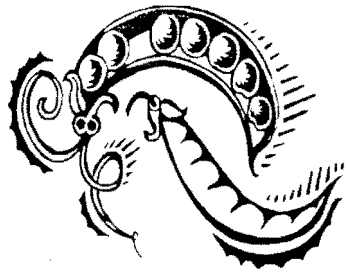
CHAPTER 8



PRODUCE TRANSPORTATION

Produce must often be transported as part of fresh handling, whether from the field to the packinghouse, from the packinghouse to storage facility, or to various destination markets. 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 cooler hours (night and early morning) can reduce the heat load on a vehicle that is transporting produce.

Refrigerated transport is highly recommended for most perishable horticultural produce. Temperature management is especially critical during long distance transport, and proper air flow is the most important factor in ensuring that the load stays cool. 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 loads should be braced away from the side walls and back door of the trailer.

Average road temperatures can be much higher than air temperatures during hot months of the year. In the western U.S., road surface temperatures can be 22 °C (40 °F) higher than the air temperature, making it difficult for refrigerated vehicles to maintain recommended temperatures.

Transit times under these conditions should be as short as possible, since deterioration will increase as temperatures increase.

Mixed loads can be a serious concern when recommended temperatures are not compatible (for example, when transporting chilling sensitive fruits with commodities that require very low temperatures). Try to avoid this situation, since either some of the produce will be injured by chilling or some of the produce will deteriorate more quickly than when handled at the recommended low temperature and your investments in postharvest handling technologies will largely be wasted.

Another problem arises 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) . Using ethylene scrubbers installed in the vehicle can reduce this problem during transport.

C.A. Transport:

avocadoes
stone fruits
pears
mangoes
asparagus
tangerines

In 1996 only 2.5% of US produce imports/exports were shipped using controlled atmosphere. In addition to regular shipping charges, carriers charge a standard flat fee of $1500 ($1.50 per carton for a typical 1000 carton load) making C.A. transport viable only for high value commodities.

This chapter describes postharvest technologies for transporting horticultural commodities via open and refrigerated loads. Quality and food safety can be protected by using proper loading methods and patterns, recommended features of refrigerated vehicles, and bracing techniques. We have included a sample calculation of how you can determine the refrigeration capacity required for transporting for a specific load of produce. Completing the chapter is a simple example of the costs and benefits of using ice when transporting produce, designed to assist you to complete the worksheets to determine the return on investment when adopting specific postharvest transport practices for your operations.

GENERAL DOS AND DON'TS FOR TRANSPORTING HIGH QUALITY PRODUCE

Do NOT overload vehicles.

Prevent compression damage to produce by avoiding over-filling of containers (rounded sides or bulge-packing) and stacking heavier produce at the bottom of the load.

Use strong packages (half the stacking strength of a corrugated fibreboard container can be lost during a five day trip in a high humidity environment).

Avoid rough handling during loading and unloading.

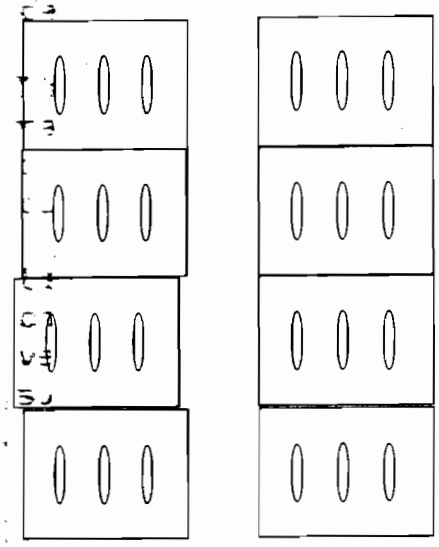
When stacking containers, be sure to allign them properly (most of the strength of a corrugated box is in the corners). A one inch overhang will decrease stacking strength by 15 to 34%.

Prevent vibration damage by using air suspension systems -- these will provide a more gentle ride during transportation.

Using suitable trays, place packing, use of plastic bags, container liners, or placing a soft pad at the top of a full box can reduce vibration damage.

Make sure the vehicle has adequate ventilation to prevent heat gain during transport.

Use a pre-loading checklist to ensure the vehicle is ready to use successfully.



Well alligned stack of cartons, has the strongest stacking strength possible

DOS AND DON'TS FOR REFRIGERATED TRANSPORT:

Ensure that vehicles are well-insulated and have doors that seal tightly and securely.

