Different Methods of Fresh Produce Shelf Life

1. Chilling
2. Control atmosphere storge and Modified atmosphere packaging
3. Novel technology
4. Treatment and handling procedures
5. Monitoring humidity
6. Individual item coverings
7. Smart stickers
8. New varieties
9. Natural antimicrobials

Extend availability of fresh fruits by chilling

In the unit operations described, a reduction in the temperature of foods slows the

Biochemical changes

Microbiological changes

that would otherwise take place during storage.

Preservation by lowering the temperature of foods has important benefits in maintaining their

Sensory characteristics

Nutritional value

to produce high quality products.

As a result these products have substantially increased in importance during the 1980s and 1990s.

Micro-organisms and enzymes **are inhibited** at *low temperatures*, but unlike *heat processing* they are **not destroyed**

- . Any increase in temperature can therefore permit the growth of pathogenic bacteria or increase the rate of spoilage of foods.
- Careful control is needed to maintain a **low storage** temperature and prepare foods quickly **under strict hygienic** conditions to prevent spoilage or food poisoning.
- The need to maintain chill temperatures throughout the distribution chain is a major cost to producers and retailers
- this technique has seen significant developments to improve efficiency, reduce costs and reduce the risk of spoilage and food poisoning.

Cold preservation

1. Refrigeration and cool storage
2. Freezing

Principle of cold preservation

- Hindering the growth or activity of microorganisms
- Delay of enzymatic reactions
- Delay of purely chemical reactions

Distinctions between refrigeration and freezing

- Temperature:

refrigeration (16 C to -2 C);

