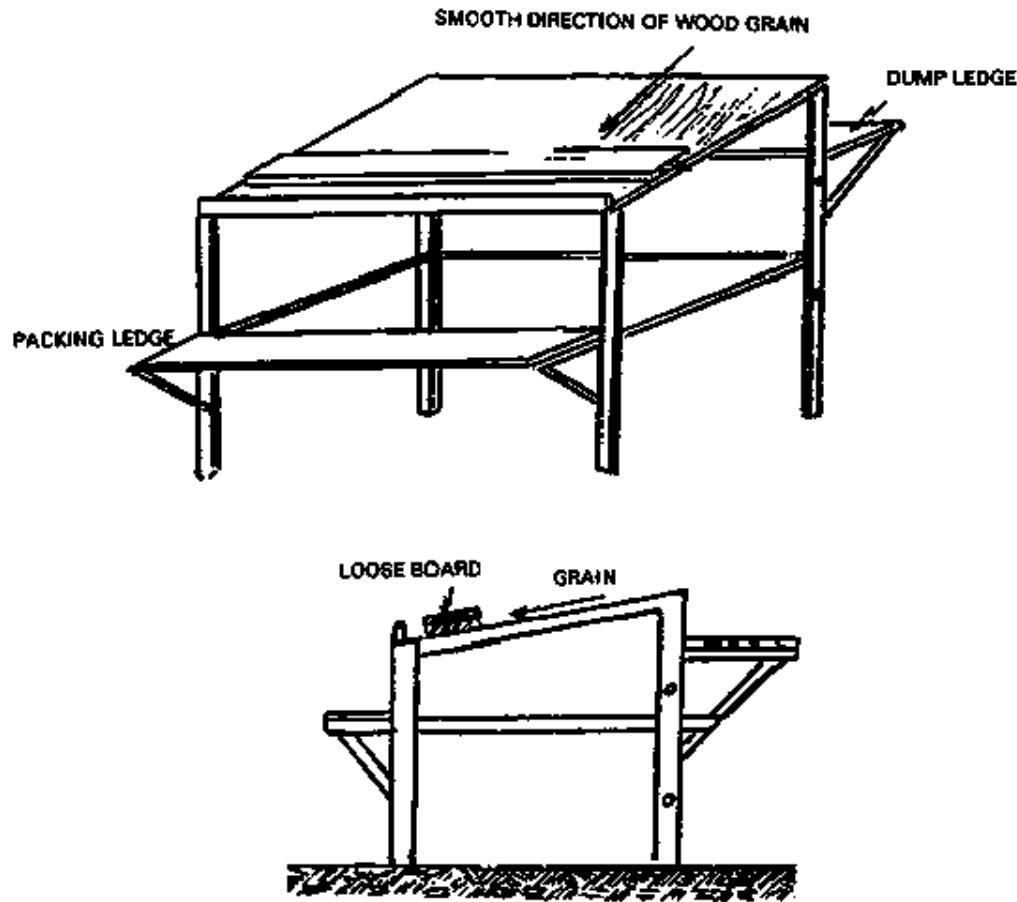
Packaging in plastic films can modify the atmosphere surrounding the produce (modified atmosphere packaging or MAP). MAP generally restricts air movement, allowing the product's normal respiration processes to reduce oxygen content and increase carbon dioxide content of the air inside the package. An additional major benefit to the use of plastic films is the reduction of water loss.

MAP can be used within a shipping container and within consumer units. Atmospheric modification can be actively generated by creating a slight vacuum in a vapor sealed package (such as an unvented polyethylene bag), and then replacing the package atmosphere with the desired gas mixture. In general, lowering oxygen and increasing carbon dioxide concentrations will be beneficial for most commodities (see the table of recommended gas mixtures for various crops, Section 7). Selection of the best polymeric film for each commodity/package size combination depends upon film permeability and the respiration rate of the commodity under the expected time/temperature conditions during handling. Absorbers of oxygen, carbon dioxide and/or ethylene can be used within packages or containers to help maintain the desired atmospheric composition.

Modified atmosphere packaging should always be considered as a supplement to proper temperature and relative humidity management. The differences between beneficial and harmful concentrations of oxygen and carbon dioxide for each kind of produce are relatively small, so great care must be taken when using these technologies.

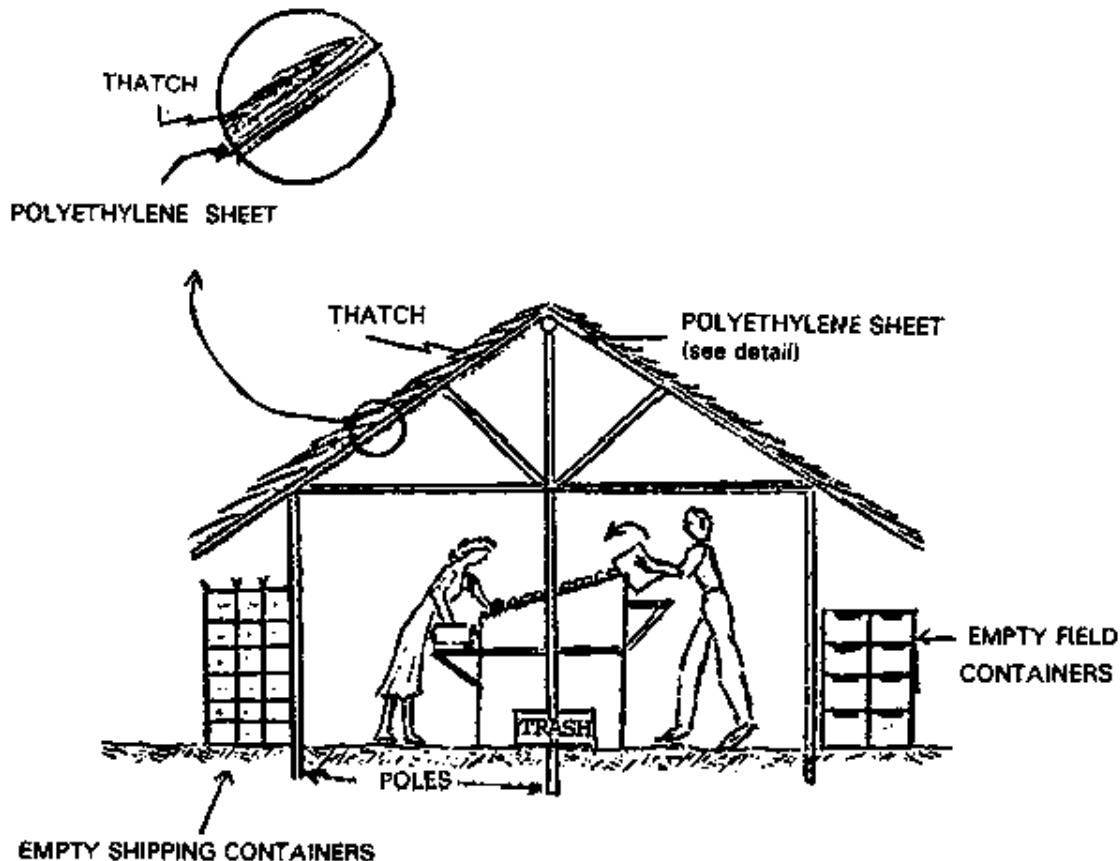
Packing practices

The packing stand illustrated in the diagram below can be bolted to a second stand of the same construction if more space is required for packing produce. When trimming is necessary, add a loose board, thick enough to reach above the height of the front rail. The front rail should be smooth and rounded.



Source: Grierson, W. 1987. Postharvest Handling Manual: Commercialization of Alternative Crops Project
Belize Agribusiness Co./Chemonics International Consulting Division/USAID

A simple field packing station can be constructed from wooden poles and a sheet of polyethylene. Thatch over the roof will provide shade and keep the station cool. The structure should be oriented so that the roof overhang keeps out the majority of the sun's rays.



Source: Grierson, W. 1987 Postharvest Handling Manual: Commercialization of Alternative Crops Project.
Belize Agribusiness Co./ Chemonics International Consulting Division/USAID

Hands of bananas, after undergoing washing to remove latex and perhaps spraying with fungicides, are typically packed into cardboard containers lined with polyethylene. The following illustrations depict one method of filling a container with the fruit in order to ensure less damage during transport. Note that the polyethylene liner is folded up over the bananas before closing the box.

(a) Wide, flat medium-to-small hand in middle of compartment



(b) Medium-length, wide hand on top, crown not touching fruit below



(c) Medium-to-short length, wide hand, crown not touching fruit below



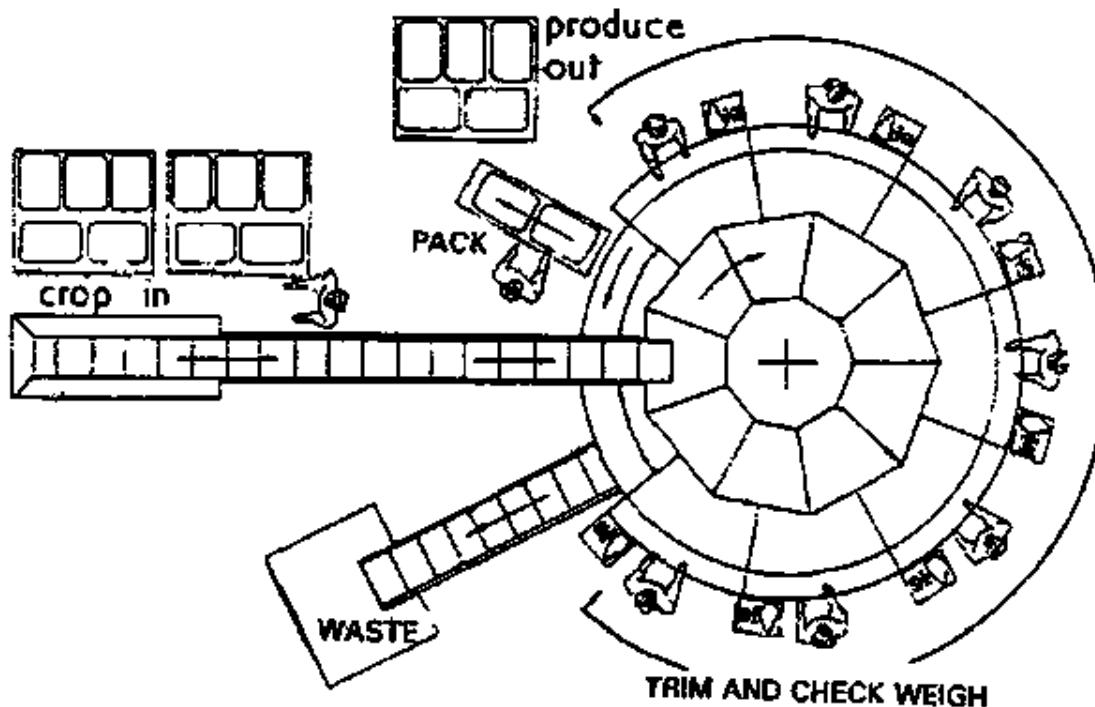
(d) One large hand, or two clusters with long fingers



Source: FAO. 1989. Prevention of Postharvest Food Losses: Fruits. Vegetables and Root Crops. A Training Manual. Rome: UNFAO. 157 PP.

A circular rotating table can be used to pack a variety of crops. The produce is fed in along a conveyor or if no conveyor is in use, simply put onto the table, where packers select the produce and fill cartons at their stations. In the illustration below, a discard belt has been added below the supply belt, allowing easy disposal of culls.

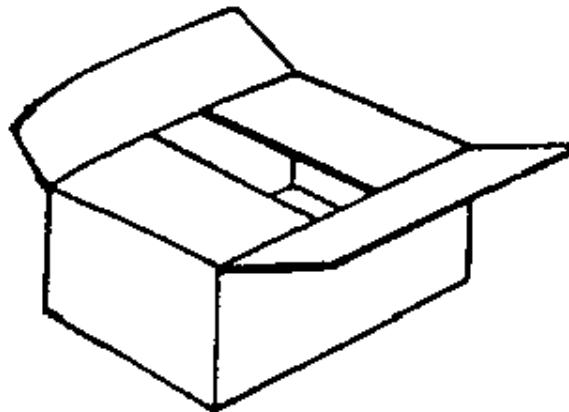
Each packer can work independently, trimming as needed and check weighing cartons on occasion.



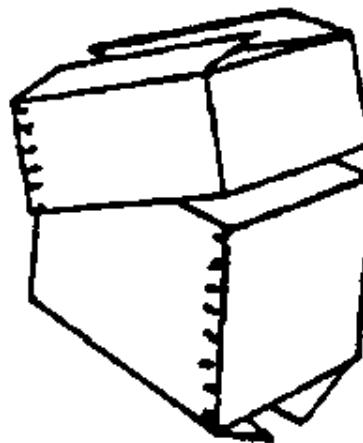
Source: National Institute of Agricultural Engineering. 1979. Preparing vegetables for supermarkets. Field Vegetable Department, Silsoe, Bedford: NIAE

Packing containers

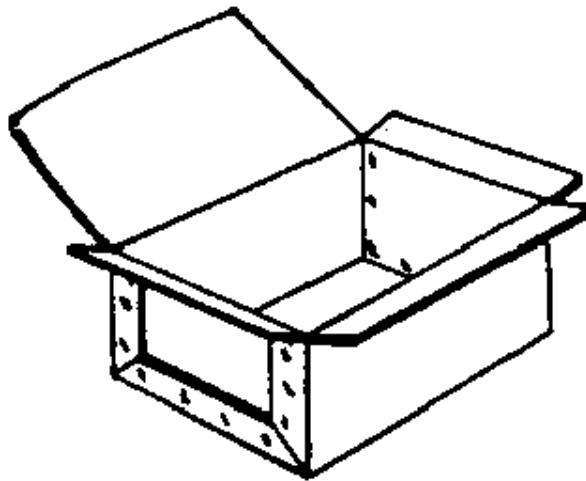
There are many types of packing containers. The three containers illustrated below are constructed from corrugated cardboard. The regular slotted container is fully collapsible and the most economical.



Telescopic containers (half or full) have the highest stacking strength and protect against bulging but are more costly.



The container known as a Bliss box has very strong corners, but is not collapsible.



Source: Peleg, K. 1985. Produce Handling Packaging and Distribution. Westport, Connecticut: AVI Publishing Co., Inc.

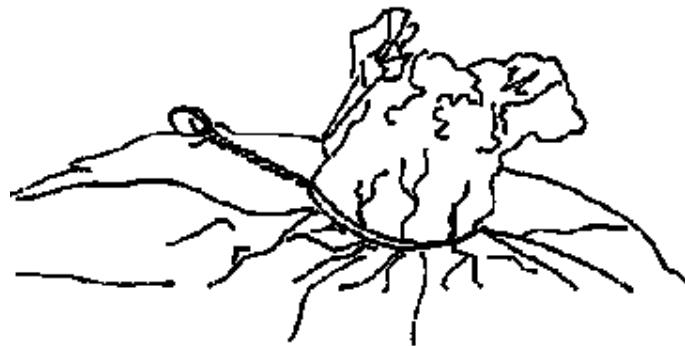
Sacks are often used to package produce, since they tend to be inexpensive and readily available. The following table provides some information regarding the characteristics of different kinds of materials used to make sacks.

Characteristics of sacks as packaging units

Sack types	Tearing and snagging	Impact	Protection against		Contamination	Notes
			Moisture absorption	Insect invasion		
Jute	Good	Good	None	None	Poor, also cause contamination by sack fibres	Bio-deterioration. Insect harbourage. Odour retention.
Cotton	Fair	Fair	None	None	Fair	High re-use value.
Woven plastics	Fair-Good	Good	None	Some protection (if closely woven)	Fair	Badly affected by ultra-violet light. Difficult to stitch.
Paper	Poor	Fair-Poor	Good - WFP multiwall sacks have plastic liners.	Some protection, better if treated.	Good	Consistent quality. Good print.

Source: Walker, D.J. (Ed) 1992. World Food Programme Food Storage Manual. Chatham, UK: Natural Resources Institute

Paper or cloth sacks can be easily closed using a length of strong wire and twisting tool.



Source: FAO. 1985. Prevention of Post-Harvest Food Losses: A Training Manual. Rome: UNFAO. 120 pp.

The table below provides examples of some types of typical mechanical damage and their effect on packaging containers.

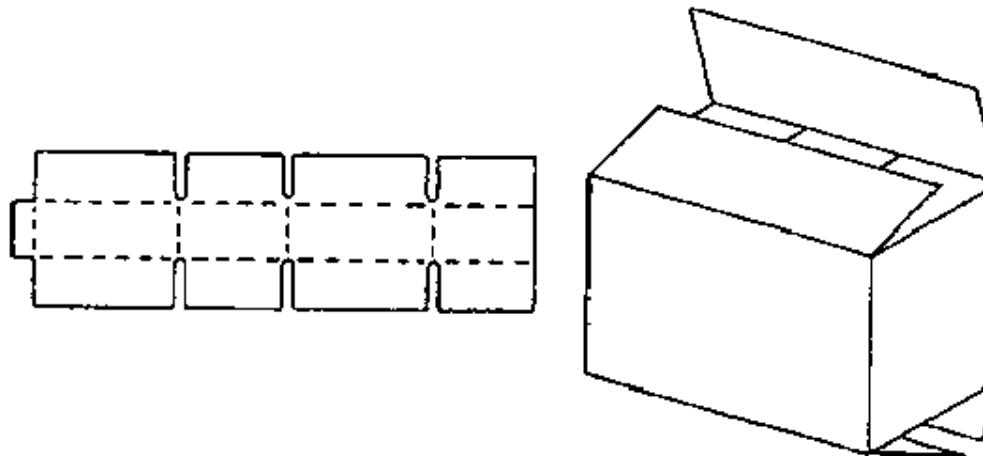
Type of damage	Container	Result	Important factors
Impact damage through dropping	Sacks - woven and paper	Splitting of seams and material causing leaking and spillage loss.	Seam strength
	Fibreboard boxes	Splitting of seams, opening of flaps causing loss of containment function. Distortion of shape reducing stacking ability.	Bursting strength Closure method
	Wooden cases	Fracture of joints, loss of containment function.	Fastenings Wood toughness
	Cans and drums	Denting, rim damage. Splitting of seams and closures causing loss of containment and spoilage of contents.	
	Plastic bottles	Splitting or shattering causes loss of contents.	Material grade Wall thickness

Compression damage through high stacking	Fibreboard boxes	Distortion of shape, seam splitting causing loss of containment and splitting of inner cartons, bags, and foil wrappings.	Box compression strength
	Plastic bottles	Distortion, collapse and sometimes splitting, causing loss of contents.	Design, material, wall thickness
Vibration	Woven sacks	Sifting out of contents.	Closeness of weave
	Corrugated fibreboard cases	Become compressed and lose their cushioning qualities. Contents more prone to impact damage.	Box compression strength
Snagging, tearing, hook damage	Sacks - woven and paper	Loss of containment function - spillage (more severe with paper sacks).	Tear strength
	Tins	Punctured, loss of contents.	Metal thickness

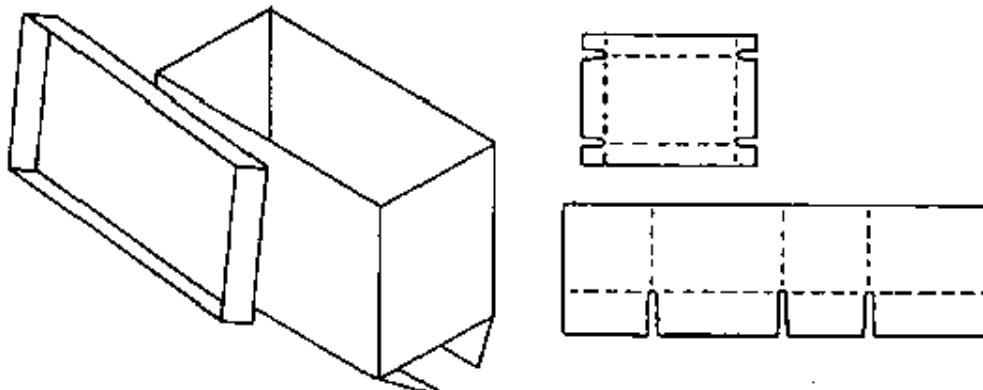
Source: Walker, D.J. (Ed.) 1992. *World Food Programme Food Storage Manual*. Chatham, UK: Natural Resources Institute

The diagrams below are for a variety of commonly used fibreboard containers. Final dimensions can be altered to suit the needs of the handler.

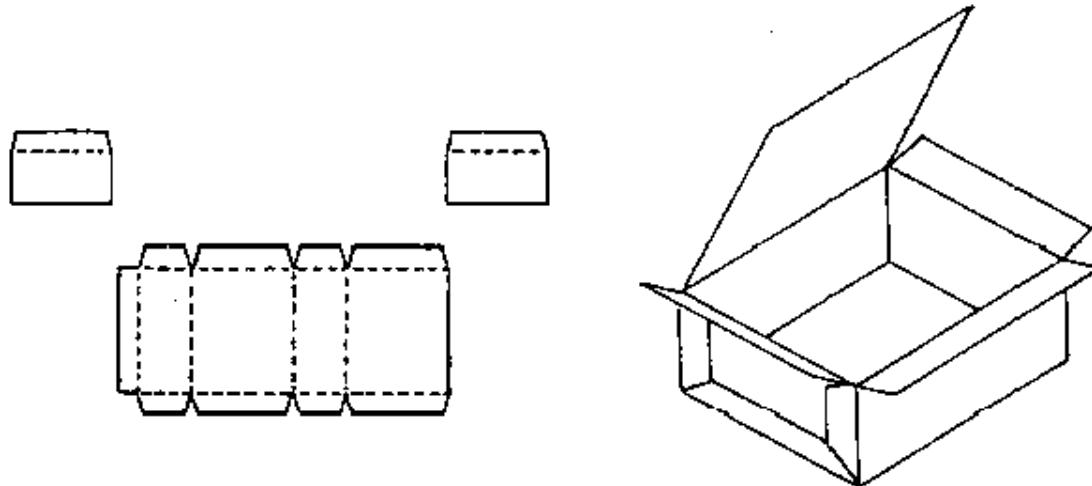
One piece box:



Two-piece box with cover:



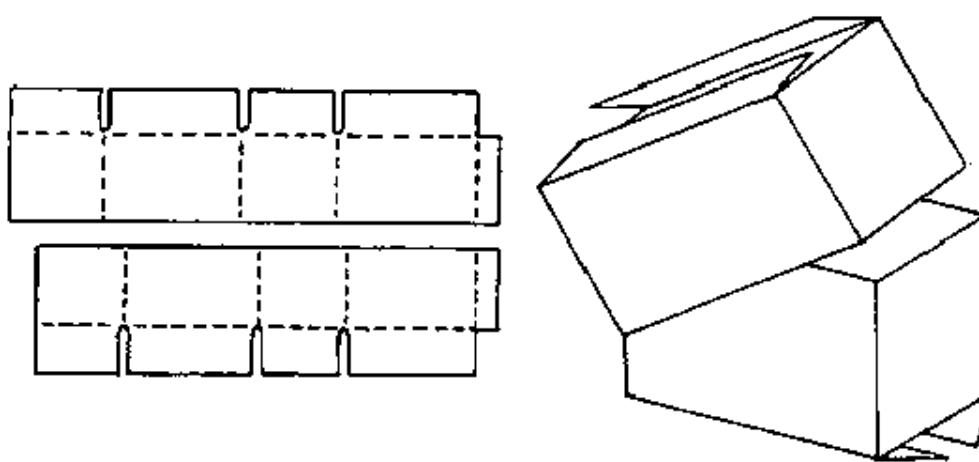
Bliss-style box:



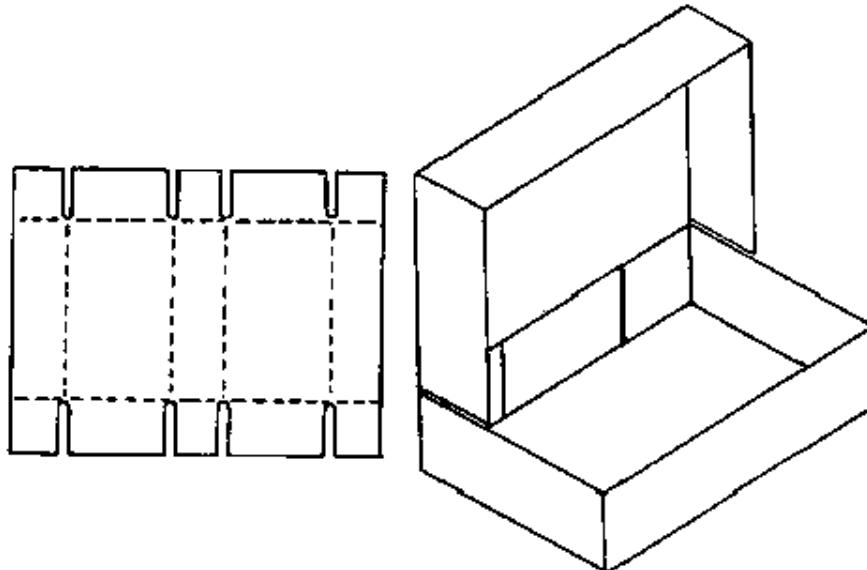
Source: McGregor, B. 1987. Tropical Products Transport Handbook. USDA, Office of Transportation, Agricultural Handbook Number 668.

The diagrams below are for a variety of commonly used fibreboard containers. Final dimensions can be altered to suit the needs of the handler.

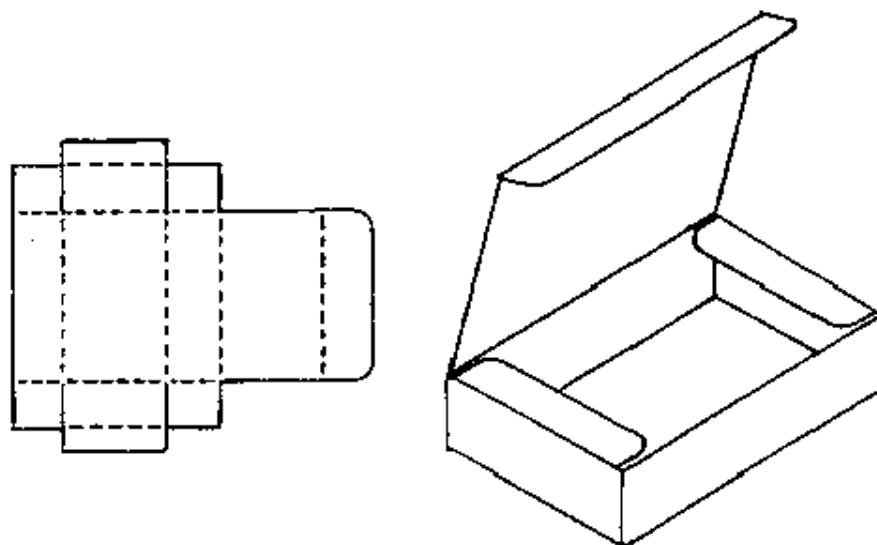
Full telescoping box:



One-piece telescoping box:



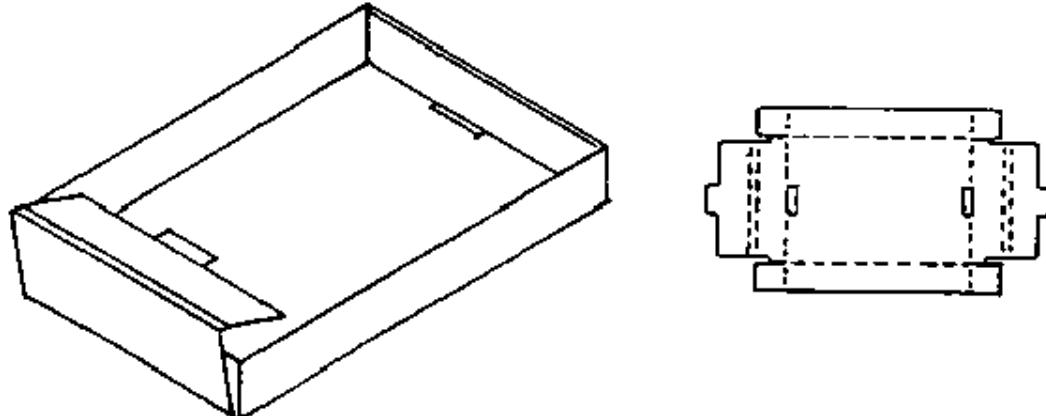
One-piece tuck-in cover box:



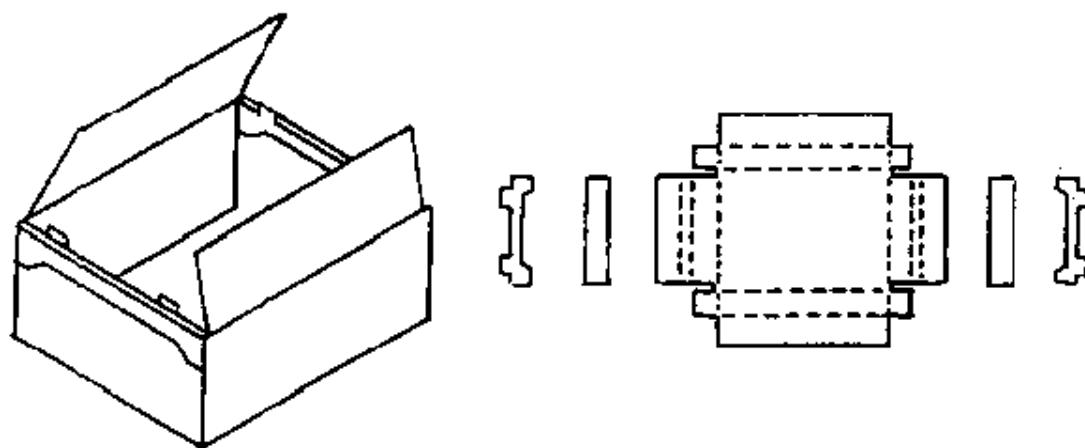
Source: McGregor, B. 1987: Tropical Products Transport Handbook. USDA, Office of Transportation, Agricultural Handbook Number 668.

The diagrams below are for a variety of commonly used fibreboard containers. Final dimensions can be altered to suit the needs of the handler.

Self-locking tray:



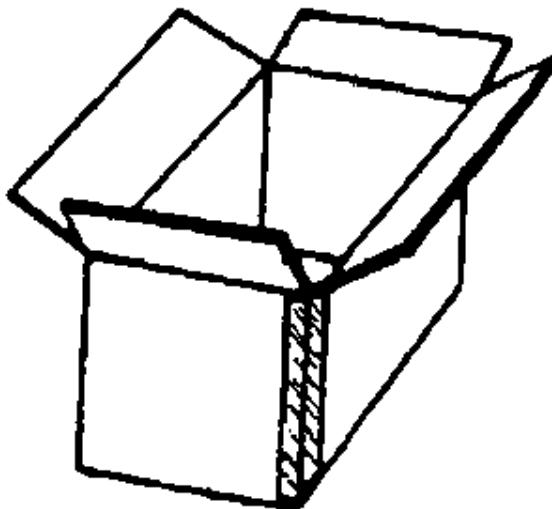
Interlocking box:



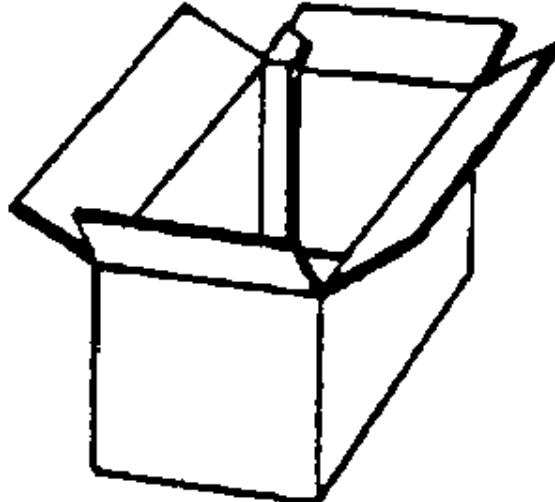
Source: McGregor, B. 1987. Tropical Products Transport Handbook. USDA, Office of Transportation, Agricultural Handbook Number 668.

Shipping containers can be designed and made by the user from fibreboard in any size and shape desired. Three types of joints are commonly used to construct sturdy boxes.

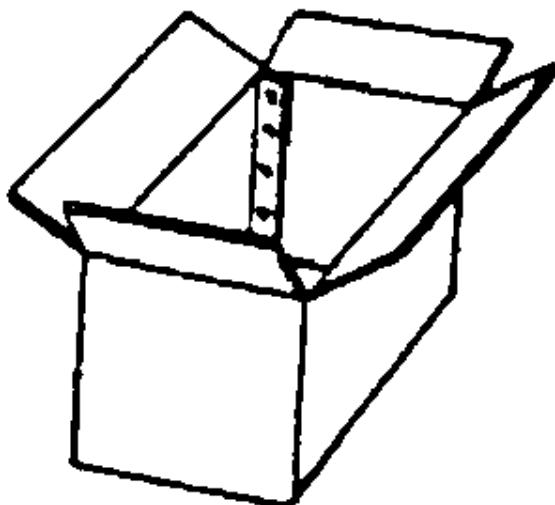
Taped joints:



Glued Joints:



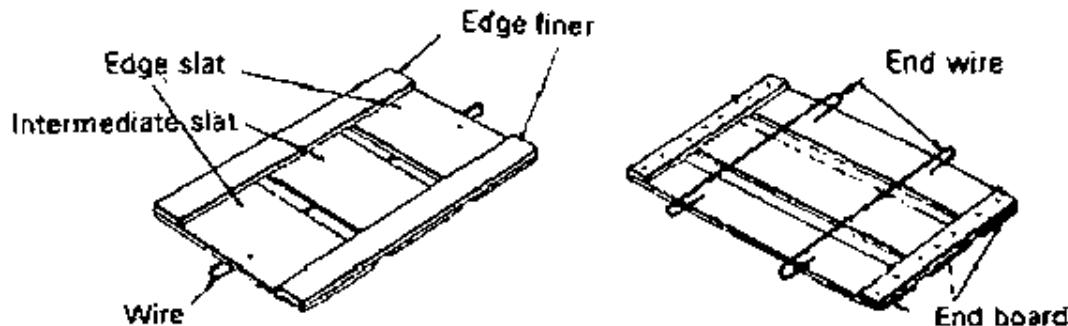
Stapled joints:



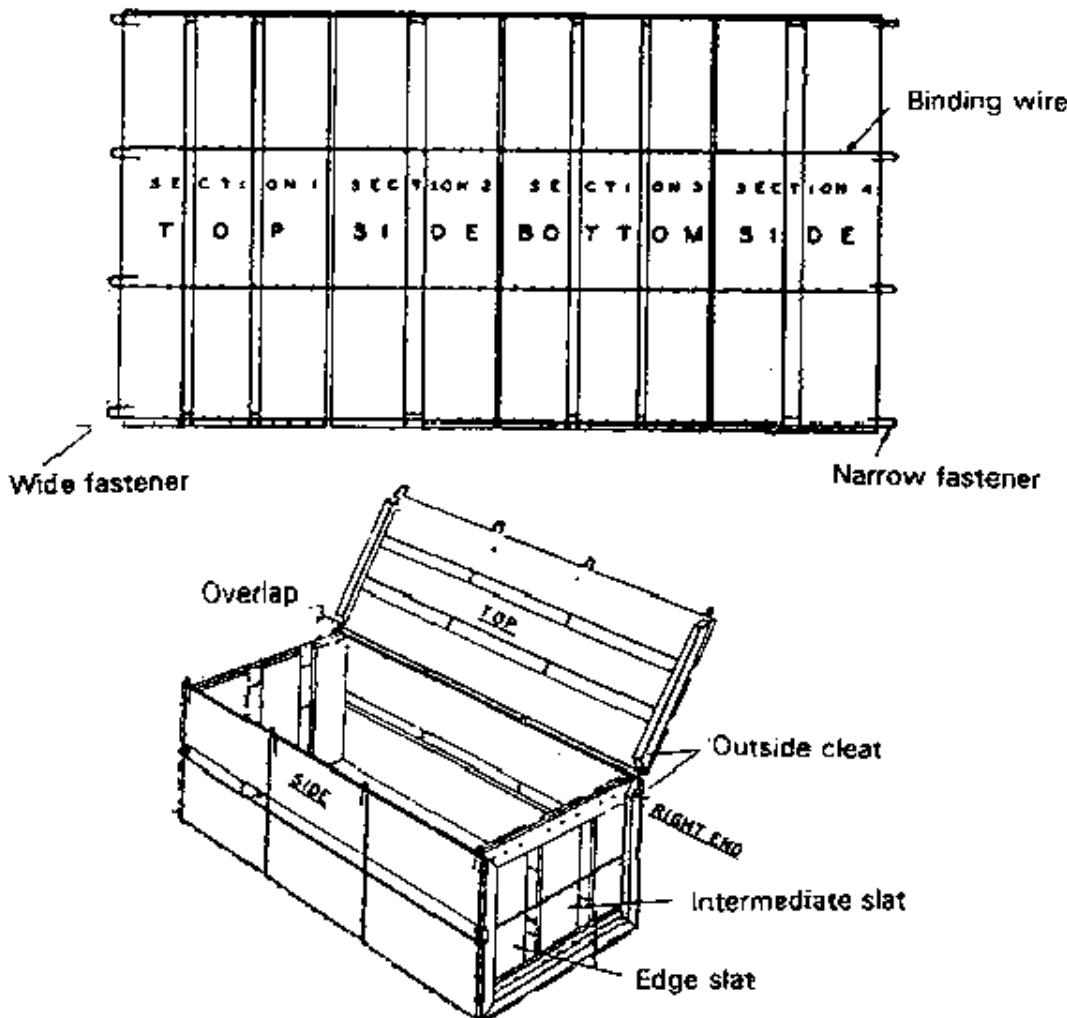
Source: Peleg, K. 1985. Produce Handling Packaging and Distribution. Westport, Connecticut: AVI Publishing Co., Inc.

Containers can be constructed from wood and wire, using the general diagrams provided below. A special closing tool makes bending the wire loops on the crate's lid easier for packers to do. Wirebound crates are used for many commodities including melons, beans, eggplant, greens, peppers, squash and citrus fruits. Package Research Laboratory (41 Pine Street, Rockaway, New Jersey 07866) can provide a list of suppliers in your area.

Ends:



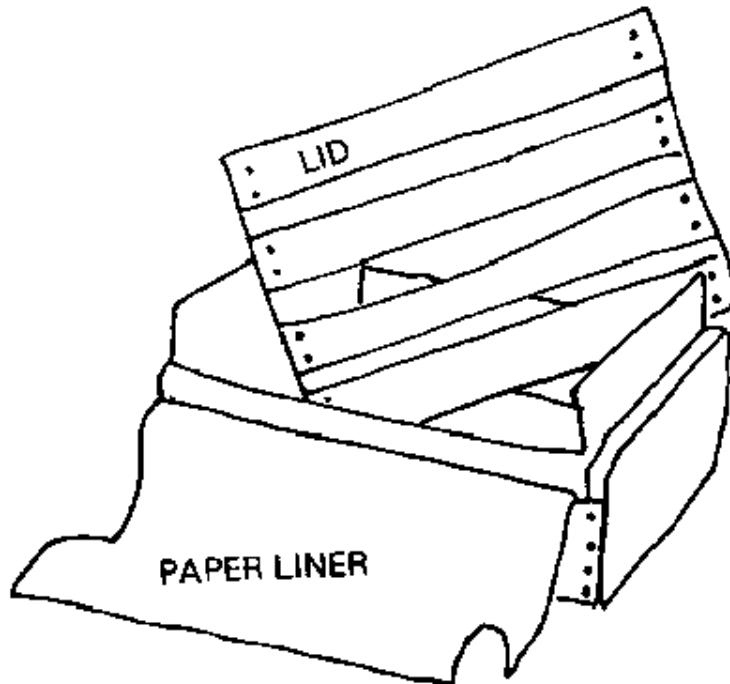
Blank for body:



Source: Peleg, K. 1985. Produce Handling Packaging and Distribution. Westport, Conn.: AVI publishing Co., Inc.

A wooden lug is the typical packing container for table grapes. This container is very sturdy and maintains its stacking strength over long periods of time at high relative humidity. Rigid plastic containers are also widely used.

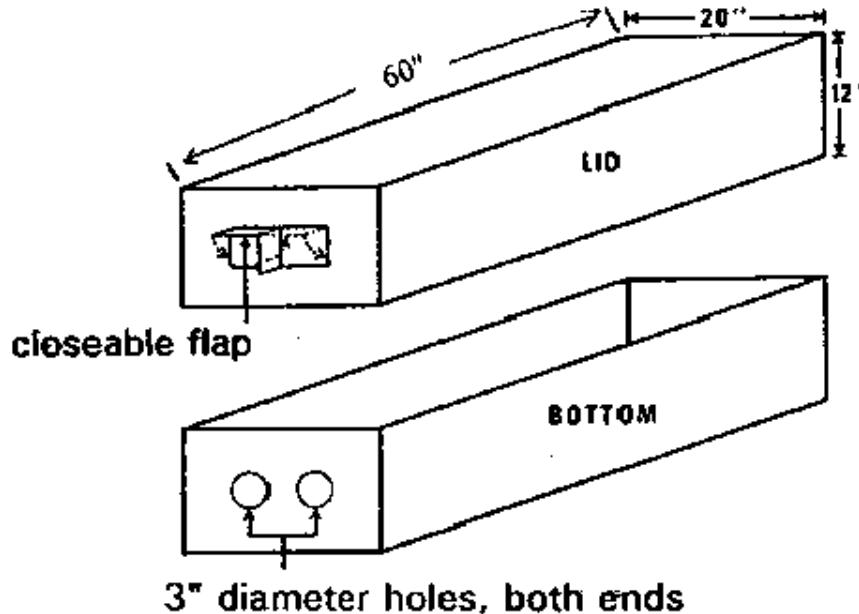
Often, a paper liner is folded over the grapes before the top is nailed closed. The liner protects the produce from dust and water condensation. If a pad containing sulfur dioxide can be enclosed with the grapes within a plastic liner as a treatment to control decay. Most commodities other than table grapes can be damaged (bleached) by sulfur dioxide treatments.



Rigid plastic or wooden containers are also used extensively for asparagus. The trimmed spears are packed upright in containers that provide for a large amount of ventilation.

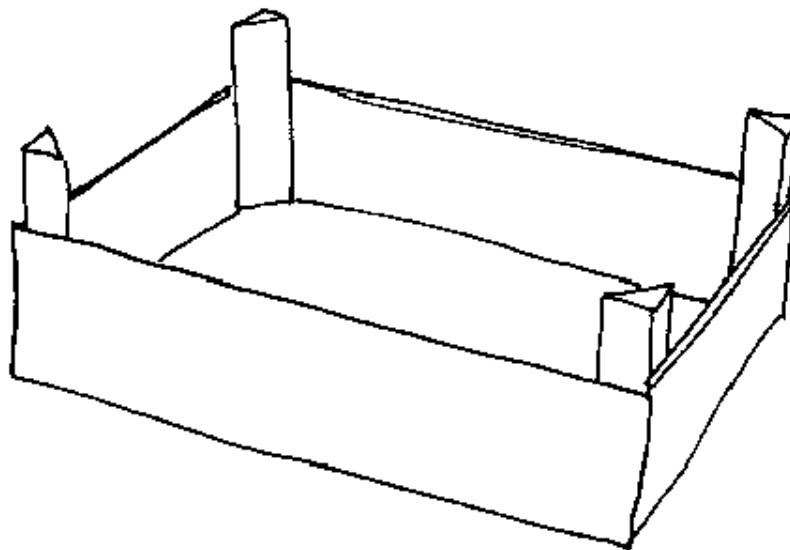


Containers for cut flowers are often long and narrow, of full telescopic design with vents at both ends to facilitate forced-air cooling. The total vent area should be 5% of the total box surface area. A closable flap can help maintain cool temperatures if boxes are temporarily delayed in transport or storage in an uncontrolled temperature environment.



Source: Rij, R. Et al. 1979. Handling, precooling and temperature management of cut flower crops for truck transportation. USDA Science and Education Administration, AAT-W-5, Leaflet 21058.

A simple wooden tray with raised corners is stackable and allows plenty of ventilation for fragile crops such as ripe tomatoes.

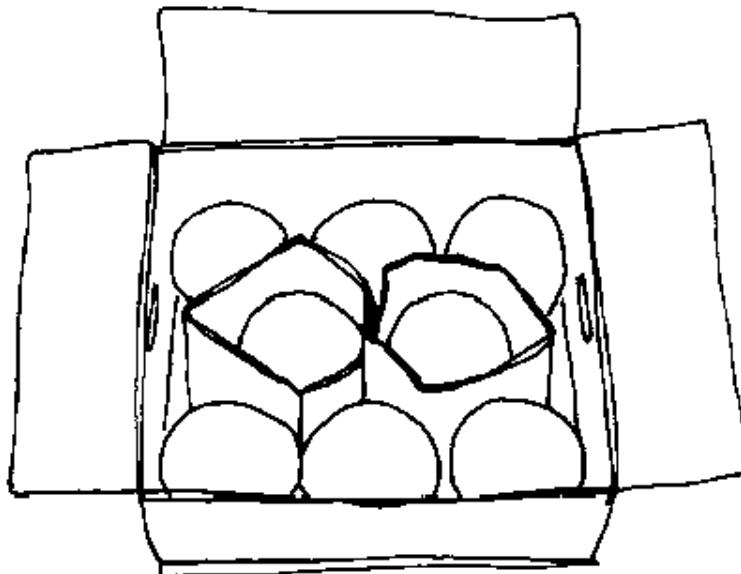


Source: FAO. 1985. Prevention of Post-Harvest Food Losses: A Training Manual. Rome: UNFAO. 120pp

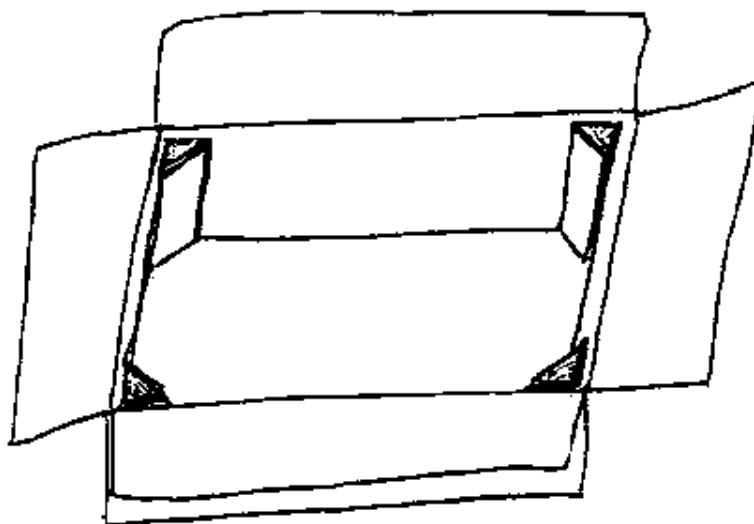
Packaging practices

Adding a fiberboard divider to a carton will increase stacking strength. The use of dividers is common with heavy crops such as melons. The dividers also prevent melons from vibrating against one another during handling and transport. Wooden inserts, or fiberboard folded into triangles and placed in all four corners can be especially useful when a carton needs strengthening.

Fiberboard divider:



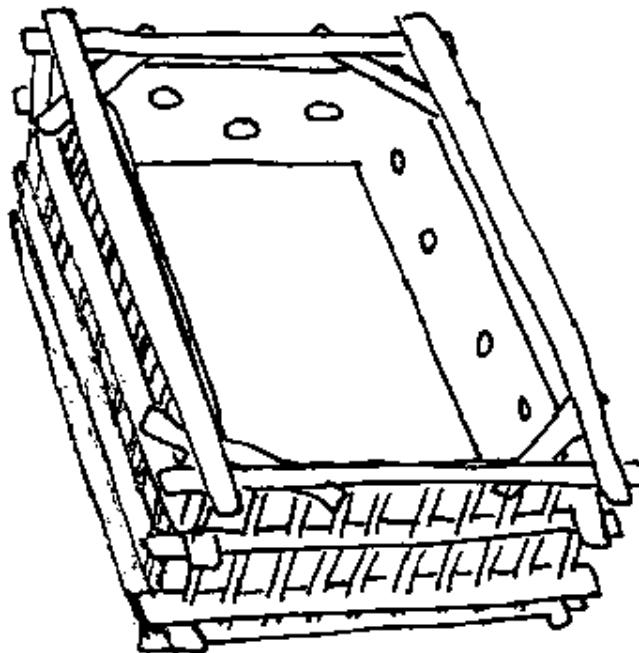
Triangular corner supports:



Source: McGregor, B. 1987. Tropical Products Transport Handbook. USDA, Office of Transportation, Agricultural Handbook Number 668.

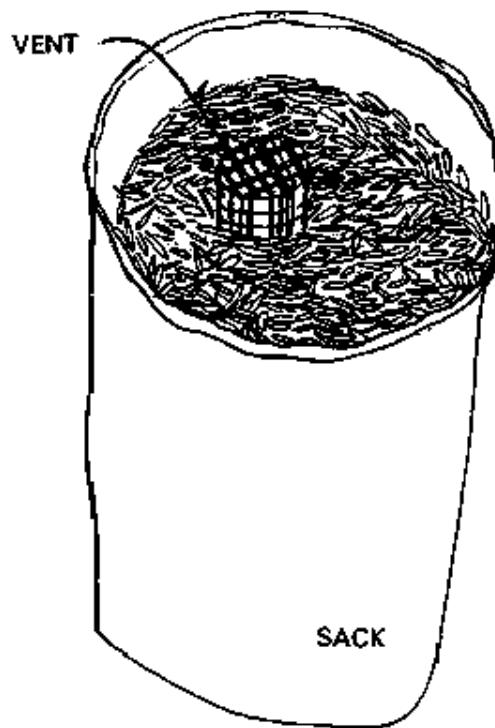
When locally made containers have sharp edges or rough inner surfaces, a simple, inexpensive inner made from fiberboard can be used to protect produce from damage during handling.