Run through the check-list for refrigerated transport before handling each load.

Look for recommended design features when purchasing new or used transport vehicles.

Pre-cool refrigerated vehicles to suit produce requirements.

Load only pre-cooled produce into vehicles from a refrigerated dock.

Do NOT allow delays when loading on an open dock-- delays will cause heat gain, especially if produce is exposed to full sun.

Turn off the refrigeration unit while loading from a open dock (leaving the unit on may cause ice to form on the refrigeration coils, blocking air circulation during transport).

Use high quality vented containers and load produce to ensure adequate air movement through the load to remove the heat generated by produce respiration.

Do NOT block air flow under or anywhere else in the load.

Monitor the supply air temperature and the return air temperature for obtaining the best performance of refrigeration units.

Avoid mixed loads if possible; or install ethylene scribbers to prevent damage to ethylene sensitive commodities.

Do NOT tranport chilling sensitive commodities when thermostats are set below 12-15 °C (53- 59 °F).

Load produce away from the side walls to prevent heat gain from the external environment.

Make sure mixed sizes of containers or unpalletized produce does not block lengthwise air flow.

Do NOT turn off the refrigeration unit during delays in transport.

Dos and Don'ts continued:

Brace the load at least 5 cm (2") away from the side walls and at least 10 cm (4") away from the rear door.

Use a portable temperature recorder to verify temperature management during transport.

TRNASPORTATION METHODS

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. Never stand upon the produce during loading or unloading.

TRANSPORTING OPEN LOADS:
Provide a thick layer of insulation and cushioning for bulk loads.

Load packaged produce in uniform stacks, braced securely to prevent damage.

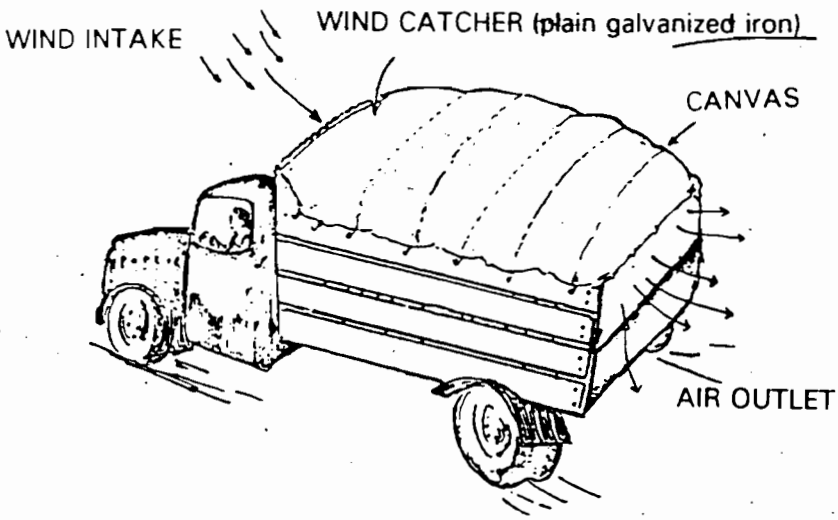
Construct a wind catcher for moving air into the vehicle during transport.

Provide channels for passive air movement beneath and up through the load (exiting at the rear of the vehicle).

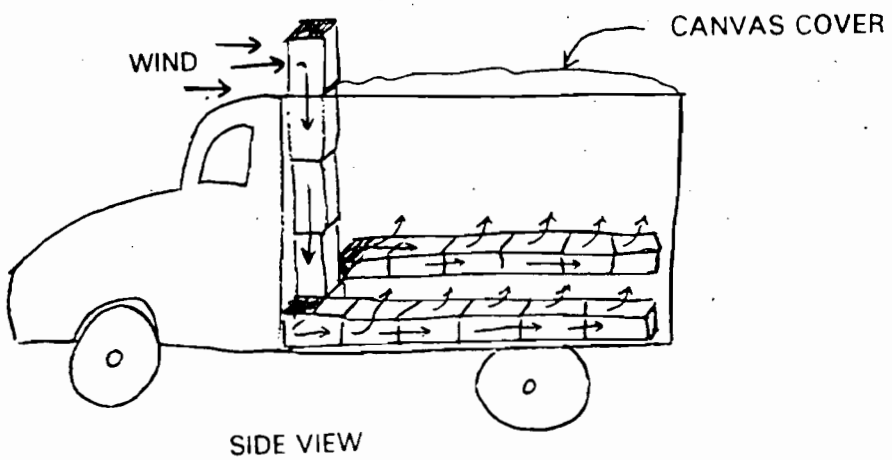
Provide shade for the load with a silver or light-colored canvas cover.