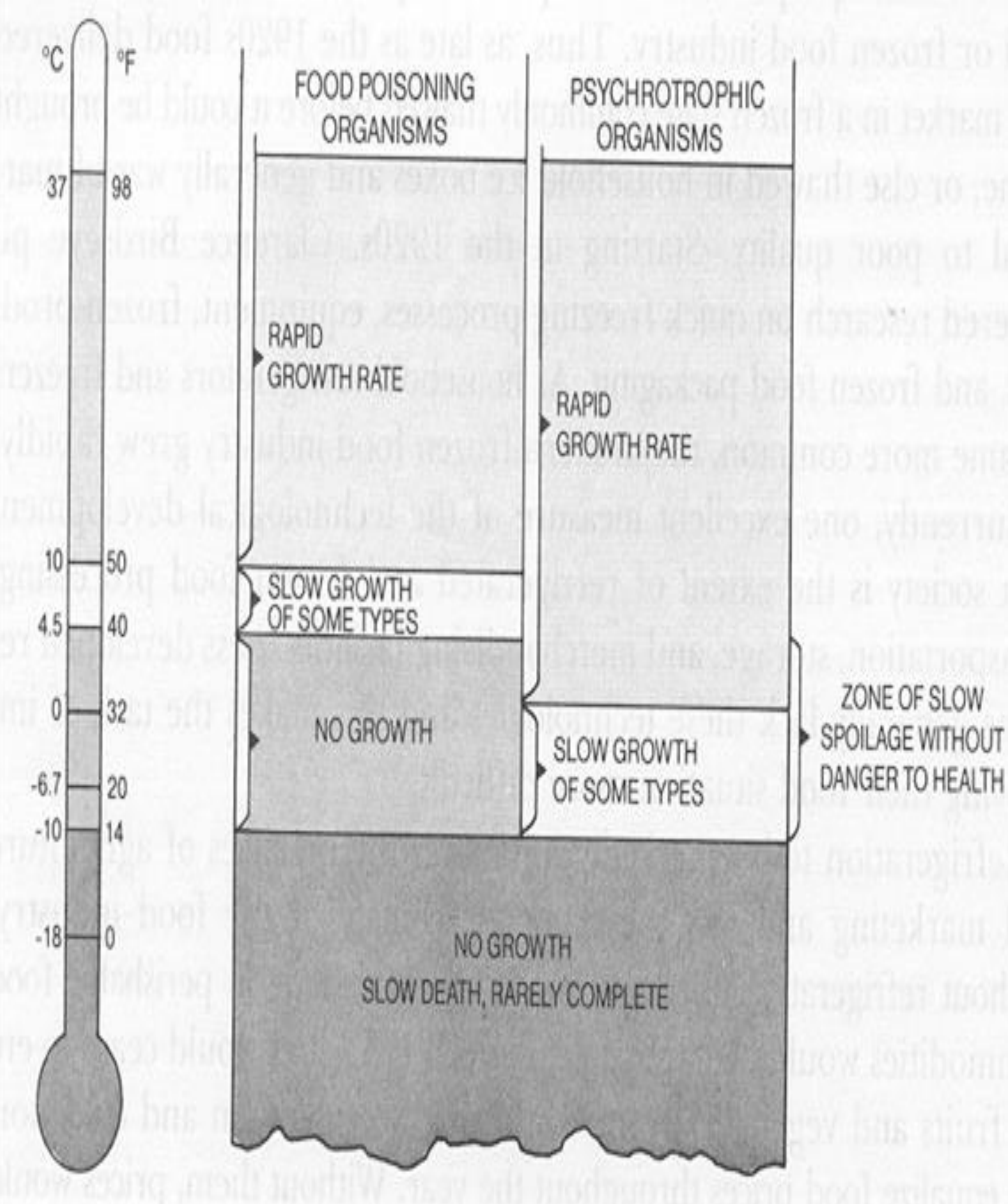
freezing - generally -18 C or below

- Storage time:

refrigeration (days or weeks);

freezing (months or years)

- Microbial activity. Below -9.5C no significant growth.



Effect of temperature on growth

Most spoilage organisms grow rapidly above 10C

Some poisoning organisms can grow slowly at 3.3 C

Psychotropic organisms can grow slowly (4.5 to -9.5 C).

Freezing does not destroy organisms completely. When food is thawed, there can be rapid multiplication and spoilage