Cardboard liner for a palm rib crate:

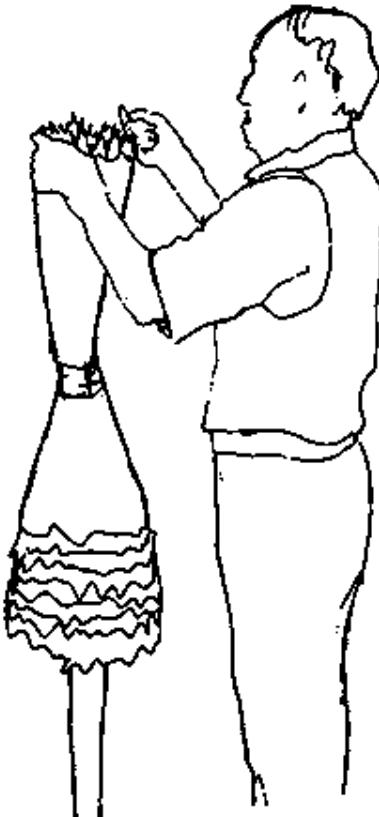


Source: Blond, R.D. 1984. The Agricultural Development Systems Project in Egypt (1979-83), USAID/Ministry of Agriculture, Egypt/University of California, Davis.

If large bags or baskets must be used for bulk packaging of fruits or vegetables, the use of a simple vent can help reduce the buildup of heat as the product respires. In the illustration below, a tube of woven bamboo (about one meter long) is used to vent a large bag of chili peppers.



Thin paper or plastic sleeves are a useful material for protecting cut flowers from damage during handling and transport. In the illustration below, a packer is pulling a sleeve up over a bunch of flowers before packing the flowers into a vented fibreboard carton. The sleeves both provide protection and help keep the bunches of flowers separate inside the box.



Source: Reid, M.S. 1992. In: Kader, A.A. (Ed.) Postharvest Technology of Horticultural Crops. University of California, Division of Agriculture and Natural Resources, Publication 3311.

Labeling

Labeling packages helps handlers to keep track of the produce as it moves through the postharvest system, and assists wholesalers and retailers in using proper practices. Labels can be preprinted on fiberboard boxes, or glued, stamped or stenciled on to containers. Brand labeling packages can aid in advertising for the product's producer, packer and/or shippers. Some shippers also provide brochures detailing storage methods or recipes for consumers.

Shipping labels can contain some or all of the following information:

- Common name of the product.
- Net weight, count and/or volume.
- Brand name.
- Name and address of packer or shipper.
- Country or region of origin.
- Size and grade.
- Recommended storage temperature.
- Special handling instructions.
- Names of approved waxes and/or pesticides used on the product.

Labeling of consumer packages is mandatory under FDA regulations. Labels must contain the name of the product, net weight, and name and address of the producer, packer or distributor.

Source: McGregor, B. 1989. Tropical Products Transport Handbook. USDA, Office of Transportation, Agricultural Handbook Number 668.

Modularization of containers

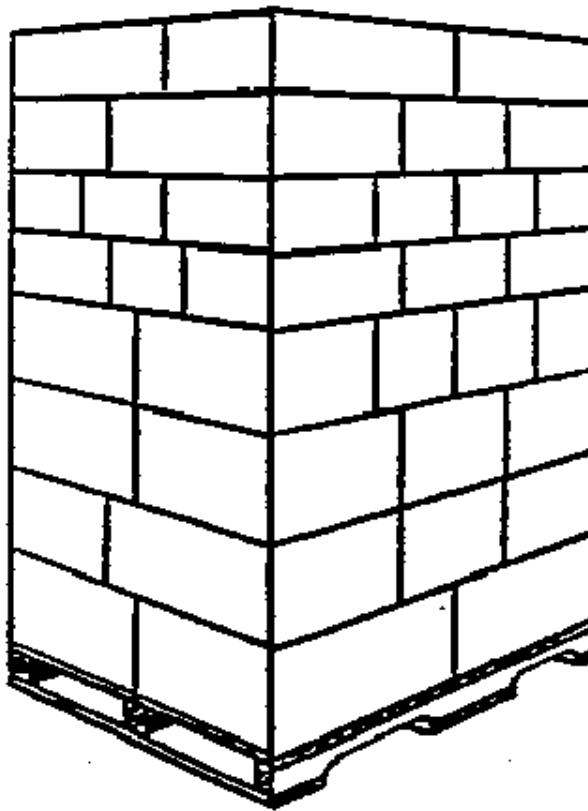
When a variety of different sized cartons are packed at the same time, using boxes in standard sizes can greatly ease future handling. When handling boxes that are non-uniform, stacks can be unstable or heavier cartons can crush lighter ones. An unstable load is likely to fall over during transport or to collapse during storage.

Recommended container sizes are shown below. These containers are part of the MUM program (Modularization, Unitization and Metrication) advocated by the USDA. They can all be stacked in a variety of patterns, depending upon their size, yet still form a stable load on a single pallet of 1000 x 1200 mm (40 x 48 inches).

MUM containers for horticultural crops:

	Outside Dimensions	Number Per Layer	Pallet Surface Area Utilized
mm	Inches		Percentage
600 x 500	(23.62 x 19.69)	4	100
500 x 400	(19.68 x 15.75)	6	100
600 x 400	(23.62 x 15.75)	5	100
500 x 333	(19.68 x 13.11)	7	97
600 x 333	(23.62 x 13.11)	6	99
500 x 300	(19.68 x 11.81)	8	100
475 x 250	(18.70 x 9.84)	10	99
400 x 300	(15.75 x 11.81)	10	100
433 x 333	(17.01 x 13.11)	8	96
400 x 250	(15.74 x 9.84)	12	100

An example of a pallet load of MUM containers:



Source: Ashby, B.H. et al. 1987. Protecting Perishable Foods During Transport by Truck. Washington, D.C.: USDA, Office of Transportation, Agricultural Handbook No. 669.

The following illustrations show the arrangement of a variety of MUM containers on a standard pallet (1000 x 1200 mm or 40 x 48 inches). Using MUM containers can save space during transport and storage, since pallet utilization is close to 100%.

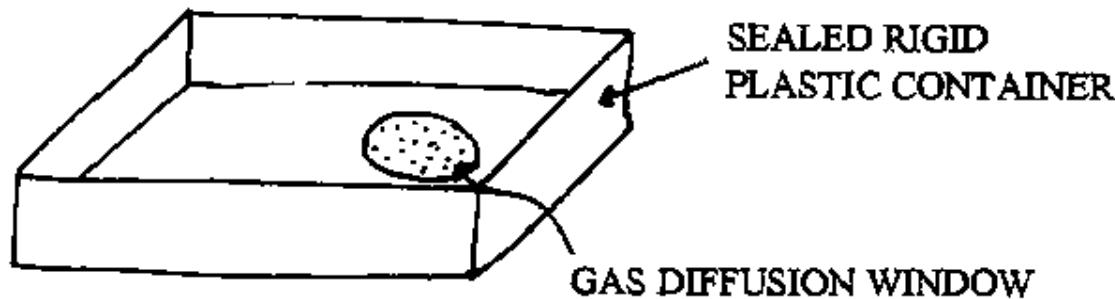
Outside dimensions: 600 x 500 mm (23.62 x 19.69") Pallet utilization 100%		Outside dimensions: 500 x 400 mm (19.68 x 15.75") Pallet utilization: 100%		Outside dimensions: 600 x 400 mm (23.62 x 15.75") Pallet utilization: 100%	
Outside dimensions: 500 x 333 mm (19.68 x 13.11") Pallet utilization: 97%		Outside dimensions: 600 x 333 mm (23.62 x 13.11") Pallet utilization: 99%		Outside dimensions: 500 x 300 mm (19.68 x 11.81") Pallet utilization: 100%	
Outside dimensions: 475 x 250 mm (18.62 x 9.84") Pallet utilization: 99%		Outside dimensions: 400 x 300 mm (15.75 x 11.81") Pallet utilization: 100%		Outside dimensions: 433 x 333 mm (17.01 x 13.11") 435 x 330 mm (17.12 x 12.99") Pallet utilization: 96%	
Outside dimensions: 400 x 250 mm (15.75 x 9.84") Pallet utilization: 100%		Outside dimensions: 400 x 333 mm (15.75 x 13.11") Pallet utilization: 99%			

Source: McGregor, B. 1989. *Tropical Products Transport Handbook*. USDA, Office of Transportation, Agricultural Handbook Number 668.

Modified atmosphere packaging (MAP)

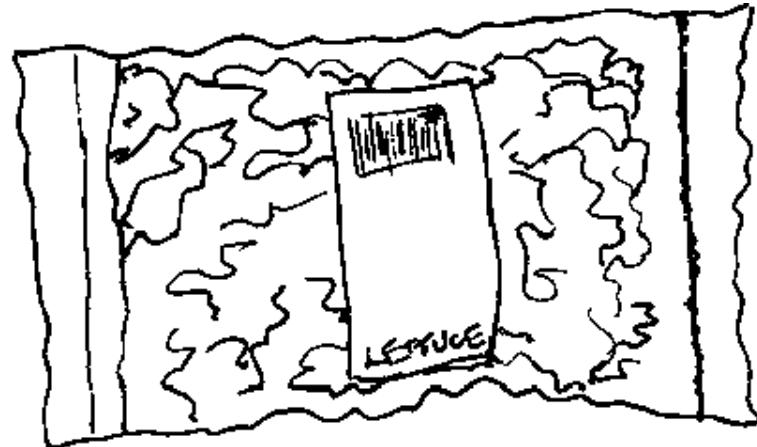
Within a consumer package: If commodity and film permeability characteristics are properly matched, an appropriate atmosphere can evolve passively through consumption of O₂ and production of CO₂ during respiration (Kader, 1992).

Some rigid plastic consumer packages are designed with a gas diffusion window.



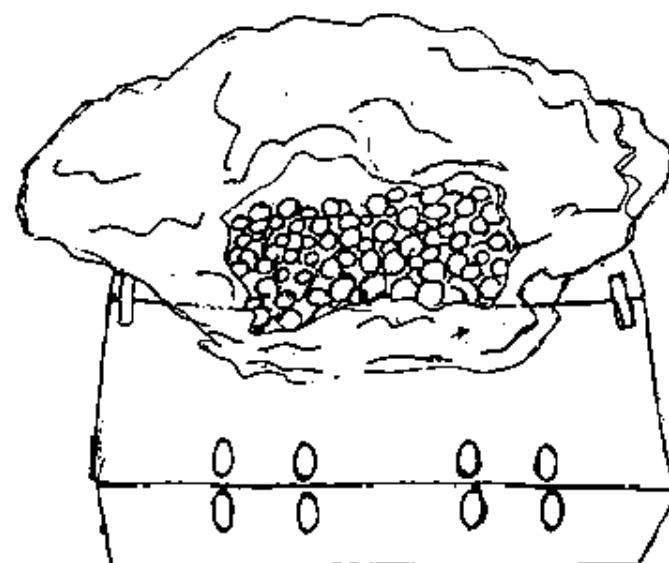
Lightly processed lettuce (shredded or chopped) can be packaged in 5-mil plastic bags. After a partial vacuum is created, a gas mixture of 30 to 50% O₂ and 4 to 6% CO₂ is introduced into the bag, which is then sealed.

SEALED PLASTIC BAG

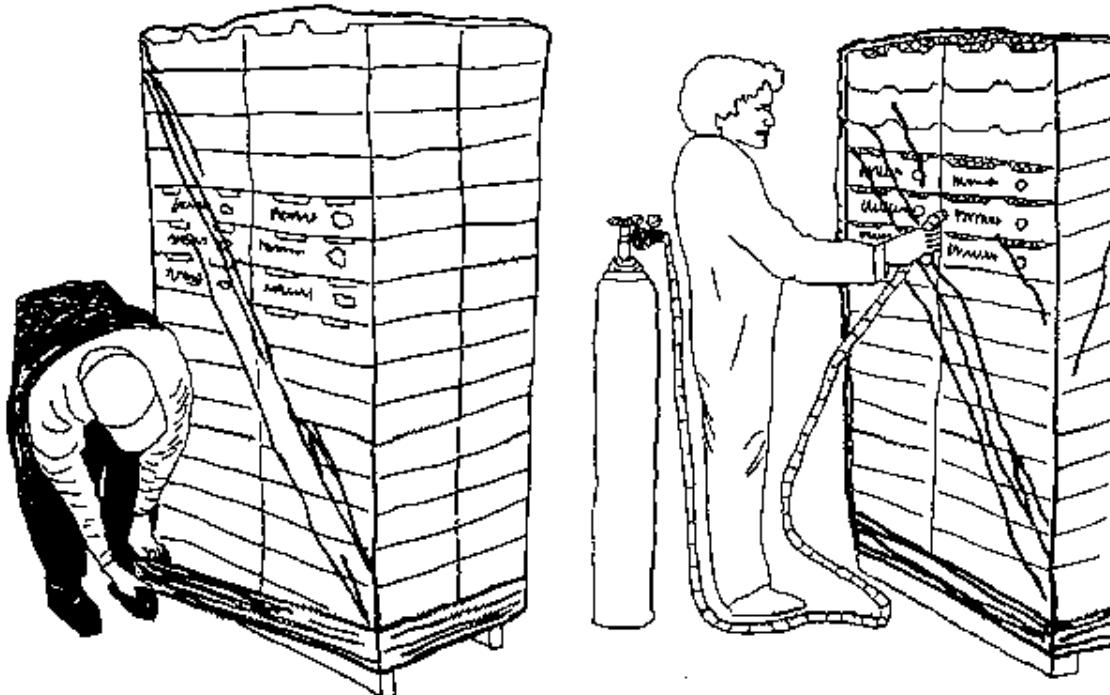


Within a shipping container: Polyethylene liners are added to shipping containers in cherry boxes, and polyethylene bags are used for bananas destined for distant markets.

PLASTIC LINER



Within a pallet: A single pallet load of produce such as strawberries can be sealed within a shroud of 5 mil polyethylene bag and a plastic sheet on the pallet base using wide tape. A slight vacuum can be introduced and 15% CO₂ added to the air introduced via a small hose.



Many plastic films are available for packaging, but very few have gas permeabilities that make them suitable for MAP. Low density polyethylene and polyvinyl chloride are the main films used in packaging fresh fruits and vegetables. Saran and polyester have such low gas permeabilities that they are suitable only for commodities with very low respiration rates. The following table provides the permeabilities of the films currently available for packaging fresh produce (Kader, 1992).

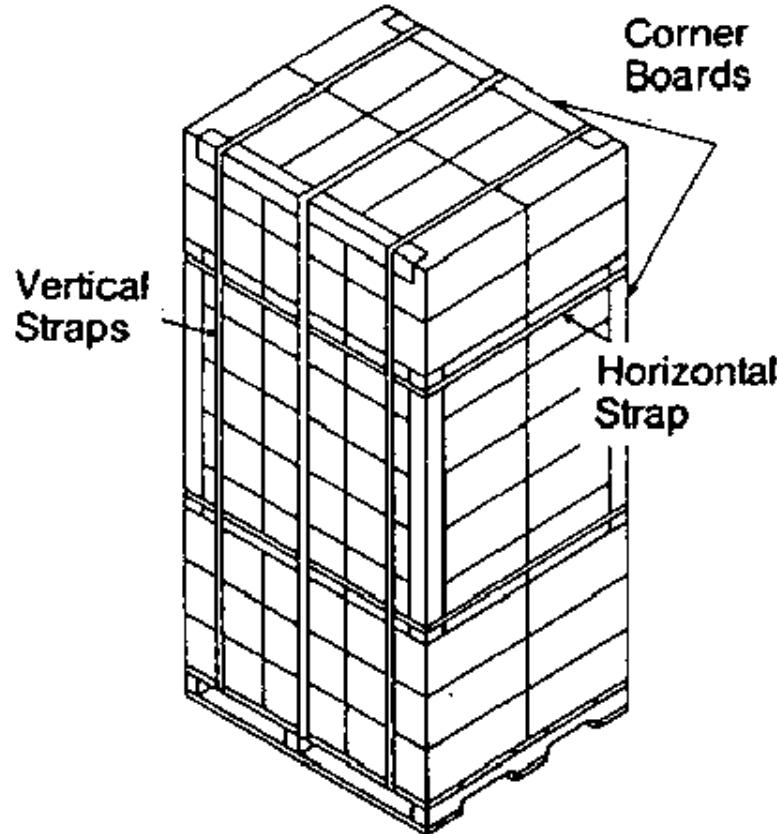
Film type	Permeabilities (cc/m ² /mil/day at 1 atm)		CO ₂ :O ₂ Ratio
	CO ₂	O ₂	
Polyethylene: low density	7,700-77,000	3,900-13,000	2.0-5.9
Polyvinyl chloride	4,263-8,138	620-2,248	3.6-6.9
Polypropylene	7,700-21,000	1,300-6,400	3.3-5.9
Polystrene	10,000-26,000	2,600-7,700	3.4-3.8
Saran	52-150	8-26	5.8-6.5
Polyester	180-390	52-130	3.0-3.5

Unit loads

Many shippers and receivers prefer to handle unit loads of produce pallets rather than handling individual shipping containers. The switch to unit loads has reduced handling, causes less damage to the containers and produce inside, and allows faster loading/ unloading of transportation vehicles.

If small scale handlers wish to use unit loads for shipping produce, either wooden pallets or slip sheets can serve as the base of the load. Using guides for aligning the boxes (such as placing the pallet to be loaded against the corner of a room, or building a set of "bounce boards" if the pallet is loaded outside) will stabilize the load. Using fiberboard, plastic or wooden containers with vertical interlocking tabs can also help improve the unit load's stability. Containers must have holes for ventilation which align when stacked squarely on top of one another. Glue can be used between layers of containers to reduce slipping, and plastic netting or plastic or metal straps should be added to secure the load. Cornerboards made from fiberboard, plastic or metal help to provide for a stable unit load.

Strapping and cornerboards on a unit load:



Sources: McGregor, B. 1989. Tropical Products Transport Handbook. USDA, Office of Transportation, Agricultural Handbook Number 668.

Ashby, B.H., et al., 1987. Protecting Perishable Foods During Transport by Truck. USDA, Office of Transportation, Agricultural Handbook Number 669.





Section 5: Decay and insect control

[Chemical controls](#)

[Controlled/modified atmosphere treatments](#)

[Heat treatments](#)

The first line of defense against insects and disease is good management during production. The second is careful harvesting and preparation for market in the field. Thirdly, sorting out damaged or decaying produce will limit contamination of the remaining, healthy produce. Yet, even when the greatest care is taken, sometimes produce must be treated to control insects or decay-causing organisms.

Certain fungi and bacteria in their germination phase are susceptible to cold, and infections can be reduced by treating produce with a few days of storage at the coldest temperature the commodity can withstand without incurring damage.

Rhizopus stolonifer and *Aspergillus niger* (black mold) can be killed when germinating by 2 or more days at 0°C (32 F) (Sommer, in Kader, 1992). On the other hand, brief hot water dips or forced-air heating can also be effective, especially for reducing the microbial load for crops such as plums, peaches, papaya, cantaloupe and stone fruits (Shewfelt, 1986), sweetpotatoes and tomatoes.

While high humidity in the storage environment is important for maintenance of high quality produce, free water on the surface of commodities can enhance germination and penetration by pathogens. When cold commodities are removed from storage and left at higher ambient temperatures, moisture from the surrounding warm air condenses on the colder product's surfaces (Sommer, in Kader, 1992). A temporary increase in ventilation rate (using a fan) or increasing exposure of the commodity to drier air can help to evaporate the condensed moisture and to reduce the chances of infection.

Cold treatments can also serve to control some insect pests, and are currently used for the control of fruit flies. Treatment requires 10 days at 0 C (32 F) or below, or 14 days at 1.7 C (35 F) or below, so treatment is only suited to commodities capable of withstanding long-term low-temperature storage such as apples, pears, grapes,

kiwifruit and persimmons (Mitchell & Kader in Kader, 1992). For produce packed before cold storage treatment, package vents should be screened to prevent the spread of insects during handling.

Hot water dips or heated air can be used for direct control of postharvest insects. In mangoes, an effective treatment is 46.4 C for 65 to 90 minutes, depending on size (Sommer & Arpaia in Kader, 1992). Fruit should not be handled immediately after heat treatment. Whenever heat is used with fresh produce, cool water showers or forced cold air should be provided to help return the fruits to their optimum temperature as soon as possible after completion of the treatment.

Control of storage insects in nuts and dried fruits and vegetables can be achieved by freezing, cold storage (less than 5 C or 41 F), heat treatments, or the exclusion of oxygen (0.5% or lower) using nitrogen. Packaging in insect-proof containers is needed to prevent subsequent insect infestation.

Some plant materials are useful as natural pesticides. Cassava leaves are known to protect harvested cassava roots from pests when used as packing material in boxes or bags during transport and short-term storage. It is thought that the leaves release cyanogens, which are toxic to insects (Aiyer, 1978). The ashes of the leaves of *Lantana* spp. and *Ochroma logopur* have been found to be very effective when used as a dust against aphids attacking stored potatoes (CIP, 1982). The pesticidal properties of the seeds of the neem tree (as an oil or aqueous extract) are becoming more widely known and used throughout the world. Native to India, neem acts as a powerful pesticide on food crops but appears to be completely non-toxic to humans, mammals and beneficial insects (NRC, 1992). Any "natural pesticide" must be shown to be safe for humans before its approval by regulatory authorities.

Chemical controls

Washing produce with chlorinated water can prevent decay caused by bacteria, mold and yeasts on the surface of produce. Calcium hypochlorite (powder) and sodium hypochlorite (liquid) are inexpensive and widely available. The effectiveness of the treatment will be decreased if organic matter is allowed to build up in the wash water. The effectiveness of chlorine increases as pH is reduced from pH 11 to pH 8, but at lower pH chlorine becomes unstable.

Fruits and vegetables can be washed with hypochlorite solution (25 ppm available chlorine for two minutes) then rinsed to control bacterial decay. Alternatively, these commodities can be dipped in hypochlorite solution (50 to 70 ppm available chlorine) then rinsed with tap water for control of bacteria, yeasts and molds.

Source: Ogawa, J.M. and Manji, B.T. 1984. in: Moline, H.E. (Ed). Postharvest Pathology of Fruits and Vegetables. University of California, Division of Agriculture and Natural Resources, UC Bulletin

1914.

There are some chemicals that are generally recognized safe (GRAS) which are used to control a variety of molds and fungi on fruit crops.

Sulfur:

Sulfur is used on bananas as a paste (0.1 % active ingredient) to control crown rot fungi.

Sulfur dioxide (SO_2) is used as a fumigant or a water spray (0.5% for 20 minutes for the initial treatment, then 0.2% for 20 minutes at 7 day intervals) on grapes to control *Botrytis*, *Rhizopus* and *Aspergillus* fungi.

Careful calculation of the amount of sulfur dioxide required to treat grapes can greatly reduce the need to vent or scrub the storage air after fumigation to remove excess SO_2 . For information on the "total utilization" fumigation technique that has been developed for treating grapes with sulfur dioxide, see Luvisi (1992).

Sodium or potassium bisulfite:

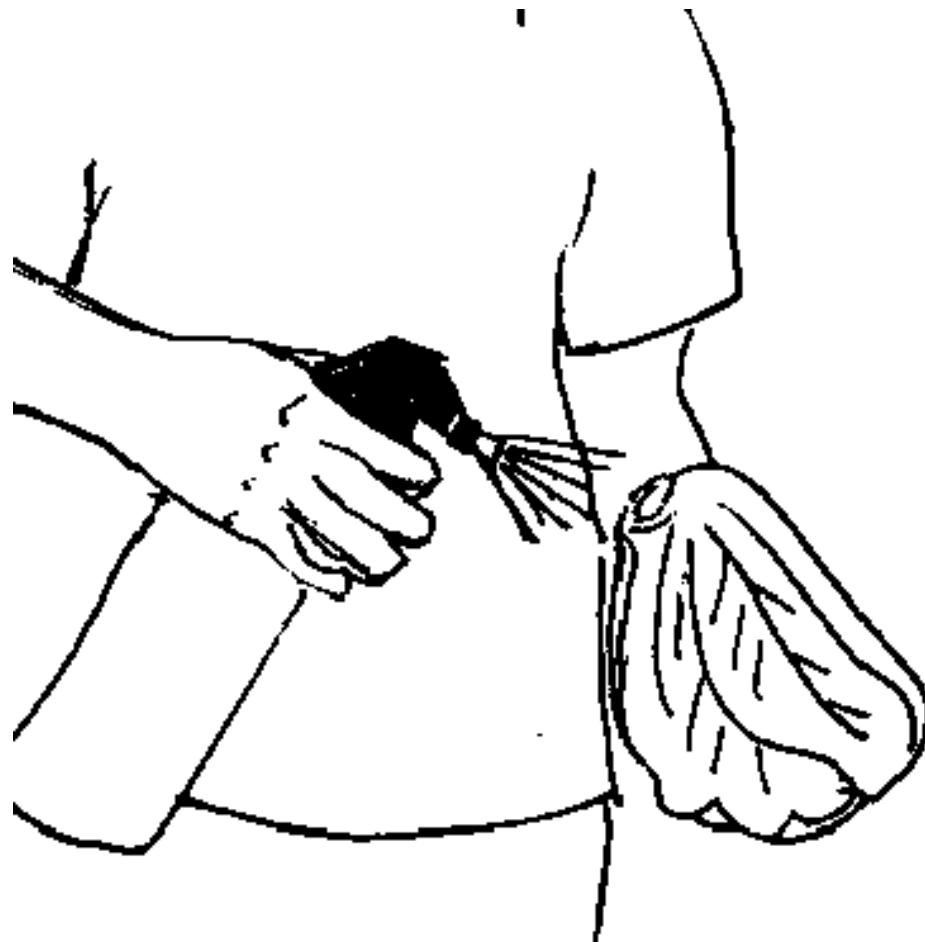
Bisulfites are used in a sawdust mixture (usually contained within a pad that can be placed inside a carton) to release SO_2 for control of molds on grapes (5 grams for a 24 to 28 lb box).

Sources: Luvisi, D.A. et al. 1992. Sulfur Dioxide Fumigation of Table Grapes. University of California, Division of Agriculture and Natural Resources, Bulletin 1932.

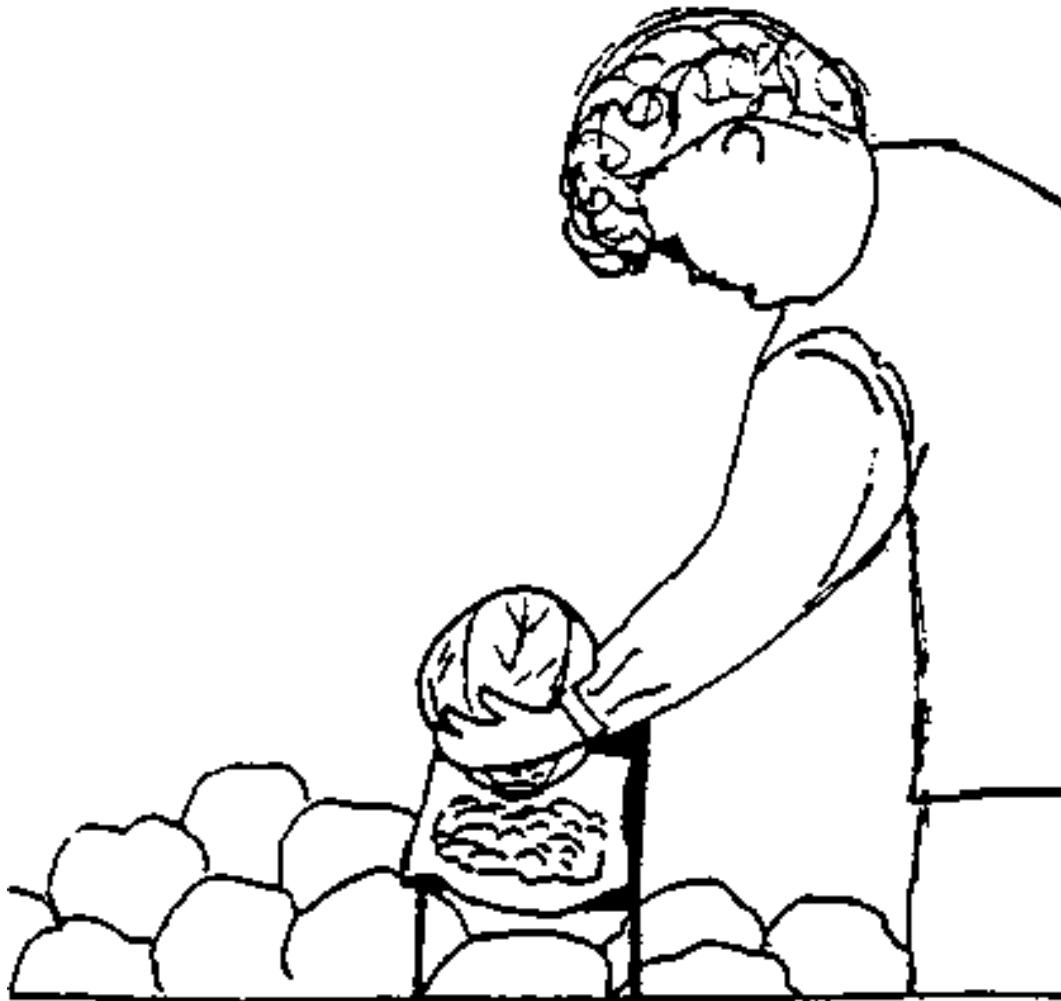
Ogawa, J.M. and Manji, B.T. 1984. in: Moline, H.E. (Ed). Postharvest Pathology of Fruits and Vegetables. University of California, Division of Agriculture and Natural Resources, UC Bulletin 1914.

Bacterial soft rot (*Erwinia*) of cabbage can be controlled by using lime powder or a 15% solution of alum (aluminum potassium sulfate) in water. After treatment of the butt-end of the cabbage heads, the produce should be allowed to dry for 20 to 30 minutes before packing.

Applying alum solution (spray or brush on):

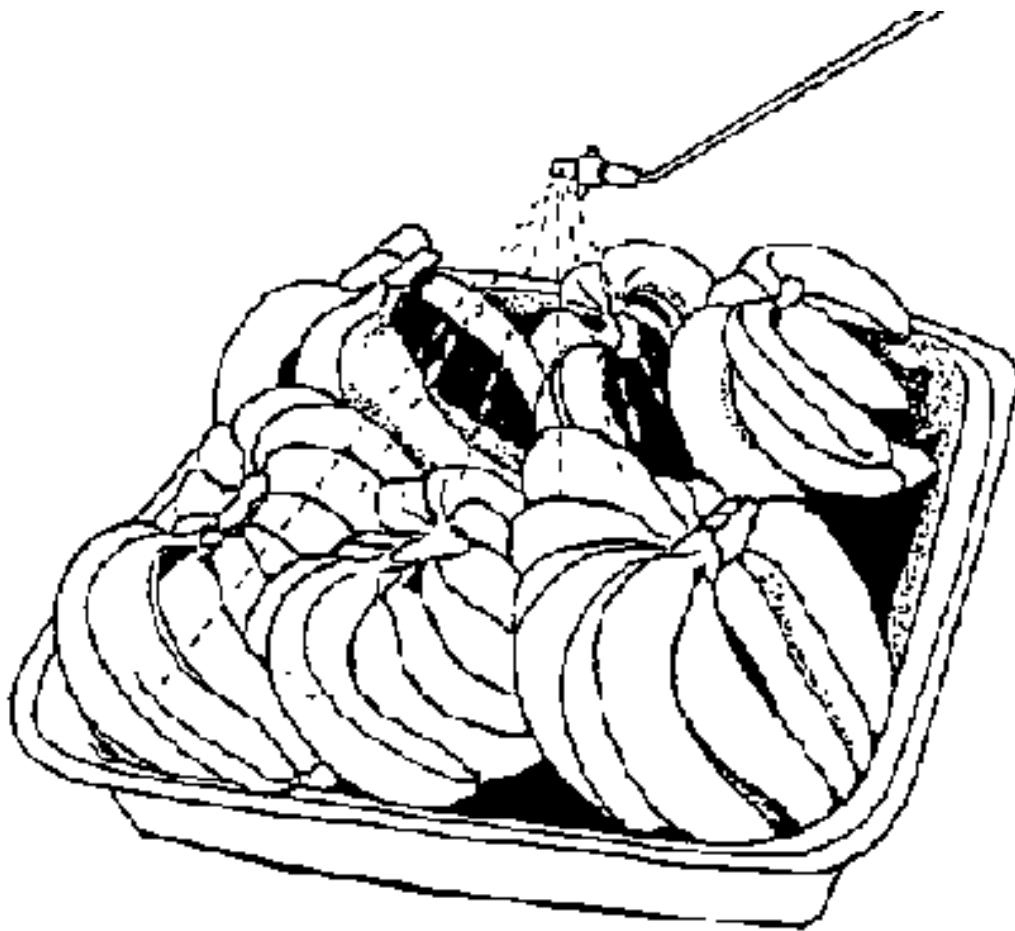


Applying lime powder (press butt-end into powder):



Source: Borromeo, E.S. and Ilag, L.L. 1984. Alum and Lime Applications: Potential Postharvest Control of Cabbage Soft Rot. Appropriate Postharvest Technology 1(1):10-12.

On occasions when fungicides must be applied to produce, a simple tray with holes punched in the bottom can be used hold the commodity while it is sprayed. In the illustration below, a hand-operated knapsack sprayer is used to spray fungicides on bananas to the stage of run-off. The bananas can then dry in the perforated tray before further handling.



Source: FAO. 1989. Prevention of Postharvest Food Losses: Fruits, Vegetables and Root Crops. A Training Manual. Rome: UNFAO. 157 pp.

When fruit is packed for export, fungicides are often applied to meet the requirements of international quality standards and to reduce deterioration during transport. The "cascade applicator" illustrated below was developed to apply fungicide uniformly and effectively by using a liquid curtain to drench the fruit.

Fruit in a perforated plastic tray is introduced on a roller conveyor belt (not shown) into the applicator. Inside a simple fan shaped deflector creates a curtain of liquid fungicide. The fruit passes under the curtain where it is drenched, then out of the applicator to drain on a tilted return tray. The tank holds up to 50 liters of fungicide solution, and a pump is mounted at the level of the tank outlet. A filter is fitted on the top of the tank to remove foreign matter from the return flow of fungicide from the applicator box and the return tray.

Fungicide Applicator:

Source: Overseas Div., AFRC. Nat'l Institute of Agricultural Engineering. 1974. Bulletin No. 6. Silsoe, Bedfordshire, England.

Controlled/modified atmosphere treatments

For commodities that tolerate high CO₂ levels, 15 to 20% CO₂-enriched air can be used as a fungistat to control decay-causing pathogens, such as *Botrytis cinerea* on strawberry, blueberry, blackberry, fresh fig and table grapes during transport. See page 77 for a description of the method for atmospheric modification within a pallet cover.

Insecticidal atmospheres (0.5% or lower O₂ and/or 40% or higher CO₂) have been shown to be an effective substitute for methyl bromide fumigation to disinfest dried fruits, nuts and vegetables. The effectiveness of insecticidal atmospheres depends upon the temperature, relative humidity, duration of exposure and life stage of the insect. Following are some examples:

1) Sweetpotato weevil (*Cylas formicarius elegantulus*) has been controlled at ambient temperature in stored tropical sweetpotatoes by treatment with low oxygen and high carbon dioxide atmospheres. At 25 C (76 F), storage in 2 to 4% oxygen and 40 to 60% carbon dioxide results in mortality of adult weevils in 2 to 7 days.

Source: Delate, K. et al. 1990. Controlled atmosphere treatments for control of sweetpotato weevil in stored tropical sweetpotatoes. *Journal of Economic Entomology* 83:461-465.

2) Codling moth (*Cydia pomonella*) in stone fruits can be controlled at 25 C (76 F) by using atmospheres of 0.5% oxygen and 10% carbon dioxide for 2 to 3 days (adult or egg) or 6 to 12 days (pupa). Normal color and firmness changes during ripening are not affected by treatment.

Source: Soderstrom, E.L. et al. 1990. Responses of codling moth life stages to high carbon dioxide or low oxygen atmospheres. *Journal of Economic Entomology* 83:472-475.

Heat treatments

Postharvest heating using hot water or hot forced-air to kill or weaken pathogens can be used as a method for decay control in fresh fruits and vegetables.

HOT WATER TREATMENTS:

Commodity	Pathogens	Temperature (C)	Time (min)	Possible injuries

Apple	<i>Gloeosporium</i> sp.	45	10	Reduced storage life
	<i>Penicillium expansum</i>			
Grapefruit	<i>Phytophthora citrophthora</i>	48	3	
Green beans	<i>Pythium butleri</i>	52	0.5	
	<i>Sclerotinia sclerotiorum</i>			
Lemon	<i>Penicillium digitatum</i>	52	5-10	
	<i>Phytophthora</i> sp.			
Mango	<i>Collectotrichum gloeosporioides</i>	52	5	No stem rot control
Melon	Fungi	57-63	0.5	
Orange	<i>Diplodia</i> sp.	53	5	Poor degreening
	<i>Phomopsis</i> sp.			
	<i>Phytophthora</i> sp.			
Papaya	Fungi	48	20	
Peach	<i>Monolinia fructicola</i>	52	2.5	Motile skin
	<i>Rhizopus stolonifer</i>			
Pepper (bell)	<i>Erwinia</i> sp.	53	1.5	Slight spotting

HOT FORCED-AIR TREATMENTS:

Commodity	Pathogens	Temperature (C)	Time (min)	RH (%)	Possible injuries
Apple	<i>Gloeosporium</i> sp.	45	15	100	Deterioration
	<i>Penicillium expansum</i>				
Melon	Fungi	30-60	35	low	Marked breakdown
Peach	<i>Monolinia fructicola</i>	54	15	80	
	<i>Rhizopus stolonifer</i>				
Strawberry	<i>Alternaria</i> sp.	43	30	98	
	<i>Botrytis</i> sp., <i>Rhizopus</i> sp.				
	<i>Cladosporium</i> sp.				

Source: Barkai-Golan, R. and Phillips, D.J. 1991. Postharvest heat treatments of fresh fruits and vegetables for decay control. Plant Disease (Nov): 1085-1089.





Section 6: Temperature and relative humidity control

- [Room cooling](#)
 - [Forced-air cooling](#)
 - [Hydro-cooling](#)
 - [Evaporative cooling](#)
 - [Night air ventilation](#)
 - [Chilling injury](#)
 - [Use of ice](#)
 - [Alternative methods of cooling](#)
 - [Increasing relative humidity](#)
-

Throughout the period between harvest and consumption, temperature control has been found to be the most important factor in maintaining product quality. Fruits, vegetables and cut flowers are living, respiring tissues separated from the parent plant. Keeping products at their lowest safe temperature (0 C or 32 F for temperate crops or 10-12 C or 50-54 F for chilling sensitive crops) will increase storage life by lowering respiration rate, decreasing sensitivity to ethylene and reducing water loss. Reducing the rate of water loss slows the rate of shriveling and wilting, causes of serious postharvest losses. It is important to avoid chilling injury, since symptoms include failure to ripen (bananas and tomatoes), development of pits or sunken areas (oranges, melons and cucumbers), brown discoloration (avocados, cherimoyas, eggplant), increased susceptibility to decay (cucumbers and beans), and development of off-flavors (tomatoes) (Shewfelt, 1990).

If a ready supply of electricity is available, mechanical refrigeration systems provide the most reliable source of cold. Methods include room cooling, forced-air cooling and evaporative cooling. A variety of portable forced-air coolers have been designed for use by small-scale growers and handlers (Talbot and Fletcher, 1993; Rij et al, 1979; Parsons-and Kasmire, 1974). However, a variety of simple methods exist for cooling produce where electricity is unavailable or too expensive. Some examples of alternative systems (from Thompson in Kader, 1992) include night air ventilation, radiant cooling, evaporative cooling, the use of ice and underground (root cellars, field clamps, caves) or high altitude storage.

Cooling involves heat transfer from produce to a cooling medium such as a source of refrigeration. Heat transfer processes include conduction, convection, radiation and evaporation.

Several simple practices are useful for cooling and enhancing storage system efficiency wherever they are used, and especially in developing countries, where energy savings may be critical. Shade should be provided over harvested produce, packing areas, for buildings used for cooling and storage and for transport vehicles. Using shade wherever possible will help to reduce the temperatures of incoming produce. Trees are a fine source of shade and can reduce ambient temperatures around packinghouses and storage areas. Light colors on buildings will reflect light (and heat) and reduce heat load. Sometimes spending money will save money, as when purchasing lighting equipment. High pressure sodium lights produce less heat and use less energy than incandescent bulbs.

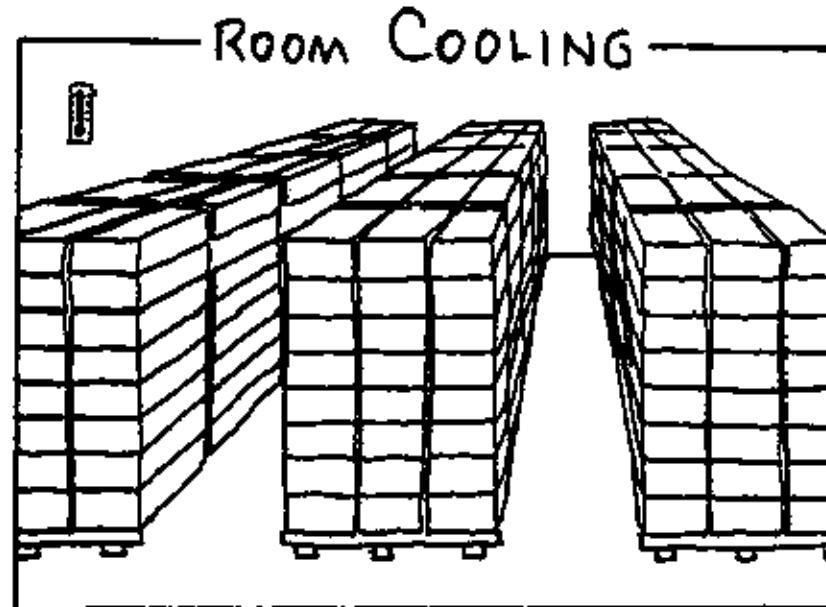
Another aspect to consider when handling fruits and vegetables is the relative humidity of the storage environment. Loss of water from produce is often associated with a loss of quality, as visual changes such as wilting or shrivelling and textural changes can take place. If using mechanical refrigeration for cooling, the larger the area of the refrigerator coils, the higher the relative humidity in the cold room will remain. It pays however, to remember that water loss may not always be undesirable, for example if produce is destined for dehydration or canning.

For fresh market produce, any method of increasing the relative humidity of the storage environment (or decreasing the vapor pressure deficit (VPD) between the commodity and its environment) will slow the rate of water loss. The best method of increasing relative humidity is to reduce temperature. Another method is to add moisture to the air around the commodity as mists, sprays, or, at last resort, by wetting the store room floor. Another way is to use vapor barriers such as waxes, polyethylene liners in boxes, coated boxes or a variety of inexpensive and recyclable packaging materials. Any added packaging materials will increase the difficulty of efficient cooling, so vented liners (about 5% of the total area of the liner) are recommended. The liner vents must line up with the package vents to facilitate cooling of the produce inside. Vented liners will decrease VPD without seriously interfering with oxygen, carbon dioxide and ethylene movement.

Room cooling

Room cooling is a relatively low cost but slow method of cooling when electricity for mechanical refrigeration is available. The greater the refrigerator's evaporator coil area, the less moisture will be lost from the product as it cools.

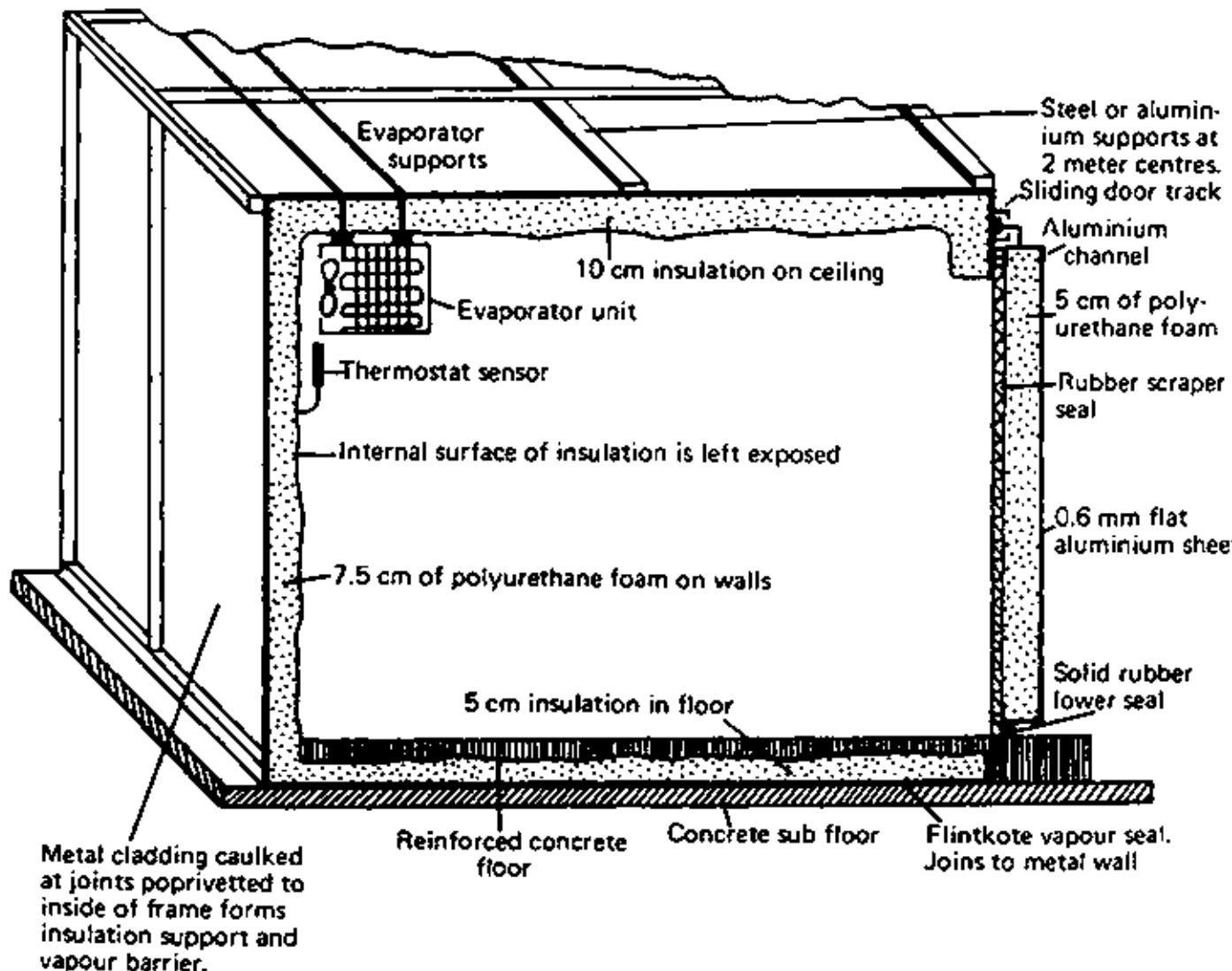
It is important to leave adequate space between the stacks of boxes inside the refrigerated room in order for produce to cool more quickly. Stacks should be narrow, about one pallet width in depth. Air circulating through the room passes over surfaces and through any open space, so cooling from the outside to the center of the stacks is mostly by conduction. (See Mitchell in Kader, 1992 for more information).



Source: Kasmire, R.F. 1977. California Tomatorama. Fresh Market Tomato Advisory Board Information Bulletin No. 17.

Low cost cold rooms can be constructed using concrete for floors and polyurethane foam as an insulator. Building the storeroom in the shape of a cube

will reduce the surface area per unit volume of storage space, thereby reducing construction and refrigeration costs. All joints should be caulked and the door should have a rubber seal.



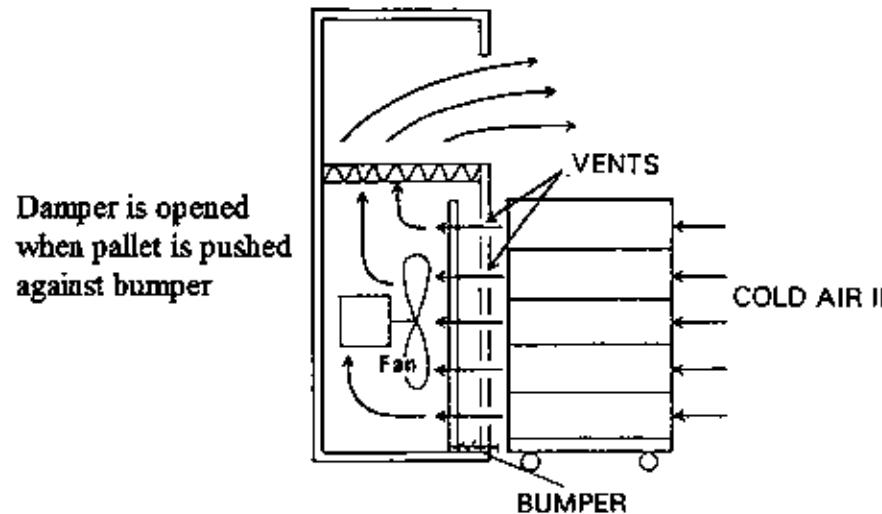
Source: Tugwell, B.L. No date. Coolroom construction for the fruit and vegetable grower. Department of Agriculture and Fisheries, South Australia. Special Bulletin 11.75.

