Post-Harvest Handling

Introduction

Physiology, Respiration, and Moisture Loss:

Fruit and vegetables are living, breathing organisms and continue to do so even after harvest. An understanding of this process is important for proper post-harvest handling of produce.

Harvesting of produce is carried out at the stage of growth which will preserve the optimum maturity, and quality, until the time of consumption. The maturing of produce continues to a point, of optimum crispness, firmness, flavor and other desired qualities. After this point, the growth process continues and 'consumer qualities' begin to decline. Produce may become tough, spongy, limp, or have other undesirable characteristics. The objective in harvest and post-harvest treatments of produce is to maintain the optimum 'consumer quality' until the projected time of consumption. Figure 1 depicts this maturing process under various conditions versus time.

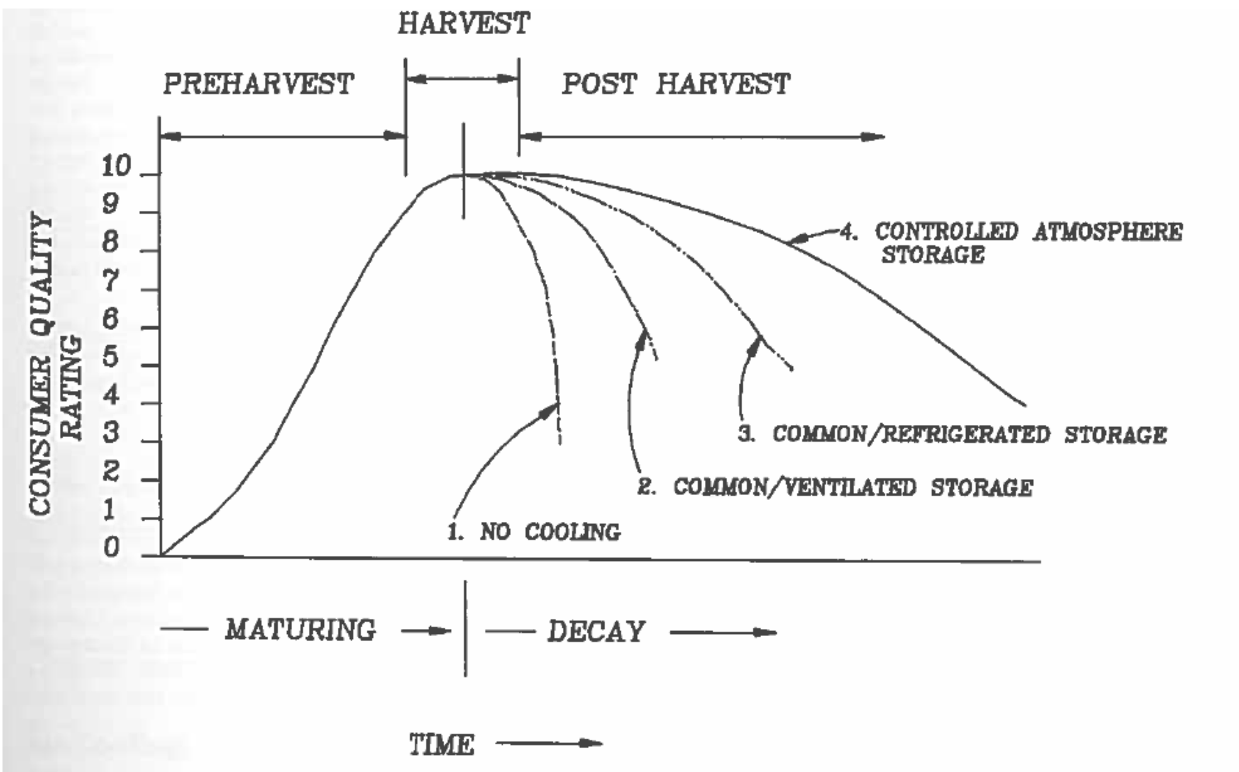

Figure 1. Maturing process of vegetables post-harvest, under various conditions.

Post-harvest maturation is influenced by the produce respiration process. This can be summarized in equation form as follows:

Sugar	+	O_2 (Oxygen)	=	CO_2 (Carbon dioxide)	+	H_2O (water)	+	Heat of respiration

High respiration accelerates product deterioration consumes sugars and other energy reserves and releases respiration heat. Respiration is highest in vegetables picked at an immature stage. To preserve the 'consumer quality' respiration must be reduced to a slower rate by cooling the product as soon as possible. An analogy is that of the fuel consumption of an engine running at idle contrasted with the fuel consumption while running at high speed and under full load. A vegetable contains the fuel (sugar) for the respiration process. The consumption of fuel is comparable to the loss in product quality. By reducing the product temperature, this maturing process can be reduced to an idle. The object in harvest and post-harvest treatment of produce is to pick the crop just before appropriate maturity and control the rate at which further maturing takes place.