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 the height of the cab. High transportation speeds and/or long distance transport during dry weather run the risk of causing excess drying of the crop.

Ventilating systems have been designed for hauling bulk loads of fresh produce. The first illustration shows a metal wind catching device which funnels air into a load covered by a canvas sheet. The second example was designed by R. Kasmire to transport 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.



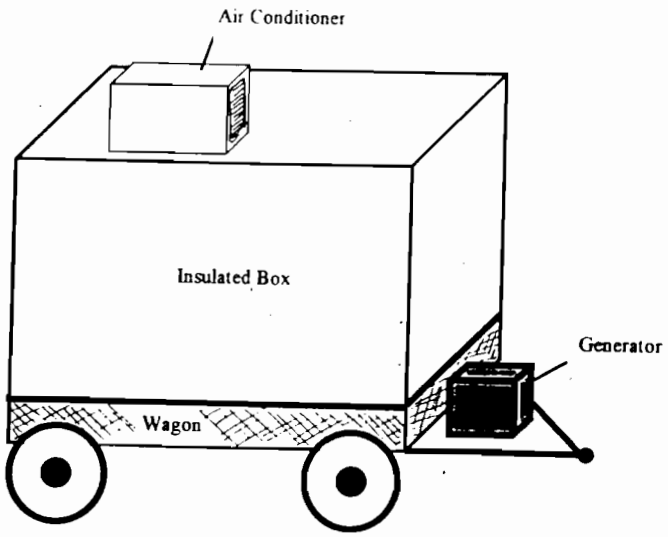
Source: Pantastico, 1980

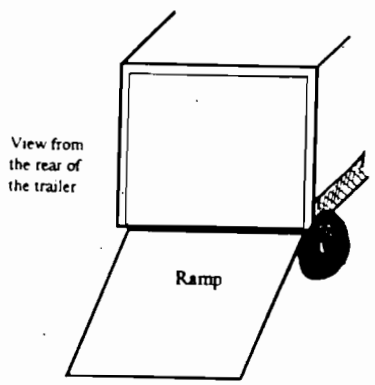


Portable Field-to-Market Coolers

This simple trailer cooler was constructed using a room-sized air conditioning unit powered by a diesel generator and an insulated storage box. The trailer can either be built as a unit with wheels, or the cooler can be loaded upon a pre-existing wagon or low-boy trailer.

The cooler is designed to be loaded at the field during the morning hours (when the air temperatures and produce temperatures are relatively low) and used to pre-cool produce during the period between harvest and packing or between field-packing and immediate marketing.



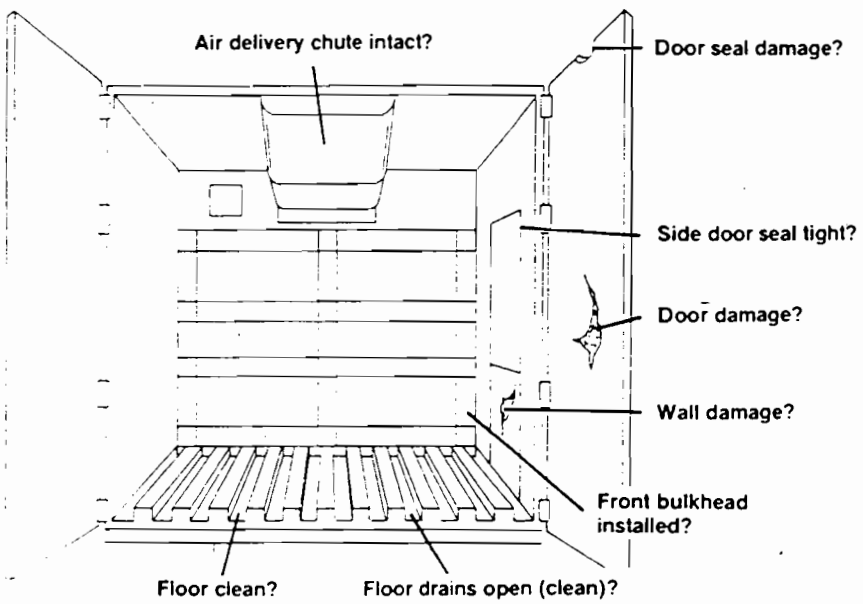


Similarly, an insulated cooler box was designed by Mejia (1991) to fit into a long-bed pick-up truck. Two standard pallet loads of produce can be cooled to 5 °C (40 °F) in about 4 hours from an ambient air temperature of 29 °C (85 °F). Mejia's design uses a stationery 3 ton mobile home air conditioning unit, to which the cooler box is connected after being loaded with produce in the field. Once produce is cooled, the box is sealed and transported to market.