Forced-air cooling

Forced-air cooling pulls or pushes air through the storage containers themselves, greatly speeding the cooling rate of any type of produce. Many types of forced-air coolers can be designed to move cold moist air over the commodities. The example provided below is a fixed unit, where a fan is housed inside

the wall of a cold room

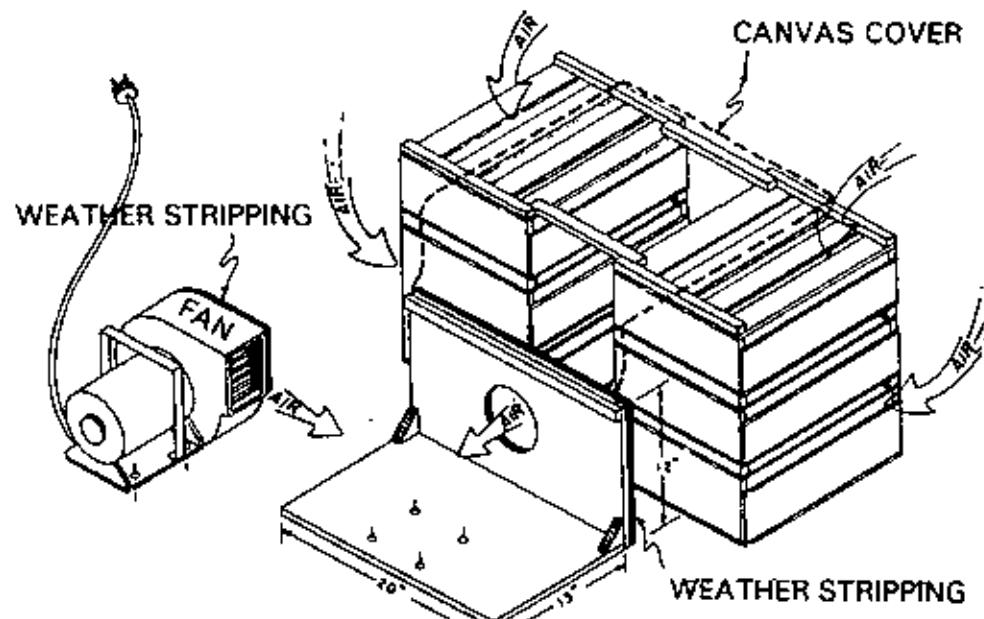
Cold wall forced-air cooler:



Source: Rij, R. et al. 1979. Handling Precooling and Temperature Management of Cut Flower Crops for Truck Transportation. USDA Science and Education Administration, AAT-W-5, UC Leaflet 21058.

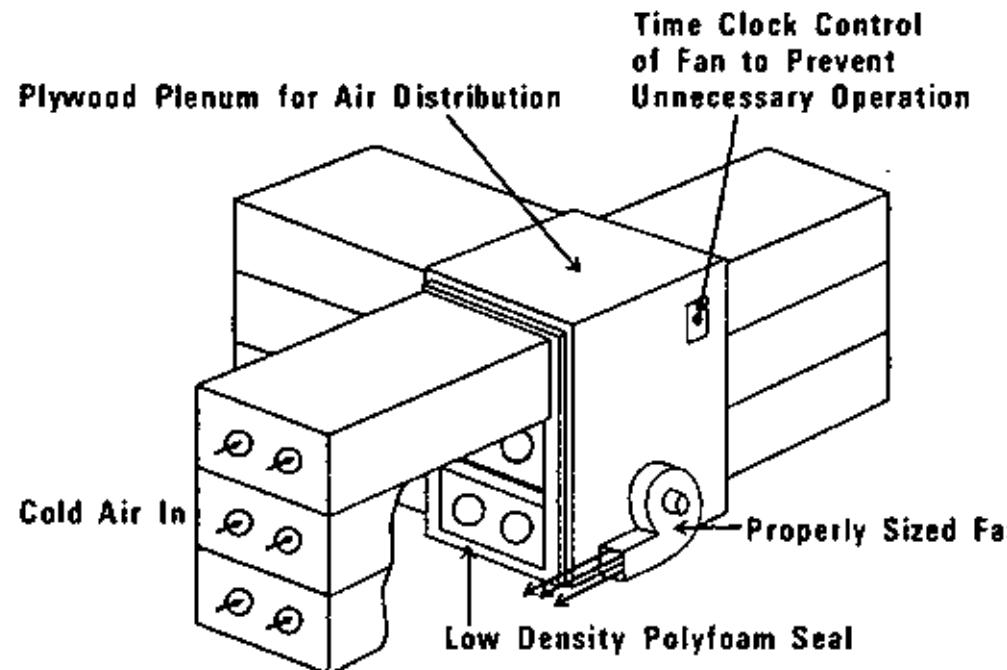
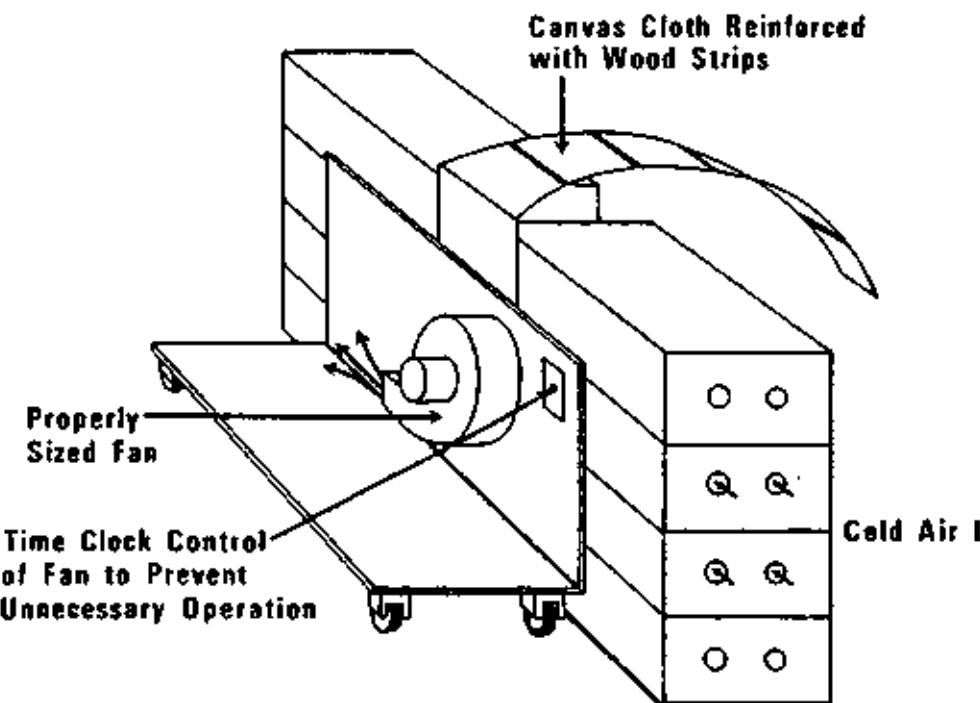
A portable forced-air cooler can be constructed using a canvas or polyethylene sheet. The sheet is rolled over the top and down the back of the boxes to the floor, sealing off the unit and forcing air to be pulled through the vents (vent area should be at least 5% of the surface area of the carton) of the cartons stacked against the cooler. This unit is designed to be used inside a refrigerated storage room.

A portable forced-air cooler:



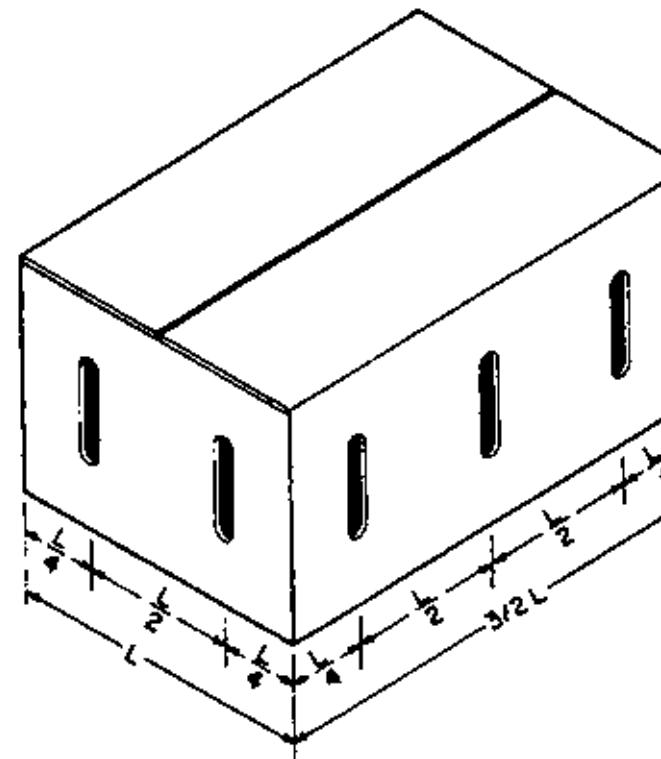
Source: Parsons, R.A. and Kasmire, R.F. 1974. Forced-air unit to rapidly cool small lots of packaged produce. University of California Cooperative Extension, OSA #272.

The illustrations below show two types of forced-air coolers. Each is equipped with a fan to pull air from the cold room through the boxed produce.



Source: Rij, R. et al. 1979. Handling, Precooling and Temperature Management of Cut Flower Crops for Truck Transportation. USDA

The illustration below shows the recommended pattern of vents for cartons used to hold produce that is to be forced-air cooled. Vents should make up 5% of the total surface area, and should be located 5 to 7.5 cm (2 to 3 inches) away from the corners. A few large vents (1.3 cm =0.5 inch wide or more) are better than many small vents.



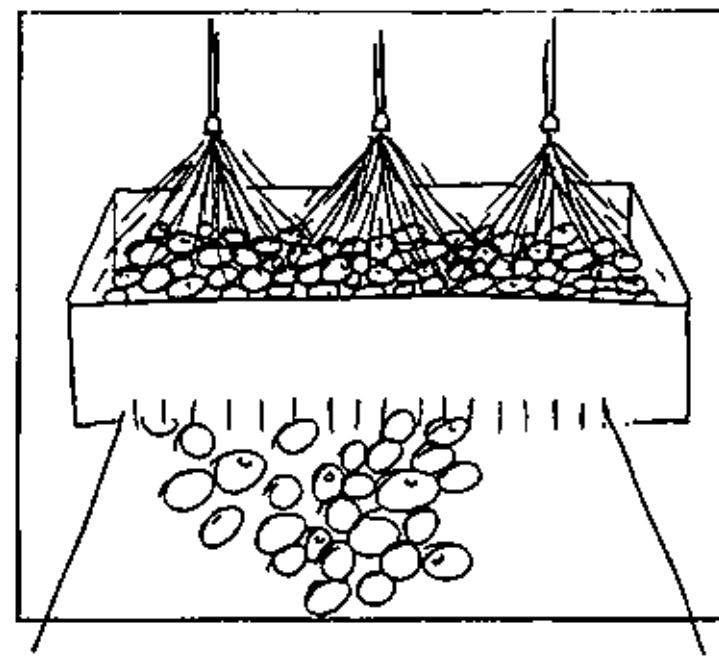
Source: Mitchell, F.G. et al. 1972. Commercial cooling of fruits and vegetables. California Agricultural Experiment Station Extension Service, Manual 43.

Hydro-cooling

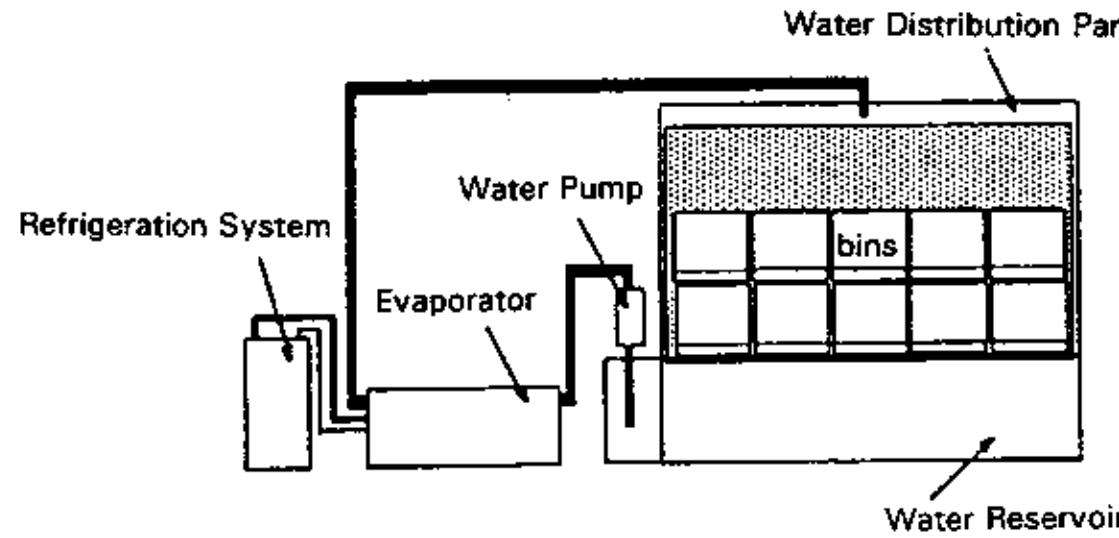
Hydro-cooling provides fast, uniform cooling for some commodities. The commodity as well its packaging materials must be tolerant of wetting, chlorine (used to sanitize the hydro-cooling water) and water beating damage (Mitchell in Kader, 1992).

The simplest version of a hydro-cooler is a tank of cold water in which produce is immersed. The type shown below showers a batch of produce with icy water as the produce moves along a conveyor. A batch-type hydro-cooler can be constructed to hold entire palletloads of produce (Thompson in Kader, 1992). Conveyors can be added to help control the time produce stays in contact with the cold water.

Hydro-cooling:



Batch-type hydro-cooler:



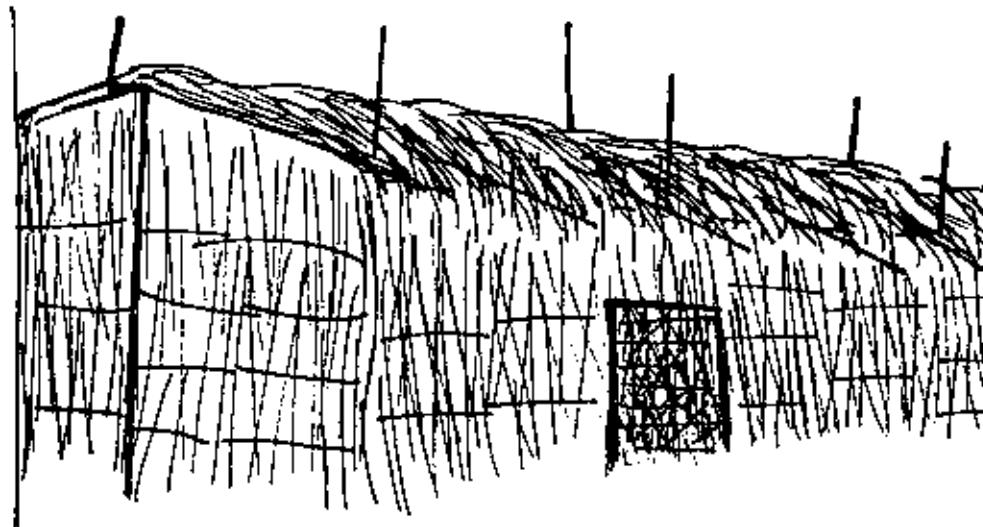
Source: Kasmire, R.F. 1977. California Tomatorama. Fresh Market Tomato Advisory Board Information Bulletin No. 17.

Evaporative cooling

These packinghouses are made from natural materials that can be moistened with water. Wetting the walls and roof first thing in the morning creates

conditions for evaporative cooling of a packinghouse that is made from straw.

Straw packinghouse:



The packinghouse illustrated below is made with walls of wire mesh that hold charcoal. By moistening the charcoal with water each morning, the structure will be evaporatively cooled during the day.

Straw packinghouse:

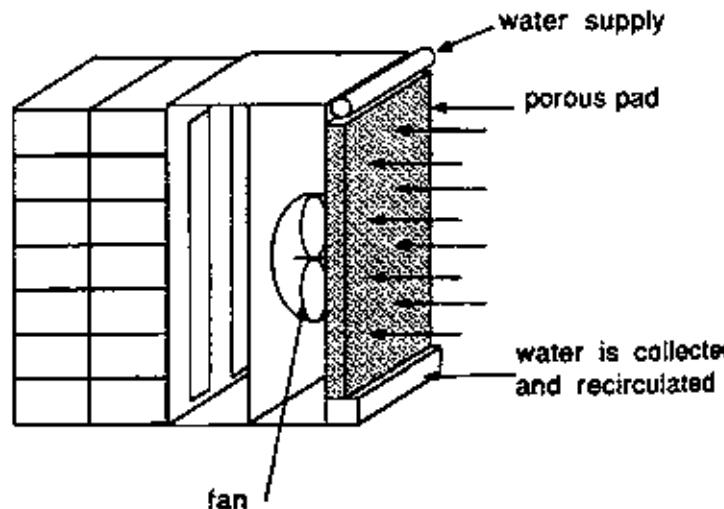


Source: FAO. 1986. Improvement of Post-Harvest Fresh Fruits and Vegetables Handling- A Manual. Bangkok: UNFAO Regional Office for Asia and the Pacific.

Evaporative coolers can be constructed to cool the air in an entire storage structure or just a few containers of produce. These coolers are best suited to lower humidity regions, since the degree of cooling is limited to 1 to 2 C (2 to 4 F) above the wet-bulb temperature. A cooling pad of wood fiber or straw is moistened and air is pulled through the pad using a small fan. In the example provided here, 0.5 gallon of water per minute is dripped onto an 8 square foot pad, providing enough moist air to cool up to 18 crates of produce in 1 to 2 hours. Water is collected in a tray at the base of the unit and recirculated.

An evaporative cooler can be combined with a forced air cooler for small lots of produce. Air is cooled by passing through the wet pad before it passes through the packages and around the produce. The air can be cooled to within a few degrees of the wet bulb temperature of ambient air.

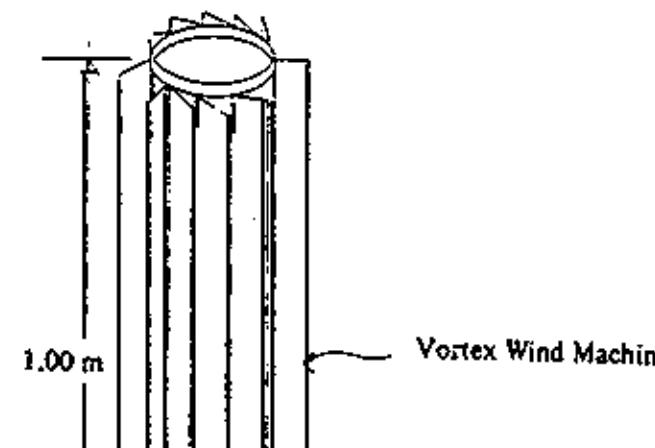
Evaporative forced-air cooler:

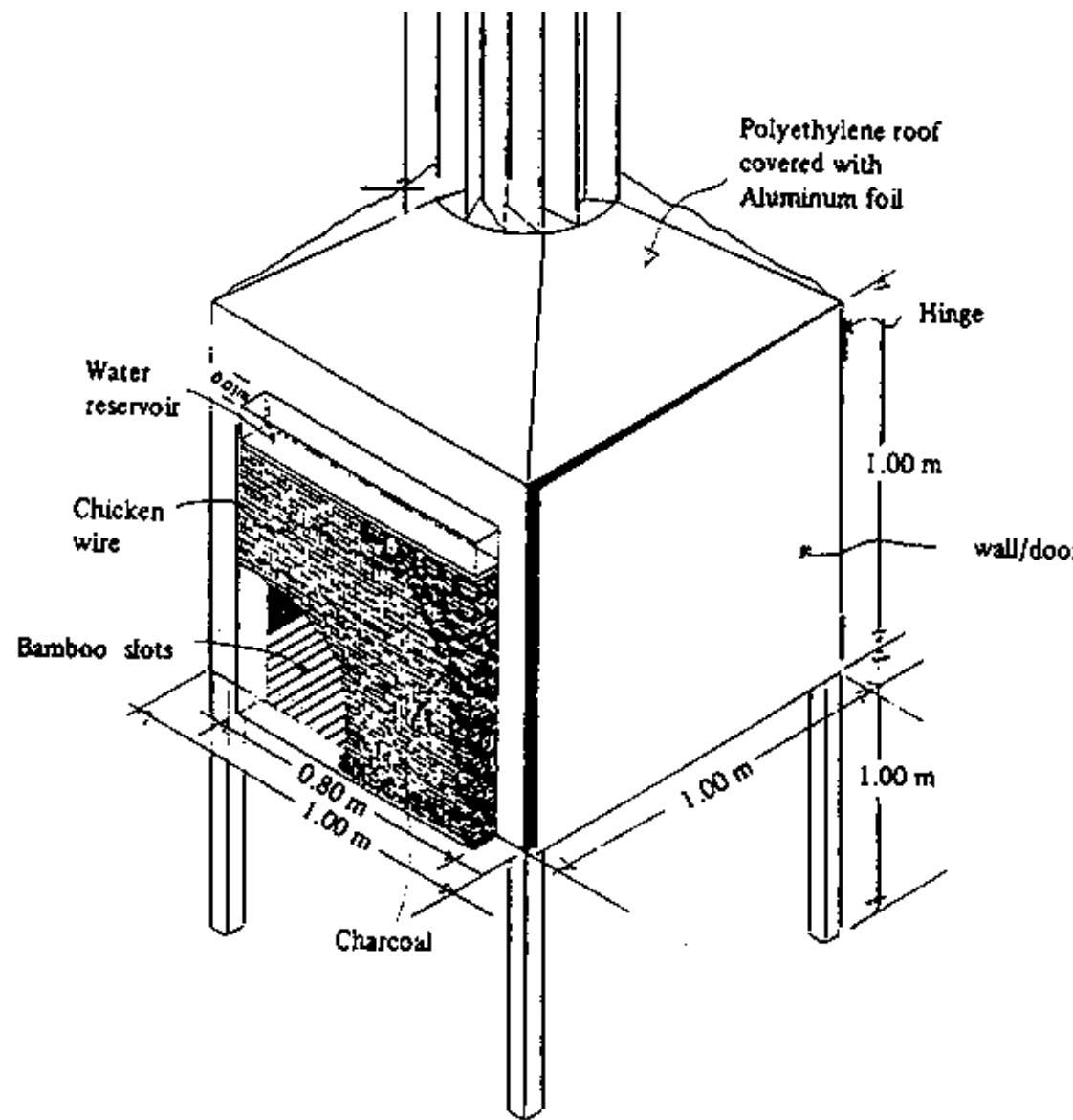


Source: Thompson, J. F. and Kasmire, R.F. 1981. An evaporative cooler for vegetable crops. California Agriculture, March-April: 20-21.

Source: Mitchell in Kader, 1992. Postharvest Technology of Horticultural Crops. University of California, Division of Agriculture and Natural Resources, Publication 3311. 296 pp.

The evaporative cooler shown below is equipped with a vortex wind machine. Chicken wire was used to construct two thin boxes on opposite sides of the cooler that hold wet chunks of charcoal or straw. Water is dripped onto the charcoal or straw, and the wind turns the turbine, sucking moist, cool air through the load of produce inside the cooler. When using this cooler, temperatures are reduced to 3 to 5 C (6 to 10 F) below ambient air temperature, while relative humidity is about 85 %.

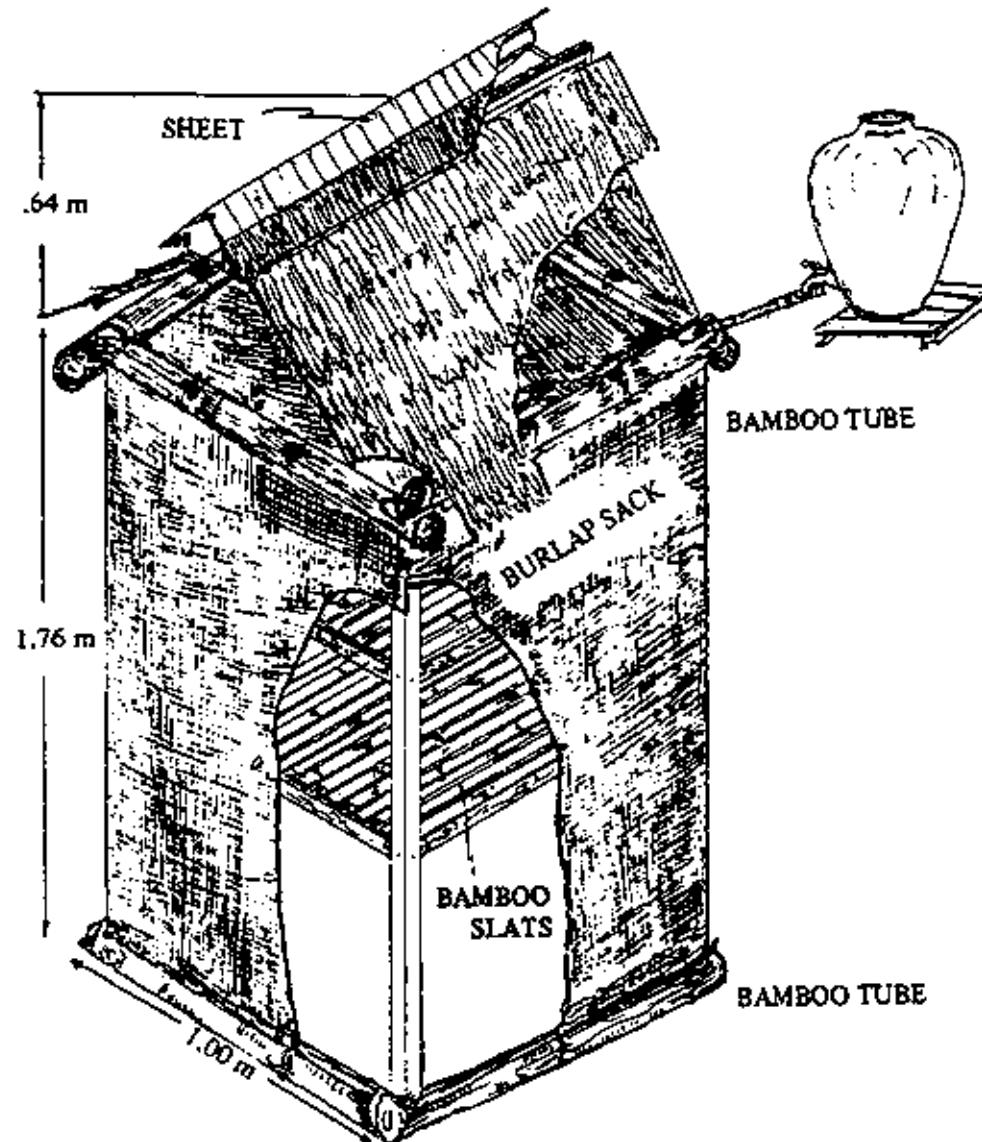




Source: Redulla, C.A. et al. 1984. Temperature and relative humidity in two types of evaporative coolers. Postharvest Research Notes, 1(1): 25-28.

Evaporative coolers can be constructed from simple materials, such as burlap and bamboo. The "drip cooler" shown here operates solely through the process of evaporation, without the use of a fan. Cooling will be enhanced if the unit is kept shaded and used in a well ventilated area.

Drip cooler:

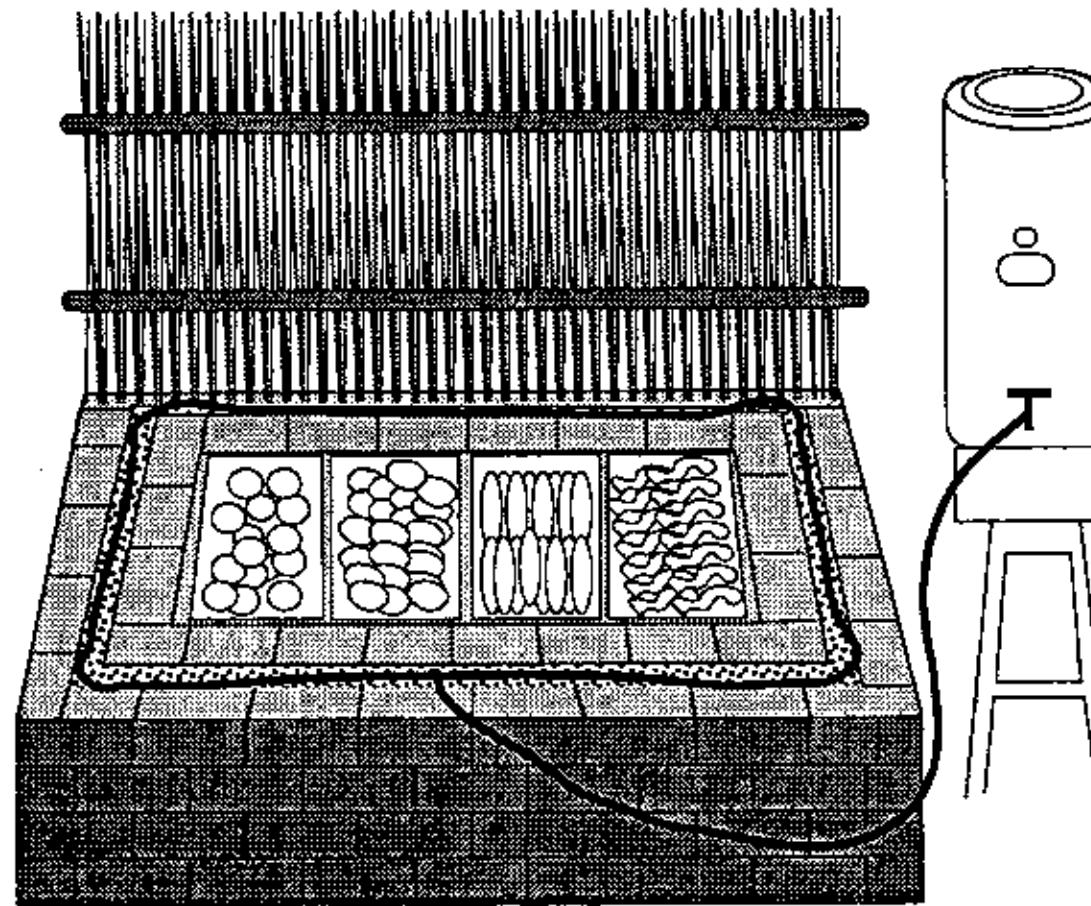


Source: Redulla, C.A. et al. 1984. Keeping perishables without refrigeration: use of a drip cooler. *Appropriate Postharvest Technology* 1(2): 13-15.

The low cost cooling chamber illustrated below is constructed from bricks. The cavity between the walls is filled with sand and the bricks and sand are kept saturated with water. Fruits and vegetables are loaded inside, and the entire chamber is covered with a rush mat, which is also kept moist. Since a relatively large amount of materials are required to construct this cold storage chamber, it may be useful only when handling high value products.

During the hot summer months in India, this chamber is reported to maintain an inside temperature between 15 and 18 C (59 and 65 F) and a relative humidity of about 95%.

Improved Zero-Energy Cool Chamber:

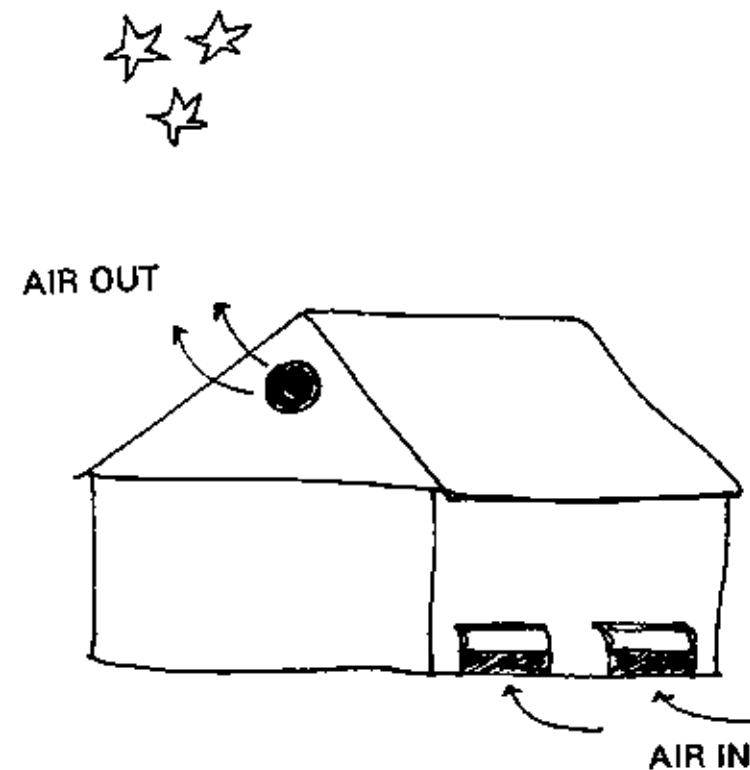


Source: Roy S.K. 1989. Postharvest technology of vegetable crops in India. Indian Horticulture. Jan-June: 7678.

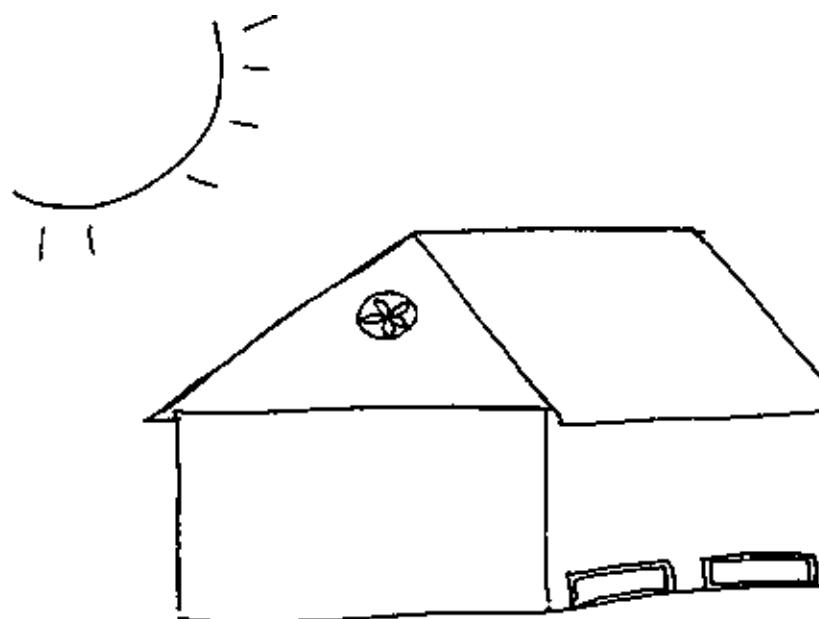
Night air ventilation

Storage structures can be cooled using night air if the difference in day and night temperature is relatively large (Thompson in Kader, 1992). The storage facility should be well insulated and vents should be located at ground level. Vents can be opened at night, and fans can be used to pull cool air through the storeroom. The structure will best maintain cool temperatures during the heat of the day if it is well insulated and vents are closed early in the morning.

Vents open:



Vents closed:



Chilling injury

Fruit and vegetable crops often are susceptible to chilling injury when cooled below 13 to 16 C (55 to 60 F). Chilling injury reduces the quality of the product and shortens shelf life. The table below provides some examples of the symptoms of chilling injury in a variety of crops. Symptoms often appear only after the commodity is returned to warmer temperatures, as when marketed.

Fruits and vegetables susceptible to chilling injury when stored at moderately low but nonfreezing temperatures

Commodity	Approximate lowest safe temperature		Character of injury when stored between 0°C and safe temperature ¹
	°C	°F	
Apples-certain cultivars	22-3	36-38	Internal browning, brown core, soggy breakdown, soft scald
Asparagus	0-2	32-36	Dull, gray-green, and limp tips
Avocados	24.5-13	40-55	Grayish-brown discoloration of flesh
Bananas, green or ripe	211.5-13	53-56	Dull color when ripened
Beans (lima)	1-4.5	34-40	Rusty brown specks, spots, or areas
Beans (snap)	27	45	Pitting and russetting
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
Guavas	24.5	40	Pulp injury, decay
Grapefruit	210	50	Scald, pitting, watery breakdown
Jicama	13-18	55-65	Surface decay, discoloration
Lemons	211-13	52-55	Pitting, membranous staining, red blotch
Limes	7-9	45-48	Pitting, turning tan with time
Mangos	210-13	50-55	Grayish scaldlike discoloration of skin, uneven ripening
Melons			
Cantaloups	22-5	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	23	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	27-10	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 hardshell 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	27-10	45-50	Watersoaking and softening, decay
Mature-green	13	55	Poor color when ripe, alternaria rot

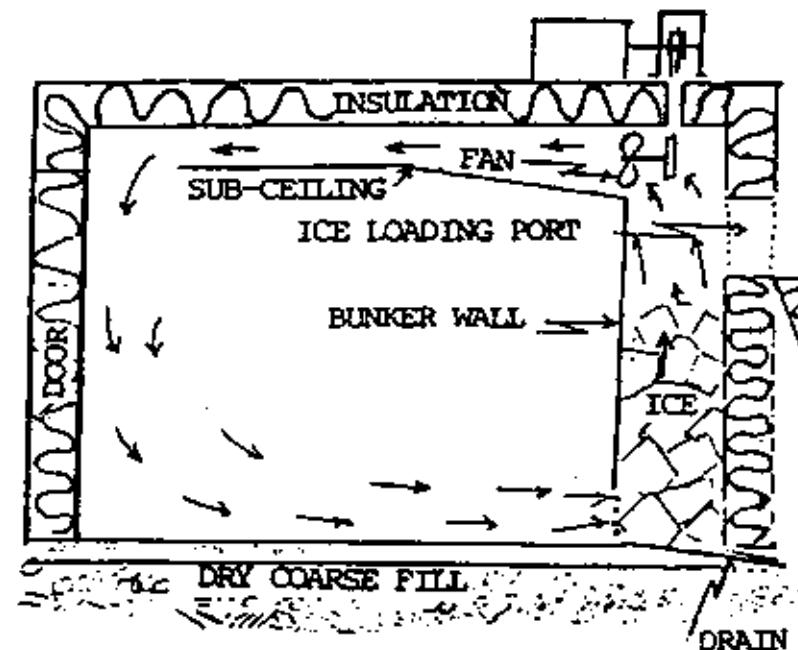
¹ Symptoms often apparent only after removal to warm temperatures, as in marketing.

Source: Harderburg, R.E., A. E. Watada, and C-Y. Wang 1986. The Commercial Storage of Fruits Vegetables, and Florist and Nursery Stocks. USDA, Agricultural Handbook No. 66.

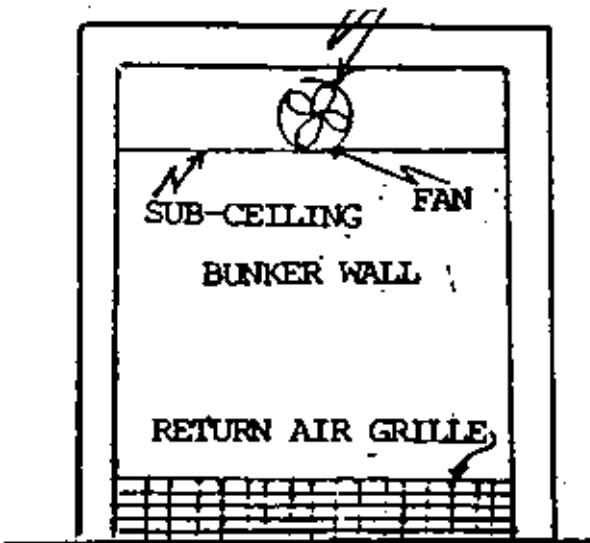
Use of ice

Ice can be used as a bunker source of refrigeration (used by passing air through a bank of ice and then through the commodity) or as top ice (laid directly in contact with the product). Ice can cool a commodity only if it melts, so good ventilation is necessary for effective cooling.

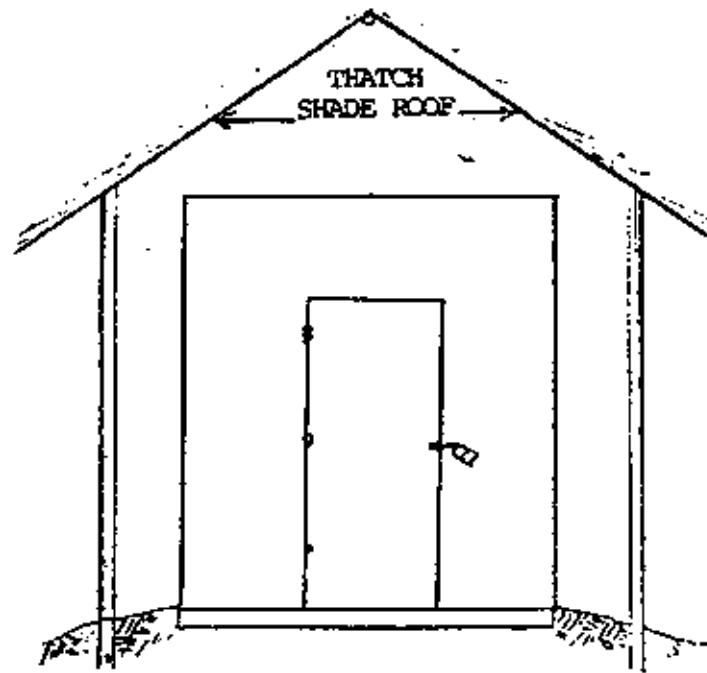
Longisection - a gasoline or diesel engine MUST be mounted outside



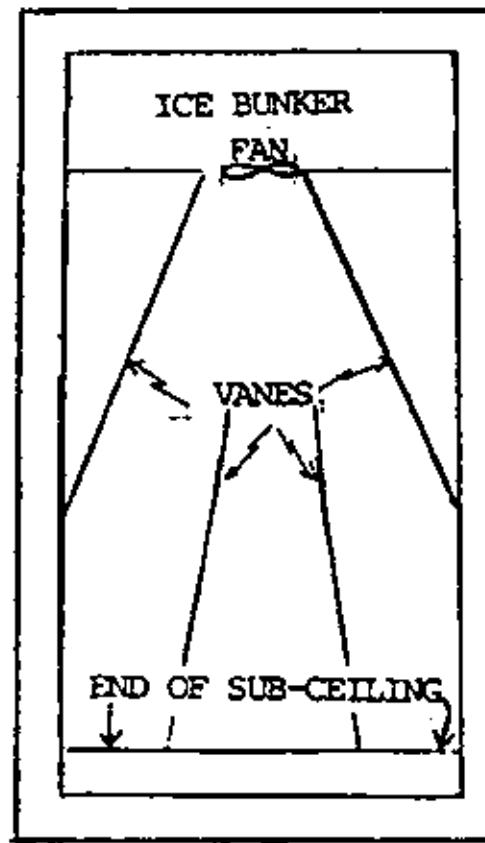
Back of Room - an electric fan motor is commonly mounted inside the cold room, fan capacity (CFM= cubic feet/min) should at least equal the empty volume of the room (i.e. $12 \times 8 \times 8 = 768$ cu ft., so, 768 CFM is minimal. more is better. for this room)



Front elevation

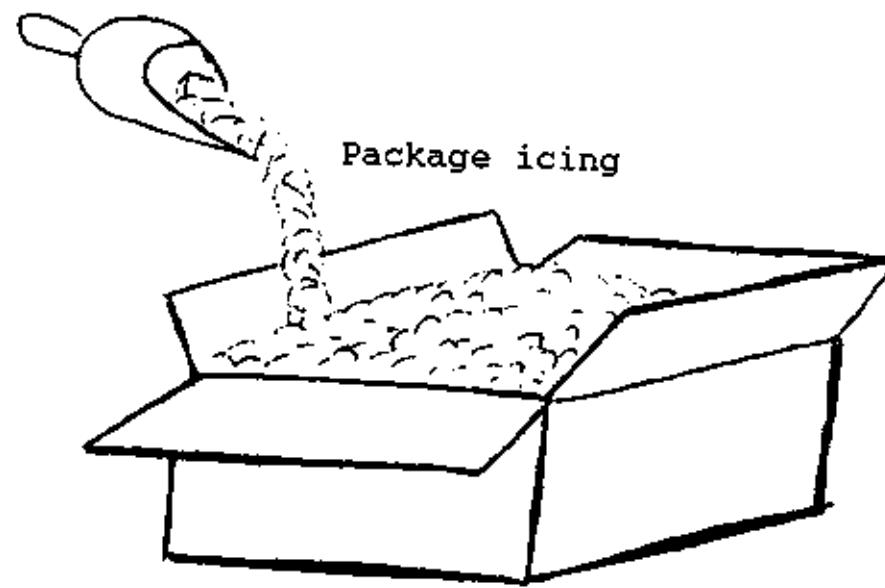


Top view - vanes over the sub-ceiling greatly improve air distribution and hence cooling



Source: Grierson, W. 1987. Postharvest Handling Manual Commercialization of Alternative Handling Crops Project. The Belize Agribusiness Company./Chenomics International/USAID.

Crushed or flaked ice for package icing can be applied directly or as a slurry in water. The use of ice to cool produce provides a high relative humidity environment around the product. Package ice can be used only with water tolerant, non-chilling sensitive products (such as: carrots, sweet corn, cantaloupes, escarole, lettuce, spinach, radishes, broccoli, green onions). and with water tolerant packages (waxed fiberboard, plastic or wood).



Top ice is used for certain products during transport to help maintain a high relative humidity. Top ice can be used only with water tolerant, non-chilling sensitive products (such as: carrots, sweet corn, cantaloupes, escarole, lettuce, spinach, radishes, broccoli, green onions), and with water tolerant packages (waxed fiberboard, or wood).

Top-ice on loads should be applied in rows rather than a solid mass. It is important not to block air circulation inside the transport vehicle.

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
turnips with tops	leeks
watercress	mustard greens
radish greens	parsnips
spinach	radishes
turnip greens	rutabagas
turnips	

Sources: Thompson, J.F. 1992. Storage Systems, pp. 69 - 78. In: Kader, A.A. (ed). Postharvest Technology of Horticultural Crops. Univ. of California, Div. of Agriculture and Natural Resources, Publication 3311.

McGregor, B.M. 1989. Tropical Products Transport Handbook. USDA, Office of Transportation, Agricultural Handbook Number 668.

Alternative methods of cooling

Radiant Cooling

Radiant cooling can be used to lower the air temperature in a storage structure if a solar collector is connected to the ventilation system of the building. By using the solar collector at night, heat will be lost to the environment. Temperatures inside the structure of 4 C (about 8 F) less than night temperature can be achieved.

Use of Well Water

Well water is often much cooler than air temperature in most regions of the world. The water temperature of a deep well tends to be in the same range as the average air temperature of the same locality. Well water can be used for hydro-cooling and as a spray or mist to maintain high relative humidity in the storage environment.

High Altitude Storage

As a rule of thumb, air temperatures decrease by 10 C (18 F) for every one kilometer increase in altitude. If handlers have an option to pack and/or store commodities at higher altitude, costs could be reduced. Cooling and storage facilities operated at high altitude would require less energy than those at sea level for the same results.

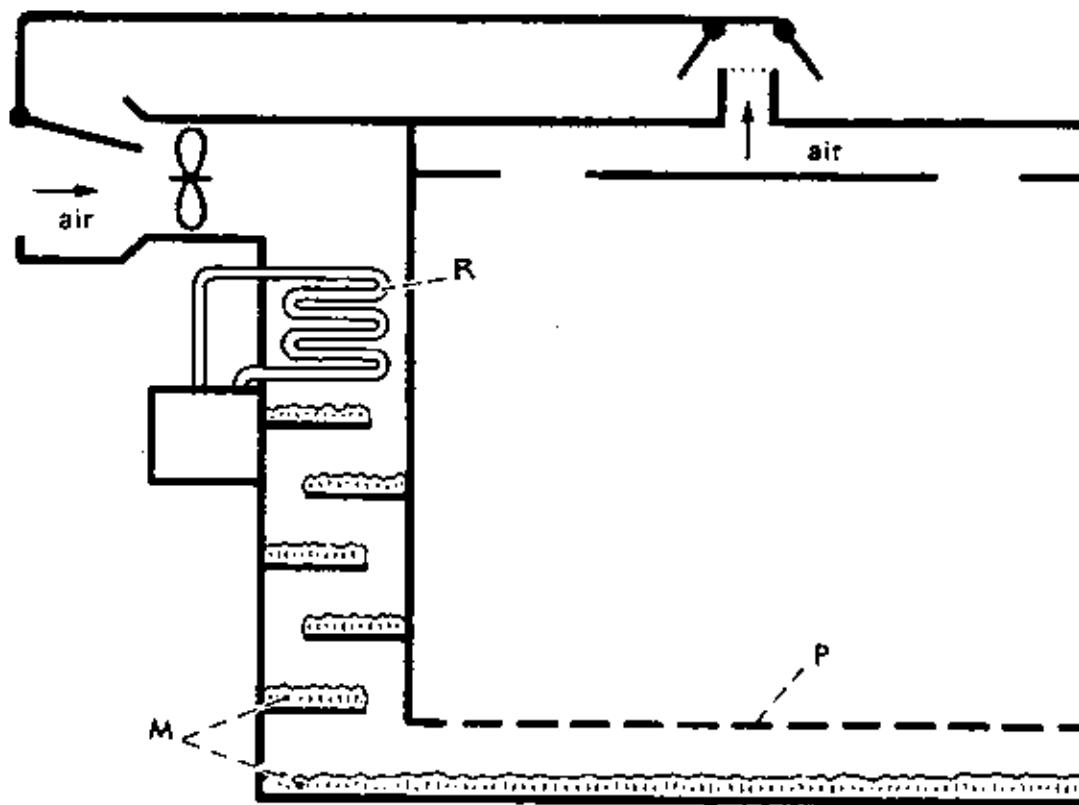
Sources: Thompson, J.F. 1992. Storage Systems, pp. 69 - 78. In: Kader, A.A. (ed). Postharvest Technology of Horticultural Crops. Univ. of California, Div. of Agriculture and Natural Resources, Publication 3311.