Also of prime importance in the post-harvest handling of produce is moisture loss. Even with the storage temperatures maintained at acceptable levels, the produce can give up its moisture by means other than respiration. This will occur because the air in the storage may act as a 'sponge', and absorb moisture if it is less than saturated (i.e. less than 100% relative humidity). Produce will release moisture in this way if the air has less than the recommended relative humidity. Table 1 depicts accepted values for produce storage temperatures and air relative humidity. The effects of the refrigeration equipment on produce moisture loss will be discussed further in the section “Equipment and Materials".

Table 1:

Recommended storage temperatures, relative humidities, storage life expectancies and the highest freezing points of fresh vegetables

Vegetable	Temperature °C	Relative humidity	Approximate length of storage period	Highest freezing point
Asparagus	0.0	95	3 weeks	-0.6
Beans, green or snap	7.2-10.0	85-90	8-10 days	-0.7
Beets, bunched	0.0	90-95	10-14 days	-0.4(tops)
topped	0.0	90-95	1-3 months	-0.9
Broccoli (Italian or sprouting)	0.0	90-95	1 week	-0.6
Brussels sprouts	0.0	90-95	1 week	-0.8
Cabbage, early	0.0	90-95	3-4 weeks	-0.9
late	0.0	90-95	3-4 months	-0.2
Carrots, bunched	0.0-1.1	95	2 weeks	
topped	0.0-1.1	95	4-5 months	-1.4
Cauliflower	0.0	90-95	2 weeks	-0.8
Celery	0.0	95+	3 months	-0.2
Corn, sweet	0.0	90-95	8 days	-0.6
Cucumbers	7.2-10.0	95	10-14 days	-0.5
Kohlrabi	0.0	90-95	2-4 weeks	-1.0
Leeks, green	0.0	90-95	1-3 months	-0.7
Lettuce, head	0.0	95	2-3 weeks	-0.2
Onion sets	0.0	70-75	5-7 months	
Onions, green	0.0	95-100	2 weeks	
Onions, dry	0.0	50-70	5-9 months	-0.3
Parsnips	0.0	95	2-4 months	-0.3
Peas, green	0.0	95	1-2 weeks	-1.2
Peppers, sweet	7.2-10.0	70-75	2-3 months	-0.7
Pumpkins	7.0-10.0	70-75	2-3 months	-0.8
Radish spring, bunched	0.0	95-100	2 weeks	-0.4
winter	0.0	95-100	2-4 months	-0.7
Rhubarb	0.0	95-100	2-3 weeks	-0.3
Rutabagas or Turnip	0.0	95-100	6 months	-1.1
Spinach	0.0	95-100	10-14 days	-0.3
Squash, summer	7.0-10.0	70-75	2 weeks	-0.5
winter	7.0-10.0	70-75	6 weeks	-0.7
zucchini	5.0	95	1-2 weeks	-0.5
Tomatoes, ripe	10.0	85-90	3-5 weeks	-0.5
mature green	13.0	85-90	2-6 weeks	-0.8

*After Agriculture Canada Publication 1532 (1974) Commercial Storage of Fruits and Vegetables.

Pre-storage Conditioning

Pre-Cooling:

Cooling the product as soon as possible following harvest is critical to ensure the consumer is provided with a product of premium quality. The effects of prolonged, rapid respiration have been discussed. Table 2 shows the respiration rates of selected produce at various temperatures prior to, during and after cooling.

Table 2 Heat of Respiration and Specific Heat of Fresh Fruits and Vegetables when Stored at Various Temperatures[1]