REFRIGERATED TRANSPORT

Small-scale postharvest cold transport can be accomplished using a cargo van fitted with a high powered air conditioning system. If a pre-cooler is not available, a 4000 to 5000 Btu window model air conditioning unit can cool produce by 17 °C (30 °F) compared to the outside air temperature. It is a good idea to humidify the environment by misting the air with cool water or covering open crates of produce with wet towels or wet burlap cloth.

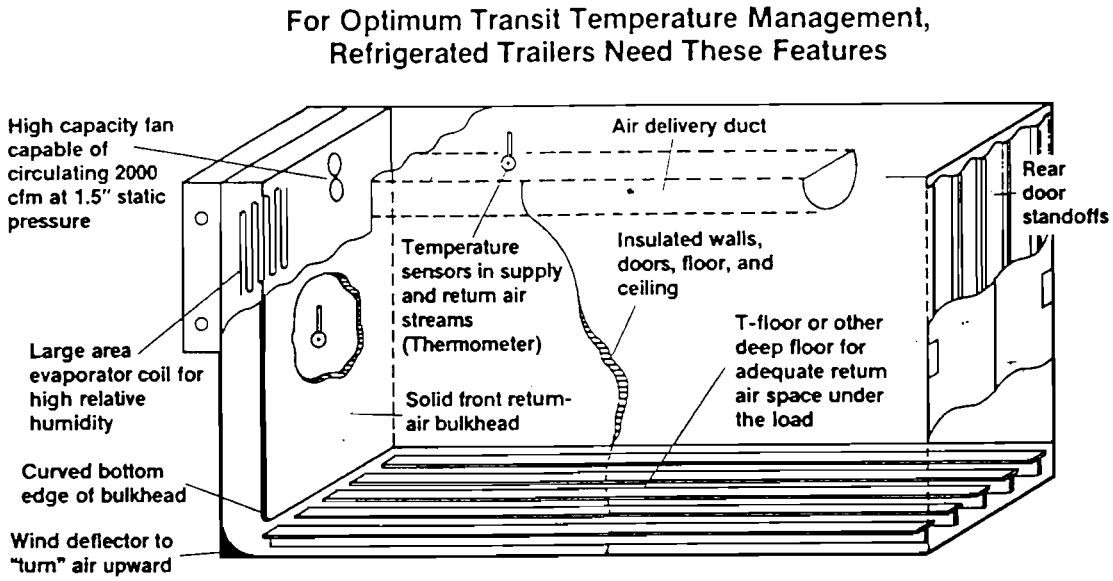
The condition of the inside of a refrigerated trailer affects its ability to maintain desired temperatures during transport. When renting, leasing or hiring an independent vehicle to transport your produce, you should always inspect the trailer before loading, and check these features: Any damage will let heat in and make temperature management much more difficult. Even when the buyer pays for shipment, checking for problems will save you time and money by helping you avoid losses and produce damage during transport.



Source: Kasmire and Hinsch, 1987

Inside width adequate for load?
Inside height adequate for load?
Door height adequate for load?
Load bars used to secure load?
Trailer precooled before loading?
Refrigeration unit operates satisfactorily?

Refrigeration Systems Components (Source: Kasmire and Hinsch, 1987)



Pre-cooling vehicles before loading:

- Vehicles to be loaded at refrigerated docks should be pre-cooled to their desired thermostat set point
- Vehicles to be rapidly loaded (15 to 20 minutes) at non-refrigerated docks should be pre-cooled to about 2 °C (5 °F) above their desired thermostat set point.
- Vehicles that will be loaded slowly (30 minutes or more) at non-refrigerated docks should be pre-cooled to about 2 ° C (5 °F) lower than a temperature halfway between ambient air temperature and the desired set point.

This will prevent accumulation of excess moisture on the vehicle's inner surfaces and reduce subsequent cycling of the refrigeration unit.