Increasing relative humidity

Refrigerated air tends to be lower in relative humidity than is beneficial for storage of most horticultural crops. The simplest method of increasing relative humidity of the storage air is to wet the floor of the room or mist the storage containers with cold water and allow the water to evaporate.

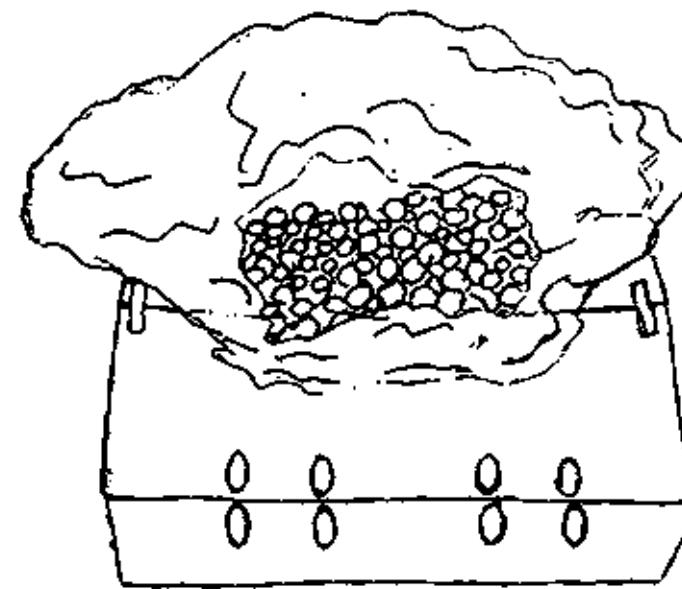
For a more permanent system of high relative humidity in the storage environment, moisture can be added to the refrigerated air. A fan draws air past the refrigerator's evaporator coils (R) then past wet moss or straw (M). The moist air is then pulled into the store-room through a perforated wall (P).

Wet moss as a moisture source inside a refrigerated storeroom:



Source: Lopez, E.G. 1983. Conservación de la Producción Agrícola. Barcelona Editorial Aedos. 188 pp.

Using a polyethylene liner in a fiberboard carton can help protect produce and reduce water loss in commodities such as cherries, nectarines, kiwifruits, bananas and herbs. Water vapor given off by the product is contained within the inner, increasing the RH around the product. The liner can also reduce abrasion damage that results from fruit rubbing against the inside of the box.





Section 7: Storage of horticultural crops

[Recommended storage temperatures](#)

[Compatibility groups for storage of fruits, vegetables and floral crops](#)

[Storage practices](#)

[Storage structures](#)

[Dried and bulb crops](#)

[Root and tuber crops](#)

[Potatoes](#)

[Controlled atmosphere \(C.A.\) storage](#)

[Relative perishability and storage life of fresh horticultural crops](#)

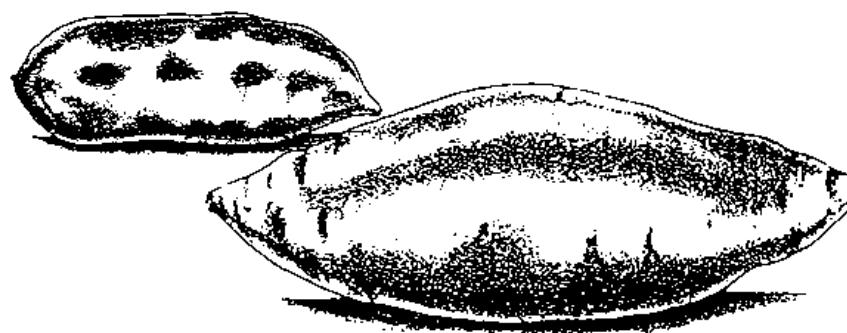
If produce is to be stored, it is important to begin with a high quality product. The lot of produce must not contain damaged or diseased units, and containers must be well ventilated and strong enough to withstand stacking. In general proper storage practices include temperature control, relative humidity control, air circulation and maintenance of space between containers for adequate ventilation, and avoiding incompatible product mixes.

Commodities stored together should be capable of tolerating the same temperature, relative humidity and level of ethylene in the storage environment. High ethylene producers (such as ripe bananas, apples, cantaloupe) can stimulate physiological changes in ethylene sensitive commodities (such as lettuce, cucumbers, carrots, potatoes, sweet potatoes) leading to often undesirable color, flavor and texture changes.

Temperature management during storage can be aided by constructing square rather than rectangular buildings. Rectangular buildings have more wall area per square feet of storage space, so more heat is conducted across the walls, making them more expensive to cool. Temperature management can also be aided by shading buildings, painting storehouses white or silver to help reflect the sun's rays, or by using sprinkler systems on the roof of a building for evaporative cooling. The United Nations' Food and Agriculture Organization (FAO) recommends the use of ferrocement for the construction of storage structures in tropical regions, with thick walls to provide insulation. Facilities located at higher altitudes can be effective, since air temperature decreases as altitude increases. Increased altitude therefore can make evaporative cooling, night cooling and radiant cooling more feasible. Underground storage for citrus crops is common in Southern China, while in Northwest China, apples are stored in caves (Liu, 1988). This system was widely used in the U.S. during the early part of this century.

Certain commodities, such as onions and garlic, store better in lower relative humidity environments. Curing these crops and allowing the external layers of tissue to dry out prior to handling and storage helps to protect them from further water loss.

The air composition in the storage environment can be manipulated by increasing or decreasing the rate of ventilation (introduction of fresh air) or by using gas absorbers such as potassium permanganate or activated charcoal. Large-scale controlled or modified atmosphere storage requires complex technology and management skills, however, some simple methods are available for handling small volumes of produce.



Recommended storage temperatures

Recommended Temperature and Relative Humidity, and Approximate Transit and Storage Life for Fruits and Vegetable Crops (see Hardenburg et al, 1986 for more complete information on individual crops).

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	4045	95	7-10 days
Beans, lima, in pods	5-6	4143	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	4044	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
Cabbage, late	0	32	98-100	5-6 months
Cactus Leaves	24	3640	90-95	3 weeks
Cactus Pear	24	36-40	90-95	3 weeks
Caimito	3	38	90	3 weeks
Calabaza	10-13	50-55	50-70	2-3 months
Calamondin	9-10	48-50	90	2 weeks
Canistel	13-15	55-60	85-90	3 weeks
Cantaloups (3/4-slip)	2-5	36-41	95	15 days
Cantaloups (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
Currants	-0.5-0	31-32	90-95	1-4 weeks
Custard apples	5-7	41-45	85-90	4-6 weeks
Daikon	0-1	32-34	95-100	4 months
Dates	-18 or 0	0 or 32	75	6-12 months
Dewberries	-0.5-0	31-32	90-95	2-3 days
Durian	4-6	39-42	85-90	6-8 weeks
Eggplants	12	54	90-95	1 week
Elderberries	-0.5-0	31-32	90-95	1-2 weeks
Endive and escarole	0	32	95-100	2-3 weeks
Feijoa	5-10	41-50	90	2-3 weeks
Figs fresh	-0.5-0	31-32	85-90	7-10 days
Garlic	0	32	65-70	6-7 months
Ginger root	13	55	65	6 months
Gooseberries	-0.5-0	31-32	90-95	34 weeks
Granadilla	10	50	85-90	3-4 weeks
Grapefruit, Calif. & Ariz.	14-15	58-60	85-90	6-8 weeks
Grapefruit, Fla. & Texas	10-15	50-60	85-90	6-8 weeks
Grapes, Vinifera	-1 to -0.5	30-31	90-95	1-6 months
Grapes, American	-0.5-0	31-32	85	2-8 weeks
Greens, leafy	0	32	95-100	10-14 days
Guavas	5-10	41-50	90	2-3 weeks
Haricot vert	4-7	4045	95	7-10 days
Horseradish	-1-0	30-32	98-100	10-12 months
Jaboticaba	13-15	55-60	90-95	2-3 days
Jackfruit	13	55	85-90	2-6 weeks
Jaffa orange	8-10	46-50	85-90	8-12 weeks
Japanese eggplant	8-12	46-54	90-95	1 week
Jerusalem Artichoke	-0.5-0	31-32	90-95	+5 months

Jicama	13-18	55-65	65-70	1-2 months
Kale	0	32	95-100	2-3 weeks
Kiwano	10-15	50-60	90	6 months
Kiwifruit	0	32	90-95	3-5 months
Kohlrabi	0	32	98-100	2-3 months
Kumquats	4	40	90-95	2-4 weeks
Langsat	11-14	52-58	85-90	2 weeks
Leeks	0	32	95-100	2-3 months
Lemons	10-13	50-55	85-90	1-6 months
Lettuce	0	32	98-100	2-3 weeks
Limes	9-10	48-50	85-90	6-8 weeks
Lo bok	0-1.5	32-35	95-100	24 months
Loganberries	-0.5-0	31-32	90-95	2-3 days
Longan	1.5	35	90-95	3-5 weeks
Loquats	0	32	90	3 weeks
Lychees	1.5	35	90-95	3-5 weeks
Malanga	7	45	70-80	3 months
Mamey	13-15	55-60	90-95	2-6 weeks
Mangoes	13	55	85-90	2-3 weeks
Mangosteen	13	55	85-90	2-4 weeks
Melons:				
Casaba	10	50	90-95	3 weeks
Crenshaw	7	45	90-95	2 weeks
Honeydew	7	45	90-95	3 weeks
Persian	7	45	90-95	2 weeks
Mushrooms	0	32	95	34 days
Nectarines	-0.5-0	31-32	90-95	2-4 weeks
Okra	7-10	45-50	90-95	7-10 days
Olives, fresh	5-10	41-50	85-90	+6 weeks
Onions, green	0	32	95-100	34 weeks
Onions, dry	0	32	65-70	1-8 months
Onion sets	0	32	65-70	6-8 months
Oranges, Calif. & Ariz.	3-9	3848	85-90	3-8 weeks
Oranges, Fla. & Texas	0-1	32-34	85-90	8-12 weeks
Papayas	7-13	45-55	85-90	1-3 weeks
Passionfruit	7-10	45-50	85-90	3-5 weeks
Parsley	0	32	95-100	2-2.5 months
Parsnips	0	32	95-100	+6 months
Peaches	-0.5-0	31-32	90-95	2-4 weeks
Pears	-1.5 to - 0.5	29-31	90-95	2-7 months
Peas, green	0	32	95-98	1-2 weeks
Peas, southern	+5	4041	95	6-8 days
Pepino	4	40	85-90	1 month
Peppers, Chili (dry)	0-10	32-50	60-70	6 months
Peppers, sweet	7-13	45-55	90-95	2-3 weeks
Persimmons, Japanese	-1	30	90	34 months
Pineapples	7-13	45-55	85-90	24 weeks
Plantain	13-14	55-58	90-95	1-5 weeks

Plums and prunes	-0.5-0	31-32	90-95	2-5 weeks
Pomegranates	5	41	90-95	2-3 months
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	4548	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
Ugli fruit	4	40	90-95	2-3 weeks
Waterchestnuts	0-2	32-36	98-100	1-2 months
Watercress	0	32	95-100	2-3 weeks
Watermelons	10-15	50-60	90	2-3 weeks
White sapote	19-21	67-70	85-90	2-3 weeks
White asparagus	0-2	32-36	95-100	2-3 weeks
Winged bean	10	50	90	4 weeks
Yams	16	61	70-80	6-7 months
Yucca root	0-5	32-41	85-90	1-2 months

Source: McGregor, B.M. 1989. Tropical Products Transport Handbook. USDA Office of Transportation, Agricultural Handbook 668.

Compatibility groups for storage of fruits, vegetables and floral crops

Group 1: Fruits and vegetables, 0 to 2°C (32 to 36°F), 90-95% relative humidity. Many products in this group produce ethylene.

apples	grapes (without sulfur dioxide)	parsnips
apricots		peaches
Asian pears	horseradish	pears
Barbados cherry	kohlrabi	persimmons
beets, topped	leeks	plums
berries (except cranberries)	longan	pomegranates
cashew apple	loquat	prunes
cherries	mushrooms	radishes
coconuts	nectarines	rutabagas
figs (not with apples)	oranges* (Florida and Texas)	turnips

*Citrus treated with biphenyl may give odors to other products

Group 2: Fruits and vegetables, 0 to 2°C (32 to 36°F), 95-100% relative humidity. Many products in this group are sensitive to ethylene.

Amaranth*	corn, sweet*	parsley*
anise	daikon*	parsnips*
artichokes*	endive*	peas*
asparagus	escarole*	pomegranate
bean sprouts	grapes (without sulfur dioxide)	raddichio
beets*		radishes*
Belgian endive	horseradish	rhubarb
berries (except cranberries)	Jerusalem artichoke	rutabagas*
	Kiwifruit	salsify
bok choy	kohlrabi*	scorzonera
broccoli*	leafy greens	snow peas
brussels sprouts*	leeks' (not with figs or grapes)	spinach*
cabbage*		turnips*
carrots*	lettuce	waterchestnut
cauliflower	lo bok	watercress*
celeriac*	mushrooms	
celery*	onions, green* (not with figs, grapes, mushrooms, rhubarb, or corn)	
cherries		

* these products can be top-iced

Group 3: Fruits and vegetables, 0 to 2°C (32 to 36°F), 65-75% relative humidity. Moisture will damage these products.

Garlic	onions, dry
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Group 4: Fruits and vegetables, 4.5°C (40°F), 90-95% relative humidity.

cactus leaves	lemons*	tamarillo
cactus pears	lychees	tangelos*
caimito	kumquat	tangerines*
cantaloupes**	mandarin*	ugli fruit*
clementine	oranges (Calif. and Arizona)	yucca root
cranberries	pepino	

- * citrus treated with biphenyl may give odors to other products.
- ** can be top-iced.

Source: McGregor, B.M. 1989. Tropical Products Transport Handbook. USDA Office of Transportation, Agricultural Handbook 668.

Group 5: Fruits and vegetables, 10°C (50°F), 85-90% relative humidity. Many of these products are sensitive to ethylene. These products also are sensitive to chilling injury.

beans	kiwano	pummelo
calamondin	malanga	squash, summer
chayote	okra	(sot shell)
cucumber	olive	tamarind
eggplant	peppers	taro root
haricot vert	potatoes, storage	

Group 6: Fruits and vegetables, 13 to 15°C (55 to 60°F), 85-90% relative humidity. Many of these products produce ethylene. These products also are sensitive to chilling injury.

atemoya	granadilla	papayas
avocados	grapefruit	passionfruit
babaco	guava	pineapple
bananas	jaboticaba	plantain
bitter melon	jackfruit	potatoes, new
black sapote	langsat	pumpkin
boniato	lemons*	rambutan
breadfruit	limes*	santol
canister	mamey	soursop
carambola	mangoes	sugar apple
cherimoya	mangosteen	squash, winter
coconuts	melons (except cantaloupes)	(hard shell)
feijoa		tomatillos
ginger root		tomatoes, ripe

*citrus treated with biphenyl may give odors to other products

Group 7: Fruits and vegetables, 18 to 21°C (65 to 70°F), 85-90% relative humidity.

jicama	sweetpotatoes*	watermelon*
pears	tomatoes,	white sapote
(for ripening)	mature green	yams*

*separate from pears and tomatoes due to ethylene sensitivity.

Group 8: Flowers and florist greens, 0 to 2°C (32 to 36°F), 90-95% relative humidity.

allium	freesia	peony, tight
aster, China	gardenia	buds
bouvardia	hyacinth	ranunculus
carnation	iris, bulbous	rose
chrysanthemum	lily	squill
crocus	lily-of-the-valley	sweet pea
cymbidium orchid	narcissus	tulip

adiantum (maidenhair)	ground pine	rhododendren
cedar	flex (holly)	salal (lemon leaf)
dagger and wood	juniper	
ferns	mistletoe	vaccinium
galax	mountain-laurel	(huckleberry)
woodwardia fern		

Source: McGregor, B.M. 1989. Tropical Products Transport Handbook. USDA Office of Transportation, Agricultural Handbook 668.

Group 9: Flowers and florist greens, 4.5°C (40°F), 90-95% relative humidity.

acacia	delphinium	orchid,
alstromeria	feverfew	cymbidium
anemone	forget-me-not	ornithogalum
aster, China	foxglove	poppy
buddleia	gaillardia	phlox
calendula	gerbera	primrose
calla	gladiolus	protect
candytuft	gloriosa	ranunculus
clarkia	gypsophilla	snapdragon
columbine	heather	snowdrop
coreopsis	laceflower	statice
cornflower	lilac, forced	stephanotis
cosmos	lupine	stevia
dahlia	marigolds	stock
daisies	mignonette	strawflower
violet	zinnia	
adiantum (maidenhair)	eucalyptus	myrtus (myrtle)
asparagus (plumosa, sprenger)	hedera	philodendren
	flex (holly)	pittosporum
buxus (boxwood)	leatherleaf (baker fern)	pothos
camellia		scotch-broomern
croton	leucothoe, drooping	smilax, southern
dracaena	magnolia	woodwardia fern

Group 10: Flowers and florist greens, 7 to 10°C (45 to 50°F), 90-95% relative humidity.

anemone	eucharis	orchid, cattleya
bird-of-paradise	gloriosa	sweet william
camellia	godeltia	
chamaedora	cordyline (ti)	palm
	podocarpus	

Group 11: Flowers and florist greens, 13 to 15°C (55 to 60°F), 90-95% relative humidity.

anthurium	heliconia	poinsetta
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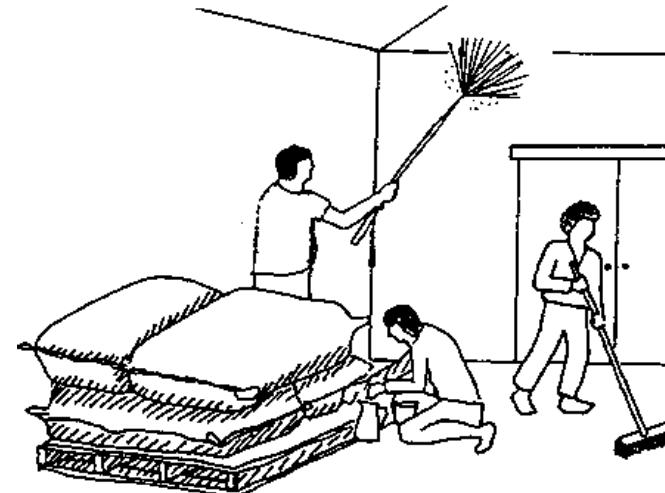
ginger	orchid, vanda	
diffenbachia	stag horn fern	

Source: McGregor, B.M. 1989. Tropical Products Transport Handbook. USDA Office of Transportation, Agricultural Handbook 668.

Storage practices

Inspecting stored produce and cleaning storage structures on a regular basis will help reduce losses by minimizing the buildup of pests and discouraging the spread of diseases.

Inspect produce and clean the storage structure:



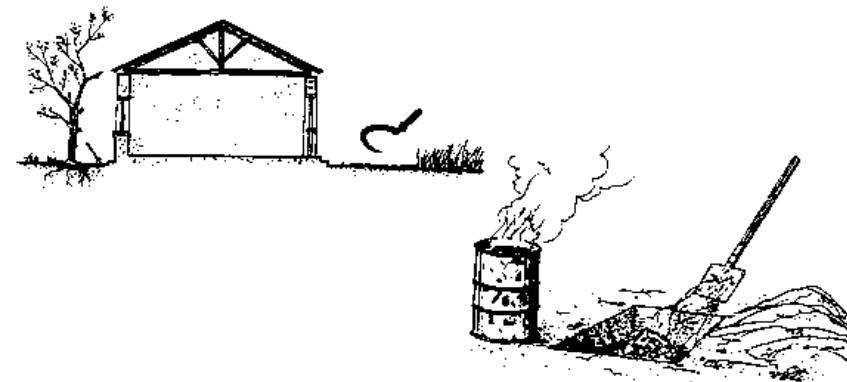
Clean and maintain the storage structure:



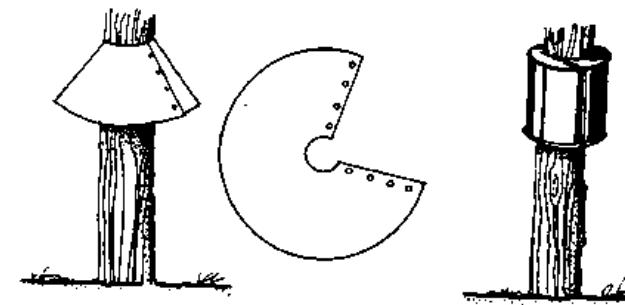
Source: FAO. 1985. Prevention of Post-Harvest Food Losses: A Training Manual. Rome: UNFAO. 120pp.

Storage facilities should be protected from rodents by keeping the immediate area clean, free from trash and weeds. Rat guards can be made from simple materials such as old tin cans or pieces of sheet metal fashioned to fit the extended legs of storage structures. If desired, more elaborate technologies can be used. Concrete floors will help prevent rodent entry, as will screens on windows, vents and drains.

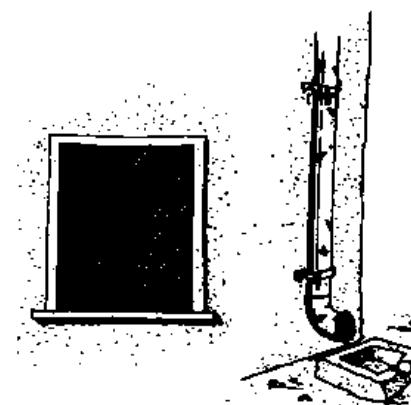
Remove trash and weeds:



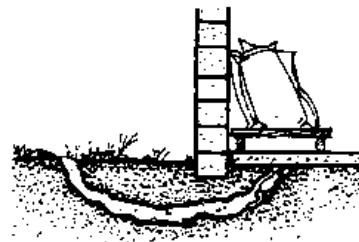
Rat guards:



Screens:



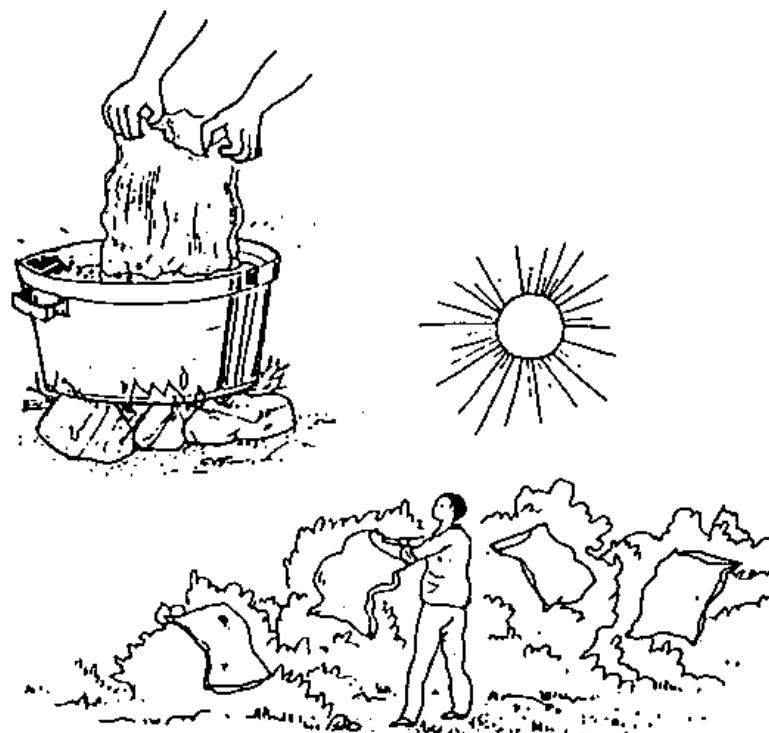
Cement floors:



Source: FAO. 1985. Prevention of Post-Harvest Food Losses: A Training Manual. Rome: UNFAO. 120 pp.

When inspecting stored produce, any spoiled or infected produce should be removed and destroyed. In some cases, produce may still be fit for consumption if used immediately perhaps as animal feed. Reusable containers and sacks should be disinfected in chlorinated or boiling water before reuse.

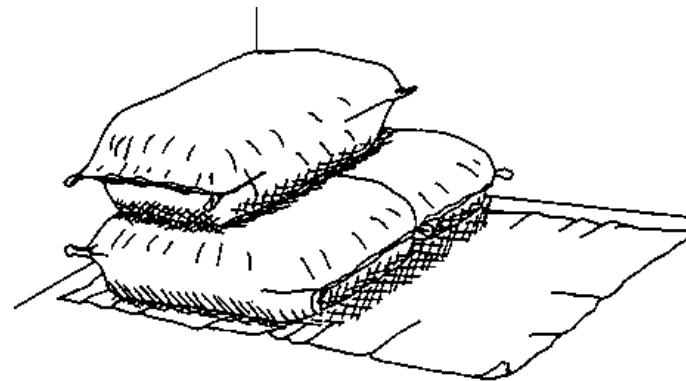
Disinfect used sacks:



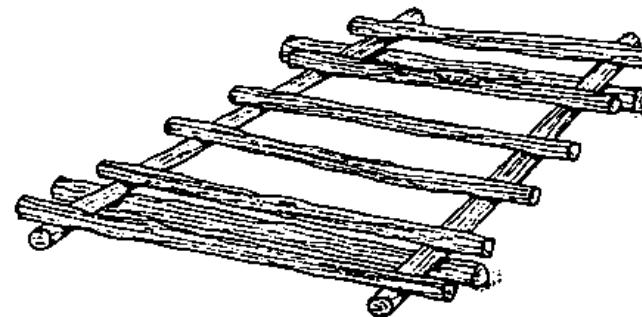
Source: FAO. 1985. Prevention of Post-Harvest Food Losses: A Training Manual. Rome: UNFAO. 120pp.

Placing materials on the floor beneath sacks or cartons of produce prevents dampness from reaching produce suited to dry conditions in storage. This helps to reduce the chance of fungal infection, while also improving ventilation and/or sanitation in the storeroom. Some examples of useful materials follow:

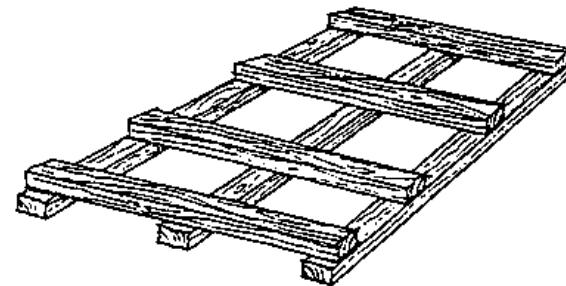
Waterproof sheets:



Poles:



Wooden pallets:

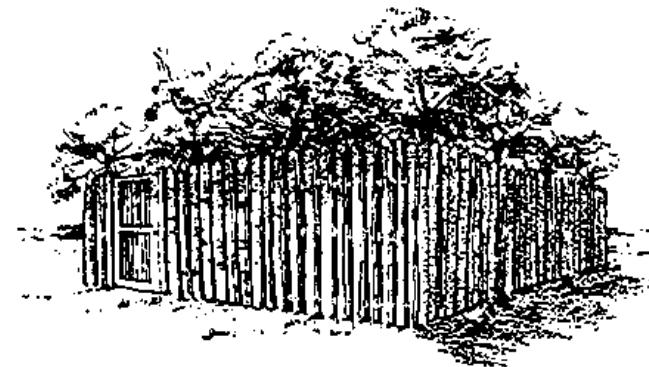


Source: FAO. 1985. Prevention of Post-Harvest Food Losses: A Training Manual. Rome: UNFAO. 120 pp.

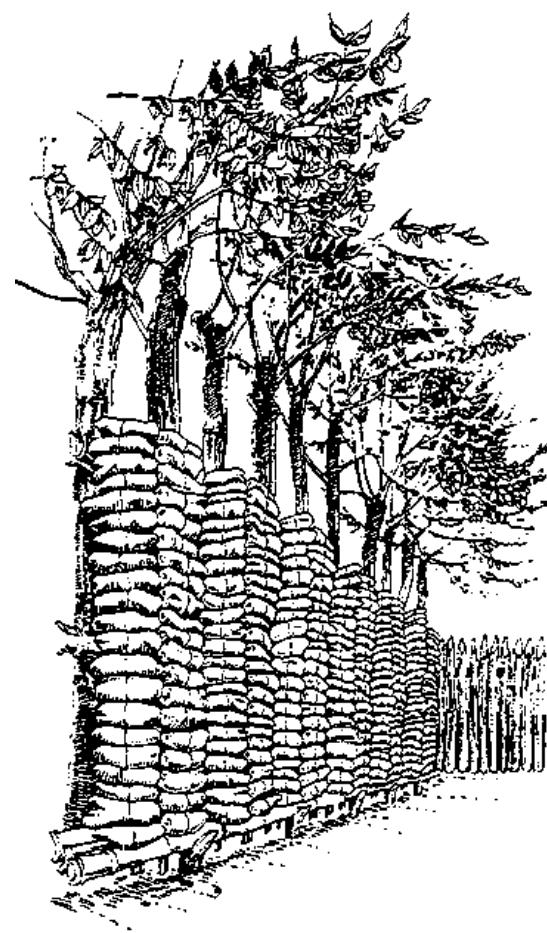
Storage structures

A yam barn is a traditional structure used in West Africa to store yams after curing. Fast-growing, live trees are used to create a rectangular structure, and form the framework of the barn as well as provide shade.

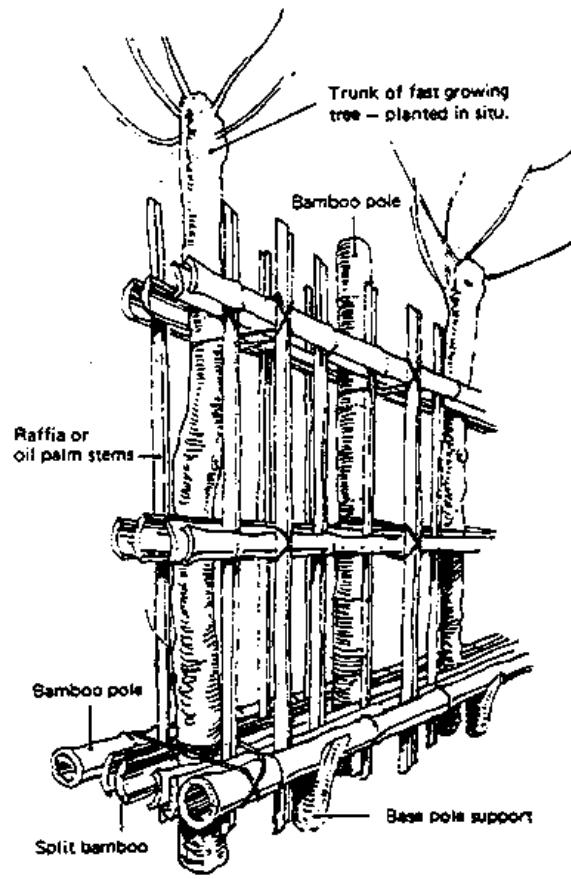
Outside view of barn with 'live' shade



Trunk of fast growing tree-planted in situ.



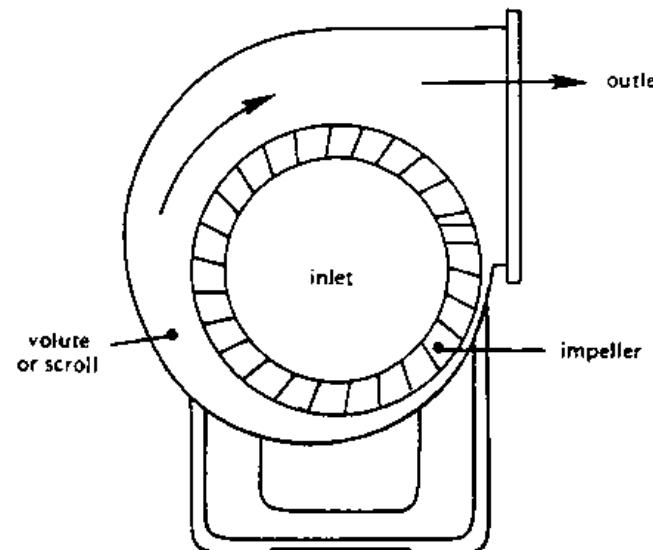
Inside of barn showing tying of yams



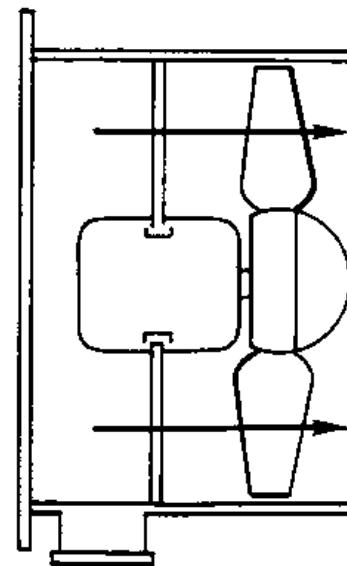
Source: Wilson, J. No date. Careful Storage of Yams: Some Basic Principles to Reduce Losses. London, England: Commonwealth Secretariat/International Institute of Tropical Agriculture.

Storage facilities require adequate ventilation in order to help extend shelf life and maintain produce quality. The following are three types of fans found in common use.

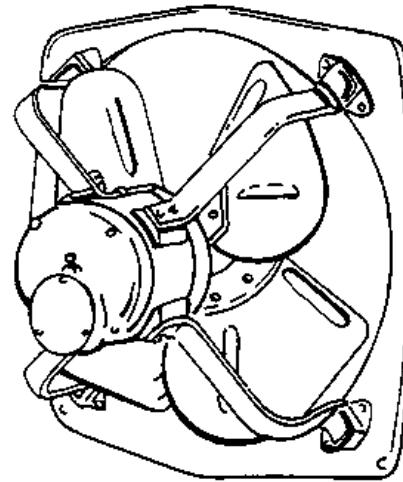
Centrifugal:



Axial flow:

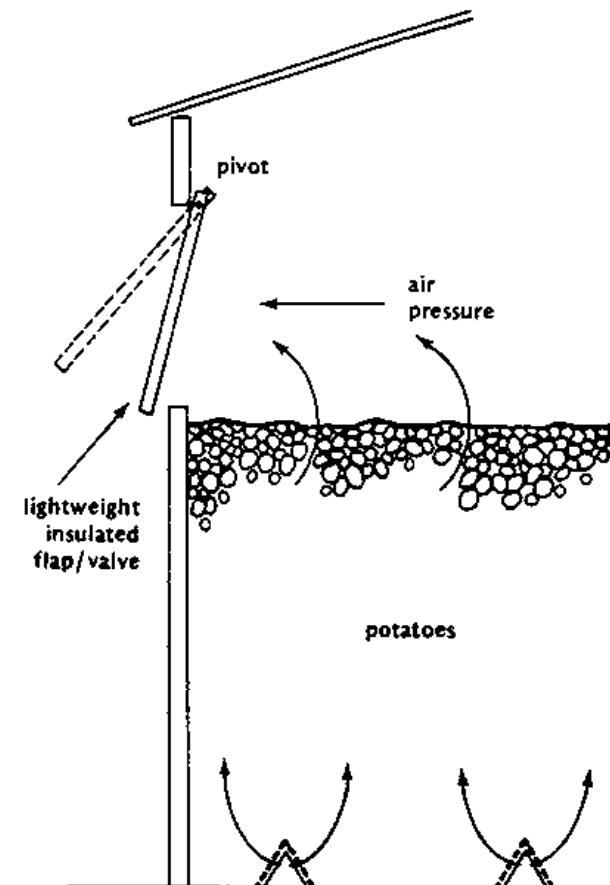


Propeller/expeller:



Source: Potato Marketing Board. No date. Control of Environment. Part 2. London: Sutton Bridge Experiment Station, Report No. 6

Ventilation in storage structures is improved if air inlets are located at the bottom of the store, while air outlets are at the top. A simple, light-proof exhaust vent is a pressure-relief flap.



Source: Potato Marketing Board. No date. Control of Environment. Part 2. London: Sutton Bridge Experiment Station, Report No. 6

Any type of building or facility used for storage of horticultural crops should be insulated for maximum effectiveness. A well insulated refrigerated building will require less electricity to keep produce cool. If the structure is to be cooled by evaporative or night air ventilation, a well insulated building will hold the cooled air longer.

Insulation R-values are listed below for some common building materials. R refers to resistance, and the higher the R-value, the higher the material's resistance to heat conduction and the better the insulating property of the material.

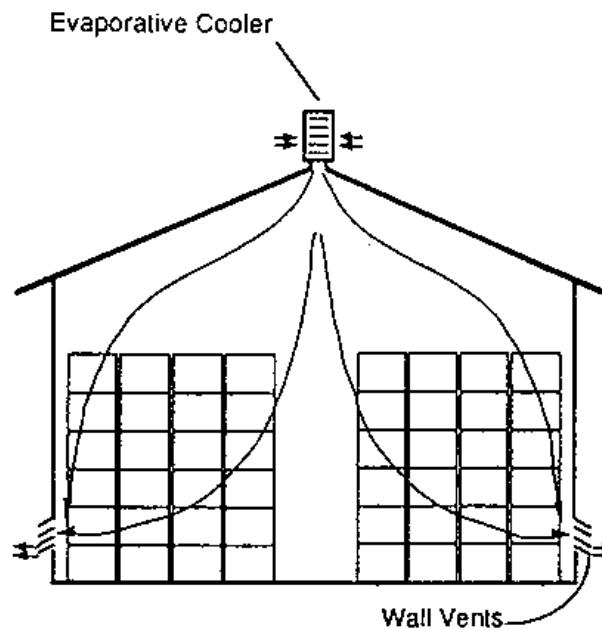
R - Value

Material	1 inch thick
Batt and Blanket Insulation	
Glass wool, mineral wool, or fiberglass	3.50
Fill-Type Insulation	
Cellulose	3.50
Glass or mineral wool	2.50-3.00
Vermiculite	2.20
Wood shavings or sawdust	2.22
Rigid Insulation	
Plain expanded extruded polystyrene	5.00
Expanded rubber	4.55
Expanded polystyrene molded beads	3.57
Aged expanded polyurethane	6.25
Glass fiber	4.00
Polyisocyanurate	8.00
Wood or cane fiber board	2.50
Foamed-in-Place Insulation	
Sprayed expanded urethane	6.25

Building Materials	Full thickness of material
Solid concrete	0.08
8-inch concrete block, open core	1.11
8-inch lightweight concrete block open core	2.00
8-inch concrete block with vermiculite in core	5.03
Lumber, fir or pine	1.25
Metal siding	<0.01
3/8-inch plywood	1.25 - 0.47
1/2-inch plywood	1.25 - 0.62
Masonite particleboard	1.06
25/32-inch insulated sheathing	2.06
1/2-inch Sheetrock	0.45
1/2-inch wood lapsiding	0.81

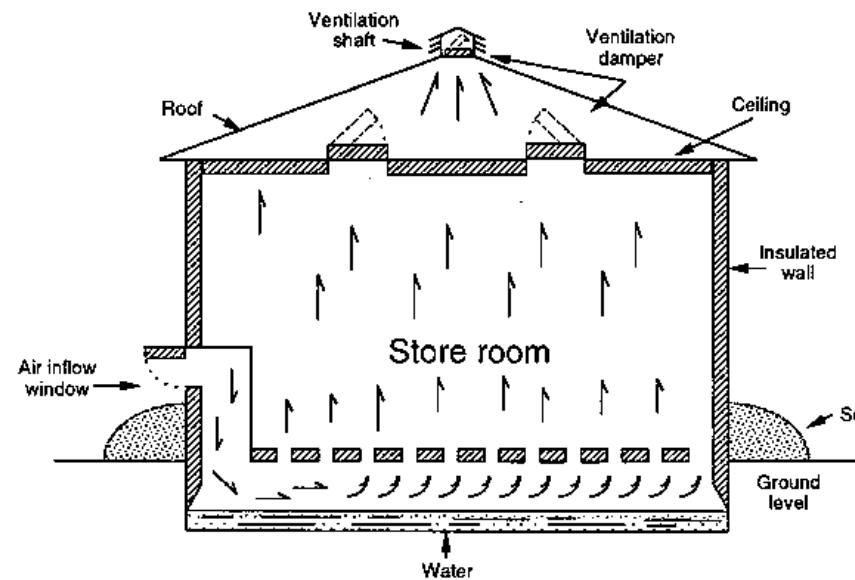
Source: Boyette, M.D. et al. No date. Design of Room Cooling Facilities: Structural and Energy Requirements. North Carolina Agricultural Extension Service.

An evaporative cooler located in the peak of a storage structure can cool an entire room of stored produce such as sweetpotatoes or other chilling sensitive crops. The vents for outside air should be located at the base of the building so that cool air is circulated throughout the room before it can exit.



Source: Thompson, J.F. and Scheuerman, R.W. 1993. Curing and Storing California Sweetpotatoes. Merced County Cooperative Extension, Merced, California 95340

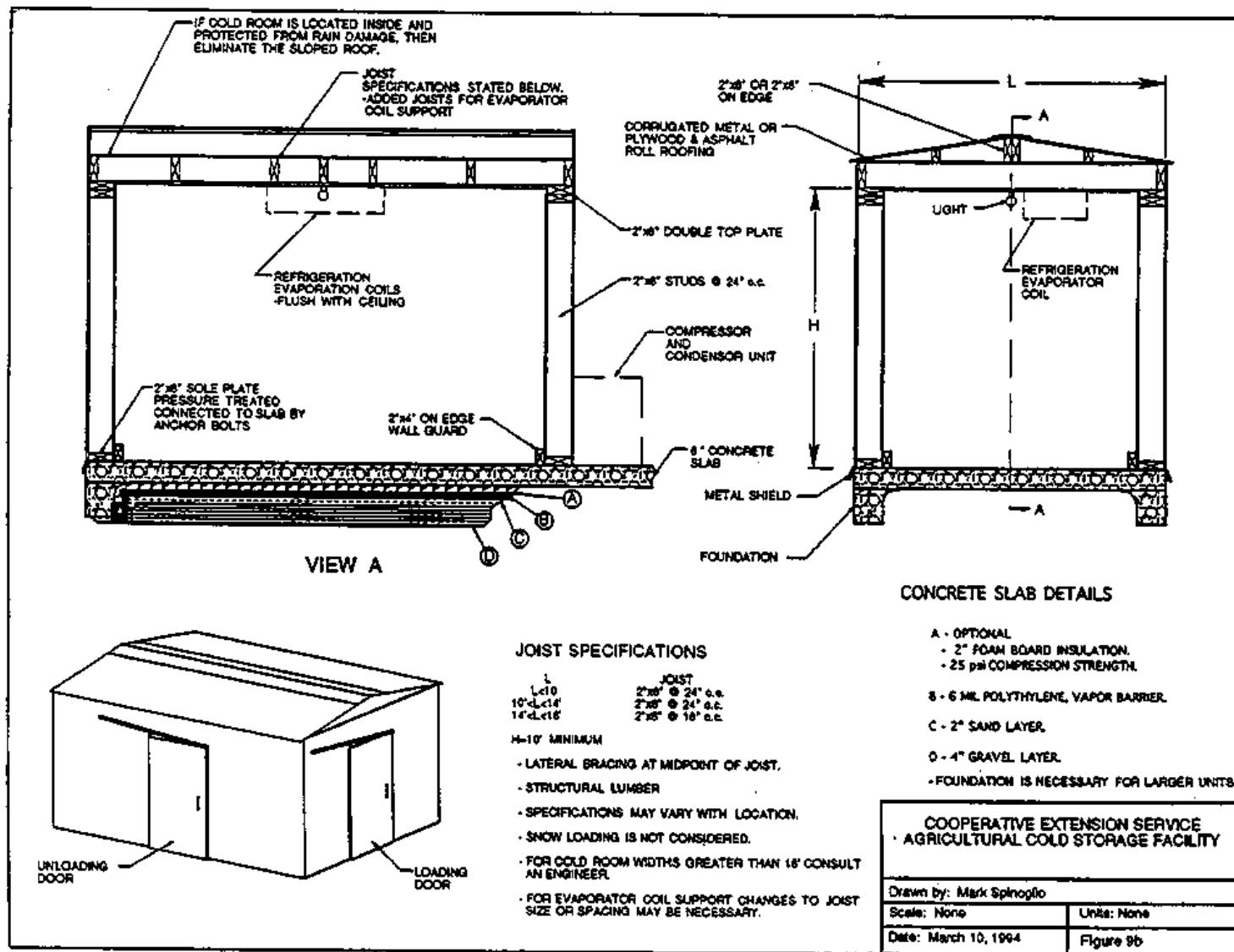
Illustrated below is a cross-sectional view of a storehouse for fruits. This system was officially approved as the standard model for farm-level storehouses by the Ministry of Construction (Korea) in 1983. Note that air inlets are at the base of the building, and the floor is perforated, allowing free movement of air. The entire building is set below ground level taking advantage of the cooling properties of soil.



Source: Seung Koo Lee, 1994. Assoc. Prof., Postharvest Technology Lab., Department of Horticulture, Seoul National University, Suwon 441-744, Korea.

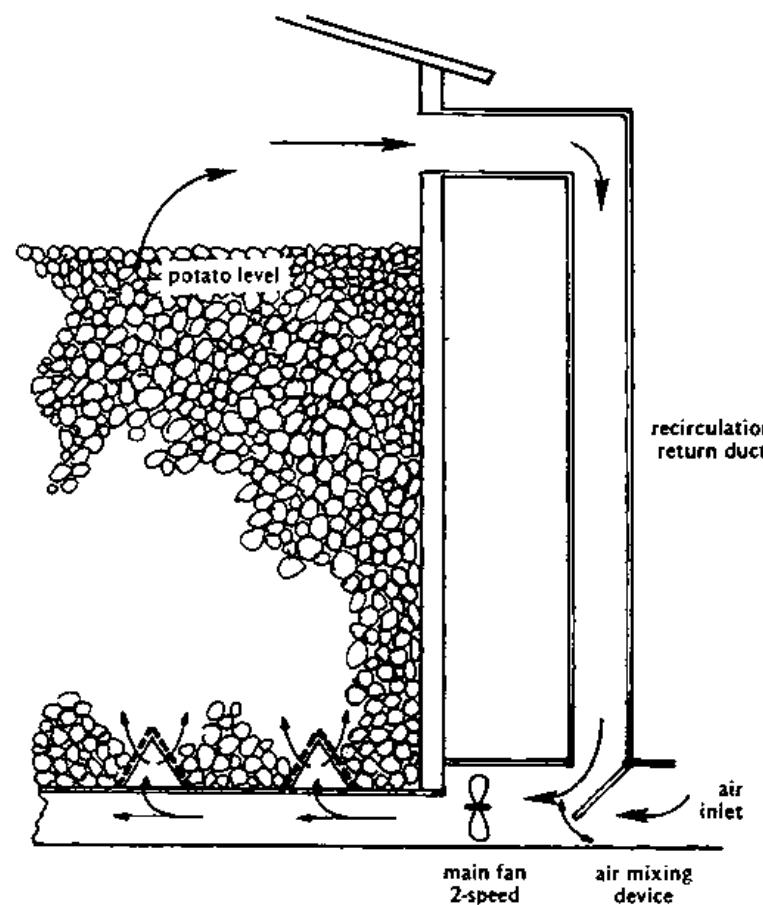
Commercially constructed cold rooms can be quite expensive, but fortunately the small-scale operator has many choices. Cold rooms can be self-constructed, purchased as prefabricated units (new or used), or made from refrigerated transportation equipment such as railway cars, highway vans or marine containers. Illustrated below is the basic plan for a self-built cold room. For more detailed information about

determining the cold room size best suited to your operation, evaluating choices when purchasing or building a cold room, refer to the source below.



Source: Thompson, J.F. and Spinoglio, M. 1994. Small-scale cold rooms for perishable commodities. Family Farm Series, Small Farm Center, University of California, Davis.

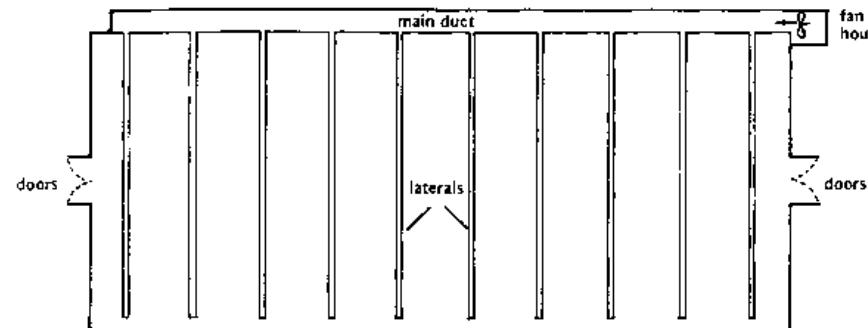
For storage facilities that are refrigerated, using outside air for ventilation is wasteful of energy. For these systems, a simple recirculation system can be designed by adding a fan below floor level and providing a free space at one end of the storeroom for cool air to return to the inlet vents.