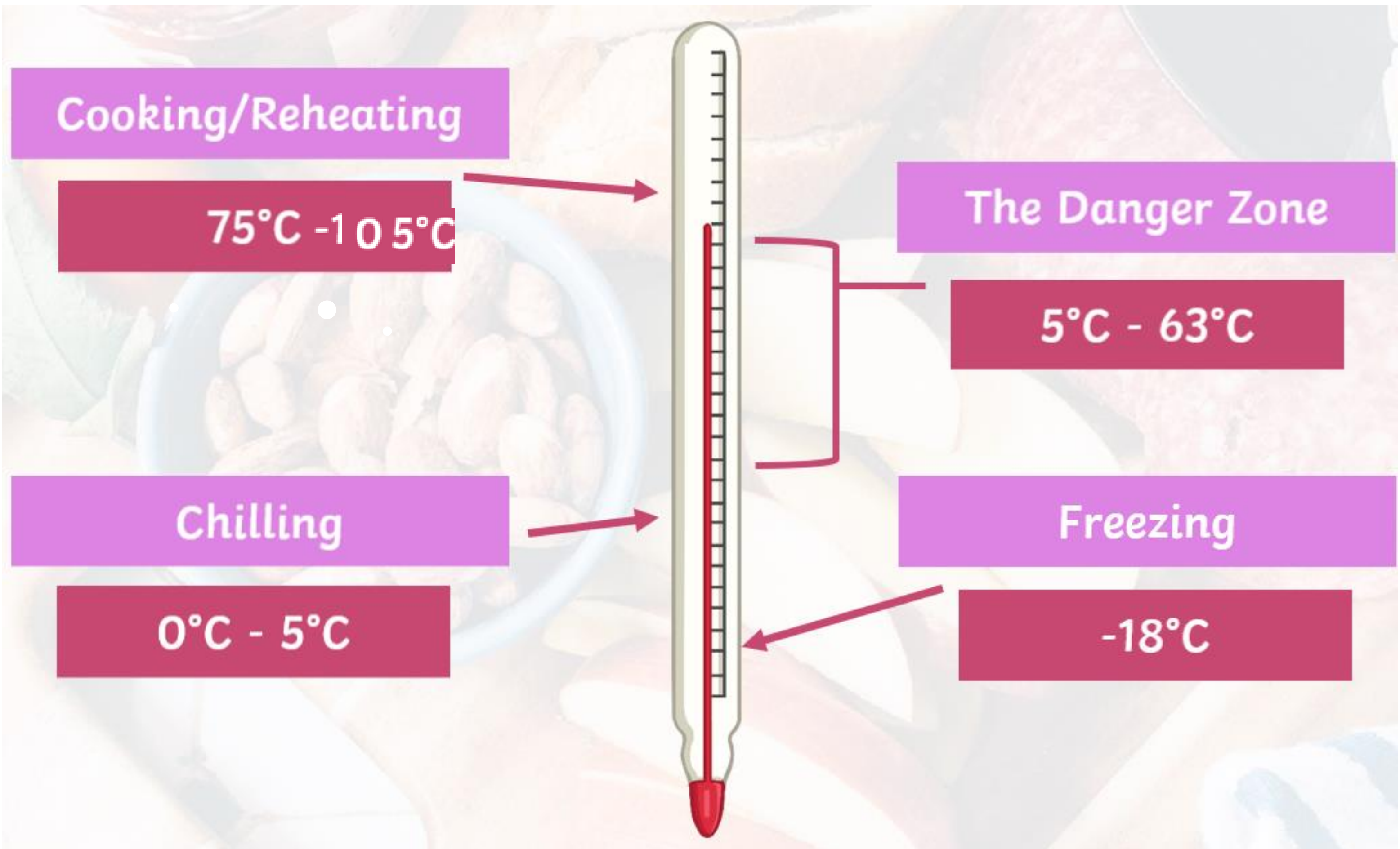

Cooking/Reheating
75°C -105°C
The Danger Zone
5°C - 63°C
Chilling
0°C - 5°C
Freezing
-18°C

TABLE 9.5. Approximate Number of Months of High-Quality Storage Life

Product	Storage Temperature		
	−18°C (0°F)	−12°C (10°F)	−6.7°C (20°F)
Orange juice (heated)	27	10	4
Peaches	12	<2	6 days
Strawberries	12	2.4	10 days
Cauliflower	12	2.4	10 days
Green beans	11–12	3	1
Green peas	11–12	3	1
Spinach	6–7	<3	¾
Raw chicken (adequately packaged)	27	15½	<8
Fried chicken	<3	<30 days	<18 days
Turkey pies or dinners	>30	9½	2½
Beef (raw)	13–14	5	<2
Pork (raw)	10	<4	<1.5
Lean fish (raw)	3	<2¼	<1.5
Fat fish (raw)	2	1½	0.8

Source: U.S. Dept. Agriculture.

Chilling

- Chilling is the unit operation in which the temperature of a food is reduced to **between --2ºC and 16ºC.**

Chilled foods are perceived by consumers as being convenient, easy to prepare, high quality and ‘healthy’, ‘natural’ and ‘fresh’.

- Metabolic activity in fresh fruits and vegetables continues for a short period after harvest. The energy required to sustain this activity comes from the respiration process .

- Respiration involves the oxidation of sugars to produce carbon dioxide, water and heat.

The production of respiratory heat at 20ºC and atmospheric pressure is given by equation.

- $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 674\ \text{kcal}$

- The storage life of a commodity is influenced by its respiratory activity.

By storing a commodity at low temperature, respiration is reduced and senescence is delayed, thus extending storage life.