Source: Picha. 1997

Estimating Refrigeration Requirements

If you ever have any doubt that a refrigerated vehicle is of adequate capacity for the load you want to transport, calculate the number of Btus of heatload that must be handled by the refrigeration system to keep the load cool. Ashby (1995) contains all the tables and sample calculations to assist you to calculate heatload for your commodity and suitation.

First you will need to calculate:
1) **Hf:** the amount of field or sensible heat left in the commodity and the package. When produce is properly pre-cooled, this is very low, since the temperature differential is low.

Hf (Btu)=
specific heat of the produce & container
x weight of the produce & container
x temperature differential

2) **Hr:** the produce's heat of respiration

Hr (Btu) =
respiration rate at average transit temperature
x time (in days)
x weight (in tons)

3) **Hl:** the amount of heat leakage through the walls and floor of the trailer. Heat transfer coefficients have been calculated for specific vehicles by their manufacturers, and depends on many things including type and thickness of insulation, size and shape of the vehicle. As a vehicle ages and insulation breaks down, the coefficient tends to increase. The estimate of heat transfer for a new 48-foot trailer with 2.5" of foam sidewall insulation is 140 Btu/ degree °F/hour. The temperature differential refers to the difference between the thermostat setting and the average outside temperature.

Hl (Btu) =
the coefficient of heat transfer
x temperature differential
x time (hours)

4) How much heat can be absorbed by the refrigerant you are using:

Mechanical refrigeration units are rated according to the number of Btus per hour the unit can remove when the temperature is 100 °F outside versus 35 °F inside the trailer.

One pound of ice will absorb 144 Btus of heat.
One pound of liquid nitrogen will absorb approximately 175 Btus of heat.

Sample calculations for a load of produce.
Use these tables to calculate the amount of refrigeration needed to cool your load of produce:

Specific heat above freezing for selected perishables (from ASHRAE, 1990)

Apples	0.87 Btu/ lb / °F
Cantaloupe	0.93
Green beans	0.91
Grapes	0.86
Potatoes	0.82
Summer squash	0.95

Approximate Heat of Respiration (from ASHRAE, 1990) in Btus/ ton / 24 hours

	32 °F	40 °F	60 °F	70 °F
Apples	700	1,350	4,900	5,700
Cantaloupe	1,200	2,050	7,950	12,000
Green beans	7,250	10,300	38,100	49,200
Grapes	600	1,200	3,500	7,200
Potatoes (cured)		2,600	4,850	6,950
Summer squash	2,700	3,600	18,250	20,050

Assumptions:
Assume a refrigerated 24 ft trailer will be loaded with apples in 30 lb. fiberboard boxes. The trailer can hold 600 boxes, for a total produce weight of 18,000 lbs (9 tons). The boxes weigh 2 lbs each, so the total weight of the boxes is 1,200 lbs. The specific heat of most wood and fiberboard boxes is 0.44 Btu / lb / °F.

The specific heat of the apples is 0.87 Btu/lb /° F, at a loading temperture of 52 °F. The desired load temperature is 32 °F and the thermostat is set at 34 F to avoid freezing damage. Average load temperature is assumed to be 40 °F. Transit time is three days during which outside average aur temperature is 75 °F. The heat transfer coefficient for the trailer is 80 Btu /°F / hour.

Hf (apples) = 0.87 Btu / lb /°F x 18,000 lbs x 20 °F = 31,320 Btus
Hf (boxes) = 0.44 x 1,200 x 20 = 10,560
Hf (total) = 41,880 Btus

Hr = 1,350 Btu / ton /day x 3 days x 9 tons = 36,450 Btus
Hl = 80 Btu / °F /hour x (75 °F- 34 °F) x 72 hours = 236,160 Btus

Hf (total) + Hr + Hl = the amount of Btus the refrigeration unit must remove in three days.
41,880 + 36,460 + 236,160 = 314,500 Btus

Amount of mechanical refrigeration needed = 314,500 Btu / 72 hours = 4368 Btu/ hour
Amount of ice needed = 314,500 Btu / 144 Btu / lb = 2,184 lbs