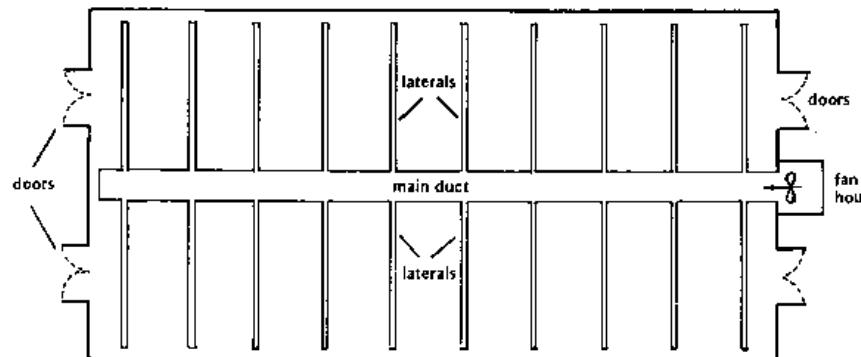
Source: Potato Marketing Board. No date. Control of Environment. Part 2. London: Sutton Bridge Experiment Station, Report No. 6

The proper arrangement of floor vents for air circulation will improve ventilation in the storage house. Lateral ducts should be 2 meters apart when measured from center to center. Air flow velocities from the main duct should be 10 to 13 meters/second.

Longitudinal main duct:



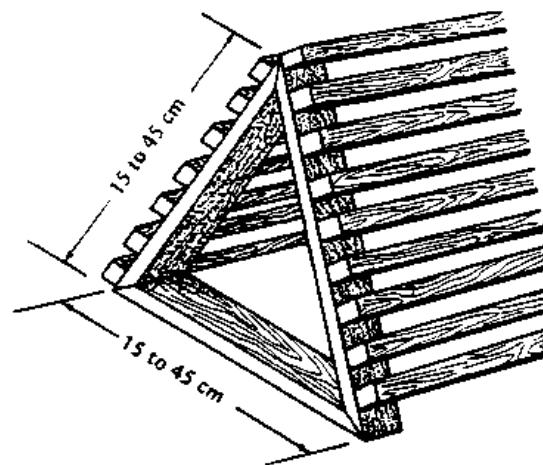
Central main duct:



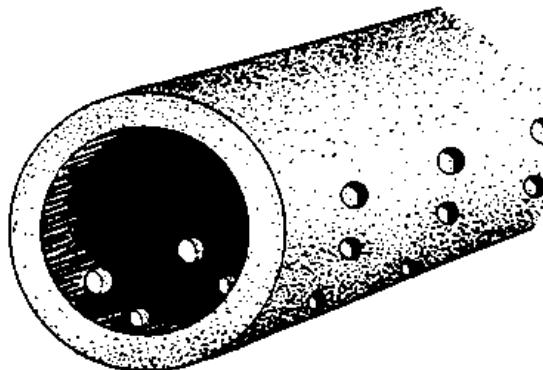
Source: Potato Marketing Board. No date. Control of Environment. Part 2. London: Sutton Bridge Experiment Station, Report No. 6

Lateral ducts can be constructed of a variety of materials. Portable vents can be made from wooden slats, in a triangular, square or rectangular design. A round tube of plastic or clay can be used if holes can be drilled without causing structural damage, or permanent ducts can be constructed below ground, using concrete blocks.

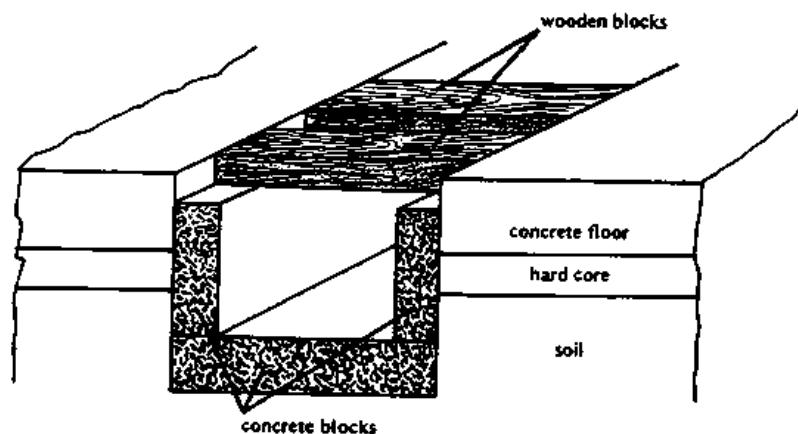
Triangular wooden duct:



Clay pipe duct:



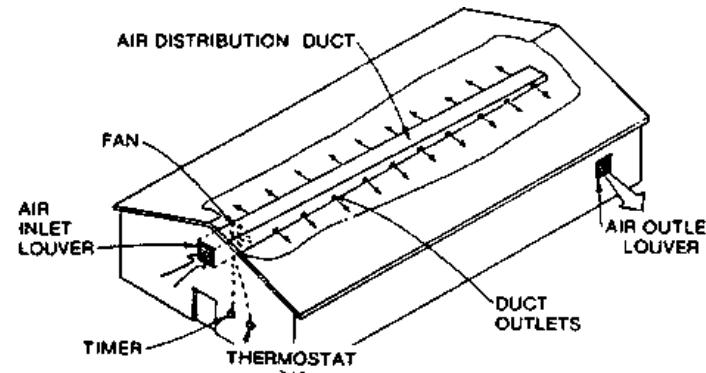
Sunken concrete duct:



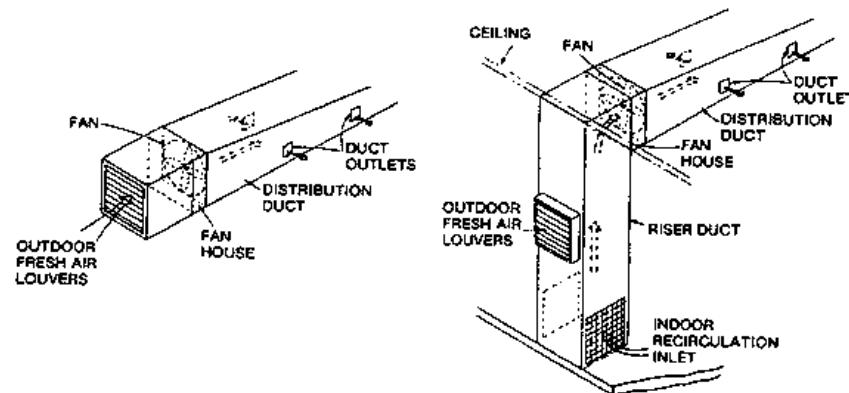
Source: Potato Marketing Board. No date. Control of Environment. Part 2. London: Sutton Bridge Experiment Station, Report No. 6

In cooler regions, suitable storage temperatures can be maintained by bringing outside air into the storage facility. Typical fan installations for a pressurized ventilation system are illustrated below. Overhead distribution of air simplifies the storehouse design. A indoor recirculation inlet can be added if refrigeration is in use. Ducts can be constructed of wood, plastic tubing or any suitable materials.

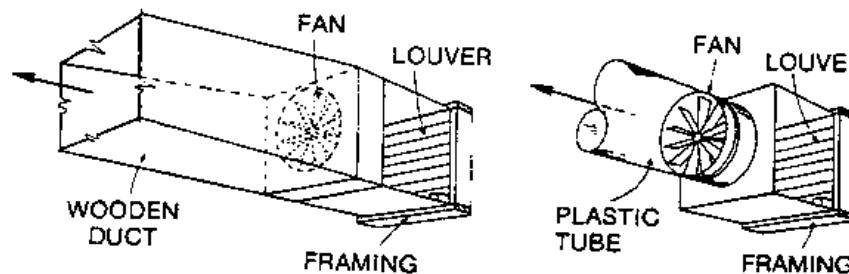
Overhead ventilation distribution system:



Outdoor inlet versus indoor/outdoor inlet:

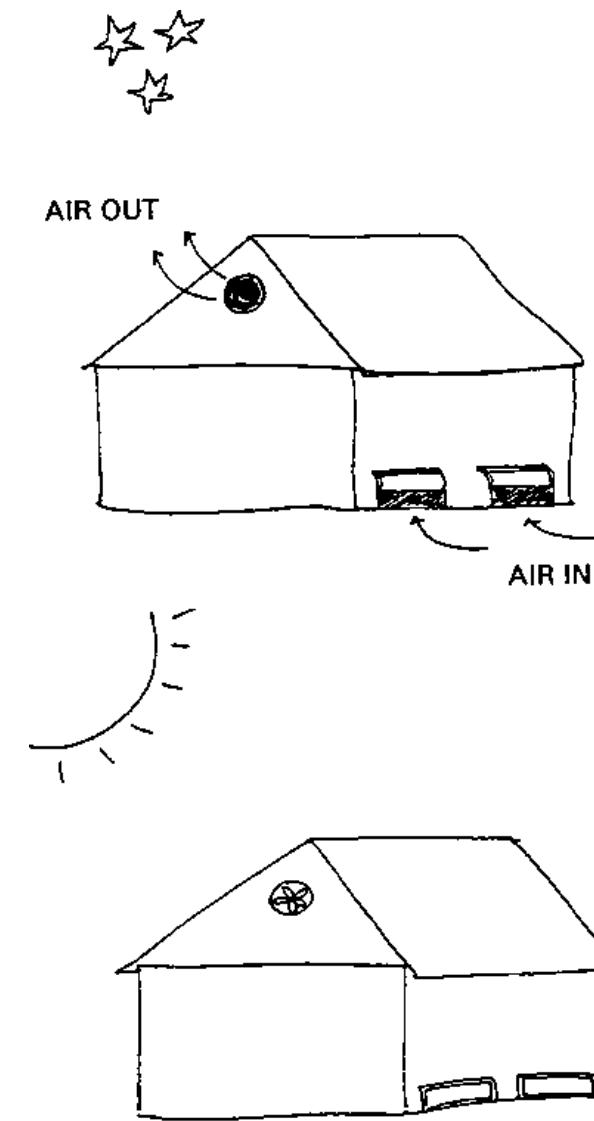


Types of ducts for air inlet fans:

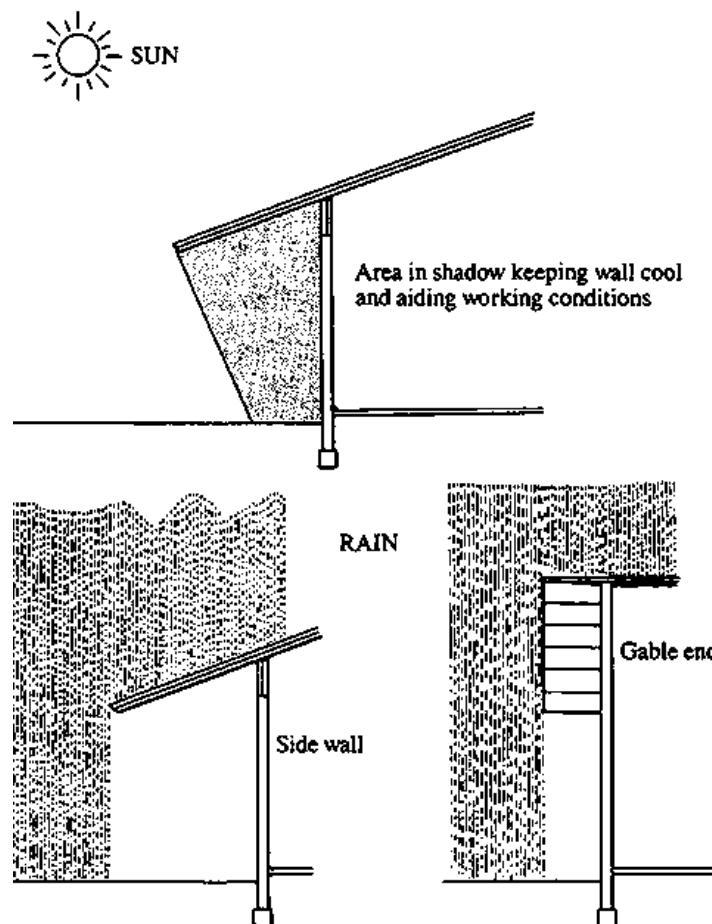


Source: Davis, R. et al. No date. Storage Recommendations for Northern Onion Growers. Cornell University Extension Information Bulletin 148

Storage structures can be cooled by ventilating at night when outside air is cool. For best results, air vents should be located at the base of the storage structure. An exhaust fan located at the top of the structure pulls the cool air through the storeroom. Vents should be closed at sunrise, and remain closed during the heat of the day.



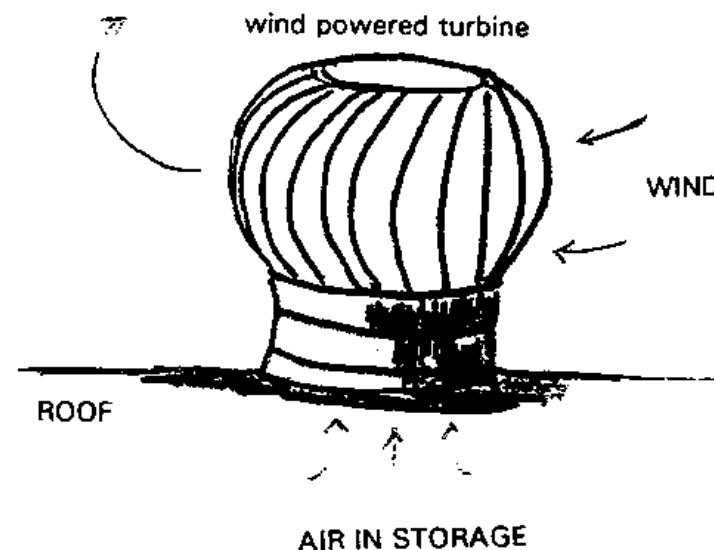
Overhanging roof extensions on storage structures are very helpful in shading the walls and ventilation openings from the sun's rays, and in providing protection from rain. An overhang of at least 1 meter (3 feet) is recommended.



Source: Walker, D.J. 1992. *World Food Programme Food Storage Manual*. Chatham, UK: Natural Resources Institute.

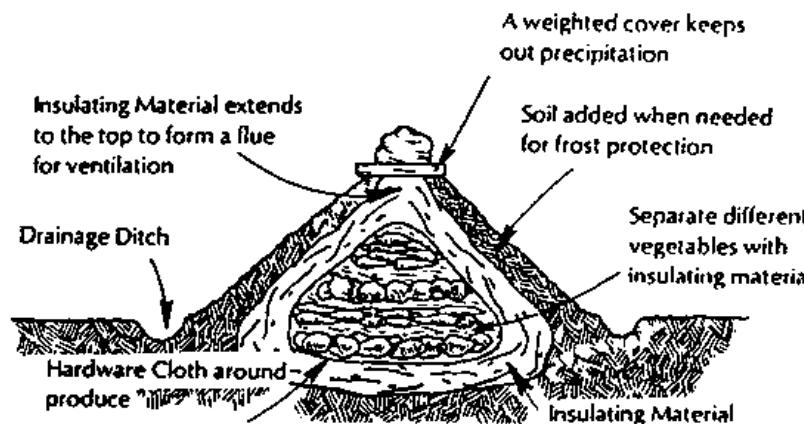
Where electricity is not available, wind-powered turbines can help keep storerooms cool by pulling air up through the building. Vents at the floor level are especially useful for cooling via night air ventilation.

The turbine illustrated below can be constructed of sheet metal that is twisted to catch the wind, and attached to a central pole that acts as the axis of rotation. Warm air in the storage room rises, causing the turbine to rotate, expelling the air and initiating an upward flow of warm air. The turbine should be placed on the peak of the roof of a storage structure.

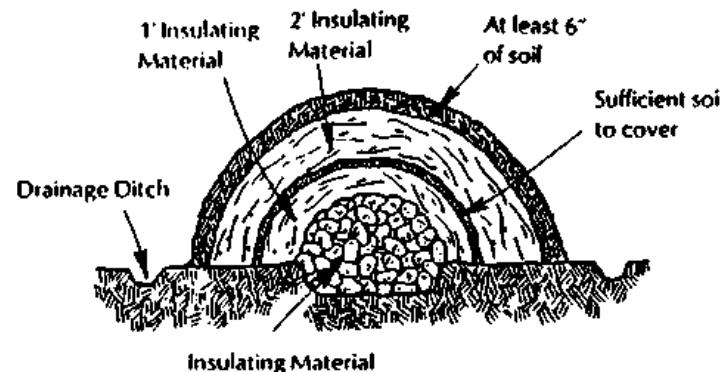


Protected surface storage is a simple method for storing small quantities of produce. The examples illustrated below are especially good for storage when night temperatures are lower than that desired for proper storage. Insulating materials such as straw can be used and protective covers can be constructed from wooden planks, plastic sheeting or layers of compacted soil.

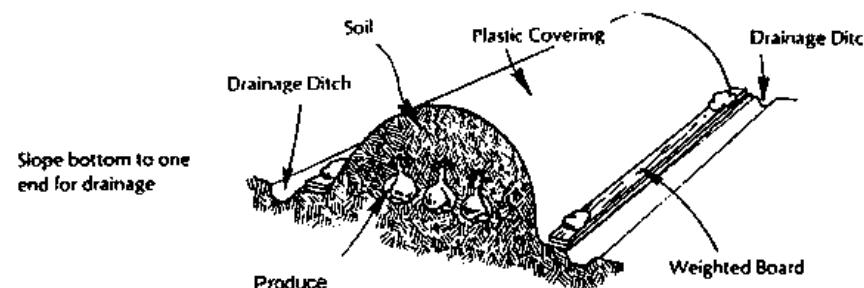
Cone-shaped pit storage:



Mound storage:



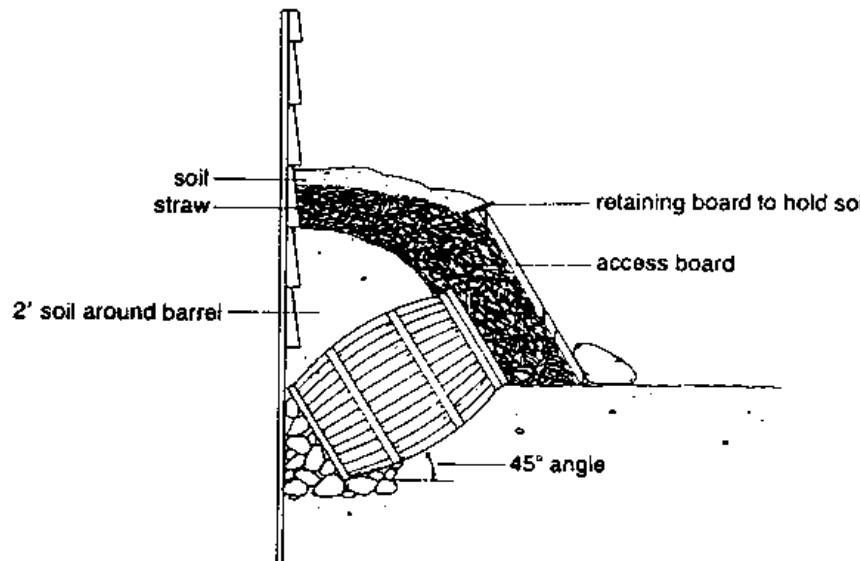
Trench storage:



Source: McKay, S. 1992. Home Storage of Fruits and Vegetables. Northeast Regional Agricultural Engineering Service Publication No. 7

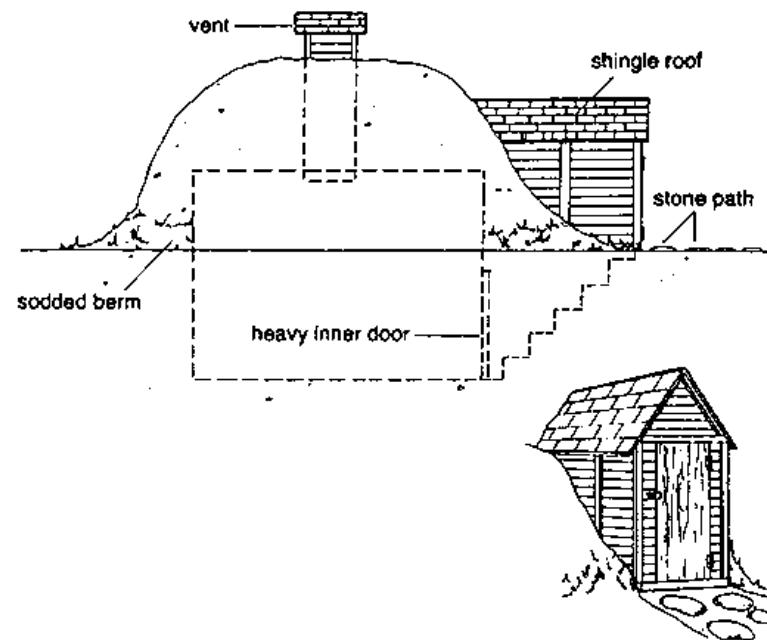
One of the simplest methods for storing small quantities of produce is to use any available container, and create a cool environment for storage by burying the container using insulating materials and soil. The example provided here employs a wooden barrel and straw for insulation.

Storage barrel:



Source: Bubel, M. and Bubel, N. 1979. Root Cellaring: The Simple, No-Processing Way to Store Fruits and Vegetables. Emmaus, PA: Rodale Press. 297 pp.

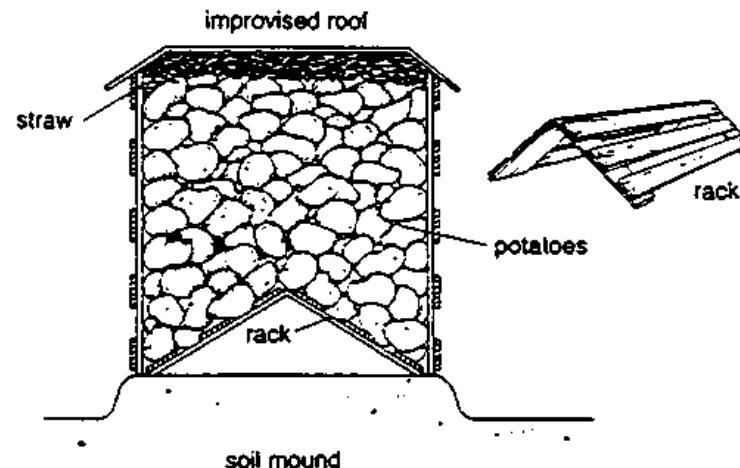
A root cellar can be constructed by digging out a pit to a depth of about 2 meters (7 to 8 feet) and framing the sides with wooden planks. The example illustrated here is about 3 by 4 meters (12 by 15 feet) in size, with a 35 cm square (one foot square) wooden chute as a roof vent



Source: Bubel, M. and Bubel, N. 1979. Root Cellaring: The Simple, No-Processing Way to Store Fruits and Vegetables. Emmaus, PA: Rodale Press. 297 pp.

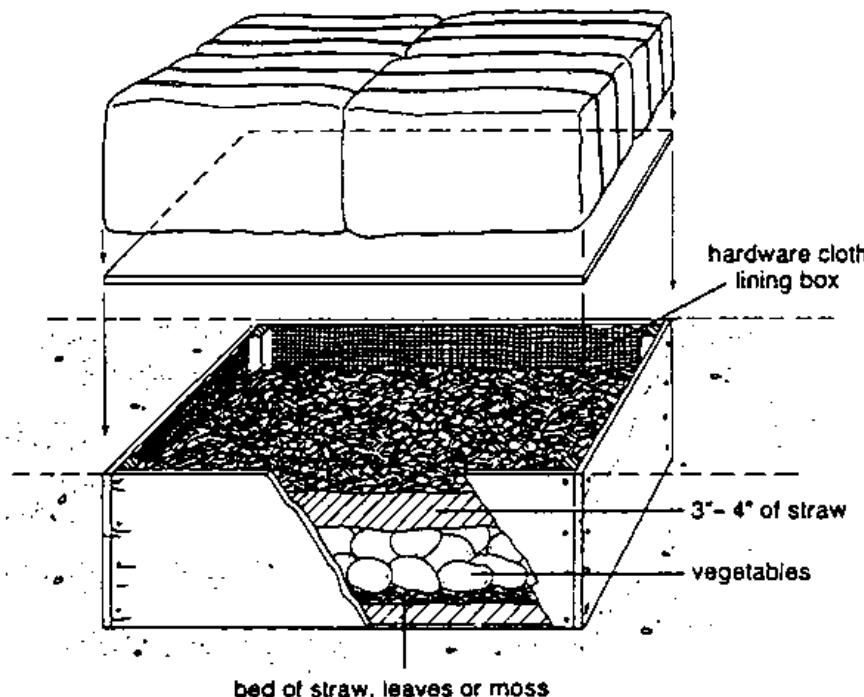
An outdoor storage bin can serve as a place to keep small quantities of potatoes in a region with a cool but not freezing climate. A wooden rack provides an air space for ventilation and straw provides insulation. The best location for such a structure would be in a shady spot.

Storage bin:



A root box, lined with hardware cloth and straw, buried to the top edge in soil will keep potatoes cool while providing protection from freezing. The wooden lid can be lifted for easy access to produce, and straw bales on top provide more insulation.

Root box:



Source: Bubel, M. and Bubel, N. 1979. Root Cellaring: The Simple No-Processing Way to Store Fruits and Vegetables. Emmaus, PA: Rodale Press. 297 pp.

Dried and bulb crops

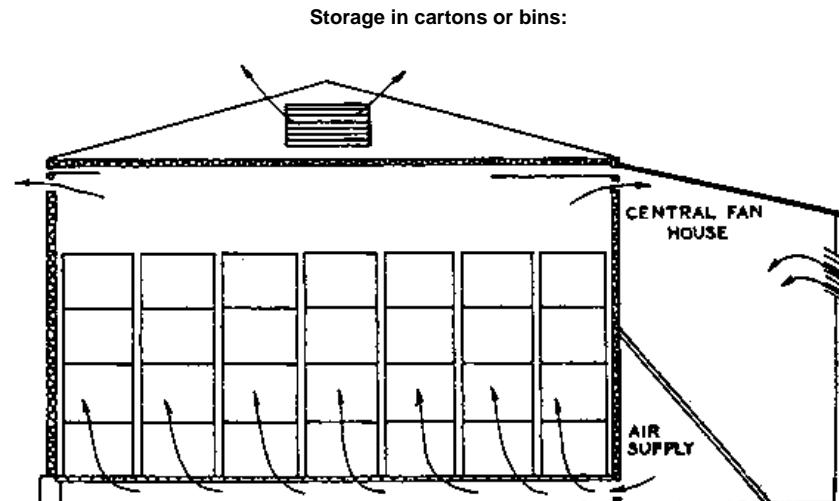
Onions, garlic and dried produce are best suited to low humidity in storage. Onions and garlic will sprout if stored at intermediate temperatures. Pungent types of onions will store longer than mild onions, which are rarely stored for more than one month (Kasmire & Cantwell in Kader, 1992). The following table lists the storage conditions recommended for these crops.

	Temperature		RH %	Potential storage duration
	C	F		
Onions	0-5	32-41	65-70	6-8 months
	28-30	82-86	65-70	1 month
Garlic	0	32	70	6-7 months
	28-30	82-86	70	1 month
Dried fruits and vegetables	<10	<50	55-60	6-12 months

Source: Bubel, M. and Bubel, N. 1979. *Root Cellaring: The Simple No-Processing Way to Store Fruits and Vegetables*. Emmaus, PA: Rodale Press. 297 pp.

For bulk storage of onions or garlic, ventilation systems should be designed to provide air into the store from the bottom of the room at a rate of 2 cubic feet per minute per cubic feet of produce. If produce is in cartons or bins, stacks must allow free movement of air. Rows of containers should be stacked parallel to the direction of the flow of air and be spaced six to seven inches apart. An adequate air supply must be provided at the bottom of each row and containers must be properly vented.

Bulk storage:



Source: Oregon State University, 1978. Onion Storage: Guidelines for Commercial Growers. Oregon State Extension Service. Extension Circular 948.

Root and tuber crops

The recommended storage conditions for root and tuber crops are listed in the following table (from Kasmire & Cantwell in Kader, 1992). Potatoes for processing are best kept at intermediate temperatures to limit the production of sugars which darken when heated during processing. Potatoes meant for consumption must also be stored in the dark, since the tubers will produce chlorophyll (turning green) and develop the toxic alkaloid solanine if kept in the light. Potatoes stored for use as "seed" are best stored in diffuse light (CIP, 1981). The chlorophyll and solanine that accumulate will aid to protect the seed potatoes from insect pests and decay organisms.

Tropical root and tuber crops must be stored at temperatures that will protect the crops from chilling, since chilling injury can cause internal browning, surface pitting and increased susceptibility to decay.

	Temperature		RH(%)	Potential storage duration
	C	F		
Potatoes				

Fresh market	4-7	39-45	95-98	10 months
Processing	8-12	47-54	95-98	10 months
Seed potatoes	0-2	32-36	95-98	10 months
Cassava	5-8	41-47	80-90	2-4 weeks
	0-5	32-41	85-95	6 months
Sweetpotato	12-14	54-58	85-90	6 months
Yam	13-15	55-59	near 100	6 months
	27-30	80-86	60-70	3-5 weeks
Ginger	12-14	54-58	65-75	6 months
Jicama	12-15	54-59	65-75	3 months
Taro	13-15	55-59	85-90	4 months

Potatoes

When storing potatoes, a field storage clamp is a low cost technology that can be designed using locally available materials for ventilation and insulation. The example illustrated here employs a wooden ventilator box and straw for insulation. The entire pile of potatoes and straw is covered with a layer of soil, which should not be highly compacted. In very cold regions, a second layer of straw and soil can be added. In hot regions, less soil is needed, but more ventilation can be added by constructing chimney type air outlets at the top of the clamp.

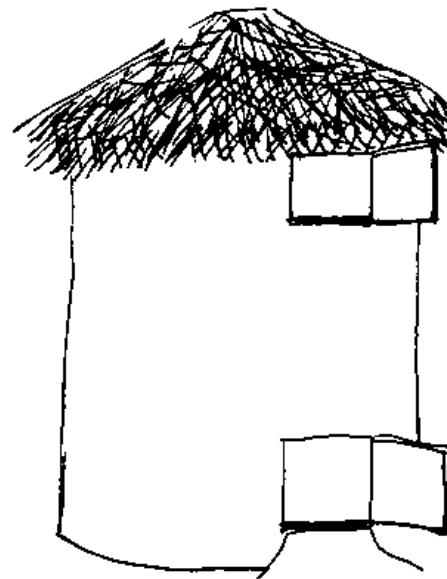
Field storage clamp:

Source: CIP. 1981. *Principles of Potato Storage*. Lima, Peru: International Potato Center (CIP). 105 pp.

Simple storage houses for potatoes can be constructed for small quantities of produce. The examples provided here can store 1 to 2 metric tons, and are used on farms and in mountain villages. The first is made from unfinished wooden planks painted white to reduce heat accumulation from the sun and covered with a large thatched roof for protection from sun and rain. It has a large door on one side for loading and unloading.

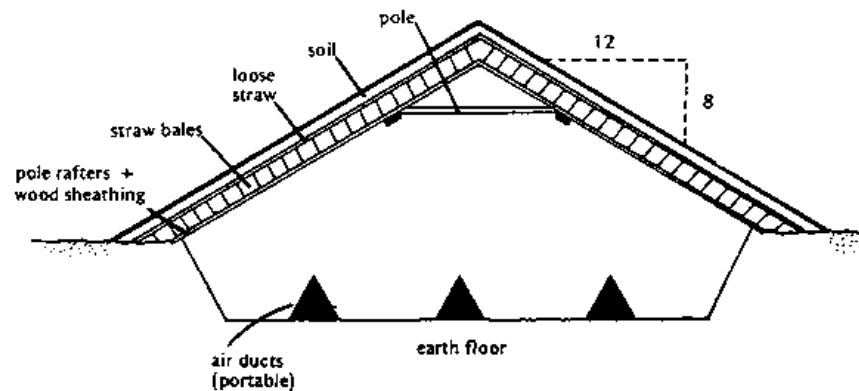


The second storage house is constructed from lath and plaster and mud bricks in a cylindrical form. It has two doors, one on top for loading, the other at the bottom for easy removal of potatoes for sale or consumption. White-wash helps reduce heat accumulation and a thatch roof protects the potatoes from rain and sun.



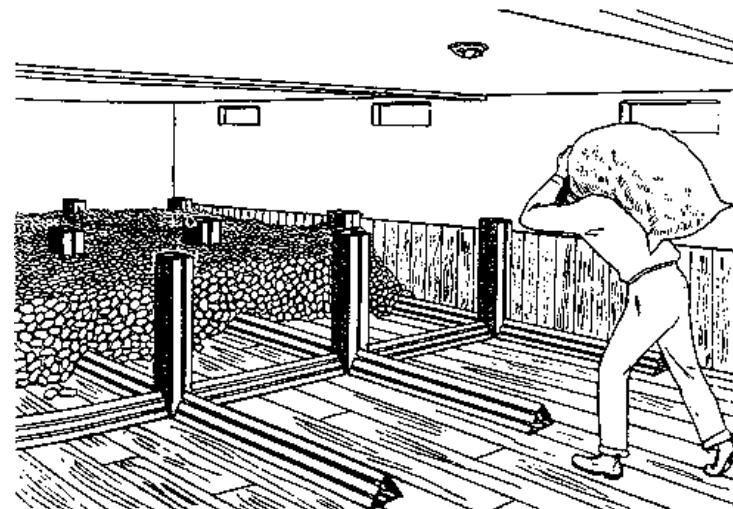
Source: CIP. 1981. Principles of Potato Storage. Lima, Peru: International Potato Center (CIP). 105 pp.

For large quantities of potatoes, a self-supporting A-frame storehouse can be constructed. A pit is dug about 10 feet deep and wooden air ducts are placed along the earthen floor. The roof of the building is constructed of wood, then covered with straw and soil.



Source: University of Idaho. No date. Idaho Potato Storage. Agricultural Experiment Station, College of Agriculture, Bulletin 410.

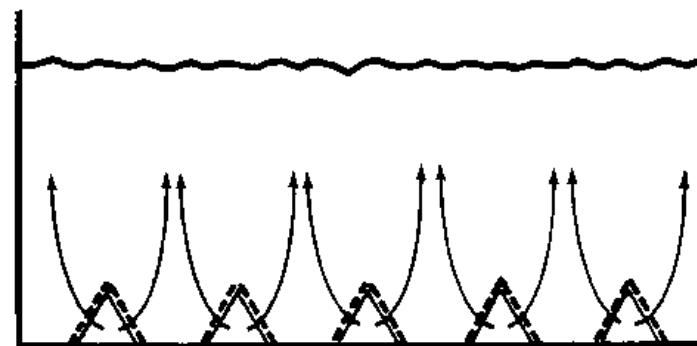
Ducts for ventilation of bulk storage rooms can be laid out vertically as well as horizontally. The storeroom for potatoes shown below provides for plenty of ventilation using simple materials. The room can be of any size or shape since air ducts can be positioned to extend evenly throughout.



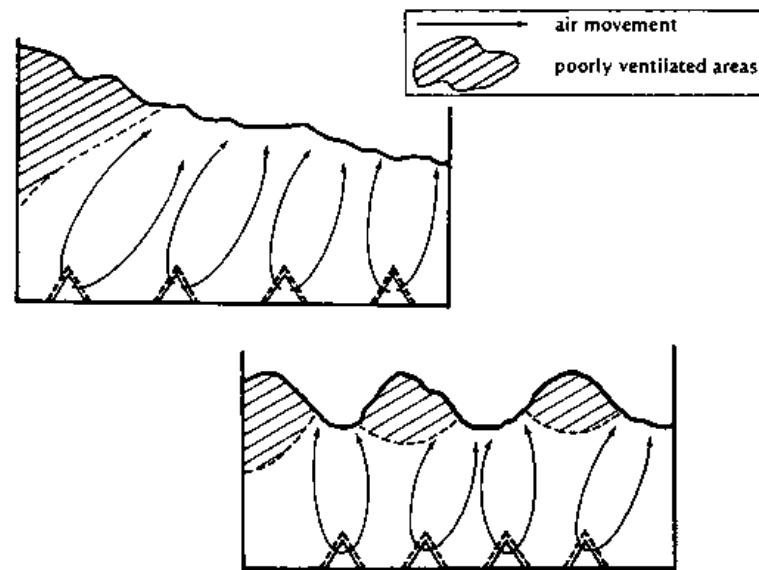
Source: Lopez, E.G. 1983. Conservación de la Producción Agrícola. Barcelona: Editorial Aedos. 188 pp.

When loading potatoes into bulk storage, even distribution of the produce is important for proper ventilation. Uneven loads will inhibit air movement and result in storage losses due to inadequate ventilation.

Even distribution of potatoes in the storeroom:



Uneven distribution of potatoes in the storeroom:



Source: CIP. 1981. Principles of Potato Storage. Lima, Peru: International Potato Center (CIP) 105 pp.

Controlled atmosphere (C.A.) storage

Controlled or modified atmosphere storage should be used as a supplement to, and not as a substitute for, proper temperature and relative humidity management. Some simple methods for modifying the composition of air in the storage environment are listed below (from Kader, 1992). Air coming into the storeroom or being recirculated within the room must pass through a monitoring and control system.

Oxygen gas control:

to DECREASE:

purging with nitrogen

- from liquid nitrogen through an evaporator
- from a membrane system nitrogen generator
- from a molecular sieve system nitrogen generator

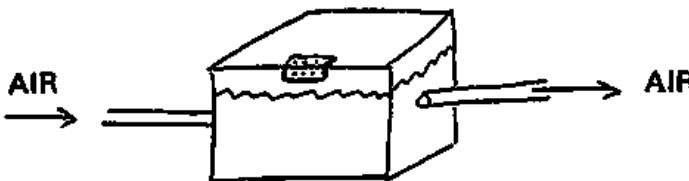
Carbon dioxide control:

to INCREASE:

- dry ice
- pressurized gas cylinder

to DECREASE:

- molecular sieve scrubber
- activated charcoal scrubber
- sodium hydroxide scrubber
- hydrated lime (use 0.6 kg of hydrated lime to treat the air used to ventilate 100 kg of fruit. Air can be directed to pass through a box, located inside or outside the C.A. storeroom).



Ethylene control:

to DECREASE:

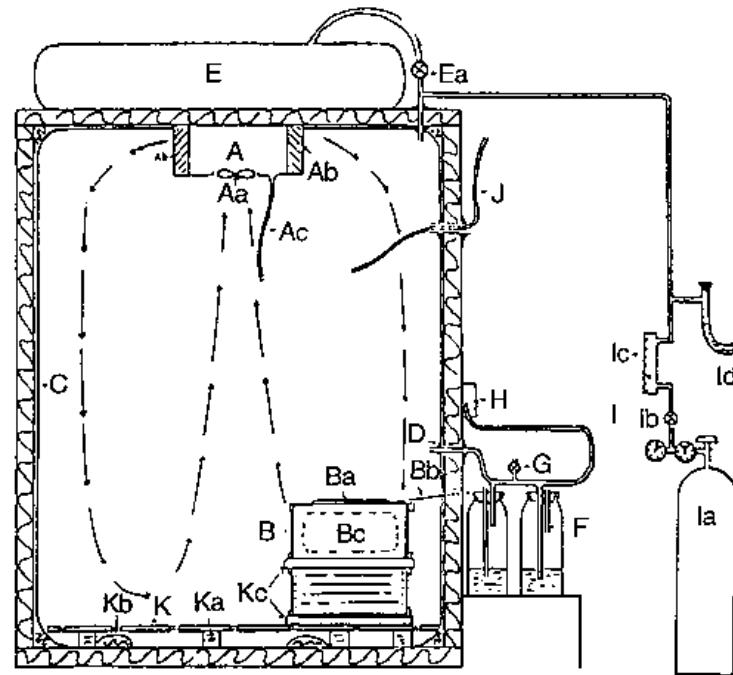
- potassium permanganate
- activated charcoal
- catalytic oxidation

Source: Vigneault, C., Raghavan, V.G.S., and Prange, R. 1994. Techniques for controlled atmosphere storage of fruits and vegetables. Research Branch, Agriculture and Agri-Food Canada, Technical Bulletin 1993-18E.

The following table is a summary of recommended conditions for controlled atmosphere storage (from Kader, 1992). Only fruits and vegetables for which commercial uses of C.A. storage are common have been included.

	Temperature range		%O ₂ range	%CO ₂ range
	C	F		
Strawberry	0-5	32-41	10	15-20
Apple	0-5	32-41	2-3	1-2
Kiwifruit	0-5	32-41	2	5
Nuts and dried fruits	0-25	32-77	0-1	0-100
Bananas	12-15	54-59	2-5	2-5
Cantaloupe	3-7	38-45	3-5	10-15
Lettuce	0-5	32-41	2-5	0
Tomatoes				
Mature green	12-20	54-68	3-5	0
Partially-ripe	8-12	47-54	3-5	0

Illustrated here is a model of a small-scale commercial C.A. storage room. Each component is labelled. For further information on construction methods, materials, and costs, please refer to the source listed below.

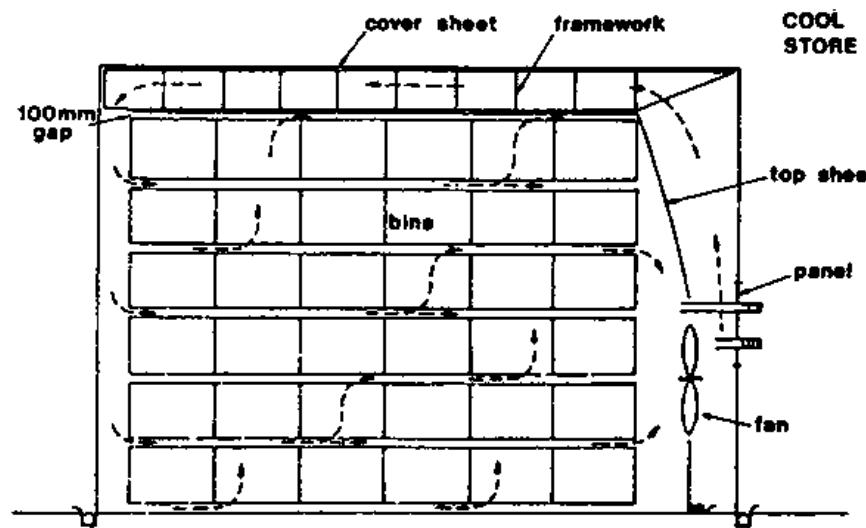


A-evaporator **Aa**-fan **Ab**-coil **Ac**-defrost drain **B**-scrubber **Ba**-slide **Bb**-wire control for scrubber **Bc**-lime **C**-sprayed-on polyurethane **D**-collar with internal pipe flange **E**-breather bag **Ea**-gate valve **F**-"automatic" relief valves **G**-manual relief valve **H**-differential pressure gauge **I**-nitrogen purging system **Ia**-nitrogen cylinder **Ib**-metering valve **Ic**-purge meter **Id**-safety valve **J**-sampling line **K**-false floor **Ka**-"2 X 4" **Kb**-polyurethane floor seal **Kc**-dunnage.

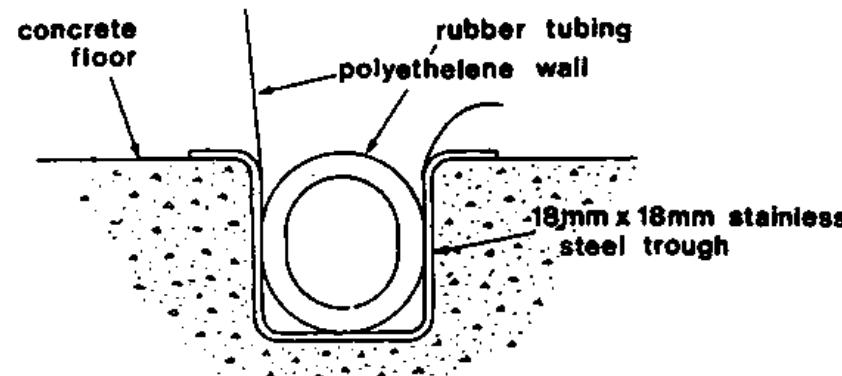
Source: Lougheed, E.C. et al. 1985. Small scale simulated commercial C.A. Storage rooms. Int'l. CA Conf. North Carolina State Univ. Hort. Report No. 126:235-247.

Controlled atmosphere storage of pallet loads of produce is also possible using a more permanent set-up for creating a gas-seal. Any number of pallets can be accommodated inside a plastic tent. A small trough constructed of sheet metal is laid in a rectangular pattern into a concrete floor of a storage structure. A 7-mil polyethylene sheet is put over the pallet load of produce, and the sheet is sealed by pushing a long piece of rubber tubing into the trough.

Typical layout of a C.A. tent:

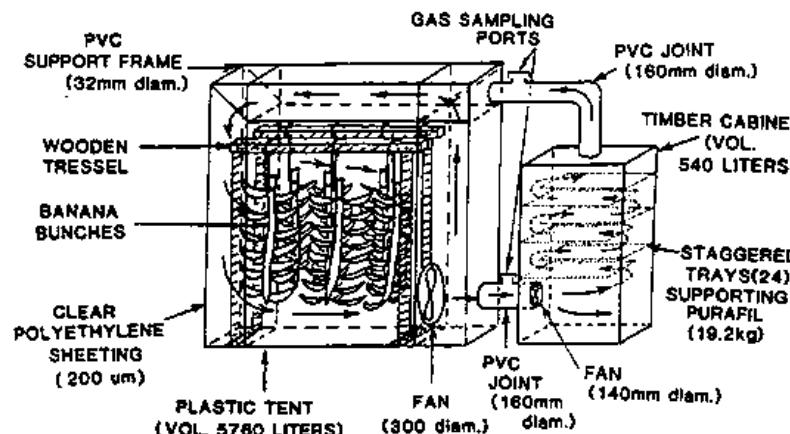


Layout of a seal in the trough on the storeroom floor:



Source: McDonald, B. 1982. Controlled atmosphere storage using plastic tents. International Institute of Refrigeration.

A low cost plastic tent fashioned from clear polyethylene sheeting can be used for controlled atmosphere storage of bunches of green bananas. A small fan serves to circulate the C.A. storage air (2% O₂ and 5% CO₂) through a chamber of potassium permanganate on aluminum oxide (Purafil). Ripening is delayed as ethylene is scrubbed from the storage air. The shelf life of bananas under these conditions is four to six weeks at ambient temperatures.



Source: Shorter, A.J. et al. 1987. Controlled atmosphere storage of bananas in bunches at ambient temperatures. CSIRO Food Research Quarterly 47:61-63.

Relative perishability and storage life of fresh horticultural crops

Classification of fresh horticultural crops according to their relative perishability and potential storage life in air at near optimum temperature and relative humidity.

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.
Very low	>16	Tree nuts, dried fruits and vegetables

Source: Kader, A.A. 1993. Postharvest Handling. In: Preece, J.E. and Read, P.E., The Biology of Horticulture- An Introductory Textbook. New York: John Wiley & Sons. pp. 353-377.





Section 8: Transportation of horticultural crops

[Open vehicles](#)

[Refrigerated trailers](#)

[Stacking patterns/handstacked](#)

[Stacking patterns/pallet and slip sheet loads](#)

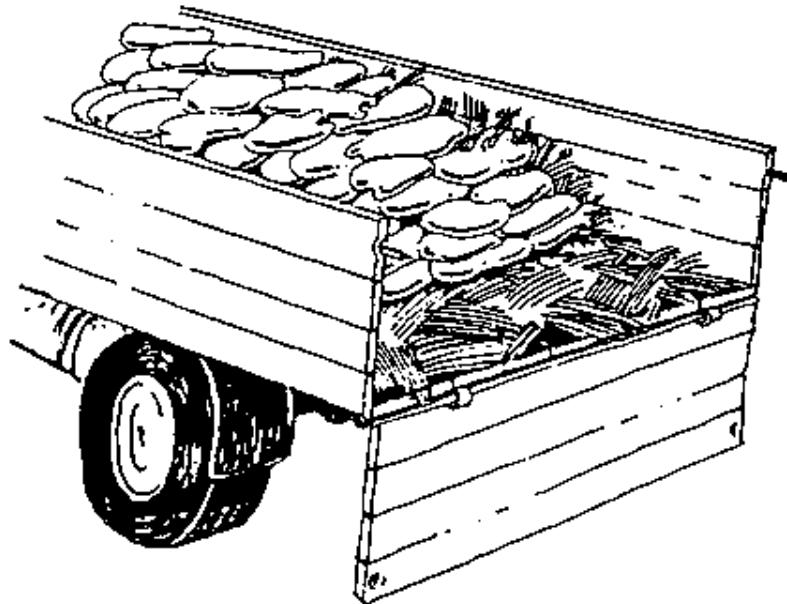
[Bracing the load](#)

Temperature management is critical during long distance transport, so loads must be stacked to enable proper air circulation to carry away heat from the produce itself as well as incoming heat from the atmosphere and off the road. Transport vehicles should be well insulated to maintain cool environments for pre-cooled commodities and well ventilated to allow air movement through the produce. During transport, produce must be stacked in ways that minimize damage, then be braced and secured. An open air vehicle can be loaded in such a way that air can pass through the load, and provide some cooling of the produce as the vehicle moves. Traveling during the night and early morning can reduce the heat load on a vehicle that is transporting produce.

Mixed loads can be a serious concern when temperature optima are not compatible (for example, when transporting chilling sensitive fruits with commodities that require very low temperatures) or when ethylene producing commodities and ethylene sensitive commodities are transported together. High ethylene producers (such as ripe bananas, apples, cantaloupe) can induce physiological disorders and/or undesirable changes in color, flavor and texture in ethylene sensitive commodities (such as lettuce, cucumbers, carrots, potatoes, sweet potatoes).