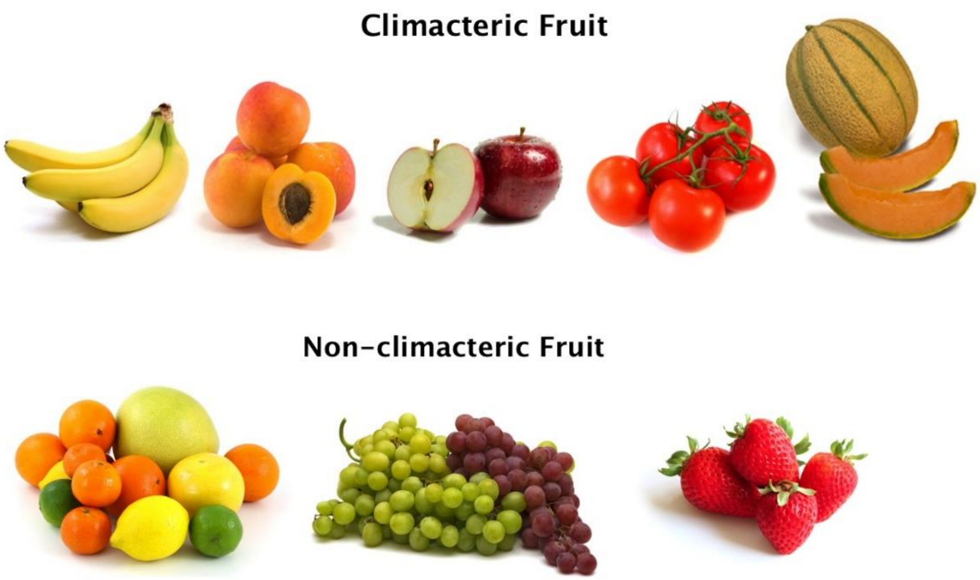
Proper control of the oxygen and carbon dioxide concentrations surrounding a commodity is also effective in reducing the rate of respiration.

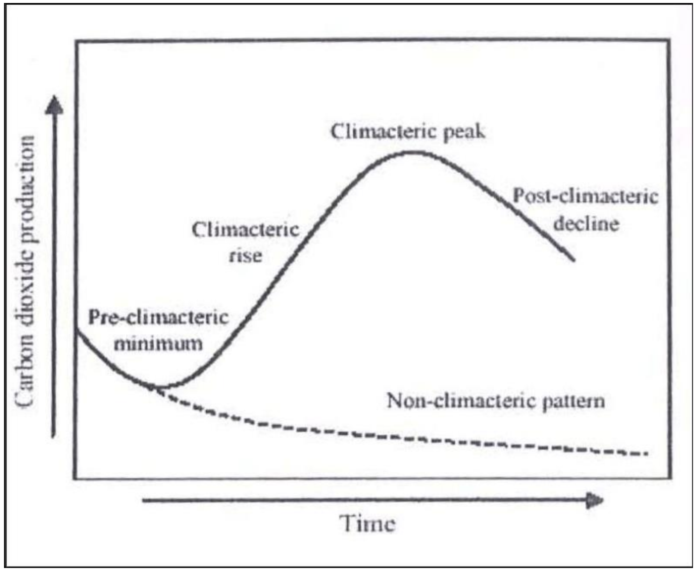
To chill fresh foods it is necessary to remove both

. Sensible heat (Field heat)

Heat generated by respiratory activity (Vital heat)

- The rate of respiration of fresh fruits is not necessarily constant at a constant storage temperature.
- Fruits which undergo **'Climacteric'** ripening show a short but abrupt increase in the rate of respiration which occurs near to the point of optimum ripeness.





Changes in foods during cool storage are influenced by:

- The growing conditions
- Varieties of plants
- Feeding practices of animals
- Conditions of harvest and slaughter
- Sanitation
- Damage to tissues
- Temperature of cool storage
- Mixture of food in cool storage

Examples of changes in food

- Too low temperature brings about a cold damage to fruits and vegetables i.e.
- weakened physiological state decrease resistance to microbial spoilage
- delay in ripening
- loss in vitamins (C)
- changes in carbohydrate composition
- exchange of flavors between foods
- loss of firmness and crispiness
- changes in color of red meat
- oxidation of fats
- staling of baked goods
- softening of tissue and drip page from fish
- lumping and caking of granular foods

Benefits from cooling

- Benefits of cool storage other than preservation
- **Control the rates of chemical and enzymatic reactions**
- **Control the rates of growth and metabolism of desirable microorganisms**

- Examples of benefits from cooling
- Aging of wines
- Aging of meat
- Ripening of cheese
- Improvement in peeling and pitting of peaches
- Reduction in changes in flavor during extraction and straining of citrus juices
- Improvement in meat and bread cutting
- Increase the solubility of CO_2
- precipitates waxes from edible oils

Chilled foods are grouped into three categories according to their storage temperature range as follows (Hendley, 1985):

1. -1ºC to+1ºC

fresh fish, meats, sausages and ground meats, smoked meats and breaded fish .