Refrigerated Vehicles-- Pre-loading Checklist

___ Refrigeration unit operating properly?

___ Thermostat calibrated?

___ Refrigeration air chutes and ducts properly installed and in good repair?

___ Door seals in good condition?

___ Doors seal tightly when closed?

___ Walls free of cracks and holes?

___ Front bulkhead installed?

___ Floor drains open?

___ Inside of vehicle clean and odor-free?

___ Floor grooves free of debris?

___ Inside height, width, length adequate for load?

___ Load braces and other devices available to secure load?

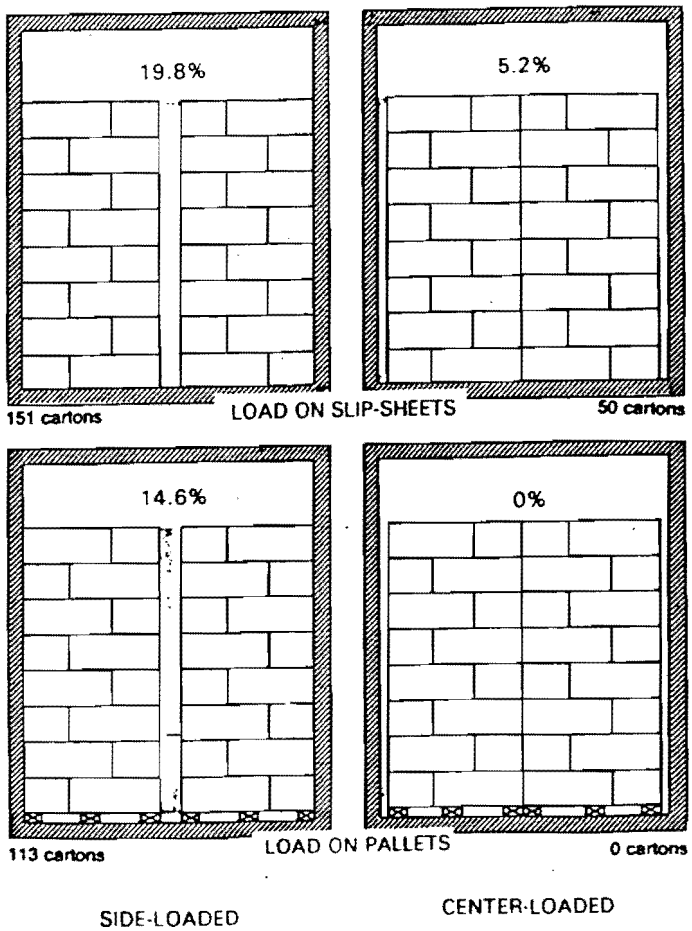
___ Is the vehicle trailer pre-cooled (or pre-warmed)?

Source: Ashby, 1995

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.