Commodity	Heat of Respiration, Btu per ton per day at indicated temperature[2]					Specific Heat Btu/lb °F
	32°F	40°-41°F	59°-60°F	68°-70°F	77°-80°F	
Asparagus	6,200-13,200	13,000-23,100	25,500-51,500	38,300-59,200	81,800-104,700	.94
Beans, snap	5,500-9,000	9,200-11,400	32,100-44,100	45,400-53,000	-	.91
Beets, topped	2,700	4,100	7,200	-	-	.90
Broccoli, sprouting	4,100-4,700	7,600-35,200	38,200-74,800	61,200-75,000	123,200-193,600	.92
Brussels sprouts	2,200-6,600	4,800-10,600	14,100-29,900	18,900-37,800	-	.88
Cabbage	1,000-1,400	1,700-2,700	4,100-5,700	6,100-10,800	10,700-14,000	.94
Carrots	2,100-4,500	2,800-5,800	5,700-11,800	10,100-20,900	-	.91
Cauliflower, trimmed	3,600-4,200	4,200-4,800	9,400-10,800	16,500-18,900	18,500-30,800	.93
Celery	1,600	2,400	8,200	14,200	-	.95
Corn, sweet, with husks	6,600-11,300	9,400-18,300	33,300-38,400	59,000-68,400	62,000-95,800	.79
Cucumbers	-	-	3,300-7,300	3,100-10,600	4,200-12,100	.97
Leeks	2,100-3,700	4,300-6,400	18,200-25,700	-	23,600-26,100	.88
Lettuce, head	1,300-3,700	2,900-4,400	7,000-9,900	11,200-13,200	16,100-20,100	.96
Melons:						
Cantaloupes	1,100-1,300	1,900-2,200	7,400-8,500	9,800-14,200	13,700-15,700	.94
Parsnips	2,600-3,400	1,900-3,900	7,100-9,400	-	-	.83
Peas, green, shelled	10,400-16,600	17,400-21,400	-	76,700-122,400	-	.79
Peppers, sweet	-	1,100-4,700	4,400-12,600	5,000-14,300	7,900-16,300	.94
Potatoes, immature	-	2,600	2,900-6,800	4,000-9,900	-	.85
Potatoes, mature	-	600-1,900	1,300-2,600	1,800-3,500	-	.82
Spinach	4,200-4,900	7,600-12,700	29,500-49,200	37,900-63,200	-	.94

[1] Summarized from USDA Handbook 66.

[2] Values may be reduced as much as 50% during CA storage.

The heat to be removed in cooling the product is referred to as field heat. It can be represented in equation form as follows:

Q	=	W	X	C	X	T
(Field Heat)		(Product Weight)		(Specific Heat)		(Temperature Change)

The precooling capacity is the rate at which this heat can be removed and is expressed in either British Thermal Units per Hour (btu/hr) or kilowatts (kW). The actual cooling capacity is arrived at through a balance between the desired rate of cooling to preserve product quality, and the type, size and cost of the equipment to achieve those results.

Several methods are available for removing the field heat and reducing the respiration rate.

Air-Cooling:

The most common method of reducing product temperature is by air cooling. This is accomplished by forcing cold air around and past the produce. The rate of cooling is dependent upon the following:

(1) Air Temperature;
(2) Air flow rate past the produce and;
(3) The rate at which heat can move through and out of the product to the air.

The third factor can differ for each product type and variety.

A number of factors are considered in designing an air pre-cooling system. The product's response to the air flow rate and temperature must be known or determined. This can be accomplished by placing produce in crates or bins in the air flow, and in temperature conditions as it will actually be in the post-harvest system. Its temperature variation versus time is then measured. Published values from previous work are available and are normally expressed as one-half or seven-eighths cooling time (this is the time taken to cool the produce 1/2 or 7/8 of the difference between the initial product temperature and the temperature of the cooling medium). These figures are then used to determine the cooling capacity required for the anticipated harvest rate, and subsequently size the refrigeration equipment. A typical air flow requirement for cooling is 5 cubic meters of air per minute per kilogram of product. (Note: in air precooling systems the heat given off by the respiration of the crop during cooling can be significant and therefore should be included in any heat balance calculations.)

Hydro-cooling:

Hydro cooling systems take advantage of the increased heat transfer rate between the product and refrigerated water. Cooling times much faster than those obtained with air systems are possible. The equipment is sized by similar methods as air precooling but, due to the faster cooling times needed, larger capacity equipment is indicated. Hydro cooling is done most effectively by submerging the produce in water, however, by spraying large volumes of water over it, acceptable cooling results can also be attained.

Vacuum Cooling:

The fastest cooling method for vegetables with a high surface area to volume ratio (i.e. lettuce), is vacuum cooling. Its main advantage is in pre-cooling produce which tends to have slow cooling rates with air or water methods. Cooling is accomplished by 'forcing' water to boil at low pressure (i.e. Vacuum) and thus extracting heat from the product. Cooling is achieved in several minutes. Caution must be taken to ensure that over cooling of the crop does not result. Since cooling is accomplished by evaporating moisture, over-cooling will result in freezing and/or dehydration of the product. Pre-cooling is usually limited to 1/2 to 3/4 cool (1/2 to 3/4 of the difference between initial and desired temperature) and the remainder of the heat extracted by other methods. The other advantage of vacuum cooling is that product can be packaged in cartons prior to cooling. This can result in less handling of the crop and therefore faster processing from field to storage.