Open vehicles

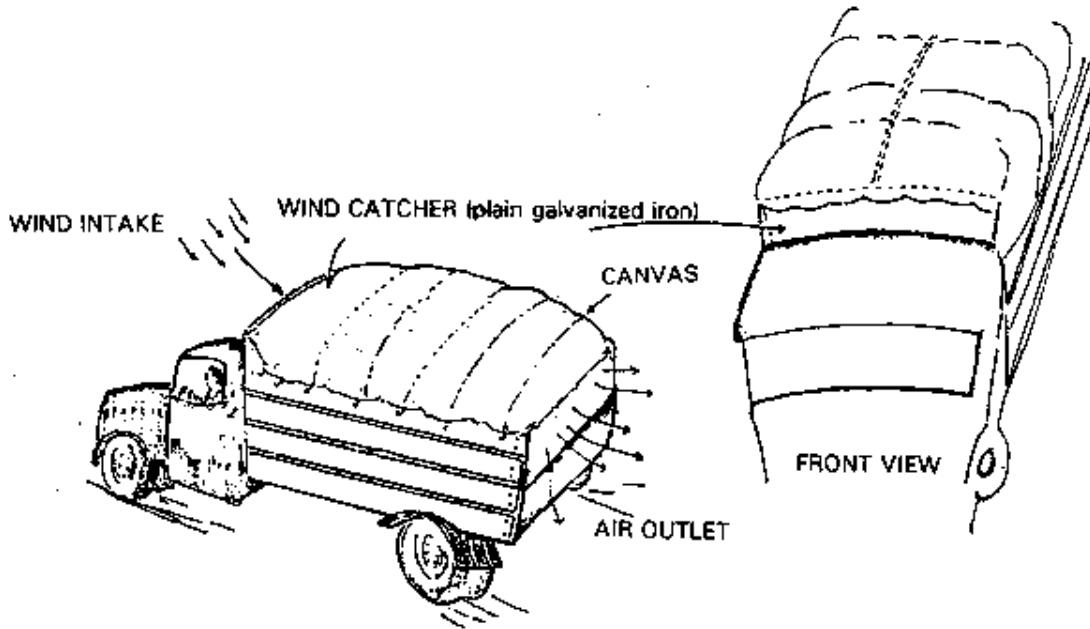
Bulk loads of produce should be carefully loaded so as not to cause mechanical damage. Vehicles can be padded or lined with a thick layer of straw. Woven mats or sacks can be used in the beds of small vehicles. Other loads should not be placed on top of the bulk commodity.



Source: Wilson, J. No date. Careful Storage of Yams: Some Principles to Reduce Losses. London:

Commonwealth Secretariat/ International Institute of Tropical Agriculture.

Cooling open loads is desirable whenever possible. A truck ventilating device can be constructed for an unrefrigerated open vehicle by covering the load loosely with canvas and fashioning a wind catcher from sheet metal. The scoop should be mounted at the front of the bed and should reach somewhat higher the height of the cab. High transportation speeds and/or long distance transport run the risk of causing excess drying of the crop.

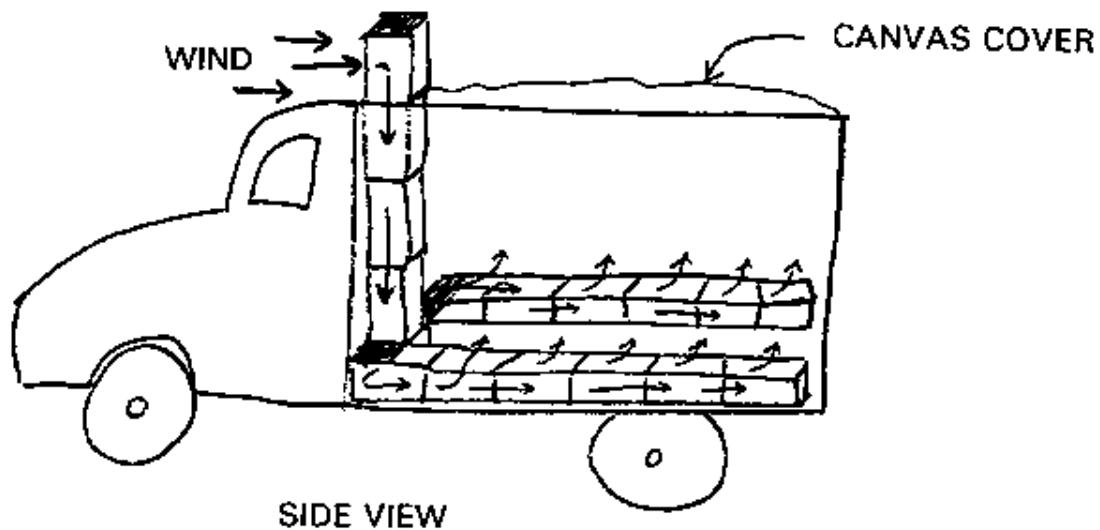
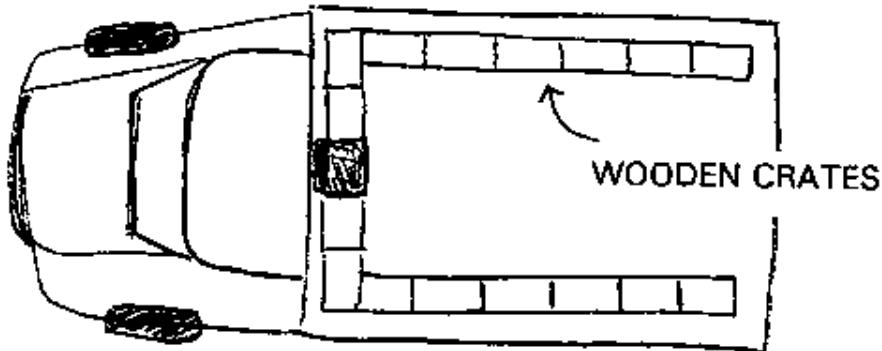


Source: Pantastico, Er. B 1980. FAO/UNEP Expert Consultation on Reduction of Food Losses in Perishable Products of Plant Origin, Working Document 2: Fruits and Vegetables. (6-9 May, Rome: FAO)

Open vehicles/bulk loads

This ventilating system was designed for hauling bulk loads of fresh fava beans in Iran. The wind catcher and ducts were constructed using wooden crates. After removing their end panels the crates were wired together into the pattern shown below. Air flows upward through the load during transport, helping to keep the produce from overheating. This system has also been used in pick-up trucks, and for hauling bulk greens and green beans. Best results are obtained when transporting during the early morning hours, before sunrise.

TOP VIEW



Source: Kasmire, R.F. 1994. Personal Communication.

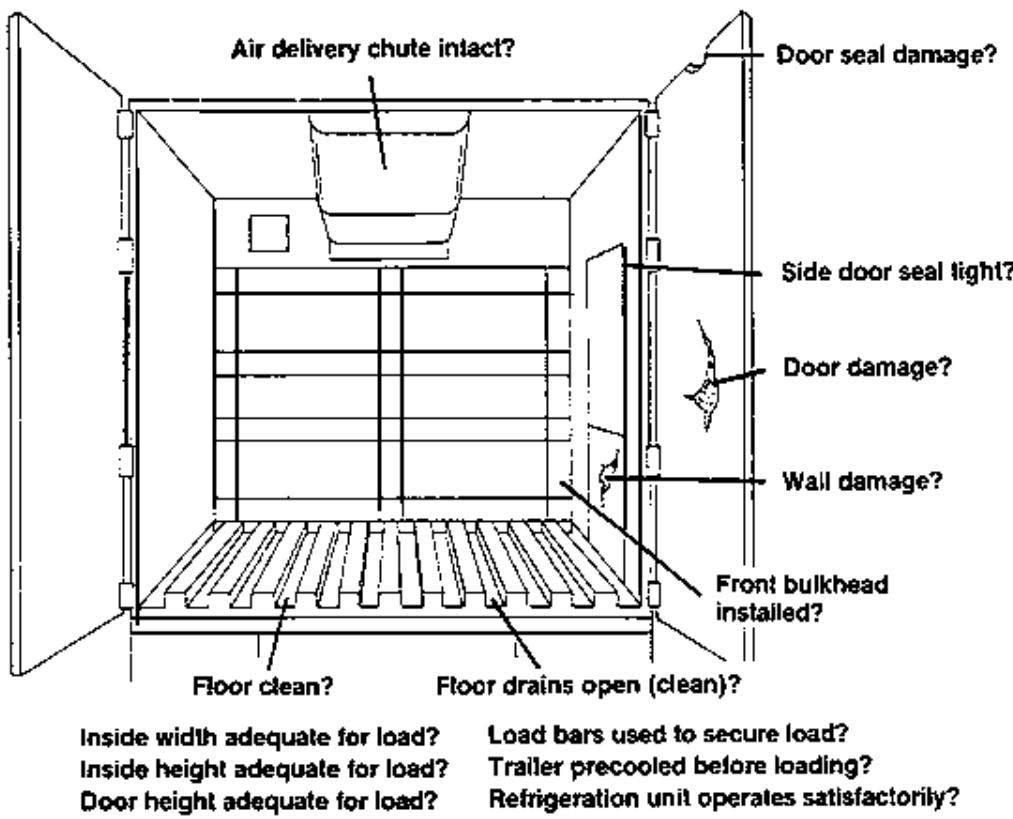
Refrigerated trailers

For optimum transport temperature management, refrigerated trailers need insulation, a high capacity refrigeration unit and fan, and an air delivery duct. The illustration below shows these and other desired features in a top-air delivery trailer.

For Optimum Transit Temperature Management, Refrigerated Trailers Need These Features

Source: Kasmire, R.F. and Hinsch, R.T. 1987. Maintaining Optimum Transit Temperatures in Refrigerated Truck Shipments of Perishables. University of California Perishables Handling Transportation Supplement No. 2.

The condition of the inside of a refrigerated trailer affects its ability to maintain desired temperatures during transport. Handlers should inspect the trailer before loading, and check these features:

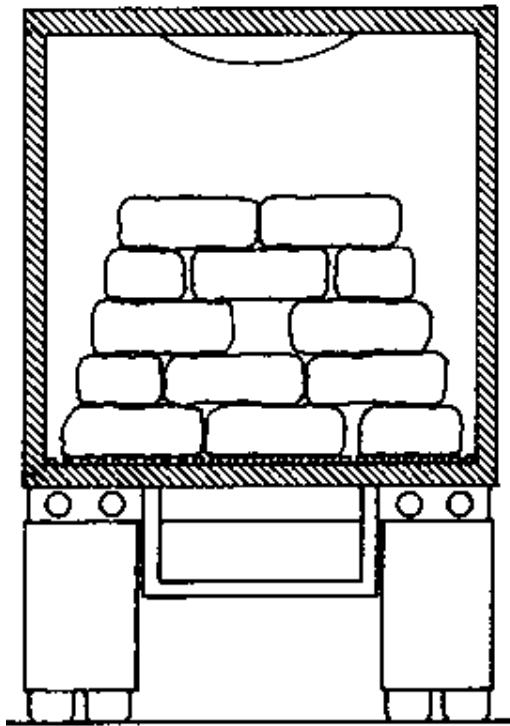


Source: Kasmire, R.F. and Hinsch, R.T. 1987. Maintaining Optimum Transit Temperatures in Refrigerated Truck Shipments of Perishables. University of California Perishables Handling Transportation Supplement No. 2.

Stacking patterns/handstacked

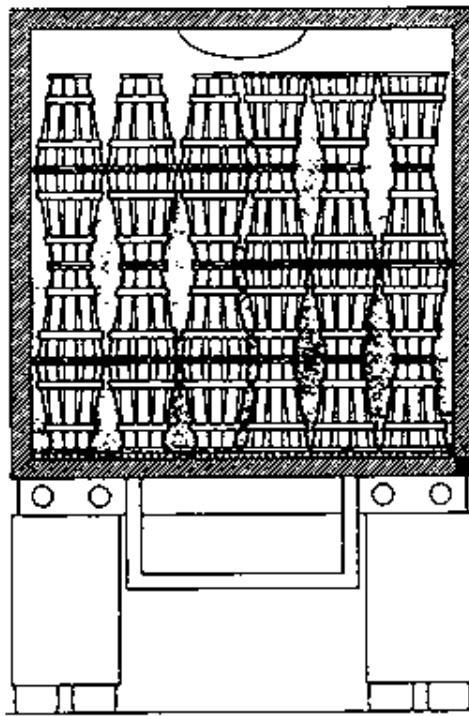
In order to reduce the conduction of heat from outside the vehicle into the load of produce, stacking patterns should reduce the amount of contact between the produce and the floor and walls of the vehicle.

Illustrated below is pyramid stacking of bags inside a refrigerated trailer.



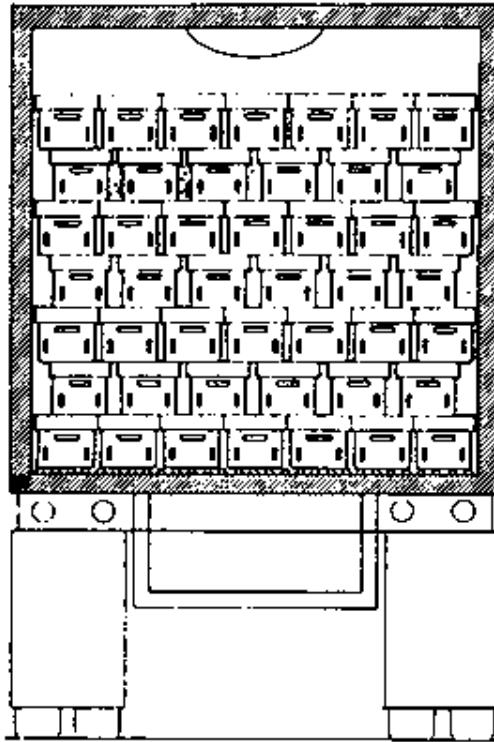
Source: Ashby, B. H. et al. 1987. Protecting Perishable Foods During Transport by Truck. Washington, D.C.: USDA, Office of Transportation, Agricultural Handbook No. 669.

Bushels of produce can be loaded into a refrigerated trailer using a pattern of alternately inverted layers that leave plenty of space between rows for air circulation.



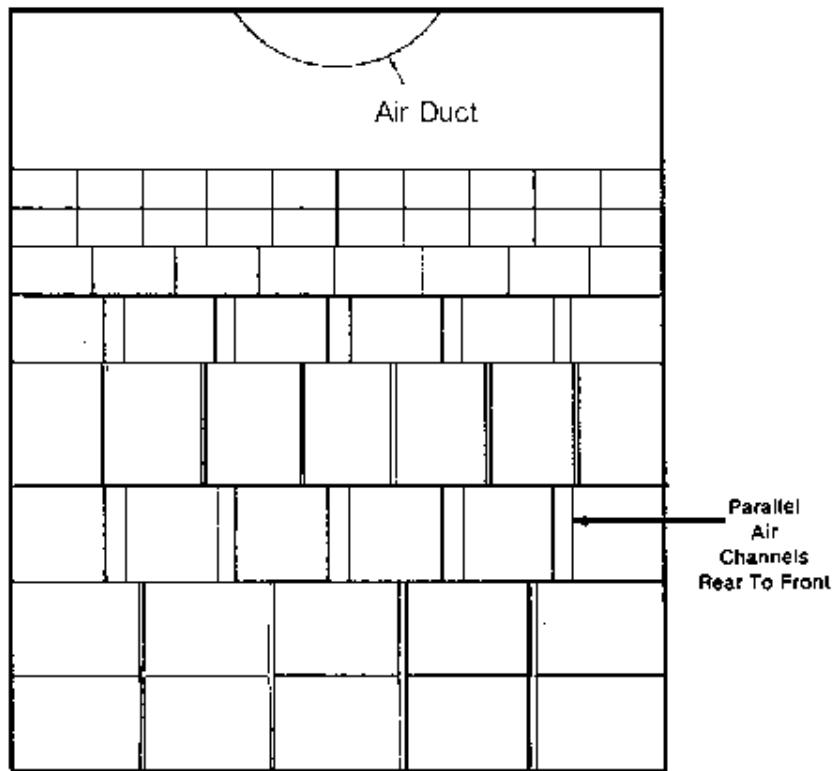
Source: Ashby, B. H. et al. 1987. Protecting Perishable Foods During Transport by Truck. Washington, D.C.: USDA, Office of Transportation, Agricultural Handbook No. 669.

Produce transported in cartons should also be stacked so as to allow adequate air circulation throughout the load. The diagram below illustrates cross-wise offset loading of partial telescopic containers. On the floor of the truck, pallets or other supports should be used to keep the cartons out of direct contact with the floor.



Source: Ashby, B. H. et al. 1987. Protecting Perishable Foods During Transport by Truck. Washington, D.C.: USDA, Office of Transportation, Agricultural Handbook No. 669.

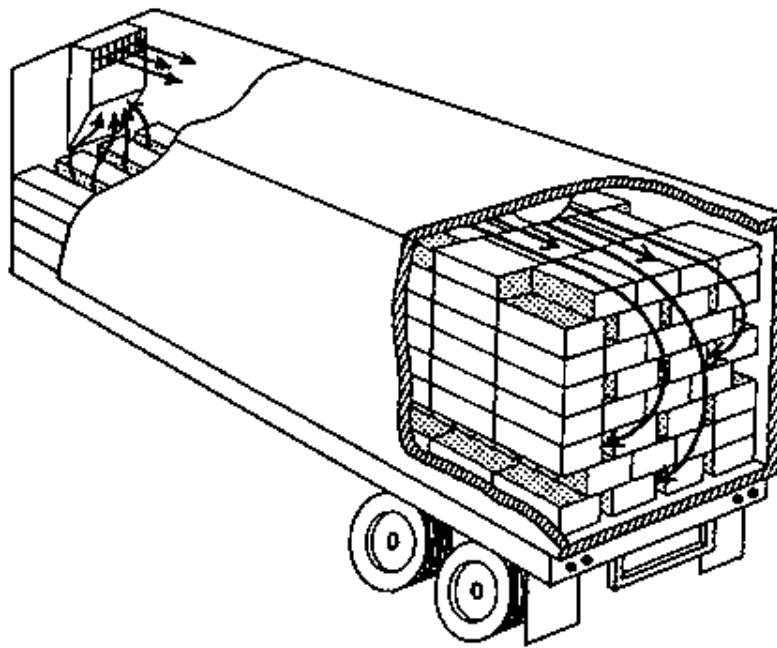
When cartons of various sizes must be loaded together, the larger, heavier containers should be placed on the bottom of the load. Parallel channels should be left for air to move through the length of the load.



Source: Nicholas, C.J. 1985. Export Handbook for U.S. Agricultural Products. USDA, Office of Transportation, Agricultural Handbook No. 593

Often the large containers used for cut flower packaging must be handstacked when loaded into a transport vehicle. The

best loading pattern for cut flowers is known as the pigeon hole pattern, where boxes are stacked in alternating solid and open layers, and channels are left down both side walls. This pattern provides channels for air circulation lengthwise through the load, and allows every box to be in direct contact with refrigerated air.

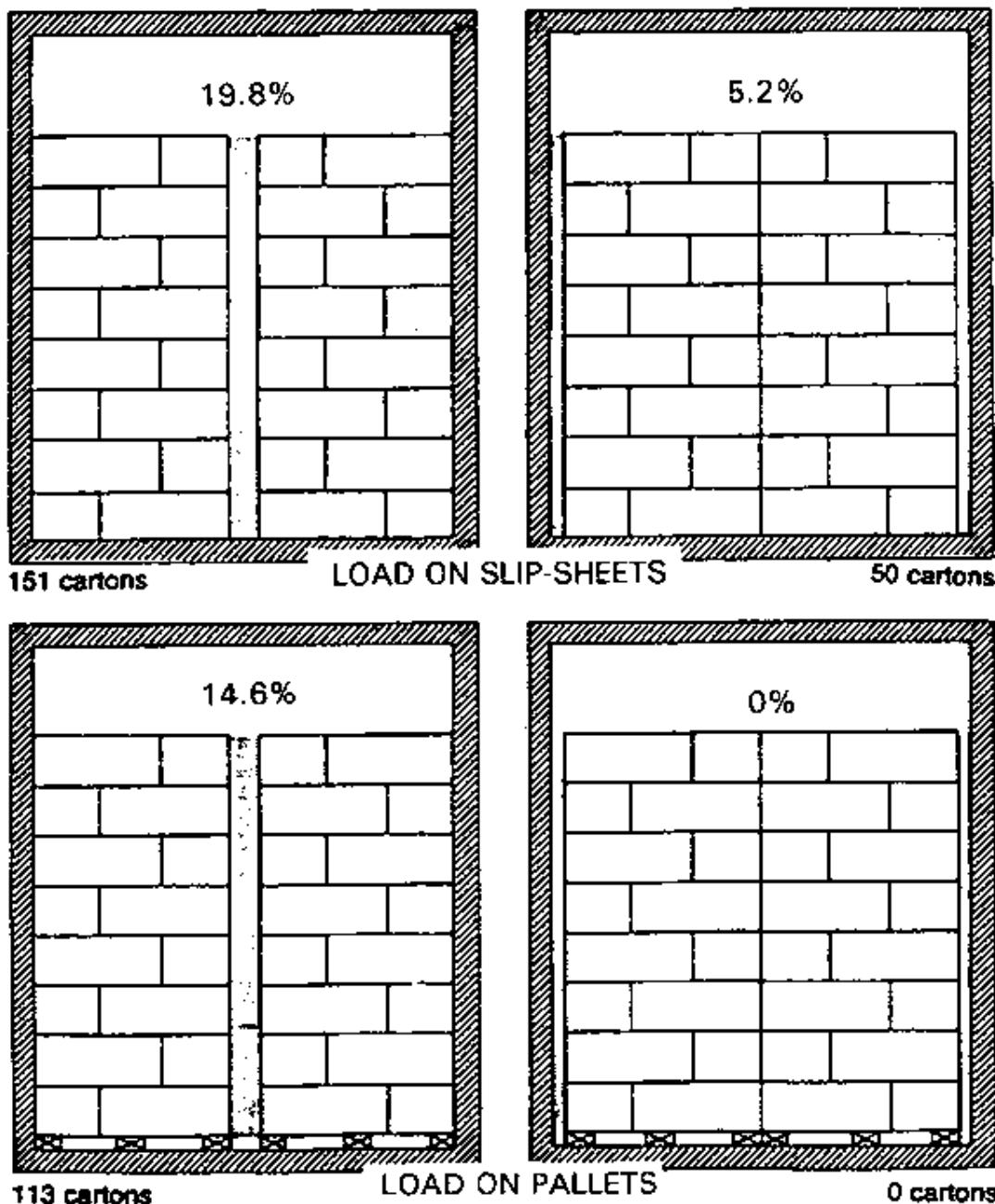


Source: Rij, R et al. 1979. Handling, Precooling and Temperature Management of Cut Flower Crops for Truck Transportation. USDA Science and Education Administration, AAT-W-5, UC Leaflet 21058.

Stacking patterns/pallet and slip sheet loads

Containers should be loaded so that they are away from the side walls and the floor of the transport vehicle in order to minimize the conduction of heat from the outside environment. In the diagrams below, the numbers of cartons refer to how many cartons would be in contact with the walls and floor of the truck when fully loaded.

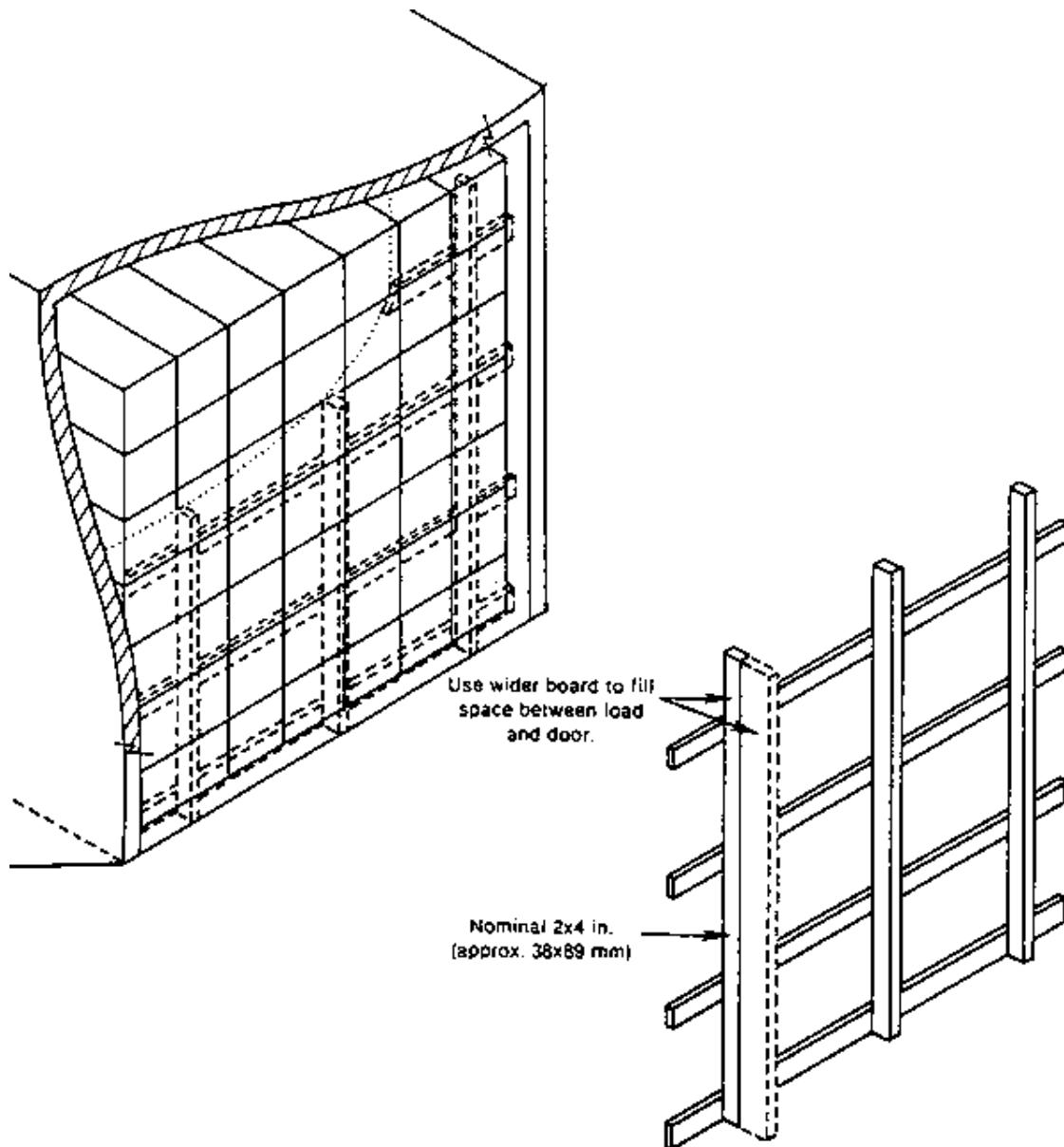
Only the load on the bottom right is fully protected from heat transfer. The use of pallets keeps the cartons off the floor, while center-loading leaves an insulating air space between the pallet loads and the outside walls.



Source: Ashby, B. H. et al. 1987. Protecting Perishable Foods During Transport by Truck. Washington, D.C.: USDA, Office of Transportation, Agricultural Handbook No. 669.

Bracing the load

There should always be a void between the last stack of produce and the back of the transport vehicle. The load should be braced to prevent shifting against the rear door during transit. If the load shifts, it can block air circulation, and fallen cartons can present great danger to workers who open the door at a destination market. A simple wooden brace can be constructed and installed to prevent damage during transport.



Source: Nicholas, C.J. 1985. Export Handbook for U.S. Agricultural Products. USDA, Office of Transportation, Agricultural Handbook No. 593





Section 9: Handling at destination

[Unloading](#)

[Storage temperatures](#)

[Sorting/repacking](#)

[Ripening](#)

[Display](#)

When handling produce at its destination, again it is important to avoid rough handling, minimize the number of handling steps, and maintain the lowest feasible temperature. If produce is to be stored before sale, then wholesale and retail markets need clean, well insulated storage rooms. Since a variety of commodities is usually being handled simultaneously at this point, it is important to remember not to mix those with different temperature requirements or store ethylene sensitive commodities near ethylene generating commodities. Stacking of non-uniform containers should be done with care to prevent collapse of weaker packages.

Before produce is sold to the consumer, the handler may wish to sort for quality, or at least to discard any damaged or decayed produce in order to give the product more market appeal. If ripeness or maturity is non-uniform, sorting at destination can provide the seller with a higher price for the better quality produce.

If the produce handled is a climacteric fruit crop that was harvested before it was ripe (bananas, tomatoes, avocados, mangoes), the handler at destination may want to ripen the produce before it is sold to the public. Sometimes commodities such as bananas are left at ambient temperatures and allowed to ripen naturally. Covering the bananas with a plastic sheet will help ripening be more uniform throughout the lot (PHTRC, 1984). Placing a simple air vent (a pipe or a tube of some sort) into the center of the pile of ripening fruit can help reduce overheating during ripening and increase subsequent shelf life. The introduction of ethylene gas or ethylene-releasing compounds into a special storage environment (known as a ripening room or cabinet, depending upon size) is a more effective way to ensure uniform ripening.

When displaying horticultural crops, single or double layers of produce are most likely to protect the commodities from compression damage and overhandling by the consumers. Temperatures of the display tables or refrigerated supermarket displays should be suited to the commodity on sale. For example, while peppers and tomatoes look pleasing when displayed with lettuce, peppers and tomatoes are chilling sensitive, while lettuce is not. Misting commodities that can tolerate surface water (lettuce, broccoli, green onions) with cool clean water can help maintain a high relative humidity around the product.

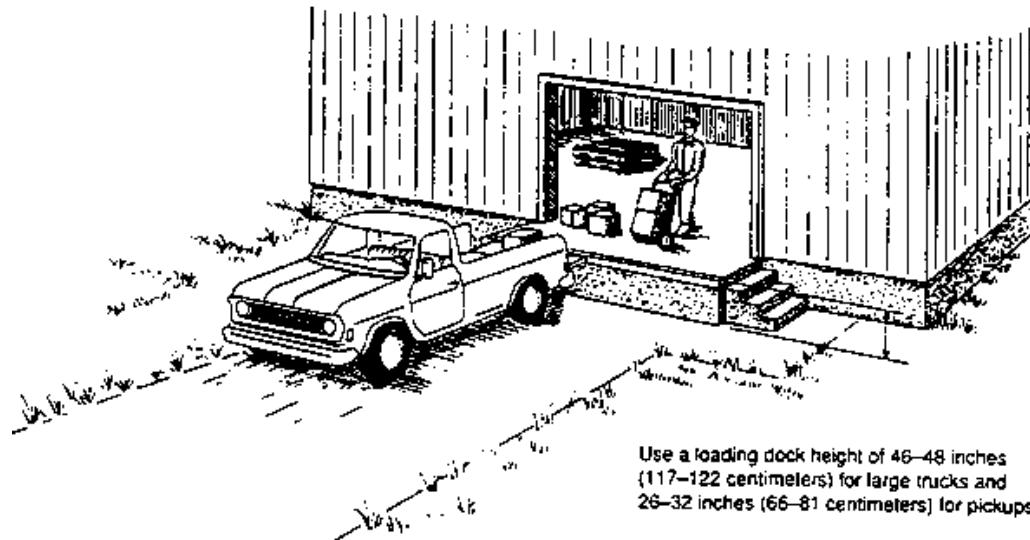
Outdoor marketplaces suffer from a lack of temperature control and high air circulation, which can lead to dessication of crops, which will be seen as shriveling and wilting. These marketplaces can often benefit by the increased use of shading and protection from prevailing winds.

Finally, the handler at destination can help reduce losses in the future by maintaining good records of the sources of losses suffered at the wholesale or retail level (Kasmire & Ahrens in Kader, 1992). Identifying whether losses were due to mechanical damage, decay/disease, immaturity or overripeness allows the handler to provide better quality feedback to produce suppliers.

Unloading

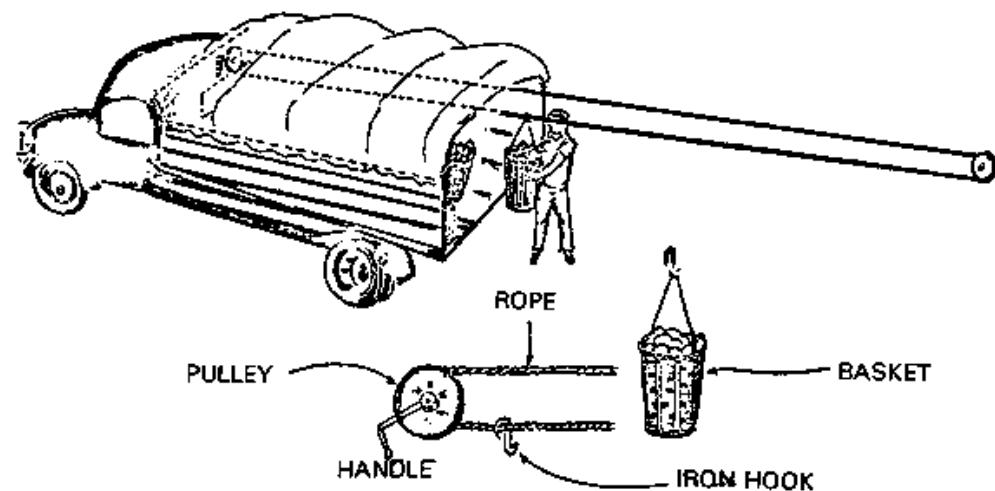
A loading dock can ease the work associated with handling horticultural produce at destination. Containers can be transferred more rapidly and with less bending and lifting.

For large trucks, a loading dock 117 to 122 cm high (46 to 48 inches) functions well, while for small trucks or pickups a height of 66 to 81 cm (26 to 32 inches) is recommended.



Source: Selders, A.W. et al. 1992. Facilities for Roadside Markets. Northeast Regional Agricultural Engineering Service/ Cornell University Cooperative Extension.

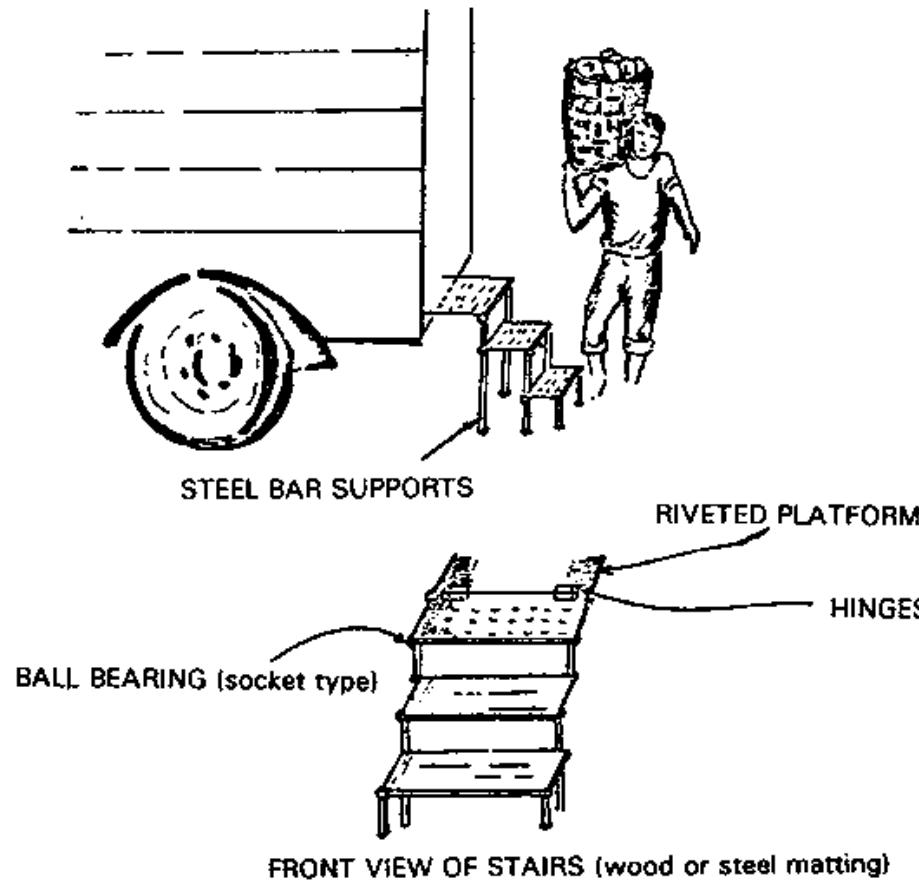
A simple device for easing the work of unloading transport vehicles can be constructed using a two pulleys and a strong rope. One pulley can be mounted inside the truck at the front of the bed, the second outside on a portable post or on a stationary object like the side of a building. Containers can be hung directly by their handles or placed into a sling.



Source: Pantastico, Er. B. 1980. FAO/UNEP Expert Consultation on Reduction of Food Losses in Perishable Products of Plant Origin. Working Document 2: Fruits and Vegetables. (6-9 May, Rome: FAO)

A simple set of stairs can be constructed to ease the work of loading and unloading produce. The stairs illustrated here can be folded and pushed back under the back of the truck when the vehicle is in motion. The steps can be made of wood or steel matting and steel bars can be used for supports.

Using a ramp is a simple and safe method for unloading produce. The ramp should be wide enough to prevent accidents and strong enough to carry the full weight of the handler plus the package she/he is carrying. Providing handtrucks or small carts can also ease the work associated with unloading.



Source: Pantastico, Er. B. 1980. FAO/UNEP Expert Consultation on Reduction of Food Losses in Perishable Products of Plant Origin. Working Document 2: Fruits and Vegetables. (6-9 May, Rome: FAO)

Storage temperatures

When produce is held at destination for a short time before marketing, the handler can help maintain quality and reduce losses by storing commodities at their most suitable temperature. However, if the storage period is five days or less, relative humidity is maintained between 85 and 95%, and the ethylene level is kept below 1 ppm ventilating or using a scrubber, most commodities can be grouped into the following three categories.

32-36°F, 0-2°C		45-50°F, 7-10°C		60-65°F, 16-18°C	
Vegetables and Melons					
anise	collard*	parsnip	basil	casaba melon	
artichoke	cut vegetables	raddichio	beans; snap, etc.	cassava	
arugula*	daikon*	radish	cactus leaves	crenshaw melon	
asparagus*	endive*	rutabaga	cucumber*	dry onions	

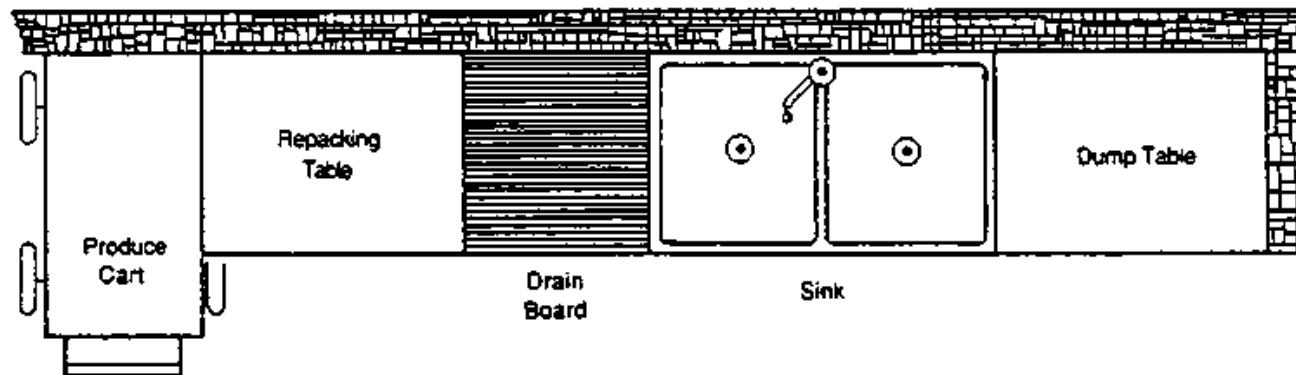
bean sprouts	escarole*	rhubarb	eggplant*	ginger
beet	garlic	salsify	Juan Canary	honeydew melon
Belgian endive*	green onion*	shallot	melon	jicama
bok choy	herbs(not basil)	spinach*	kiwano	potato
broccoli*	horseradish	snow pea*	okra*	Persian melon
broccoflower*	Jerusalem	sweet corn	pepper; bell,	pumpkin
brussel sprouts*	artichoke	sweet pea*	chili	squash; winter,
cabbage*	kale	Swiss chard	squash; summer,	hard rind
cantaloupe	kohlrabi	turnip	rind*	sweet potato*
carrot*	leek*	turnip greens*	tomatillo	taro
cauliflower*	lettuce*	waterchestnut	watermelon*	tomato; ripe
celeriac	mint	watercress*		mature green
celery*	mushroom			yam*
chard*	mustard greens*			
chicory*	parsley*			
Fruits				
apple	quince		avocado, unripe	atemoya
apricot	raspberry		cactus pear, tuna	banana
avocado, ripe	strawberry		carambola	breadfruit
blackberry			chayote	cherimoya
blueberry			cranberry	coconut
cherry			feijoa	grapefruit*
currant			guava	lemon*
cut fruits			kumquat	lime*
date			longan	mango
fig			lychee	mangosteen
gooseberry			mandarin	papaya
grape			olive	plantain
kiwifruit*			orange	pummelo
nectarine			passion fruit	rambutan
peach			pepino	sapote
pear; Asian			pineapple	soursop
European			pomegranate	
persimmon*			tamarillo	
plum			tangelo	
prune			tangerine	

* Products marked with an asterisk are sensitive to ethylene damage.

Source: Thompson, J.F. and Kader, A.A. 1995. Postharvest Outreach Program, Univ. of California, Davis.

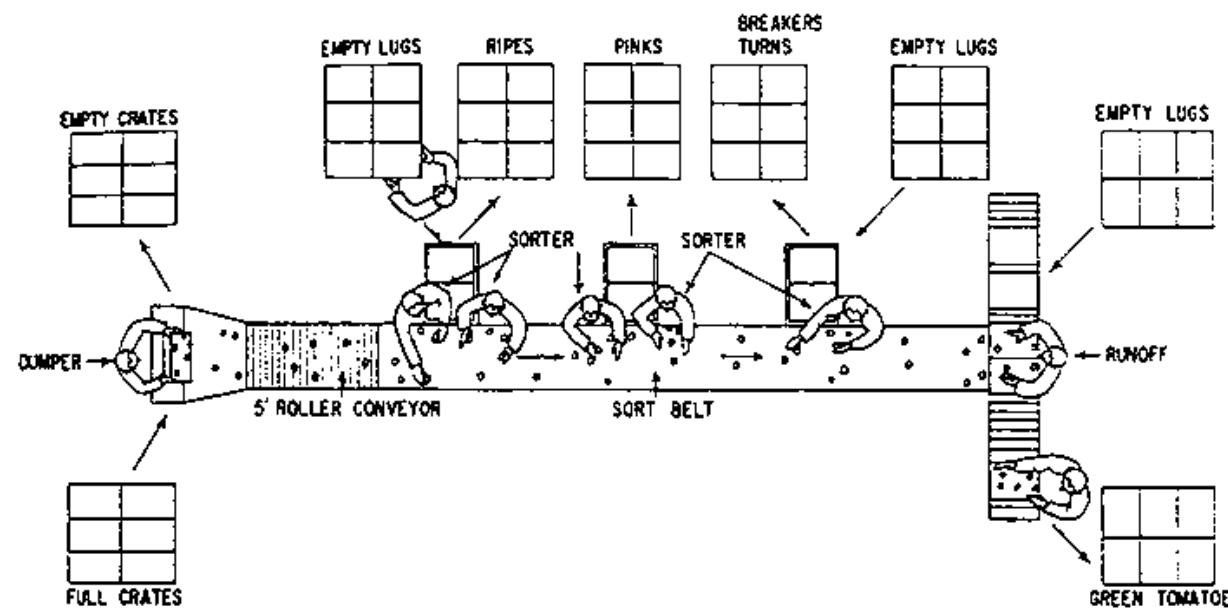
Sorting/repacking

Some produce may require washing, trimming, bunching or sorting at the wholesale or retail market level. The layout of the work station used for handling produce at destination should be organized to minimize non-productive movement. In the illustration below, a dump table is located next to a sink for washing produce, and the drain board is positioned directly next to the sink. Once produce has dried, cartons can be packed and placed onto a cart located right next to the repacking table. With this layout, a single operator could easily perform all the handling steps or several handlers could work side by side.



Source: Selders, A.W. et al. 1992. Facilities for Roadside Markets. Northeast Regional Agricultural Engineering Service/ Cornell University Cooperative Extension.

Some produce may have to be repacked by the wholesaler or retailer due to changes in quality or uneven ripening. The tomato sorting table illustrated below has work stations for up to five who select either ripes, pinks or breakers and allow the green tomatoes to run off to the end of the line. Rejects (culls) are placed in pails under the table.



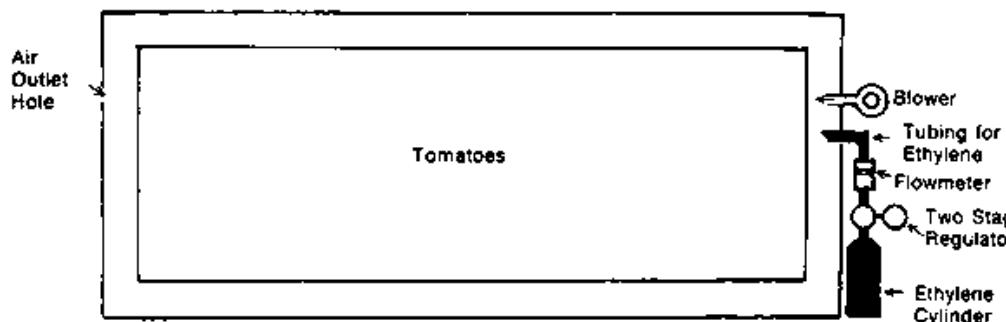
Source: USDA. No date. Tomato repacking methods and equipment. USDA Marketing Service, Transportation and Facilities Research Division, Marketing Research Report No. 597

Ripening

Some commodities may require ripening before sale at the wholesale or retail level. Ripening rooms are often used for tomatoes, citrus fruits and bananas. The use of diluted ethylene gas mixtures is safer than using pure ethylene which is explosive and flammable at concentrations of 3% or higher.

For tomatoes, technical grade ethylene gas is introduced into the room at a concentration of about 100 ppm for about 48 hours. Approximately 0.25 cubic feet/hr of ethylene gas is required for each 1000 cubic feet of ripening room volume. A small fan can be used to ensure a uniform continuous flow of ethylene into and through the room. Forced-air ripening is increasingly being used to provide more uniform temperatures and ethylene concentrations throughout the ripening room.

Continuous flow gassing:



Source: Kasmire, R.F. 1981. Continuous flow ethylene gassing of tomatoes. *California Tomatorama*. Fresh Market Tomato Advisory Board Information Bulletin No. 29.

Ripening can also be initiated by using ethylene generated by passing ethanol over a bed of activated alumina. This method is safer than using pure ethylene gas. Ethylene-releasing compounds such as ethephon {(2-chloroethyl) phosphoric acid} are sometimes used to ripen tomatoes destined for processing. When using ethephon as a spray, the amount of ethylene released will increase as pH and/or relative humidity increase.

Source: Kays, S.J. and Beaudry, R.M. 1987. Techniques for inducing ethylene effects. *Acta Horticulturae* 201:77-115.

The following table shows typical produce storage and ripening temperatures for some of the commodities that can be ripened.

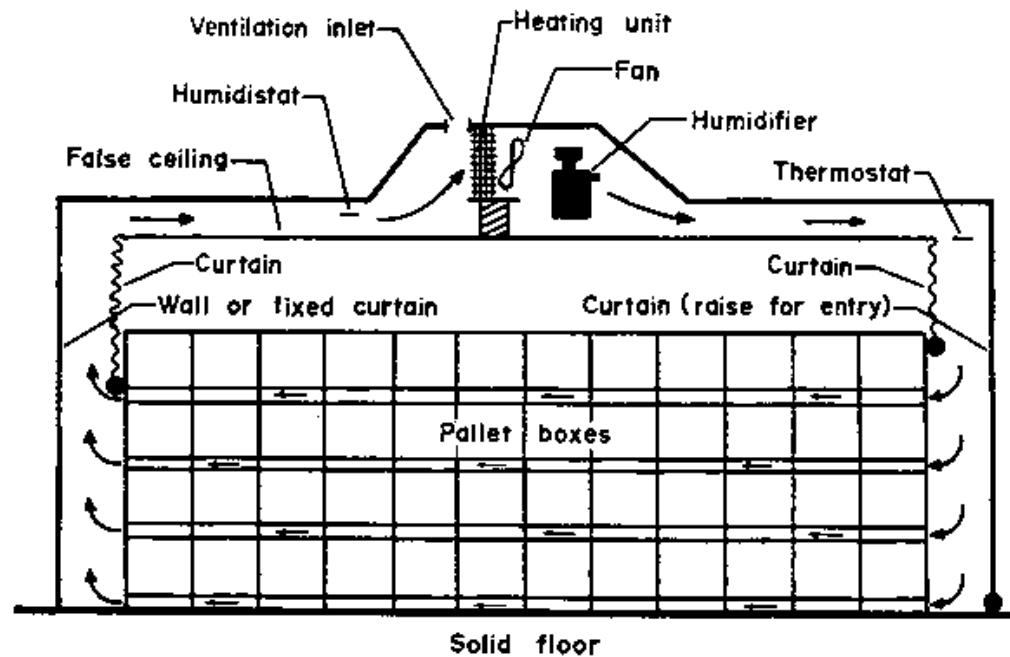
Commodity	Respiration(mg C0 ₂ / kg-hr) ¹	Ethylene conc. (ppm)	Ethylene exposure time (hr.)	Ripening temp. °F (° C)	Storage temp. temp. °F (° C)	Specific heat Btu/lb- F
avocado	62-157	10-100	12-48	59-65 (15-18)	40-55 (4.4-13)	0.81
banana	25-110	100-150	24	59-65 (15-8)	56-58 (13-14)	0.81
honey dew melon	20-27	100-150	18-24	68-77 (20-25)	45-50 (7-10)	0.94
kiwifruit	16-22	10-100	12-24	32-68 (0-20)	32-33 (0-0.5)	0.86
mango	40-200	100-150	12-24	68-72 (20-22)	56-58 (13-14)	0.85

orange degreening	22-34	1-10	24-72	68-72 (20-22)	4148 (5-9)	0.90
stone fruit	12-81	10-100	12-72	55-77 (13-253)	31-32 (-0.5-0)	0.90
tomato	2444	100-150	2448	68-77 (20-25)	50-55 (10-13)	0.95

¹Multiply by 220 to obtain heat to respiration (BTU/ton/24 hours)

Source: Thompson, J.F. 1994. Ripening facilities. Perishables Handling Newsletter, Nov. 1994. Special Issue No. 80: 5-8.