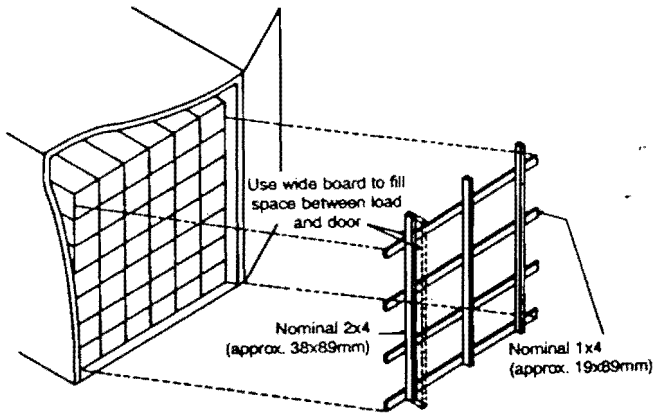


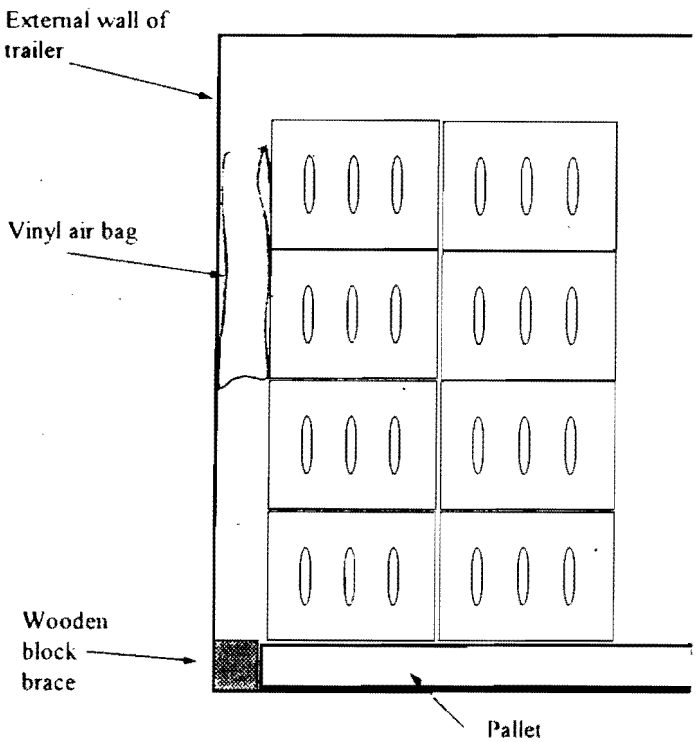
Source Ashby, B. H. et al. 1987

BRACING THE LOAD

There should always be an air space 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.

Wooden brace (rear door):





Wooden braces for side walls can be used, but they are heavy and can become expensive to build and transport. Air-filled bags made of vinyl can provide excellent bracing and 5 cm of added insulation (2" thick) against side walls. The bottom of the pallets are braced with wood blocks to prevent load shifting:

COSTS AND BENEFITS OF USING ICE FOR COOLING DURING TRANSPORT TO MARKET.

Costs:
Ice
Reduced amount of produce per load
(all other expenses are assumed to be the same)

Benefits:
Reduced water loss
Reduced decay rates
Higher quality during marketing
Longer shelf life

Example 1:

		with ice	no cooling
1/2 ton pick-up load of mixed lettuces		750 lbs	1000 lbs
cartons @ $2.50 each (20 lbs/carton)		38 cartons = $95	50 cartons=$125
ice ($0.50/10 lbs)	$0.05/lb	250 lbs = $12.50	0
water loss/decay rate		5%	10%
losses		(37.50 lbs)	(100 lbs)
Produce available to sell		712.5 lbs	900 lbs
Quality grades	highest ($1.19/lb)	90% =$742)	60%=($535)
	second ($0.69.lb)	10% =($49)	30%=($186)
	lowest ($0.25/lb)	0%	20% =($45)
Market value		$812	$766
Costs containers		($95)	($125)
ice		($12.50)	0
Potential net sales per load		$704.50	$641

USE OF ICE DURING TRANSPORT:
Remember to consider the added weight of the ice when calculating vehicle loads.

Use package ice or apply ice in channels or windrows (do not block air flow by applying in a uniform solid layer).

Avoid setting the thermostat too low in a refrigerated vehicle (below 2 °C or 35 °F)--this will cause ice to freeze solid and create a barrier to air flow.

Example 2: Transporting fresh peas in wooden crates from Punjab to Gujarat State in December.

	with ice	no co ·ling
Market location	Gujarat	Punjab
open load of fresh peas	500 kg	700 kg
crates @ Rs 20 (20 kg/crate)	25 crates= Rs 500	35 crates = Rs 700
ice (Rs 25/100 kgs) Rs 0.25/kg	250 kg = Rs 65	0
water loss/decay rate	5%	15%
losses	(25 kg)	(105 kg)
Produce available to sell	475 kg	595 kg
Market value	Rs 20/kg	Rs 5/kg
	Rs 9500	Rs 2975
Costs containers	(Rs 500)	(Rs 700)
ice	(Rs 65)	0
Potential net sales per load	Rs 8935	Rs 2275

Profits will depend upon the cost of transport. Fees for freight can be quite high (up to Rs 6000 per load) before the use of ice for cooling peas in December becomes unprofitable.

SOURCES OF TRANSPORT EQUIPMENT AND SUPPLIES

ethylene absorbers	DeltaTRAK Inc.
ethylene scrubbers	TUBAMET AG
ice-packs, ice wraps, freezable gel-filled or water-filled bags "cool guard"	Aladdin Industries, Inc. Cargo Technology Corp. IFC
loading guide	TransFRESH Corp.
mini-reefers (slip in cooler for pick-ups)	CMF Corp.
refrigeration system	Carrier Transicold
temperature/humidity data loggers	DeltaTRAK Inc. Dickson Sensitech Inc.
temperature recorders	DeltaTRAK Inc. Dickson
therma-cover	ThermaGard, Inc.
transport services	Roadway Express SeaLand Service, Inc.

For addresses and phone/FAX numbers for suppliers, please refer to Appendix D.

air suspensions?

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