Flaked Ice or Slush Ice Cooling:

Flaked and slush ice is normally used for reducing product temperature from the precooled temperature to the final desired storage temperature. The product releases heat much slower as the product temperature approaches that of the cooling medium, as is the situation in the later stages of precooling. Also if the product is to be packaged immediately following precooling, this final 'ice' cooling can be done in the carton as the product is being shipped or stored. This 'iced' cooling alleviates the difficulties caused by the insulating characteristics of the packages and cartons.

In calculating the ice requirements for this final cooling, the latent heat of fusion (heat required to convert ice to water) is used. 335 KJ of heat is required to melt one kg of ice at 0.0° C. The total amount of ice required is determined from the heat to be removed from the product, the heat of respiration and the heat gained from the surroundings.

Storage Methods

The objective of product storage is to continue to preserve the 'consumer quality' until the time of consumption. Respiration and moisture loss must continue to be restricted during this period.

Storages are designed to control three conditions: first is temperature; second is relative humidity and third is gas concentrations of the air. The latter is presently being used only for selected crops in specialized storages. All storages involve restricting the supply of inputs to the respiration process (i.e. heat, oxygen) and effecting saturation of the "demand" for a product of respiration (i.e. carbon dioxide). The types of storage in use at present are summarized in the order in which they have developed.

Common Storage:

In the absence of refrigeration equipment, a common storage relies on precooling by cool ambient conditions at harvest (i.e. produce is cool before entering). Temperature control during storage is by ventilation with cool outside air and may be possible only during the night in early fall. During the winter period, ventilation to maintain desired temperature must be done with caution to avoid freezing and excessive product moisture loss by the cold, dry air. For this reason, this type of storage is acceptable only for selected produce. Product which is relatively resistant to moisture loss and has a relatively low respiration rate can be stored for specific periods. In order to maintain 'consumer quality' to February and later, very strict control must be maintained on the temperature in the storage and mechanical humidification is advisable. Often a high storage loss is accepted in this system rather than pursue the alternative which is a more sophisticated, and expensive storage system. However, as the demand for high quality produce by the consumer increases, the amount of product lost due to storage may warrant the expense of an alternate type of system.

Common Refrigerated:

In this type of storage, refrigeration equipment controls the temperature, and increased insulation and sealing reduces heat gain and air infiltration. Refrigeration equipment properly specified and supplied will provide a close tolerance on temperature control (typically ± 1°C). The main disadvantage in this system is the continuing moisture removal from the air - and therefore product - by the evaporator coils. This is evident by the ice buildup and/or condensate run off from the coils. The evaporator coils are designed to provide their rated cooling capacity at a specific t.d. value. The minimum t.d. value is normally 3 to 4°C. This value is a relationship between the coil temperature and the inlet and exhaust air temperature across the coils. The dehumidifying effect of an evaporator coil is inherent in its design. If the resulting condensation of moisture from the air causes an excessively low relative humidity, then humidification must also be designed into the storage.

Only certain types of produce are suited to extended term refrigerated common storages. The continued moisture loss by the product is normally the determining factor in achieving the maximum length of storage.

Jacketed:

In any storage, the objective is to minimize the difference between the temperature of the refrigerating medium and the air in order to minimize the dehumidification of the air. As pointed out previously, a td. of 3 to 4° C is normally minimum for a conventional refrigerating coil system.

A jacketed storage system accomplishes a lower t.d. value by increasing the surface area of the cooling medium to effect the cooling process by small temperature differences. Construction of the building is similar to other storages but with an air recirculation chamber around the inside walls and ceiling of the room. The product is "sealed" inside the room by a polyethylene jacket. The air recirculated around the outside of the jacket (in the "chamber") is cooled by a conventional refrigeration system and is maintained at a low relative humidity. Inside the room, the air is at high relative humidity and the desired temperature. It is critical in this system that no air leakage occurs between the room and refrigeration air, or outside air.

The main advantage of this system is the high relative humidities which can be maintained in the storage room. Also by reducing the relative humidity of the recirculated air, the refrigeration system will operate at a higher efficiency due to a higher t.d. and reduced freezing on the coils.

Disadvantages include slow heat removal rates across the polyethylene jacket making it inappropriate for precooling requirements; somewhat more expensive in regard to construction costs than common refrigerated storage; more complicated with two separate air recirculation systems -one inside the storage room and one around the jacket chamber, and the difficulty in avoiding air leakage across the jacket over prolonged periods of time.