The following illustration is a degreening room designed for use with citrus in pallet boxes. The ceiling of the room is relatively high, allowing boxes to be stacked at least four high. A false ceiling is added to provide for adequate air movement throughout the room. For more detailed information on room construction, temperature and relative humidity management and air circulation, refer to the article entitled "Ripening Facilities" (Thompson, 1994) in the reference section of the manual.

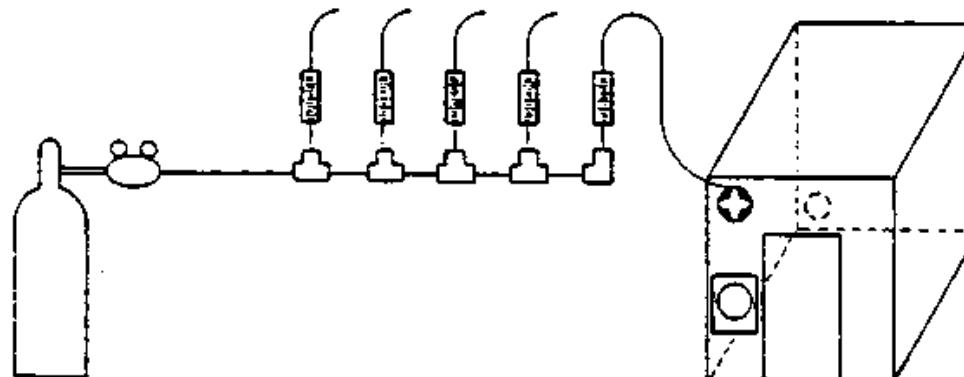


Source: USDA. No date. Modernizing Handling Systems for Florida Citrus from Picking to Packing Line. Agricultural Research Service, Marketing Research Report No. 914.

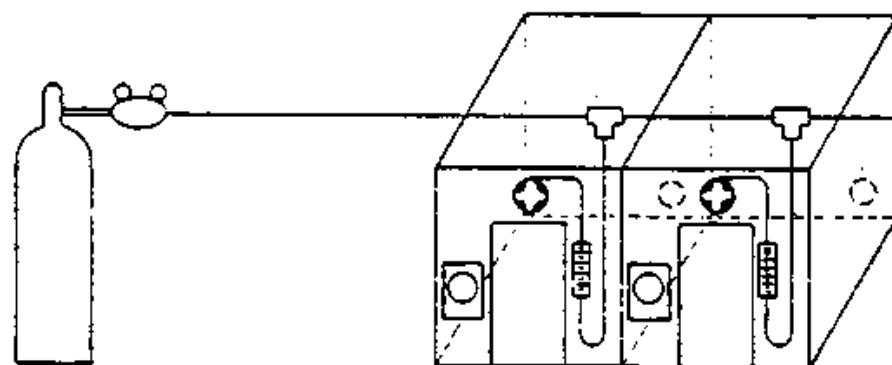
Several small ripening rooms may be more useful than a single large room for small scale handlers, since the amount of product handled at destination may vary from time to time. In this case, flow through systems can be designed to allow the use of one or more rooms at the same time.

Flowmeters can be located in one place for ease of monitoring, or can be strung out in a line. Locating all the flowmeters in one place requires the use of more tubing than if flowmeters are located in each ripening room. For more information and details on how to set up a flow through system for ripening fruit, see Sherman and Gull (1981).

Flowmeters in one location

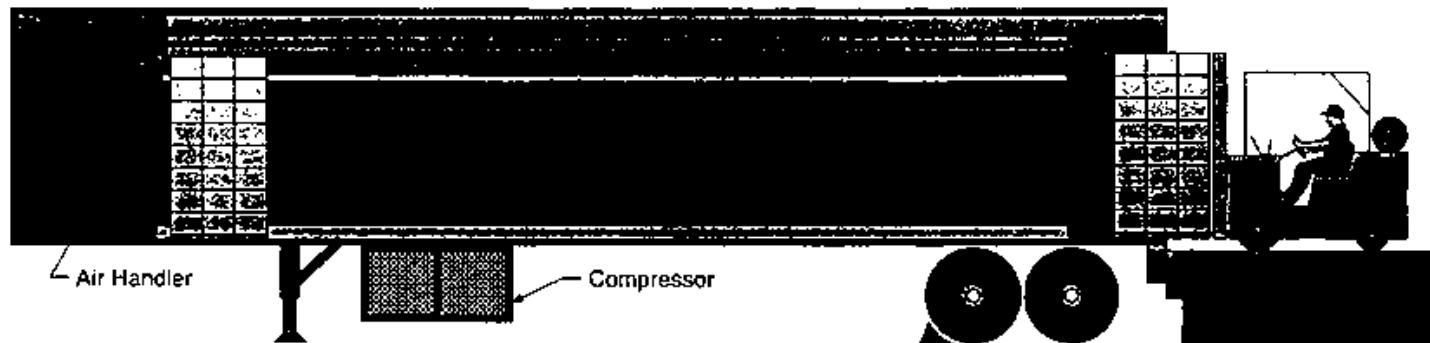


Flowmeters located in each ripening room



Source: Sherman, M. and Gull, D.D. 1981. A flow through system for introducing ethylene in tomato ripening rooms. University of Florida/IFAS, Vegetable Crops Fact Sheet 30.

Small-scale handlers can now lease portable ripening facilities from a variety of companies in the United States. The self-contained, portable system illustrated below features a 20 pallet capacity, high capacity air flow and is simple to operate. All that is needed is a loading dock and a supply of 220V electricity.

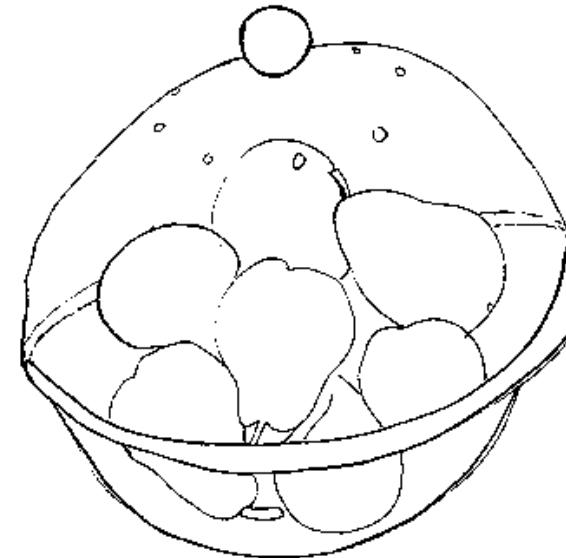


Source: Modular Ripening Company, Inc. 1994. Norfolk Virginia

Small-scale wholesalers and retailers can ripen fruits in bins or large cartons by placing a small quantity of ethylene-generating produce such as ripe bananas in with the produce to be ripened. Cover the bin or carton with a plastic sheet for 24 hours, then remove the plastic cover.

A simple way to ripen fruits at home in small amounts is to use a ripening bowl. Fruits that require ripening should be placed into the bowl with a ripe apple or ripe banana (or any other high ethylene-generating product). The bowl shown below is made of clear molded plastic and has ventilation holes around the top. Using this method, ripening will take from one to four days.

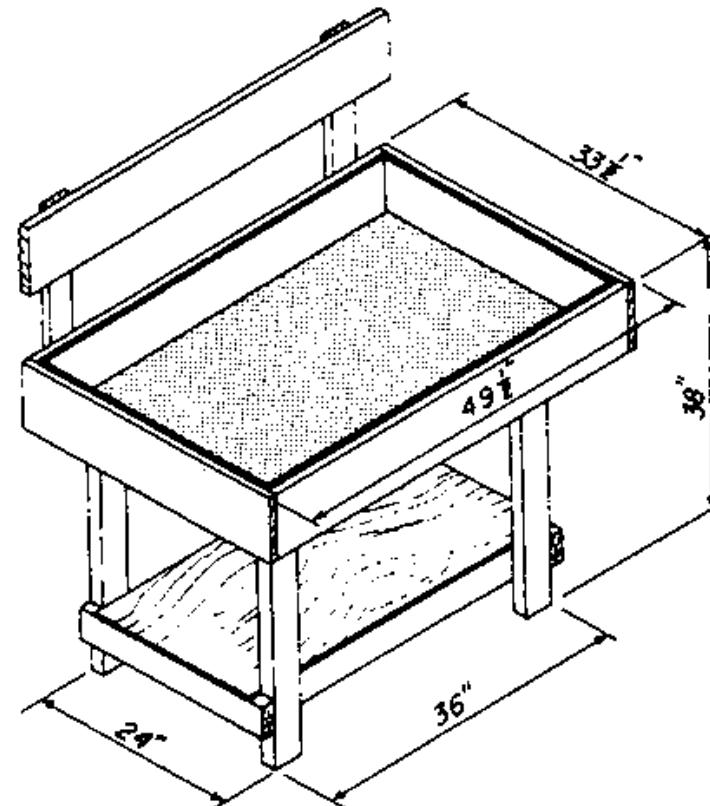
Home ripening is also possible using another, extremely low-tech practice-- place fruits to be ripened into a paper bag with a ripe piece of fruit, close loosely and check in a few days.



Display

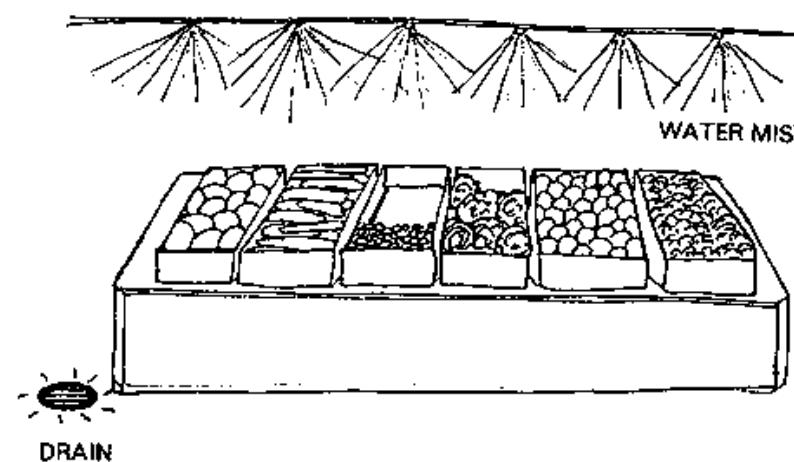
This wooden display table is designed to be used for commodities such as cruciferous crops or leafy green vegetables that tolerate cooling with ice. The table can be used in the horizontal position or as a tilted display. For more complete design specifications, contact the Cornell University Extension Service, 304 Riley-Robb Hall, Ithaca, New York, 14853.

Four to five lbs of crushed ice per square foot of display space are required for cooling per day. A catch pail should be provided for melt water. To minimize ice needs, the display tray should be insulated and kept out of the direct sun.

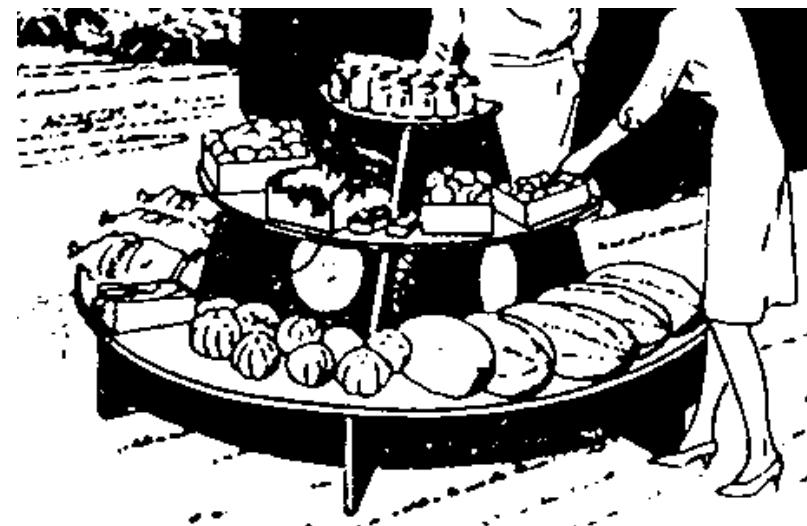


Source: Bartsch, J.A. et al. No date. Construction and management of an iced produce display. Cornell University, Agricultural Engineering Extension Bull. 438.

High relative humidity can be maintained during display by misting leafy vegetables and water tolerant crops with clean, cold water. A simple sprinkler device can be constructed by perforating a pipe with tiny holes and connecting it to a hose. If this display is used outdoors, shade should be provided.



A simple semi-circular display table can be constructed from one four foot by eight foot sheet of plywood. Plans for the table illustrated below and for other market stands are available from Cornell University Extension, 304 Riley-Robb Hall, Ithaca, New York 14853.



Source: Agricultural and Biological Engineering. No date. Description and Price List of Plans for Storages and Market Stands for Fruit and Vegetables. Cornell University Extension Bulletin 851-S.





Section 10: Processing of horticultural crops

[Processing equipment](#)

[Preparation for processing](#)

[Solar drying](#)

[Forced-air dehydrators](#)

[Oil-burning dehydrators](#)

[Electric dehydrators](#)

[Oven drying](#)

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[Canning](#)

[Juicing](#)

[Other methods of processing](#)

When conditions are not suitable for storage or immediate marketing of fresh produce, many horticultural crops can be processed using simple technologies. There are some processing methods that can be used by small-scale handlers, including drying, fermenting, canning, freezing, preserving and juicing. Fruits, vegetables and flowers can all be dried and stored for use or sale in the future. Fermentation is popular throughout the world as a food preservation method, and over 3,500 individual fermented foods have been described by Campbell-Platt (1987). Fruits and vegetables can be canned or frozen, and fruits are often preserved in sugar or juiced.

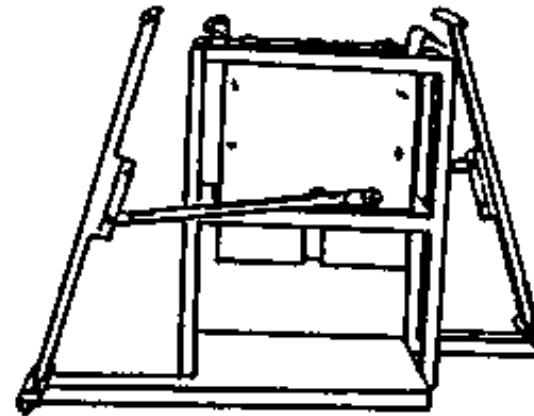
Intermediate Technology Publications* in association with CTA published a guide to appropriate equipment entitled [Small-Scale Food Processing](#) (1992) by Fellows and Hampton. We encourage you to use this directory to find more information on the processes introduced in this manual, or to locate specific equipment and local manufacturers.

* Intermediate Technology Publications, 9 King Street, London WC2E 8HW, UK

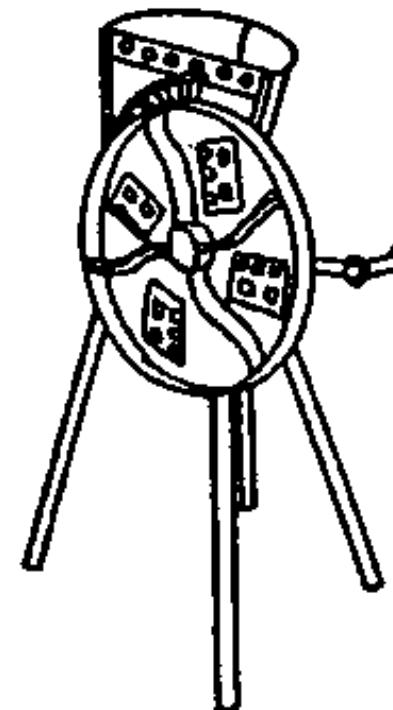
Processing equipment

A catalog of postharvest processing equipment is available from Intermediate Technology Publications. Included are driers, storage containers, cleaners, hand mills, power mills, shellers, decorticators (seed removers), oil processing equipment, fruit presses, and root crop cutters/graters. Some examples are shown below.

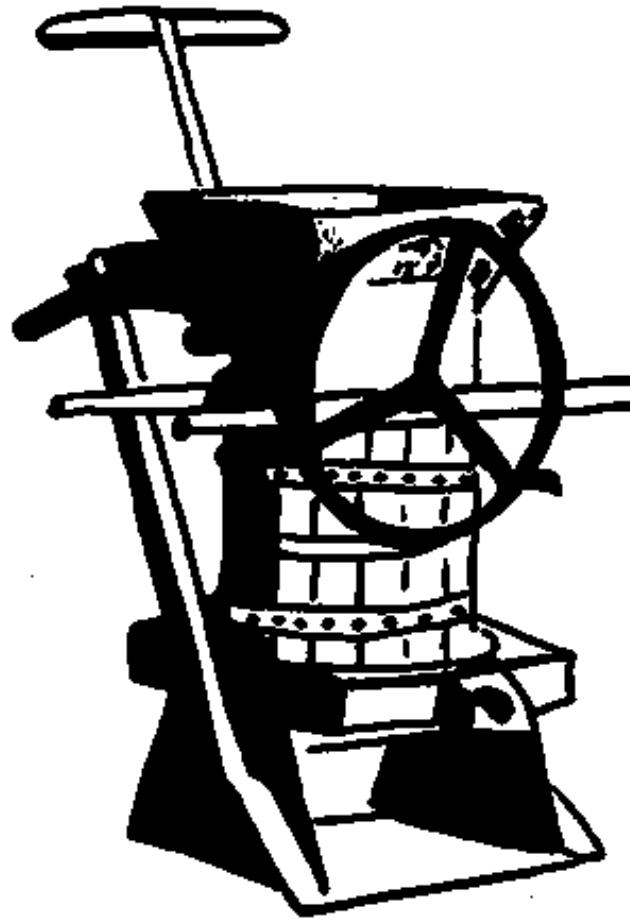
Two-man cassava grater:



Four-bladed root chopper:



Hand-operated fruit press:



Source: Intermediate Technology Publications, 1987. Post-harvest Crop Processing: Some tools for agriculture. Intermediate Technology Publications. London, England. 29 pp.

Preparation for processing

Some produce requires blanching before freezing or drying, and fruits such as apples, pears, peaches and apricots are sometimes treated with sulfur being dried. Blanching by boiling water bath or in steam ends certain enzymatic reactions in the product and helps retain color and flavor after processing. Sulfuring {burn one tablespoon of sulfur powder per pound (35 ml per kg) of fruit or dip fruit in a 1% potassium metabisulfite solution for one minute} helps prevent darkening, loss of flavor and loss of vitamin C.

Blanching times for selected commodities {use one gallon of water per pound (8 liters per kg) of produce}:

Commodity	Blanching time in boiling water (minutes)
Broccoli	3
Green Beans	3
Cabbage (wedges)	5
Carrots	5
Cauliflower	3 (add 4 teaspoons of salt)
Corn	7
Eggplant -	4 (add 1/2 cup lemon juice)
Leafy greens	2
Mushrooms	3 to 5
Peas	2
Potatoes (new)	4 to 10
Pumpkin	until soft
Zucchini/summer squash	3

Source: Chioffi, N. and Mead, S. 1991. *Keeping the Harvest*. Pownal, Vermont: Storey Publishing.

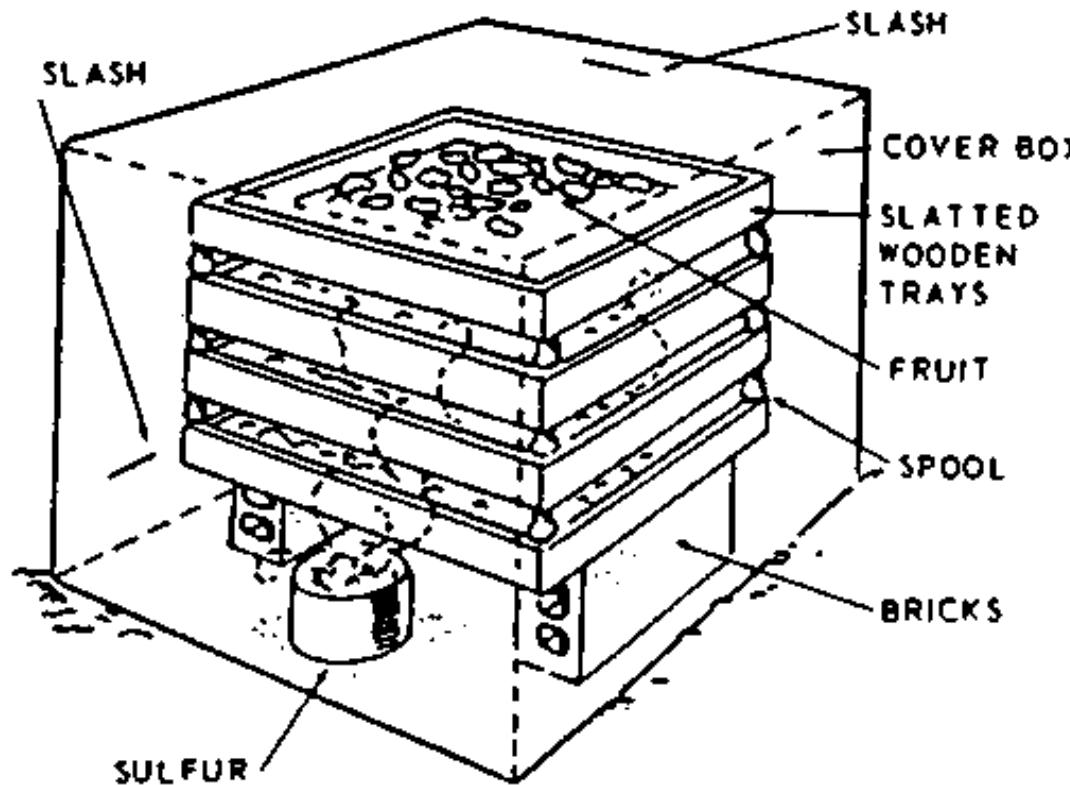
Sulfuring times for selected fruits:

Commodity	Sulfuring Time
Apples	45 minutes
Apricots	2 hours
Peaches	3 hours
Pears	5 hours

Source: Miller, M. et al. 1981. Drying Foods at Home. University of California, Division of Agricultural Science, Leaflet 2785.

A low cost sulfuring box can be constructed from a large cardboard box that is slashed in several places to allow adequate ventilation. Trays for drying be stacked using bricks and wooden spools as spacers. The trays must be made completely of wood, since sulfur fumes will corrode metal. The entire assembly must be located out of doors, preferably on bare soil.

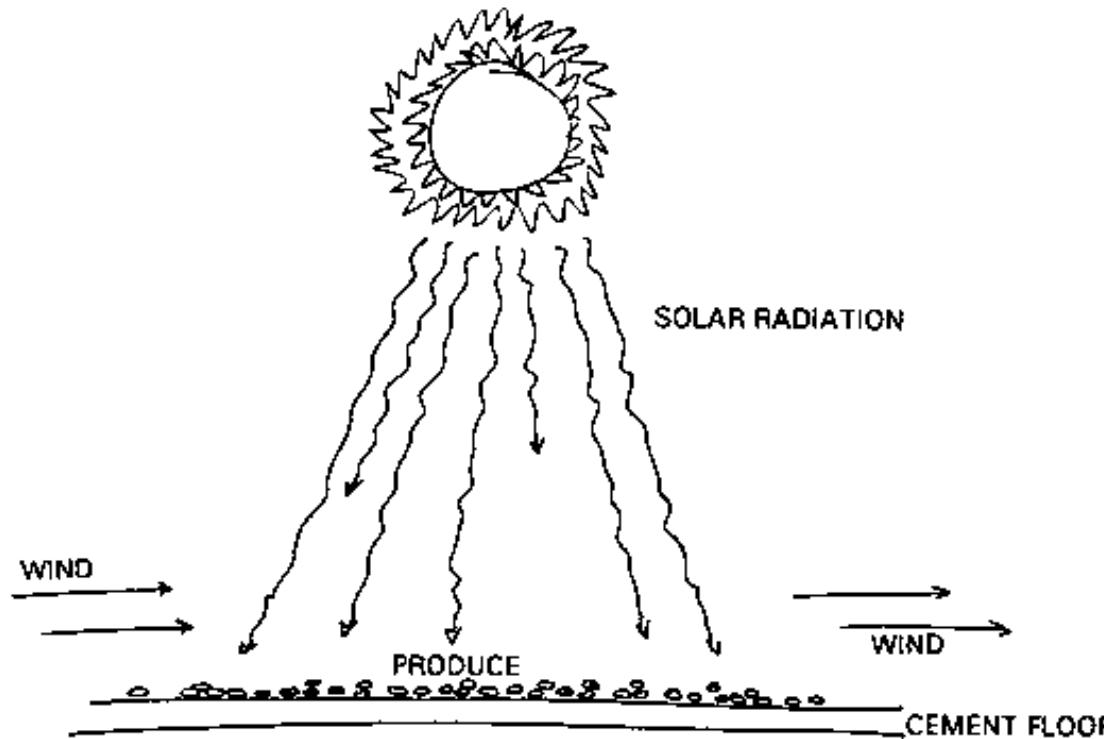
Use one tablespoon of sulfur powder per pound (35 mls per kg) of fruit. Place the sulfur in a container well away from the side of the box since it will become quite hot. Seal the bottom edges of the box with soil.



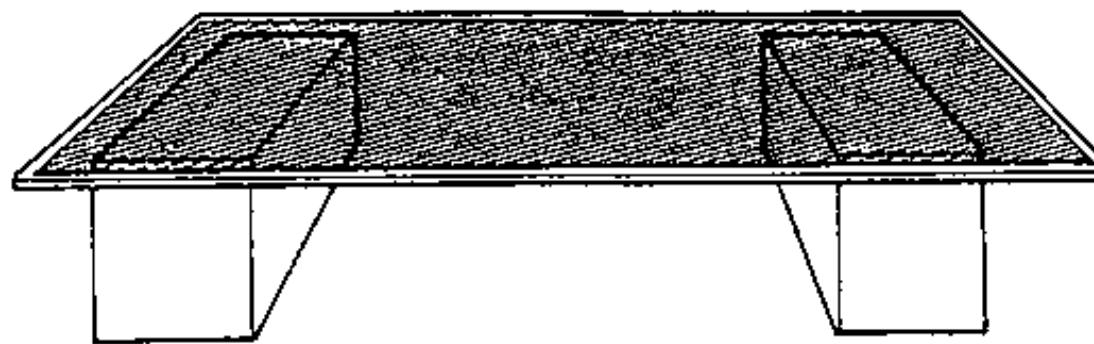
Source: Miller, M. et al. 1981. Drying Foods at Home. University of California, Division of Agricultural Science, Leaflet 2785.

Solar drying

Horticultural produce can be dried using direct or indirect solar radiation. The simplest method for solar drying is to lay produce directly upon a flat black surface and allow the sun and wind to dry the crop. Nuts can be dried effectively in this way.

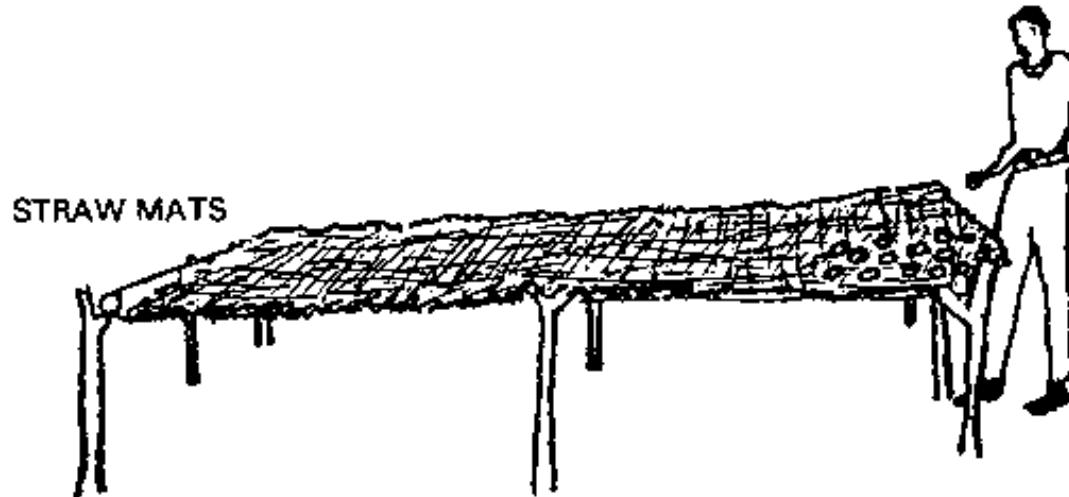


Simple direct driers can be made from trays of screening material propped upon wooden or concrete blocks to allow air to circulate under the produce. A layer of cheesecloth can be draped loosely over the produce, protecting it from insects and birds while drying.



A simple method for solar drying is to construct a raised platform from wood and cover the frame with loosely woven mats. In the illustration below, sliced fresh tomatoes are being dried in direct sunlight on straw mats. Air can pass over and below the produce, speeding drying and reducing losses due to overheating.

STRAW MATS



Source: Kitinoja, L. 1992. Consultancy for Africare/ USAID on food processing in the Ouadhai, Chad, Central Africa. Extension Systems International, 73 Antelope Street, Woodland, California 95695.

In order to improve the efficiency of drying, some sort of structure must be used to capture solar radiation. Various types of solar driers have been developed and are illustrated below.

Drier type	Description	Schematic view of typical example
Direct cabinet	Drying Chamber is glazed and no separate solar collector is used.	
Indirect cabinet	Solar collector is used which is separate from the drying chamber, which has no transparent surfaces.	
Mixed mode or Hybrid cabinet	Drying chamber is partially or fully glazed, and a separate solar collector is used.	
Tunnel	Usually a hoop framed structure with one or two layers of film plastic glazing. Usually a direct drier, but can be indirect if black plastic film is used for the inner layer of glazing.	

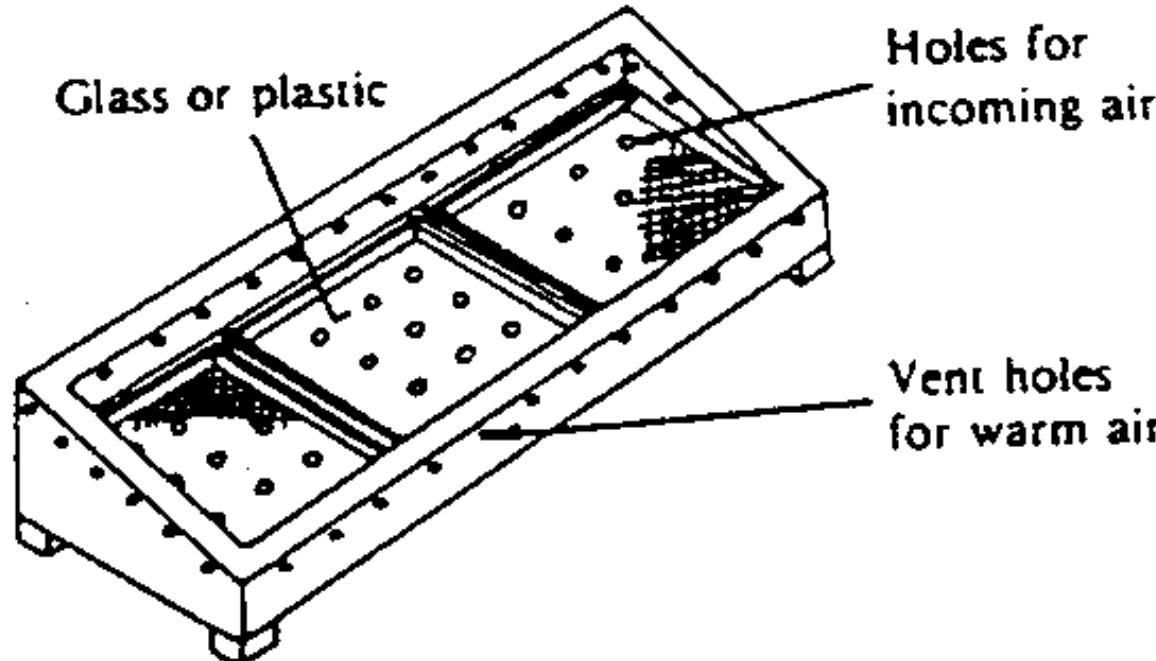
Low tunnel	Direct drier similar to the above but built close to the ground, and usually able to hold only one layer of produce.	
Tent	Direct drier with straight rather than curved frame members-	
Bin	Any drier, but usually indirect with forced convection air flow, which can dry deep layers (typically 300 mm or more) of the produce.	

* indicates glazed surface

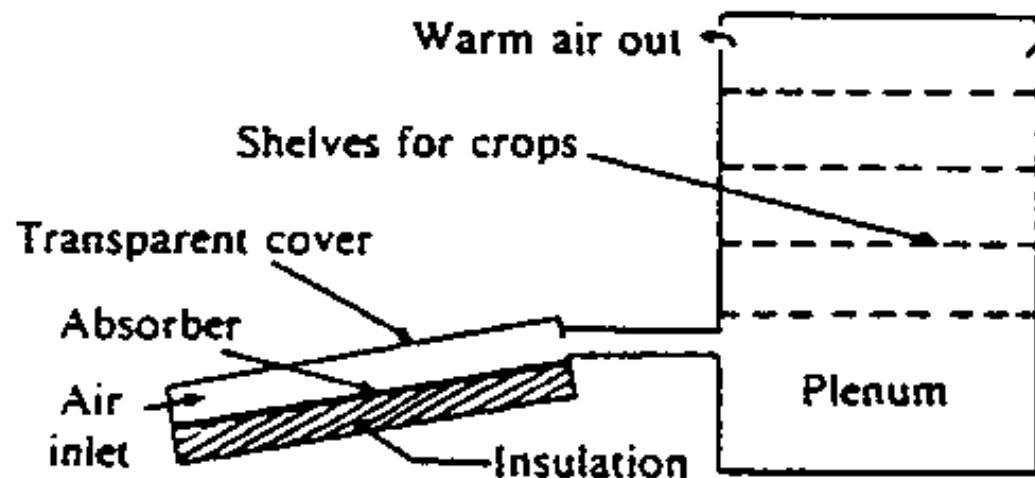
Source: Fuller, R.J. 1993. Solar Drying of Horticultural Produce: Present Practice and Future Prospects. Postharvest News and Information 4(5): 131N-136N.

More complex models of solar driers have glass or clear plastic windows that cover the produce, providing some protection from insects while capturing more of the heat of the sun.

Direct solar drier:



Indirect driers are constructed so the sun shines upon a solar collector (a shallow box, the insides painted black, topped with a pane of glass) heating air which then moves upward through a stack of four to six trays loaded with produce.



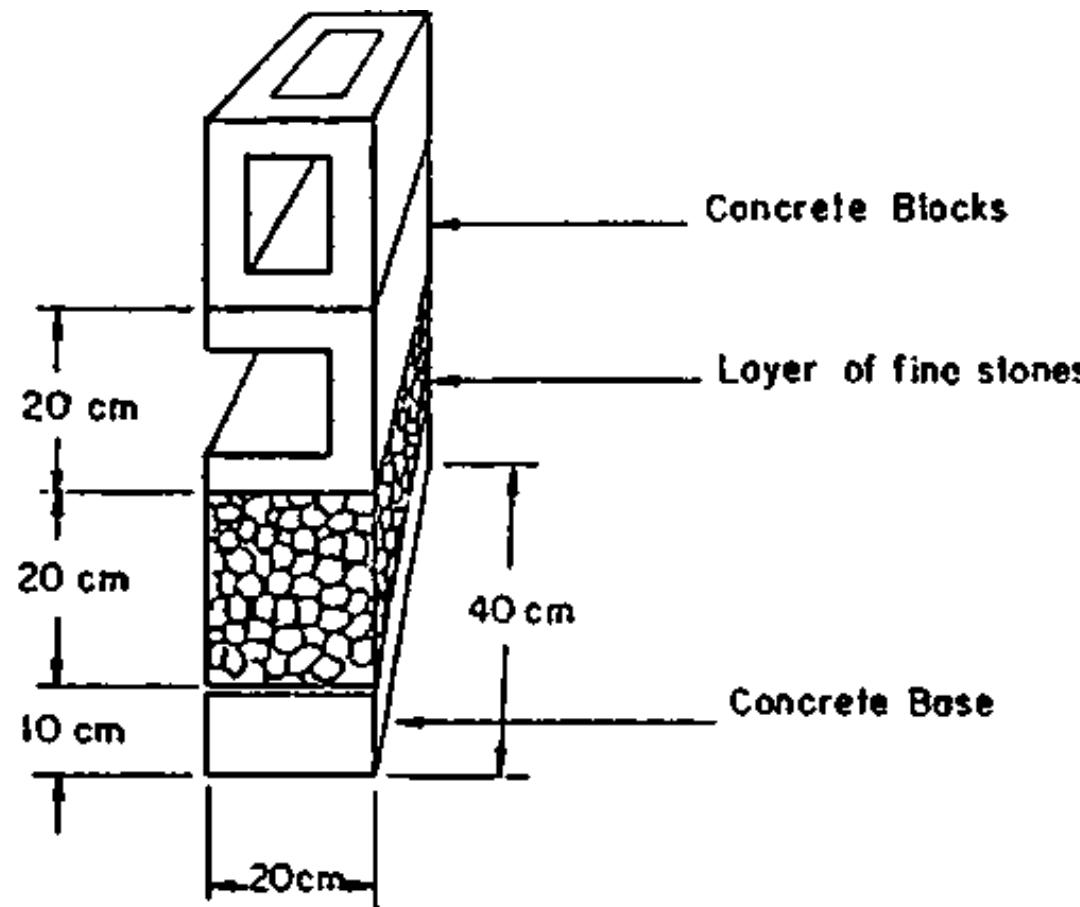
Source: Yaciuk, G. 1982. Food Drying: Proceedings of a Workshop held at Edmonton, Alberta, 6-9 July 1981. Ottawa, Ontario: IDRC 104 pp.

The solar drier for cassava chips illustrated below consists of a solar collector, a fan, and drying bin. The solar collector is constructed on a concrete base, using a layer of fine stones and two layers of concrete blocks, all covered with polyethylene.

The air heated within the collector is then forced through the perforated floor of the drying bin. The walls at the top of the bin, below the overhanging roof, are made of screen, allowing for easy movement of air through the produce.

The solar dryer:

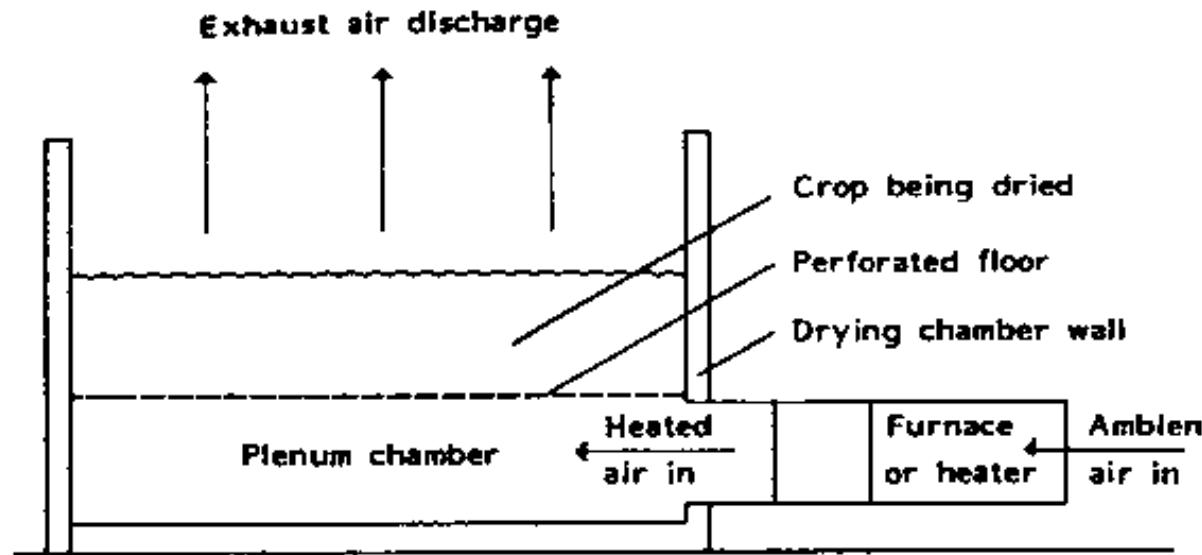
Detail of the solar collector:



Source: Best, R., Alonso, L. and Velez, C. 1983. The development of a through circulation solar heated air dryer for cassava chips 6th Symposium, International Society for Tropical Root Crops. (Lima, Peru, Feb. 21-26, 1983).

Forced-air dehydrators

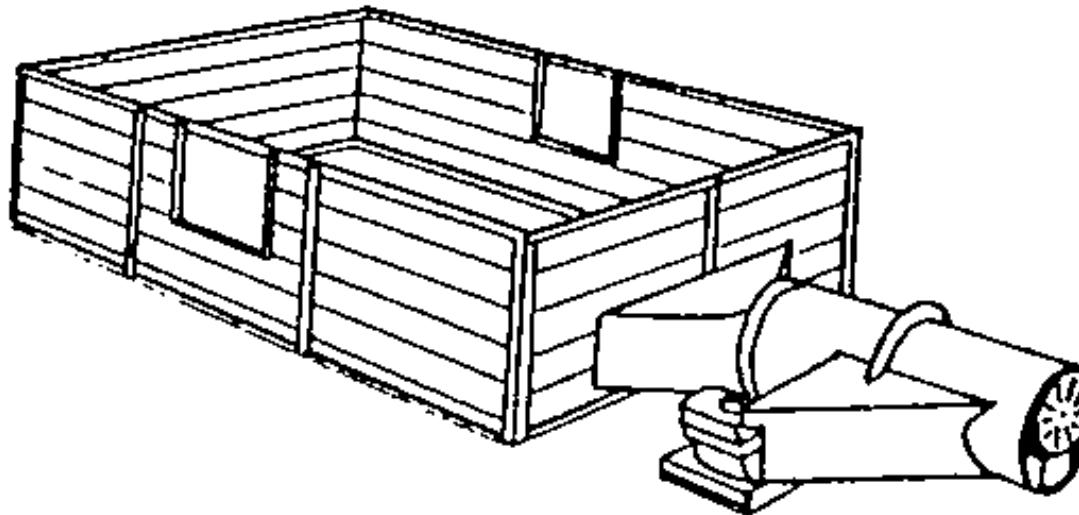
Nut crops can be dried in bulk using a dehydrator that combines a steady stream of air with an external source of heat. The plenum chamber below the produce is covered with a floor of perforated sheet metal or wooden slats. A fan located between the furnace and the plenum chamber moves the hot air through the drying produce.



Source: FAO. 1985. Prevention of Post-Harvest Food Losses: A Training Manual. Rome: UNFAO. 120 pp.

Oil-burning dehydrators

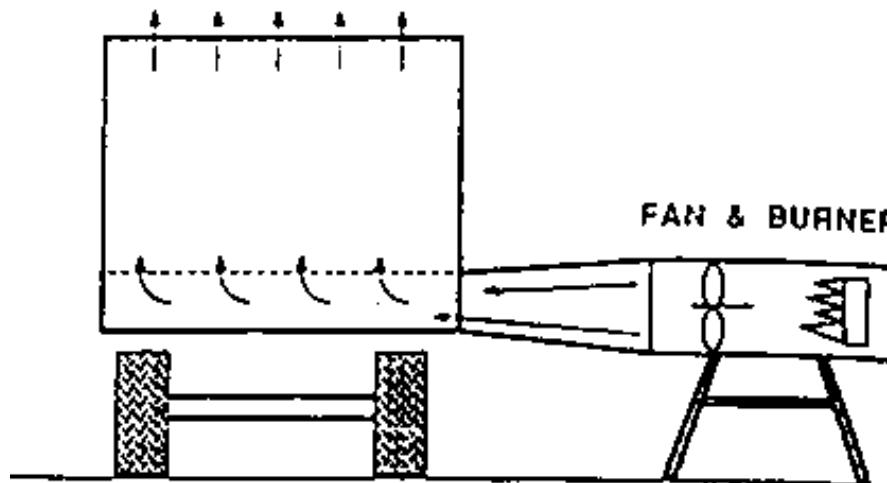
The batch-dryer illustrated below is constructed of wood, has an axial type fan and burns kerosene or diesel oil. A wide variety of dryers are available from manufacturers around the world.



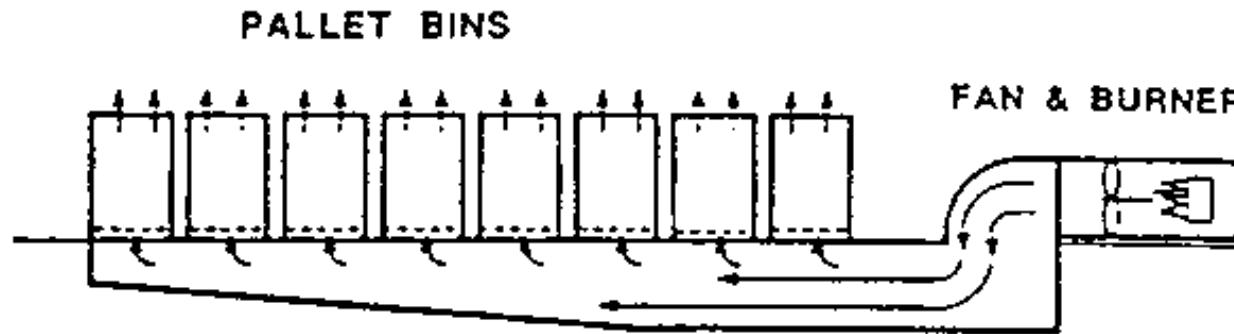
Source: Clarke, B. 1987. Post-Harvest Crop Processing: Some Tools for Agriculture. London, UK: Intermediate Technology Publications.

Two types of dehydrators are commonly used for drying small volumes of nut crops. A wagon with a perforated floor can be transported from the field and connected to a portable burner batch drying. A stationary "pot-hole" dehydrator is designed to move heated air along a plenum under a fixed platform Individual bins of nuts are placed upon the platform and are dried as heat rises up through the perforated floor.

Wagon Dehydrator:



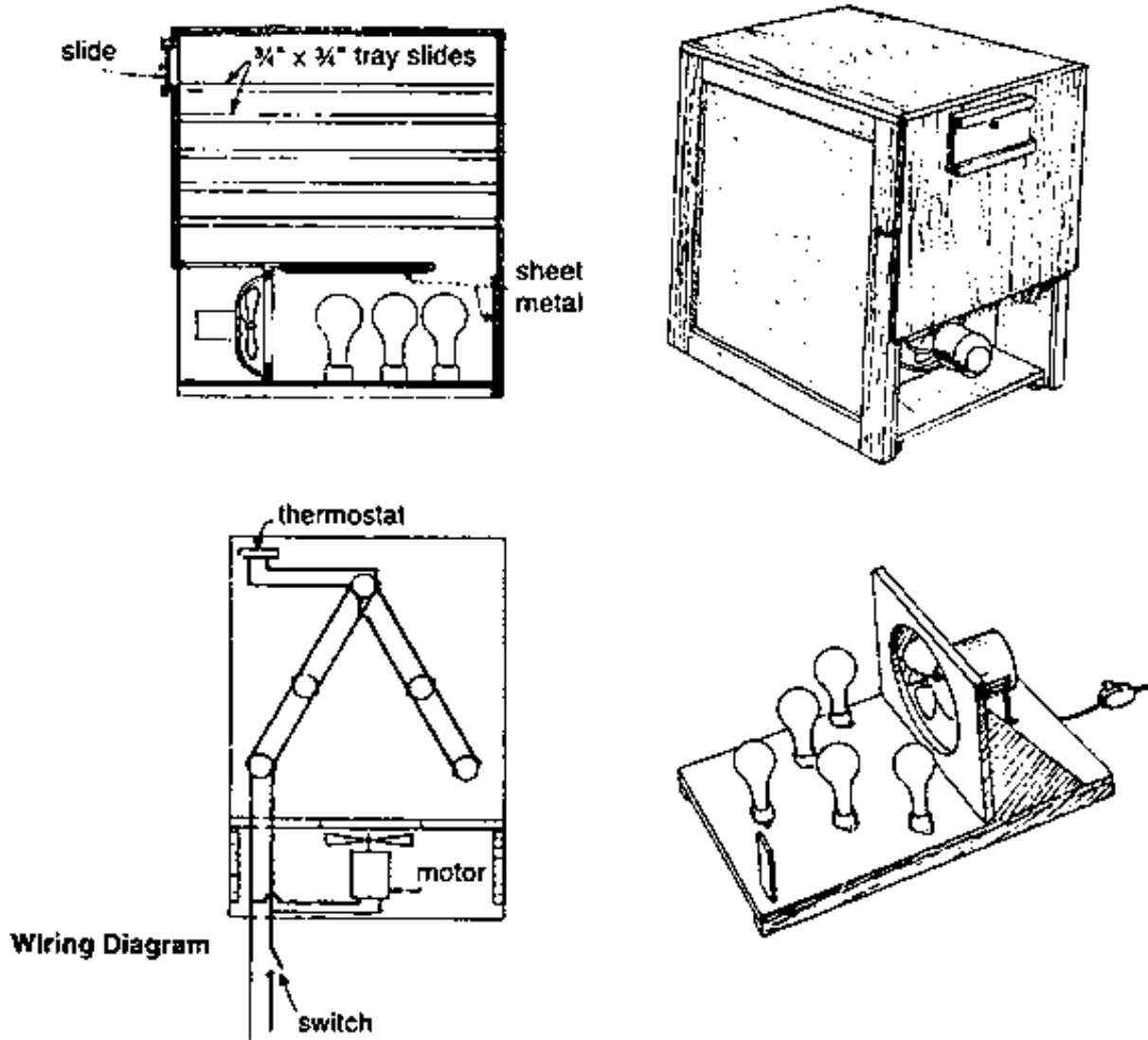
Pot-Hole Dehydrator:



Source: Kader, A.A. and Thompson, J.F. 1992. In: Kader, AA. (Ed). Postharvest Technology of Horticultural Crops. University of California, Division of Agriculture and Natural Resources, Publication 3311.