Controlled Atmosphere:

Controlled atmosphere (CA) storage is constructed similarly to a common refrigerated storage except that extreme care must be taken in insulating, interior cladding and sealing, to ensure absolute air tightness. In order to test for air tightness, the room can be pressurized and held at a raised air pressure for a period of several hours.

Prior to placing in the storage, the produce must be precooled to the desired temperature. Following this, the room is sealed and the oxygen level is reduced (by scrubbing or burning) and the carbon dioxide levels are increased to predetermined levels. A refrigeration system is used to maintain the desired temperature in the store as in common refrigerated storages. Since the respiration process is effectively minimized, and the relative humidities are maintained at a reasonably high level, the produce can be held for extended periods of time with only minimal loss in product quality.

At present only selected produce such as cabbage can be held under controlled atmosphere conditions. Further research is necessary to broaden the scope of produce which can be held in this manner.
A C.A. storage may be relatively expensive to construct and maintain since a perfect air seal is necessary. In addition, a refrigeration system is required although the capacity requirements during storage may not be as high as for conventional storages.

Equipment and Materials

Insulation:

The main purpose of insulation is to reduce the transfer of heat to and from the storage room. In addition to its heat transfer qualities it should also be selected with the following criteria as well:

(1) Resistant to the transfer and absorption of moisture.
(2) Aid in the sealing of the storage room from air and gas leakage.
(3) Be of long life (not prone to deterioration or decay).
(4) Protect the structural components of the building from decay.

There are several types of rigid insulations available which meet these specifications. The most common are the extruded ‘polymer type' insulations.

Interior Cladding:

Many types of materials have been tried as interior cladding in storages and many have met with little success in withstanding the elements. High humidities have accelerated the failure rate of most materials.

Wood products - even those designed for exterior service - have not had an acceptable life span. Rigid polyethylene sheets 3/16"- 1.4" thick and pre-coated metal cladding appear to provide the essential qualities. When selecting cladding material, specify the following criteria:

(1) Moisture proof- against absorption and transmittance.
(2) Sealable at all corners and edges (moisture, air and gas).
(3) Impermeable and not conducive to microbial growth and decay.
(4) Can be readily cleaned and disinfected.

Although the initial cost of the cladding meeting these criteria may appear high, experience with wood and other products has shown their short life span makes them even more expensive.

Refrigeration Equipment:

A refrigeration system involves a closed cycle process in which heat is absorbed as a liquid, is evaporated to a gas, and the heat dissipated as it is compressed to a liquid. This is for the purpose of transferring heat from a low temperature source and exhausting it at a higher temperature. In this case the low temperature source is the produce, through the evaporator, and the high temperature exhaust is through the condenser/compressor. See Fig. 2