Electric dehydrators

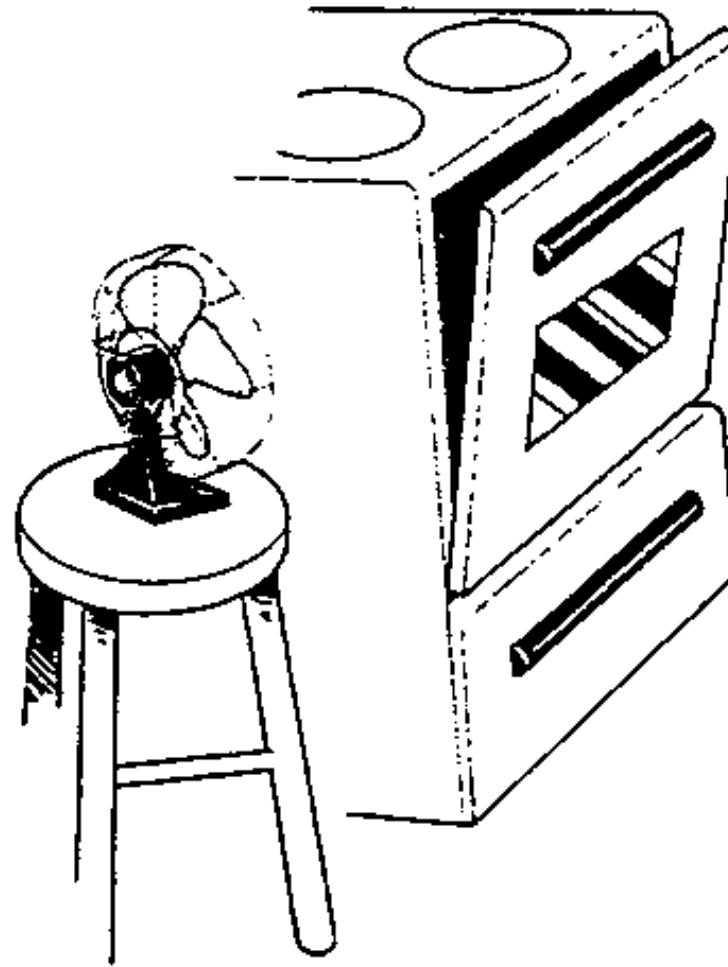
A simple electric dehydrator can be constructed using plywood, sheet metal a small fan, five household lightbulbs with porcelain mounting fixtures and some screening material. The drier shown below is 32 inches long by 21 inches wide and 30 inches high, and contains racks for five trays. The fan and the sheet metal lining the bottom compartment help conduct heat upward through the box.



Source: Chioffi, N. and Mead, G. 1991. Keeping the Harvest. Pownal, Vermont: Storey Publishing

Oven drying

Fruits and vegetables can be dried in a home oven if the oven can be run at a low temperature. Place the prepared produce on baking or metal screen trays, set the oven temperature at 140 degrees F and leave the door ajar (2 to 4 inches). Drying time can be reduced if ventilation is increased by using a small fan placed outside the oven.



Source: Georgia Cooperative Extension Service. 1984. So Easy to Preserve. University of Georgia, Athens, Georgia.

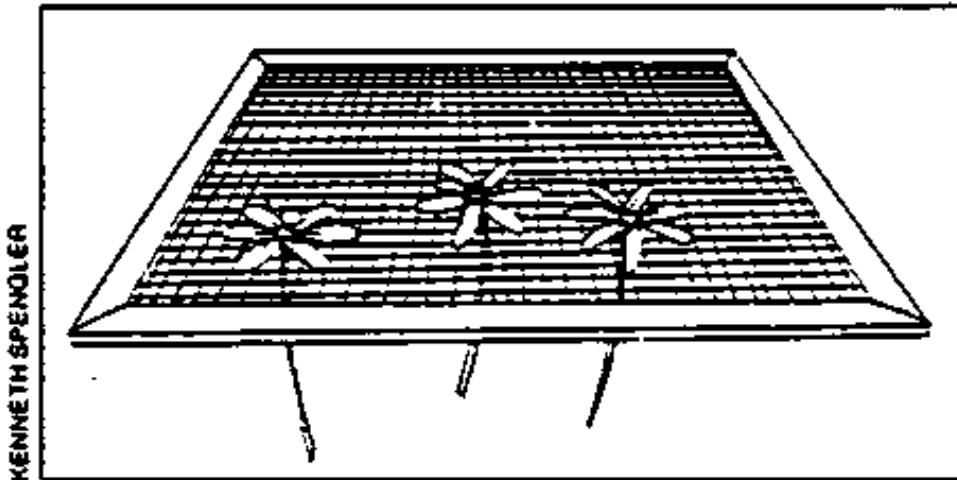
Drying flowers

Cut flowers can be air dried by hanging upside down or while supported by chicken wire. Certain flowers will look more natural if left standing in a vase while they dry. Anthurium dries best if left to dry very slowly. Cut the stems at a sharp angle, and place the flowers into a vase containing two inches of water. In all cases, flowers should be left to air dry in a dark, well area.

Flowers that dry best if left standing: strawflower, delphinium, larkspur, okra pods

Flowers that dry best while hanging upside down: chrysanthemum, amaranthus, African daisy, statice, marigold

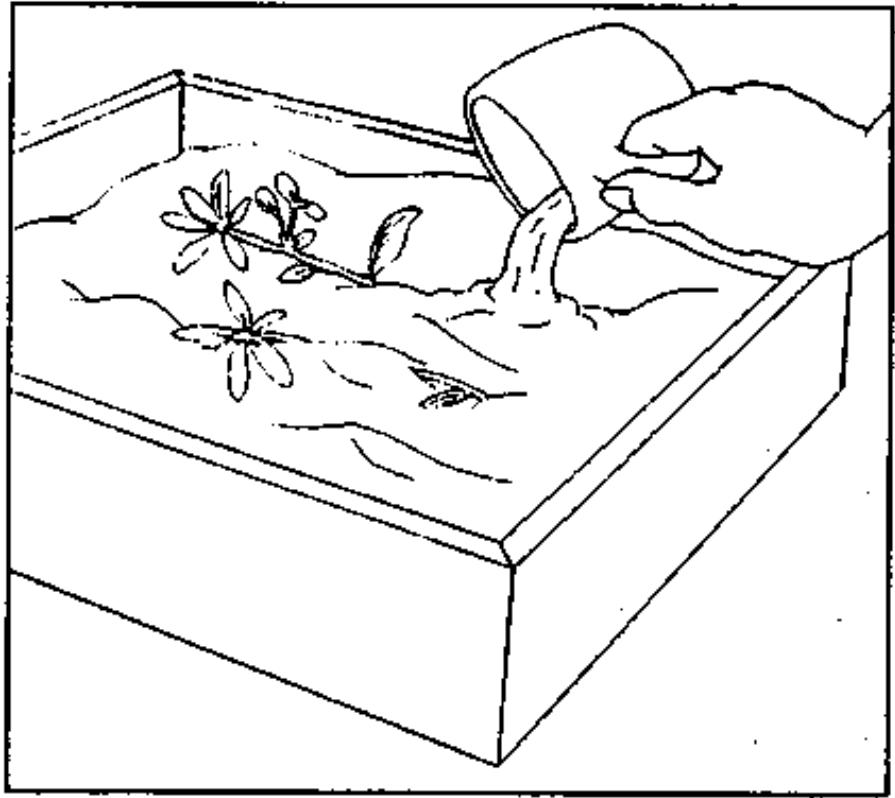
African daisy supported on a screen of chicken wire:



Source: Rogers, B.R. 1988. The Encyclopaedia of Everlastings. New York: Michael Friedman Publishing Group, Inc. 191 pp.

Cut flowers can be dried quickly and easily in sand or silica gel. Sand used for drying flowers should be clean? smooth and the finer the better. Starting with one inch of sand in a container, place the flower to be dried on the sand and gently cover the entire flower with more sand. The container should be left uncovered and flowers should be dried in about three weeks. Flowers that dry well in sand are shasta daisy, lily-of-the-valley, cosmos, dahlia, sweet william carnation, stock, freesia and narcissus.

Drying flowers in sand:



Silica gel is relatively expensive but reusable if heated to dry out the gel between uses. To use, cover the flower as with sand, then tightly seal the container. Check for drying in two to three days. Silica gel is especially useful for drying fragile plants and flowers with delicate colors.

Flowers that dry best in silica gel are allium, anemone, cornflower, roses, tulip and zinnia.

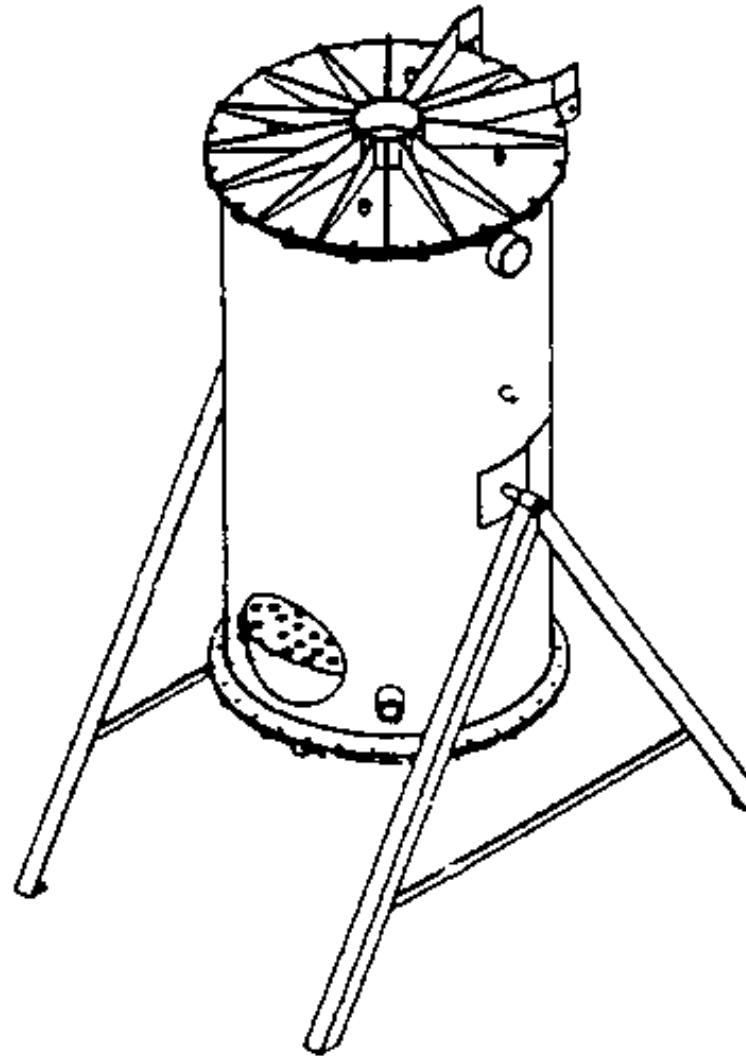
Source: Rogers, B.R. 1988. The Encyclopaedia of Everlastings. New York: Michael Friedman Publishing Group, Inc. 191 pp.

Extraction of essential oils from aromatic plants

The steam extraction unit illustrated below was first constructed for experimental extraction of essential oils from small quantities of aromatic plants. This 500 liter (130 gallon), stainless steel vessel may be used by small scale processors, as it extracts up to 100 ml (3.5 fluid ounces) of essential oils per distillation and can be operated by a single individual.

The model shown below is portable if mounted on a trailer. Steam is introduced at the bottom of the vessel, and moves through a layer of plant material which rests upon a perforated stainless steel plate. Steam, water vapor and extracted volatiles exit the tank at the top, then pass through a water cooled aluminum condenser. The tank can be tilted for ease in emptying, cleaning, and reloading.

The steam extractor:



The condenser:

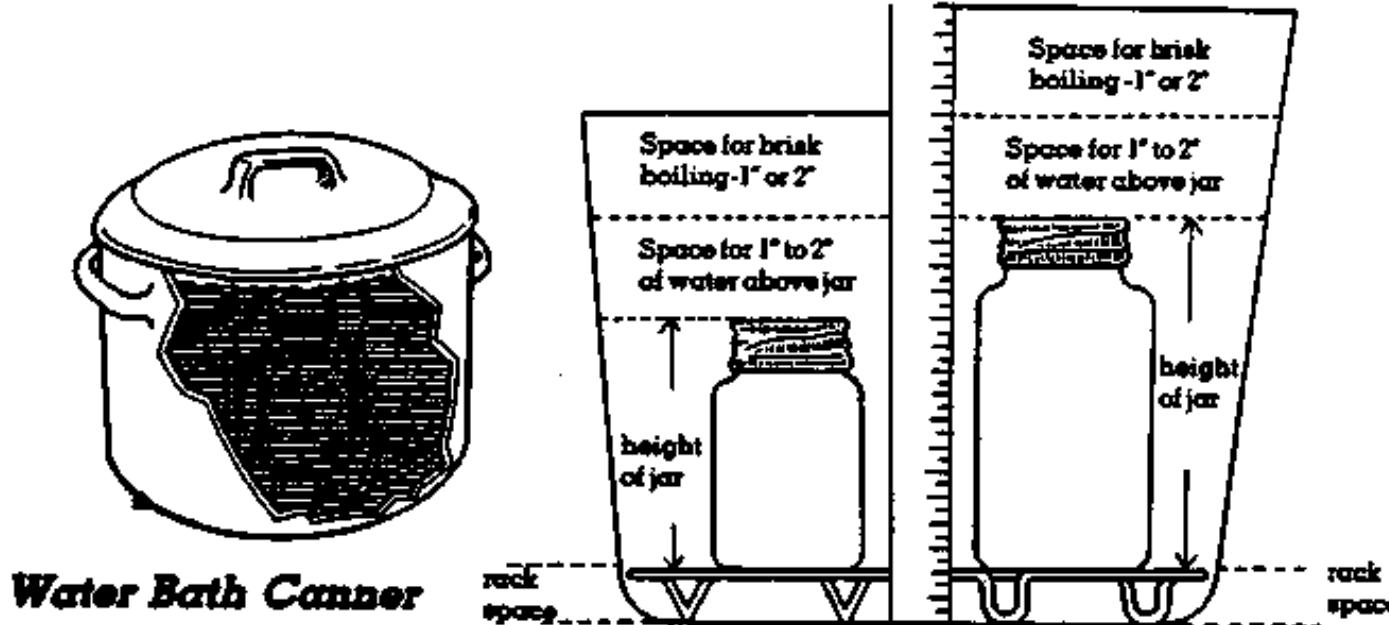


Source: Alkire, B.H. and Simon, J.E. 1992. A portable steam distillation unit for essential oil crops. *Hort Technology* 2(4): 473-476.

Canning

Two types of canners are commonly used to process horticultural crops. The first is a water bath canner, which is a large pot with a loose cover and a rack to hold jars off the bottom. The pot should be deep enough to cover the canning jars by one to two inches and still have another inch of space to allow brisk boiling. The diameter of the pot should be no more than four inches wider than the diameter of the stove's burner to ensure even heating.

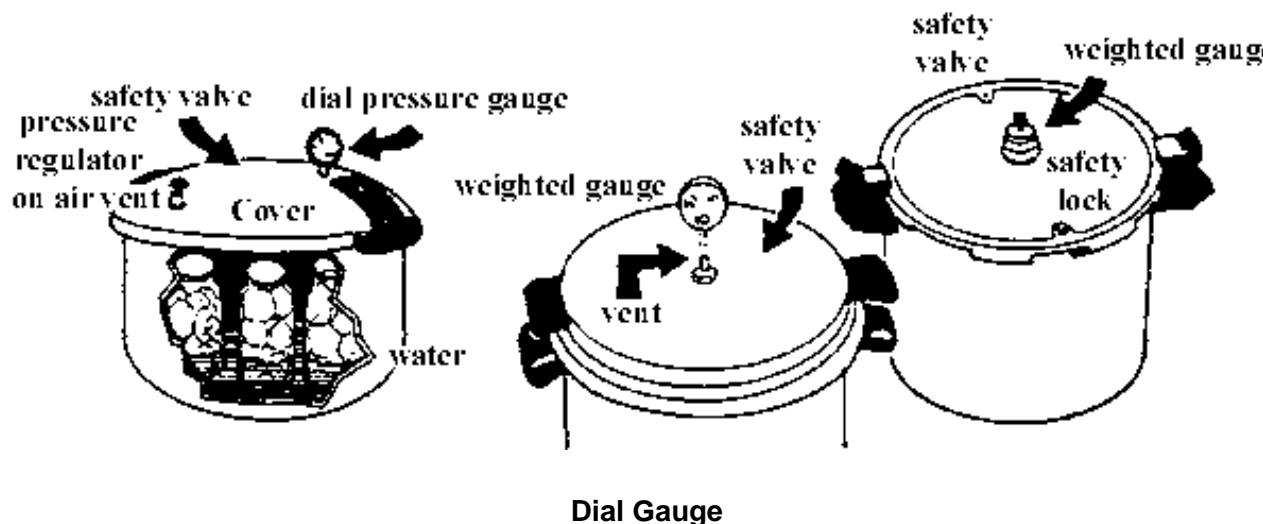
Acidic foods such as fruits, tomatoes, pickles and relishes, and high sugar foods such as jams, jellies, syrups and marmalades can be safely processed using a boiling water bath.



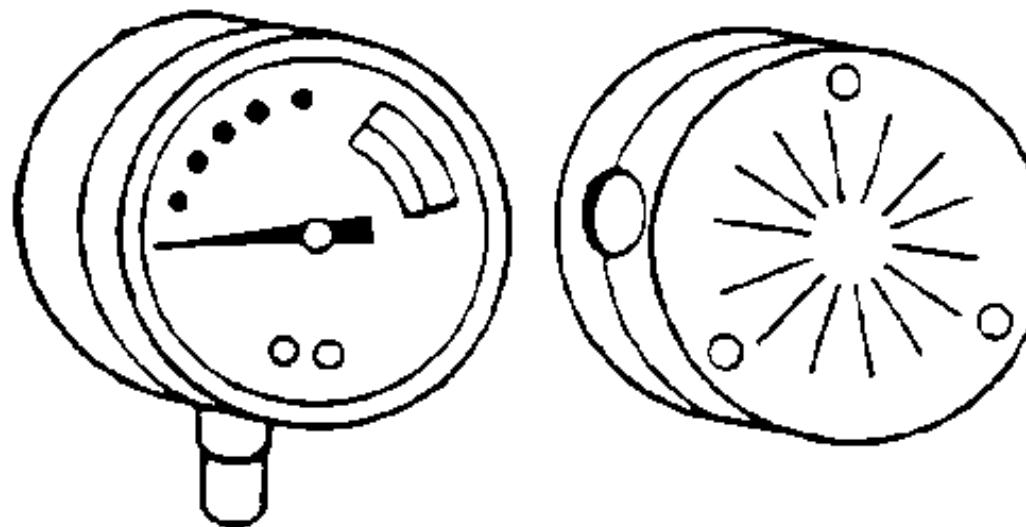
Source: Georgia Cooperative Extension Service. 1984. So Easy to Preserve. University of Georgia, Athens, Georgia.

A pressure canner is recommended for processing low acid foods such as vegetables. A pressure canner is a specially made heavy pot with a locking lid, an inner rack and a steam vent in the lid. The vent can be adjusted using a weight, valve or screw, depending on the type of canner. A pressure gauge registers the air pressure inside the canner. A dial gauge gives a reading of the actual pressure, while weighted gauges will rock gently when the canner is at the proper pressure. Ten pounds of pressure at 115 C (240 F) is recommended for canning vegetables.

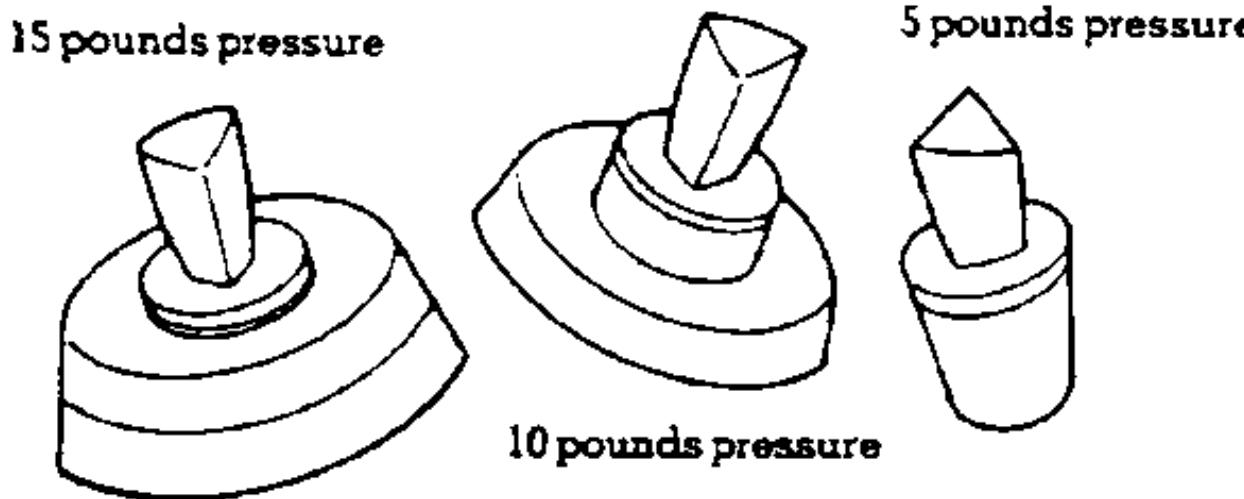
Pressure Canners



Dial Gauge



Weighted Gauges

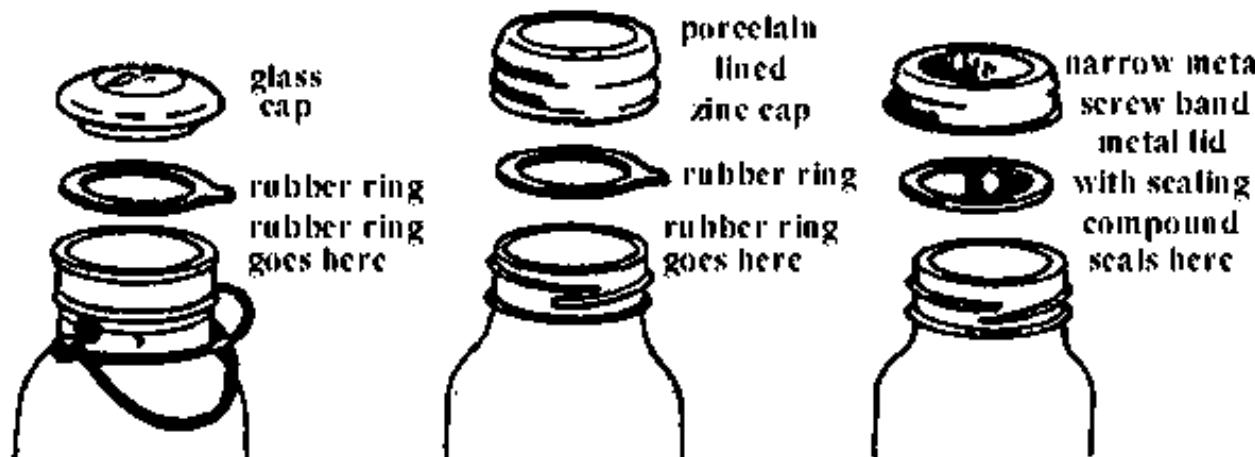


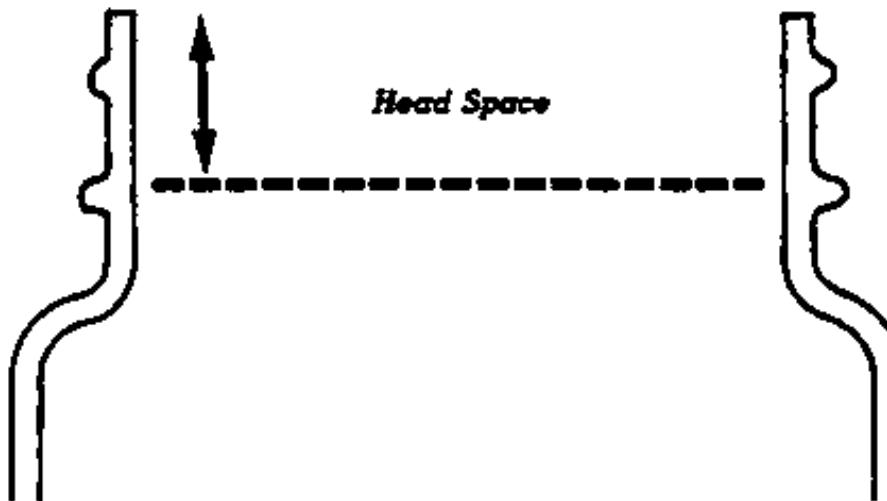
Source: Georgia Cooperative Extension Service. 1984. So Easy to Preserve. University of Georgia, Athens, Georgia.

There are three types of glass canning jars used for processing horticultural crops. The ball type jar and the zinc capped jar both require rubber rings as seals. These can sometimes be difficult to obtain, but if locally available, make excellent containers. Currently the canning jar with a two-pieced lid is the most commonly used container.

No matter which jar is used, when filling containers, it is important to leave a small amount of headspace to allow for expansion of the food while processing. If a jar is filled too full, it may explode. If too much headspace is left, the food may spoil, since all the extra air may not be driven out during processing.

Canning jars and lids, L to R: ball type jar, zinc lid and two-piece





Source: Georgia Cooperative Extension Service. 1984. So Easy to Preserve. University of Georgia, Athens, Georgia.

Juicing

Fruits

To process tomatoes or fruits to juices, fruits are simmered in water or their own juice in a stainless steel, glass or enamelware pot. When tender, the product is cut into pieces and pressed through a food mill, colander or several layers of cheesecloth. Sugar or lemon juice can be added, to taste.

The juices must then be either frozen or canned for storage. Juices can be frozen in jars or freezer containers (leave 1/2 inch headspace). Most fruit juices can be canned in a boiling water bath for 20 minutes, but apple and grape juices can be processed in hot water (82 C or 180 F) for 30 minutes.

Vegetables

Vegetables should be chopped or shredded, then simmered for 45 to 50 minutes until mushy. The juice can then be pressed or strained from the vegetable pulp, and frozen or canned. Canning vegetable juices requires processing at ten pounds of pressure in a pressure canner. Pints should be processed for 55 minutes, and quart jars for 85 minutes.

Source: Stoner, C.H. (Ed). 1977. Stocking Up. Emmaus, Penn: Rodale Press.

Other methods of processing

Freezing

Most vegetables should be blanched before freezing to prevent loss of flavor and color during storage. Freezing temperatures are best set between -21 to -18 C (0 to 5 F).

Packages for freezing should be moisture proof and vapor proof and contain as little air as possible to prevent oxidation during storage. Heavy plastic bags, heavy aluminum foil, glass freezer jars and waxed freezer cartons all make good containers.

Jellies, Jams and Preserves

Making jams, jellies and other high sugar preserves requires a balance of fruit, acid, pectin and sugar for best results. Underripe fruits contain more pectin than ripe fruits, and apple juice is a good source of natural pectin. If fruits are low in acid, lemon juice can be added to the mixture of fruit and sugar. Cane or beet sugar is better for making preserves than honey or corn syrup.

To preserve fruits, cook on medium heat until the mixture "sheets" from a spoon. Avoid overcooking since this will lower the jelling capacity of the mixture. Pour into containers and seal with paraffin wax (jellies only). The other preserves should be processed in a boiling water bath for five minutes.

Fermentation

When lactic acid bacteria in foods convert carbohydrates to lactic acid, food is preserved by the resulting low pH. Sauerkraut (cabbage) and wine (grapes) are two examples of thousands of fermented foods made around the world. For more information and recipes, see Chioffi and Mead (1991).

Acidification

Pickling is a simple processing method that can be used with many types of fruits and vegetables. Brine solution (9 parts cider or white vinegar, 1 part non-iodized salt, 9 parts water, plus flavorings and spices) is poured over the product into glass canning jars (leave 1/2 inch headspace). Brined pickles are sealed and left at ambient temperature for three or more weeks, while fresh pack pickles are processed in a boiling water bath for 10 minutes.

Source: USDA. 1977. Canning, Freezing and Storing Garden Produce. USDA Agricultural Information Bulletin 410.





General references

Aiyer, RS. et al. 1978. No-cost method for preserving fresh cassava roots. Cassava Newsletter 4: 8-9. Cali, Colombia: CIAT.

ASEAN-PHTRC. 1984. Village Level Handling of Fruits and Vegetables: Traditional Practices and Technological Innovations. Postharvest Horticulture and Training Center, College of Agriculture, University of the Philippines at Los Baños. Extension Bulletin No. 1

Broustead, P.J. and New, J.H 1986. Packaging of fruit and vegetables: a study of models for the manufacture of corrugated fibreboard boxes in developing countries. London: TDRI. (for information contact NRI, Central Avenue, Chatham Maritime, Kent, ME4 4TB, United Kingdom).

Campbell-Platt, G. 1987. Fermented Foods of the World: Dictionary and Guide. Stonam, Massachusetts: Butterworth Heineman.

CIP. 1982. Annual Report. Lima, Peru: International Potato Center.

FAO. 1989. Prevention of Post-Harvest Food Losses: Fruit. Vegetables and Root Crops. A Training Manual. Rome: UNFAO. 157 pp.

FAO. 1986. Improvement of Post-Harvest Fresh Fruits and Vegetables Handling. Regional Office for Asia and the Pacific. Maliwan Mansion, Phra Atit Road, Bangkok, 10200, Thailand.

Fellows, P. and Hampton, A 1992. Small-Scale Food Processing A Guide to Appropriate Equipment. London: Intermediate Technology Publications

Grierson, W. 1987. Postharvest Handling Manual, Commercialization of Alternative Crops Project. Belize Agribusiness Company/USAID/Chemonics International Consulting Division, 2000 M Street, N.W., Suite 200, Washington, D.C. 20036.

Hardenburg, R.E.. et al. 1986. The Commercial Storage of Fruits. Vegetables. and Florist and Nursery Stocks. USDA Agriculture Handbook 66. 130 pp.

Harvey, E. et al. 1990. Harvesting and postharvest handling of papayas in the Caribbean. Bridgetown, Barbados: Inter-American Institute for Cooperation on Agriculture (IICA).

Hunsigi, G. 1989. Agricultural Fibres for Paper Pulp. Outlook on Agriculture 18 (3): 96-103.

Kader, AA (ed). 1992. Postharvest Technology of Horticultural Crops (2nd Edition). UC Publication 3311. University of California, Division of Agriculture and Natural Resources, Oakland, California 94608.

Kupferman, E.M. 1990. Life after benlate: an update on the alternatives. Washington State University Tree Fruit Postharvest Journal 1(1): 13-15.

Liu, F.W.. 1988. Developing practical methods and facilities for handling fruits in order to maintain quality and reduce losses. Postharvest Handling of Tropical and Subtropical Fruit Crops, Food and Fertilizer Technical Center for the Asian and Pacific Region, Taipei 10616, Taiwan.

Mitchell, F.G., Guillon, R., R.A.. Parsons. 1972. Commercial Cooling of Fruits and Vegetables. U.C. Extension Manual 43, University of California, Division of Agricultural Sciences, Oakland, California 94608.

Moline, HE. 1984. Postharvest Pathology of Fruits and Vegetables: Postharvest Losses in Perishable Crops. U.C. Bulletin 1914, University of California, Division of Agriculture and Natural Resources, Oakland, California 94608.

NRC. 1992. Neem: A Tree for Solving Global Problems. Washington, D.C.: Bostid Publishing Co. 141 pp.

Natural Resources Institute. 1994. Manual for Horticultural Export Quality Assurance. Chatham, UK: Natural Resources Institute.

Pantastico, Er. B. 1980. FAO/UNEP Expert Consultation on Reduction of Food Losses in Perishable Products of Plant Origin. (6 May 1980, FAO,, Rome). 54 pp.

Proctor, F.J. 1985. Post-harvest handling of tropical fruit for export. The Courier 92: 83-86.

Reyes, M. U. 1988. Design Concept and Operation of ASEAN Packinghouse Equipment for Fruits and Vegetables. Postharvest Training and Research Center, University of the Philippines at Los Baños, College of Agriculture, Laguna.

Shewfelt, R.L. 1990. Quality of Fruits and Vegetables. A Scientific Status Summary by the Institute of Food Technologists' Expert Panel on Food Safety and Nutrition. Institute of Food Technologists, 221 North LaSalle Street, Chicago, Illinois 60601.

Shewfelt, R.L. 1986. Postharvest treatment for extending shelf life of fruits and vegetables. Food Technology 40(5):7078, 89.

Shewfelt R.L. and Prussia, S.E. (eds). 1993. Postharvest Handling A Systems Approach. San Diego: Academic Press, 358 pp.

Talbot, M. T. and Fletcher, J.H 1993. Design and Development of a Portable Forced-Air Cooler. Proceedings of the Florida State Horticultural Society 106:249-255.

Thompson, J.F. 1994. Ripening facilities. Perishables Handling Newsletter. University of California, Davis, Special Issue No. 80: 5-8.

Walker, D. J. 1992. World Food Programme Food Storage Manual Chatham, UK: Natural Resources Institute.





Appendix A: Manufacturers and suppliers of postharvest technology materials and equipment for small-scale horticultural handlers

The following list is alphabetized by product, and organized by Section topic. The list is not meant to be comprehensive, but to be a starting point for gathering information on postharvest technologies offered for sale by companies around the world. It is hoped that users of the manual will communicate with the authors regarding additional manufacturers or suppliers, and let us know about the technologies they provide. Appendix B provides the mailing addresses, telephone and FAX numbers for the businesses included in this list.

Harvesting and Preparation for Market	
bucket liners/ bucket skirts	Rod Smith Canvas Co.
gloves	Pacific 4/Ranch Brand Supply Co.
harnesses	Orchard Equipment and Supply Co. Rod Smith Canvas Co.
harvesting aids for field packing	Ramsay Welding and Machine Inc.
harvesting equipment/potatoes	Thomas E. Moore, Inc.
harvesting tools	Farber Bag & Supply Co. Orchard Equipment and Supply Co.
ladders	Orchard Equipment and Supply Co. Stokes Ladders, Inc. Pacific 4/Ranch Brand Supply Co.
nut harvesters, shakers	N H Savage Equipment Inc.
picking containers	Buckhorn Friend Manufacturing Corp. Glacier Valley Enterprises Hydro-Gardens, Inc.

	Orchard Equipment and Supply Co.
	Rod Smith Canvas Co.
potato separator/ cleaner	Sorting Technology, Inc.
reusable plastic containers	Buckhorn
safety supplies	Pacific 4/Ranch Brand Supply Co.
U-pick containers	Rockford Package Supply Inc.
	Packinghouse Operations
brusher/washer	Northwest Int'l Equipment Co.
	Orchard Equipment and Supply Co.
chlorination system	American Machinery
cleaners	Brogdex Co.
	Orchard Equipment and Supply Co.
conveyors	Agri-Tech, Inc.
	Michigan Orchard Supply
	Northwest Int'l Equipment Co.
	Sorting Technology, Inc.
dumpers bin	Agri-Tech, Inc.
	Durand-Wayland, Inc.
	Orchard Equipment and Supply Co.
	Northwest Int'l Equipment Co.
field boxes, crates, buckets or baskets	Durand-Wayland, Inc.
water dump	Michigan Orchard Supply
fruit and vegetable waxes	Brogdex Co.
	Michigan Orchard Supply
	Orchard Equipment and Supply Co.
gloves	Pacific 4/ Ranch Brand Supply Co.
inspection roller tables	Market Farm Implement
	Orchard Equipment and Supply Co.
	TEW Manufacturing Corp.
lifting/handling equipment	
folding mini-dolly	Seal-o-Matic
fork lift attachment for tractor	Orchard Equipment and Supply Co.
pallet jack	Market Farm Implement
packing line equipment	Ag-Pak

	American Machinery	
	TEW Manufacturing Co.	
rotary tables	Market Farm Implement	
	Michigan Orchard Supply	
	Orchard Equipment and Supply Co.	
sizers chain sizers	Michigan Orchard Supply	
	TEW Manufacturing Corp.	
expanding rollers	Northwest Int'l Equipment Co.	
nut sizers	N H Savage Equipment, Inc.	
onion sizers	Chinook Packing Equipment	
sizing rings	Orchard Equipment and Supply Co.	
washers and waxers	Agri-Tech, Inc.	
	Durand-Wayland, Inc.	
	Market Farm Implement	
	Michigan Orchard Supply	
	Orchard Equipment and Supply Co.	
	TEW Manufacturing Corp.	
	Packing and Packaging Materials	
bagging equipment	Chinook Packaging Equipment	
	Thomas E. Moore, Inc.	
bag sealers	Seal-o-Matic	
	Thomas E. Moore, Inc.	
bags, paper	Rockford Package Supply, Inc.	
	Pacific 4/Ranch Brand Supply Co.	
bags, plastic	Rockford Package Supply, Inc.	
bags, net	Northwest Int'l Equipment Co.	
	Rockford Package Supply, Inc.	
boxes cardboard	Rockford Package Supply, Inc.	
cucumbers, tomatoes	Hydro-Gardens, Inc.	
wirebound	Dyer Fruit Box Mfg. Co.	
	Elberta Crate and Box Co.	
	Franklin Crates, Inc.	
	Growers Containers Coop, Inc.	
	Triplay y Maderas de Durango	

broccoli buncher	Market Farm Implement
fruit protector trays	Rockford Package Supply, Inc.
pads/foam, paper	Rockford Package Supply, Inc.
reusable plastic containers	Buckhorn
scales	Seal-o-Matic
shrink wrap equipment	Rockford Package Supply Co. Seal-o-Matic Hydro-Gardens, Inc.
staplers	Market Farm Implement Rockford Package Supply Co. Seal-o-Matic
tapes, tape dispensers	Rockford Package Supply Co. Seal-o-Matic
	Insect and Decay Control
automatic chlorine dispenser	Orchard Equipment and Supply Co.
fungicides	Brogdex Co.
sprayers knap-sack, backpack	Orchard Equipment and Supply Co.
sulfur dioxide pads	Zellerbach
	Temperature and Relative Humidity Control
air-exhaust doors/ louvers	Industrial Ventilation, Inc.
	Hydro-Gardens, Inc.
evaporative cooling pads	Hydro-Gardens, Inc.
hydro-coolers	Clarksville Machine Works
	Northwest Int'l Equipment Co.
	Robic Refrigeration Inc.
forced-air coolers	Mobile Forced Air Cooling Services
humidifiers	Industrial Ventilation, Inc.
ice storage	Robic Refrigeration Inc.
refrigeration equipment	Calif. Atmospheres
	Hydro-Gardens, Inc.
wind turbines	Cool Attic
	Storage of Horticultural Crops
C. A. equipment	California Controlled Atmospheres

ethylene absorbers	DeltaTRAK Inc.
	Ethylene Control
	Extendalife Systems
ethylene scrubbers	TUBAMET AG
fans	Industrial Ventilation, Inc.
ventilation systems	Industrial Ventilation, Inc.
	Transportation of Horticultural Crops
ethylene absorbers	DeltaTRAK Inc.
	Ethylene Control
	Extendalife Systems
ethylene scrubbers	TUBAMET AG
temperature/humidity data loggers	DeltaTRAK Inc.
temperature recorders	DeltaTRAK Inc.
	Handling at Destination and Marketing
displays	Kason Market Products
ethylene generators	American Ripener Co.
	Catalytic Generators, Inc.
	Precision Generators Company, Inc.
market containers	Rockford Package Supply Co.
portable ripening facilities	the De-Green Machine
	Modular Ripening Company, Inc.
refrigerated, forced-air ripening facilities	Cool Care Consulting, Inc.
ripening cabinet	Catalytic Generators, Inc.
ripening room	American Ripener Co.
ripening room supplies	American Ripener Co.
	Catalytic Generators, Inc.
	Processing of Horticultural Crops
almond hulling, drying	Mid-State Manufacturing
apple parer/corer	Orchard Equipment and Supply Co.
bottle capper	Countryside General Store
bottling equipment	Orchard Equipment and Supply Co.
can sealer	Countryside General Store
cider jugs, plastic	Rockford Package Supply Co.

electric food drier	Garden Way Country Kitchen
hand-press	Michigan Orchard Supply
	Orchard Equipment and Supply Co.
	Garden Way Country Kitchen
processing equipment	Frontier Technology, Inc.
	Intermediate Technology Publications
juice presses/non-citrus	Goodnature Products, Inc.
	Orchard Equipment and Supply Co.
rubber seals for canning jars/Ball jar seals	Italglass Corp.
	Alltrista Corporation





Appendix B: Addresses, telephone and fax numbers of manufacturers and suppliers

Alltrista Corporation, Muncie, Indiana 47305

Ag-Pak Inc. Gasport, NY 14067.
(716) 772-2651, TELEX 6+6865.

Agri-Tech Inc. P.O. Box 448, 100 Lakeview Drive, Woodstock Virginia 22664.
(703) 459-2142, FAX (703) 459-4731.

American Machinery Corp. 2730 Eunice Ave. P.O. Box 3228, Orlando, FL 32802.
(407) 295-2581.

American Ripener Co., Inc. 803 Pressley Road, Suite 106, Charlotte, North Carolina 28217.
(704) 527-8813, FAX (704) 527-6705.

Brogdex Company 1441 West Second Street, Pomona, California 91766.
(909) 622-1021, FAX (909) 629-4564.

Buckhorn 55 West Technocenter Drive, Milford, Ohio 45150.
(513) 831-4402, FAX (513) 831-5474.

California Controlled Atmospheres 39138 Road 56, Dinuba, California 93618.
(209) 591-8874, FAX (209) 591-8896.

Catalytic Generators, Inc. 1185 Pineridge Road, Norfolk, Virginia 23451.
(804) 855 0191, FAX (804) 855-4155.

Chinook Packing Equipment P.O. Box 15554, Boise, Idaho 83715.
(208) 384-5418, FAX (208) 855-4155.

Clarksville Machine Works, P.O. Box 378, Clarksville, Arkansas 72830
(501) 754-7161

Cool Attic, P.O. Box 728, Mineral Wells, Texas 76067
(800) 433-1626, FAX (817) 325-9311

Cool Care Consulting Inc. 2300 Glades Avenue, Suite 100, East Tower, Boca Raton, Florida 33431.
(407) 392-2241, FAX (407) 392-2839.

Countryside General Store Highway 19 East S.U., Waterloo, Wisconsin 53594.

the De-Green Machine, 4995 Fairview Ave. Linthicum, Maryland 21090
(410) 799-9553, (800) 286-RIPE

DeltaTRAK Inc. P.O. Box 398, Pleasanton, California 94566.
(510) 426-3011, FAX (510) 846-1147.

Durand-Wayland, Inc. P.O. Box 1404, LaGrange, Georgia 30241.
(706) 882-8161, FAX (706) 882-8161.

Dyer Fruit Box Manufacturing Co. 130 Parkview Drive, P.O. Box 245,
Dyer, Tennessee 38330. (901) 692-2241.

Elberta Crate and Box Co. P.O. Box 795, Bainbridge, Georgia 31717. (912) 246-2266.

Ethylene Control Incorporated, 8232 E. Dinuba, Selma, California 93662.
(800) 200-1909. FAX (209) 896-3232.

Extendalife Systems, 360 Beacham Street, Chelsea, MA 02150.
(617) 887-2011. FAX (617) 88+5789.

Farber Bag & Supply Co. 8733 Kapp Dr. P.O. Box 78, Poesta, IA 52068-0078.
(800) 553-9068. FAX (319) 583-2701.

Franklin Crates, Inc. P.O. Box 275, Micanopy, Florida 32667.
(904) 466-3141.

Friend Manufacturing Corp. P.O. Box 385, Prospect Street, Gasport, New York 14067.
(716) 772-2622, FAX (716) 772-2370.

Frontier Technology, Inc. 609 N. Eastern Ave. Allegan, MI 49010.
(616) 673-9464. FAX (616) 673-9629.

Garden Way Country Kitchen 48 Maple Street, P.O. Box 944, Burlington, Vermont 05401.

Glacier Valley Enterprises. S 2907 County Hwy., A Baraboo, WI 53913-9744.
(608) 356-6670. (800) 236-6670.

Goodnature Products Inc. P.O. Box 866, Buffalo, New York 14240.
(716) 855-3325. FAX (716) 855-3328.

Growers Container Cooperative, Inc. P.O. Box 491355, Leesburg, Florida 34748.
(904) 787-3579

Hydro-Gardens, Inc. P.O. Box 25845, Colorado Springs, Colorado 80936.
(719) 495-2266/(800) 634-6362, FAX (719) 531-0506.

Industrial Ventilation, Inc. 960 Broadway, Suite 460, Boise, Idaho 83706.
(208) 344-3531, FAX (208) 344-3540.

Intermediate Technology Publications. 9 King Street, London WC2E 8HW, UK.
Tel: 0602-784-505

ItalGlass Corp. (wholesalers) (305) 781-3003.

Kason Market Products, 3010 Willow Street, Franklin Park, Illinois 60131
(708) 455-7973, (800) 733-7973, FAX (708) 455-6256

Market Farm Implement RD # 2, Box 206, Friedens, Pennsylvania 15541.
(814) 443-1931, FAX (814) 445-2238.

Michigan Orchard Supply 07078 73 1/2 Street, Southhaven, Michigan 49090.
(616) 637-1111/(800) 637-6426, FAX (616) 637-7419.

Mid-State Manufacturing P.O. Box 807, Ripon, California 95366.
(209) 599-4181, FAX (209) 599-4863.

Mobile Forced Air Cooling Services, Salisbury, Maryland (800) 272-7466
Delray Beach, Florida (800) 940-3838; Fresno, California (800) 413-4200

Modular Ripening Company, Inc. 1185 Pineridge Road, Norfolk Virginia. 23502
(800) 235-0459

Thomas E. Moore Inc. P.O. Box 794, Dover, Delaware 19903.
(302) 653-2000, FAX (302) 653-3476.

NSW Corp. 530 Gregory Avenue, Roanoke, Virginia 24016.
(703) 981-0362, FAX (703) 345-8421.

Northwest International Equipment Co. Inc. P.O. Box 10932, Yakima, Washington 98909.
(509) 575-1950, FAX (509) 452-3307.

Orchard Equipment and Supply Co. P.O. Box 540, Route 116, Conway, Massachusetts 01341.
(413) 369-4335/(800) 634-5557, FAX (413) 369-4431.

Precision Generators Company, Inc. 153 South Birdneck Road, Virginian Beach, Virginia 23451
(800) 337-1777

Ramsey Welding and Machine Inc. 478 Brunkin, Salinas, California 93901.
(408) 422-6429, FAX (408) 422-9254.

Rockford Package Supply Inc. 10421 Northland Drive, Rockford, Mississippi 49341.
(800) 444 7225, FAX (616) 866-4921.

Robic Refrigeration Inc. 1105 North Broadway, P.O. Box 109, Turlock California 95381.
(209) 632-8851, FAX (209) 632-5303.

N.H. Savage Equipment Inc. 400 Industrial Road, Madill, Oklahoma 73446.
(405) 795-3394, FAX (405) 795-2448.

Seal-o-Matic Co. 900 Passaic Avenue, East Newark New Jersey 07029.
(201) 481-6500, FAX (201) 485-7818.

Rod Smith Canvas Co. 2514 Easy Street, Wenatchee, Washington, 98801.
(509) 663-1967, FAX (509) 662-1780.

Sorting Technology Inc. P.O. Box 479, American Falls, Idaho 83211.
(208) 226-2727, FAX (208) 226-2750.

Stokes Ladders, Inc. 4545 Renfro Drive, P.O. Box 445, Kelseyville, California 95451.
(707) 279 4306/(800) 842-7775, FAX (707) 279-2232.

TEW Manufacturing Corp. P.O. Box 87, Penfield, NY 14526.
(716) 586-6120

Triplay y Maderas de Durango, Juarez 104 South, Durango, Dgo., Mexico.
Tel: (52) 181-1-32-08.

TUBAMET AG P.B. 879, FL-9490 Vaduz, Europe.
Tel: (41)75-232-81-41, FAX (41) 75-232-66-41.

Zellerbach 4603 East Vine Street. Fresno, California 93725.
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