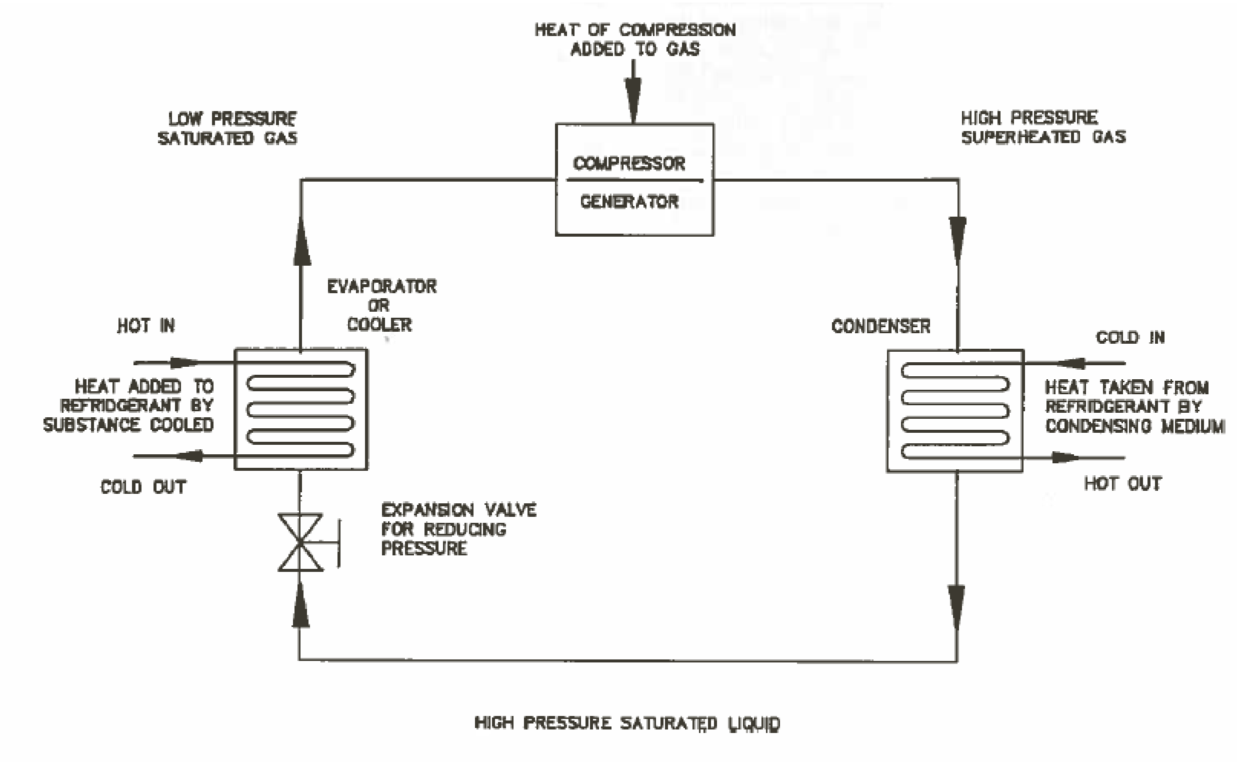

Figure 2. Closed cycle refrigeration system.

In removing heat from produce the following processes occur within the system:

(1) A cooling medium (air or water) is recirculated around the product.
(2) Heat moves from the product to the air or water.
(3) The cooling medium is recirculated past the refrigeration coils.
(4) Heat is removed from the cooling medium and transferred to the refrigerant - as with conventional evaporator coils. With an ice-bank® system, the initial cooling medium is the air which is recirculated through both the product and the cooling tower; a secondary cooling medium of water is used to collect the heat from the air and move it to the ice tank where the freeze/thaw cycle of water transfers this heat to the evaporating refrigerant in the "ice plates" (or pipes).
(5) The heat is removed from the refrigerant by the compressor and condenser.

The main components of the refrigeration system are the evaporator coils, the compressor, the condenser and the necessary valves and controls to effect the cycle.

In a conventional refrigeration system, the evaporator coils have the most obvious effect on stored produce. The temperature maintained on the coils is controlled by the rate of the refrigerant evaporation process. The t.d. value, as previously described, directly relates this temperature to the design storage temperature. Also, all the heat from the storage must be absorbed by the evaporation process. Therefore, in specifying the evaporator coils they must have a low t.d. value (3 to 4° C) (or higher if the RH can be lower) and have a cooling capacity, equal to the heat to be removed from the storage. In conjunction with this are the fans which recirculate the storage air past the coils. Again this fan capacity is directly matched to the heat load. It is a common misconception that these fans are to remove the heat from the produce and transfer it to the coils. This is not so! A secondary air recirculation system is necessary to assist in the transfer of heat from the product to the air. The evaporator-coil fans only assist in moving the air past the coils at the pre-determined rate and thus only to transfer the heat to the coils.

In an ice-bank® system however, the air recirculation fan is designed to move air past the product and the secondary cooling medium which is the recirculated water. The designed rate is in the range of 2 to 8 cubic meters per hour per kilogram of product to be cooled. The rate of water recirculation in this system is designed to maintain an air temperature of 1 to 2° C at the design capacity. The compressor and condenser equipment is equivalent for both the conventional and ice-bank® system.

In selecting and specifying equipment types for storage the following information is necessary in order for the equipment supplier to properly size the equipment:

(1) Maximum and normal product harvest rates - specify each type of product separately – express in both kg/hr. and kg/day and include total load.
(2) Maximum and normal product temperature at harvest.
(3) Desired storage temperature.
(4) Maximum time allowable for cooling.
(5) Desired storage Relative Humidity.

With this information the supplier can propose a size and type of equipment which will meet your requirements. The proposal from the supplier should include the specific performance figures for his equipment, such as capacity in KW, t.d., evaporator temperature, discharge temperature and compressor horsepower.

Should you wish assistance in interpreting the information provided with the refrigeration equipment or other components of the storage, your extension agricultural engineer can be of assistance.

Grading and Packing

Refer to the Canada Agricultural Products Standards Act, Fresh Fruit and Vegetable Regulations for grade requirements.

An integrated grading and packing system can take many forms depending on the crop to be packed, the volume of product and the intended market. It will incorporate one or more of the following features: a method of grading and culling the product; washing, disinfection, and disease control; waxing, film wrapping or labelling of product units and, finally, packing of units in boxes or crates, which may include package ice.

There are many suppliers of packing and grading equipment. Choose machinery and layouts which suit the particular situation and which are flexible enough to accommodate anticipated future changes. It is imperative that the final production line is free from "bottle necks" to allow free passage of product from field to storage or shipping container.

In many cases, packing precedes pre-cooling; containers then must be designed to facilitate the chosen pre-cooling method (water proofed, ventilated, etc.) Grading, packing, and pre-cooling must occupy the minimum length of time possible and subsequent re- warming before ultimate storage or shipping should be avoided.

Sanitation and Disease Control

Every effort should be made to minimize the effect of rot and mold organisms in storage rooms. In addition to attacking stored produce, they can cause deterioration of wooden containers and structural materials, and cause objectionable odors that may taint stored produce. In advance of loading, a storeroom should be thoroughly cleaned. The storage bins, walls and floors should be washed thoroughly with hot soapy water using a high pressure spray and rinse, ensuring that all mud and crop residue is removed. This is followed by a spray of live steam or disinfectant (consult Publication 1400A for disinfectant recommendations). The choice of disinfectant will depend on price, and type of surface being treated. Some disinfectants are corrosive on metal or plastic. More porous materials such as brick and wood require more thorough cleaning than concrete, metal or plastic surfaces. The surface should be kept wet with disinfectant for at least 10 minutes, preferably 30 minutes. Be sure to protect all electrical equipment while washing or disinfecting. When rooms are not in use growth of molds can be reduced by keeping the room warm and ventilated. Regular washing and disinfection of machinery, and harvest and grading tools, is also recommended.

Immature or over-mature produce should not be considered for long term storage. Careful handling to eliminate bruising or rupturing of the skin is imperative to reduce deterioration during storage. In order to reduce pathogen growth on stored produce, condensation of water should be avoided by adjusting temperature, humidity and air circulation.

In mixed storage rooms that include fruits, vegetables, eggs and/or dairy products, activated carbon air filters may be used to prevent odor contamination.

Storage Compatibility

It may be necessary to use the same store room or storage facility for several vegetables or fruits. Certain crops cannot be stored in the same store room because they will reduce the quality of other products. This is particularly important in long term storage. Some fruits (i.e. apples, pears, tomatoes) produce a volatile gas, ethylene, which can initiate sprouting of potatoes, carrots and onions; cause senescence of leafy vegetables; and induce bitterness in carrots. Vegetables should not be stored in rooms with these fruits or in rooms that have just been used for long term storage of these fruits.

Onions can transfer their flavor to other vegetables and root crops such as potato may impart an earthy flavor to fruits. Other vegetables are incompatible because they require different temperatures or humidities. Table 3 can be used as a guide if it is necessary to store several commodities together.

Table 3 Storage Compatibility of Fresh Fruits and Vegetables*

*After Agriculture Canada Publication 1478E (1978) Home Storage Room for Fruits and Vegetables.

☐ Compatible

0 Compatible if commodity requiring high humidity is enclosed in polyethylene liner.

1 Undesirable for optimal storage quality due to differing temperature requirements. Short-term holding may be possible by maintaining storage temperature at the minimum allowable for the low-temperature sensitive commodity.

2 Undesirable flavor transfer may develop in storage. This can be reduced by storing one of the commodities in a perforated polyethylene garbage bag.

3 Incompatible for long storage periods due to cross-commodity deterioration of produce quality.

	Apples	Apricots	Asparagus	Beans, green	Beans, lima	Beets, bunched	Beets, topped	Blackberries	Broccoli	Brussels sprouts	Cabbage	Carrots	Cauliflower	Celery	Cherries, sweet	Cherries, sour	Corn, sweet	Cranberries	Cucumbers	Eggplant	Endive (escarole)	Garlic, dry	Grapes	Horseradish	Kohlrabi	Leeks, green	Lettuce	Melons, cantaloupe	Melons, honeydew	Melons, watermelon	Mushrooms	Onions, green	Onions, dry	Parsnips	Peaches	Pears, Bartlett	Pears, winter	Peas, green	Peppers, sweet	Plums, early	Plums, late	Potatoes, early	Potatoes, late	Pumpkins	Radish, spring	Radish, late	Raspberries	Rhubarb	Rutabaga (turnip)	Salsify	Spinach	Squash, summer	Squash, winter	Sweet potatoes	Tomatoes, ripe
Apricots																																																							
Asparagus																																																							
Beans, green																																																							
Beans, lima	1	1	1																																																				
Beets, bunched				1																																																			
Beets, topped	2			1																																																			
Blackberries	2			1																																																			
Broccoli				1		2	2																																																
Brussels sprouts				1																																																			
Cabbage	3			1																																																			
Carrots	3			1																																																			
Cauliflower	3			1																																																			
Celery				1																																																			
Cherries, sweet	0	0	0	1	0																																																		
Cherries, sour				1		2	2																																																
Corn, sweet				1		2	2																																																
Cranberries				1																																																			
Cucumbers	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																																						
Eggplant	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1																																					
Endive (escarole)	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	0																																				
Garlic, dry				1														1	1	1																																			
Grapes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0																																		
Horseradish				1		2	2											1	1	1		0																																	
Kohlrabi				1														1	1	1		0																																	
Leeks, green				1														1	1	1		0																																	
Lettuce				1														1	1	1		0																																	
Melons, cantaloupe																						0																																	
Melons, honeydew	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1																												
Melons, watermelon	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1																										
Mushrooms				1														1				0							1	1																									
Onions, green	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		2		2	2	2	2	2	2	2																								
Onions, dry	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		2		2	2	2	2	2	2	2	2																							
Parsnips	2	2	2	2	2													1	1	1		0							1	1		2	2																						
Peaches				1		2	2											1	1	1		0							1	1		2	2																						
Pears, Bartlett				1		2	2			3	3	3						1	1	1		0							1	1		2	2																						
Pears, winter				1		2	2			3	3	3						1	1	1		0							1	1		2	2																						
Peas, green				1														1	1	1		0							1	1		2	2																						
Peppers, sweet	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1			1		2	2	1	1	1	1	1																	
Plums, early	1	1		1		2	2	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1		1		1	2	2	1	1	1	1	1	1																
Plums, late	1	1		1		2	2											1	1	1		0							1	1		2	2						1	1															
Potatoes, early	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	2	2	1	1	2	2	1	1	1	1	1		1	1														
Potatoes, late	2			1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	2	1	2	1	2	2	1	1	1	1	1	1		1	1													
Pumpkins	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1			1	1	2	2	1	1	1	1	1		1	1		1												
Radish, spring				1														1	1	1		0							1	1									1	1		1	1	1											
Radish, late				1														1	1	1		0							1	1									1	1		1	1	1											
Raspberries				1		2	2											1	1	1		0							1	1		2	2						1	1		1	1	1											
Rhubarb				1														1	1	1		0							1	1		2	2						1	1		1	1	1											
Rutabaga (turnip)	2	2		2	2			2						2	2	2	2	1	1	1		0	2						2	2		2	2		2	2	2	1	1	2	2		1	1			2	2							
Salsify				1														1	1	1		0							1	1		2	2						1	1		1	1	1											
Spinach				1														1	1	1		0							1	1		2	2						1	1		1	1	1											
Squash, summer	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1			1	1	2	2	1	1	1	1	1		1	1		1		1	1	1	1	1	1	1				
Squash, winter	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1			1	1	2	2	1	1	1	1	1		1	1		1		1	1	1	1	1	1	1				
Sweet potatoes	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Tomatoes, ripe																																2	2															2							
Tomatoes, mature green	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1

Bibliography

This document was originally part of the Vegetable Production in Atlantic Canada Guide Produced by the APASCC Advisory Committee on Vegetable Production, it was reformatted and updated by Perennia in 2017.

Agriculture Canada 1974. Commercial Storage of Fruit and Vegetables. Publication 1532. (Revision due 1986)

Government of Canada 1981. Canada Agricultural Products Standards Act. Fresh Fruit and Vegetable Regulations.

Ryall, A.L and W.J. Upton 1978. Handling, Transportation and Storage of Fruits and Vegetables, Vol. I Vegetables and Melons (2nd edn.). AVI, Connecticut

U.S. Dept. of Agriculture. 1986. The Commercial Storage of Fruits, Vegetables and Nursery Stocks. Agriculture Handbook 66.

U. of California 1984. Post-harvest Pathology of Fruits and Vegetables: Post harvest losses in Perishable Crops. Bulletin 1914. (Also published as Publication NE-87 of the U.S. North Eastern Regional Research Program).

U. of California 1985. Post-harvest Technology of Horticultural Crops. Special Publication 3311.

Wills, R.B.H., T.H. Lee, D. Graham, W.B. McGlassen and E.G. Hall. 1982. Postharvest. An Introduction to the Physiology and Handling of Fruit and Vegetables (2nd American edn.). AVI, Connecticut.
VII Mechanizing Vegetable Production