2. 0ºC to +5ºC

pasteurized canned meat, milk, cream, yoghurt, prepared salads, sandwiches, baked goods, fresh pasta, fresh soups and sauces, pizzas, pastries and unbaked dough .

3. 0ºC to +8ºC

fully cooked meats and fish pies, cooked or uncooked cured meats, butter, margarine, hard cheese, cooked rice, fruit juices and soft fruits .

Supply of chilled foods to the consumer by Sophisticated & expensive distribution systems:

- – Chill stores
- – Refrigerated transport
- – Retail chill display cabinets
- – Ownership of domestic refrigerators.

Maintaining certain conditions is a fundamental responsibility of the refrigeration engineer, and the conditions over which he or she may have some control are:

- (1) Temperature of the air or other fluid surrounding the product.
- (2) The relative humidity of air, particularly for the refrigeration of unfrozen foods.
- (3) The air velocity.
- (4) The chemical environment, such as a CO2 atmosphere

However, not all foods can be chilled E.g.

Tropical

Subtropical

some temperate fruits

suffer from **chilling injury** at 3–10°C above their freezing point.

E.g. internal or external browning, failure to ripen & skin blemishes, avocados (< 13°C), bananas (< 12–13°C).

A reduction in temperature below the minimum necessary for microbial growth extends the generation time of micro-organisms and in effect prevents or retards reproduction. This mechanism is described in detail in most microbiological texts.

The broad categories of micro-organism, based on the temperature range for growth:

1. Thermophilic
(minimum: 30–40^{o}C, optimum: 55–65^{o}C)
2. Mesophilic
(minimum: 5–10^{o}C, optimum: 30–40^{o}C)
3. Psychrophilic
(minimum: -0–5^{o}C, optimum: 12–18^{o}C).

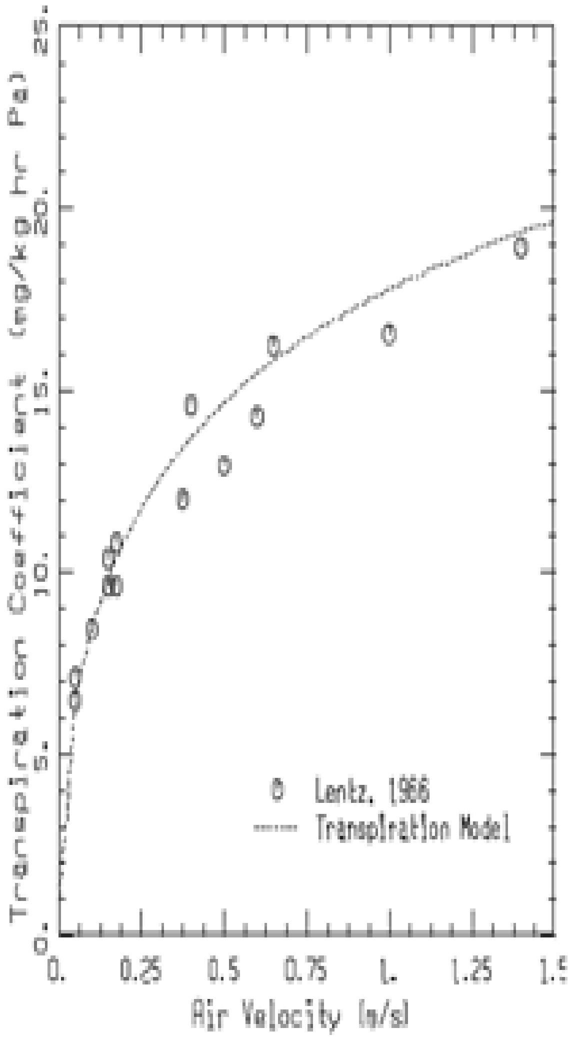
- Chilling prevents the growth of thermophilic and many mesophilic micro-organisms.

- The main microbiological concerns with chilled foods are a number of pathogens that can grow during extended refrigerated storage below 5ºC, or as a result of any increase in temperature (temperature abuse) and thus cause food poisoning.

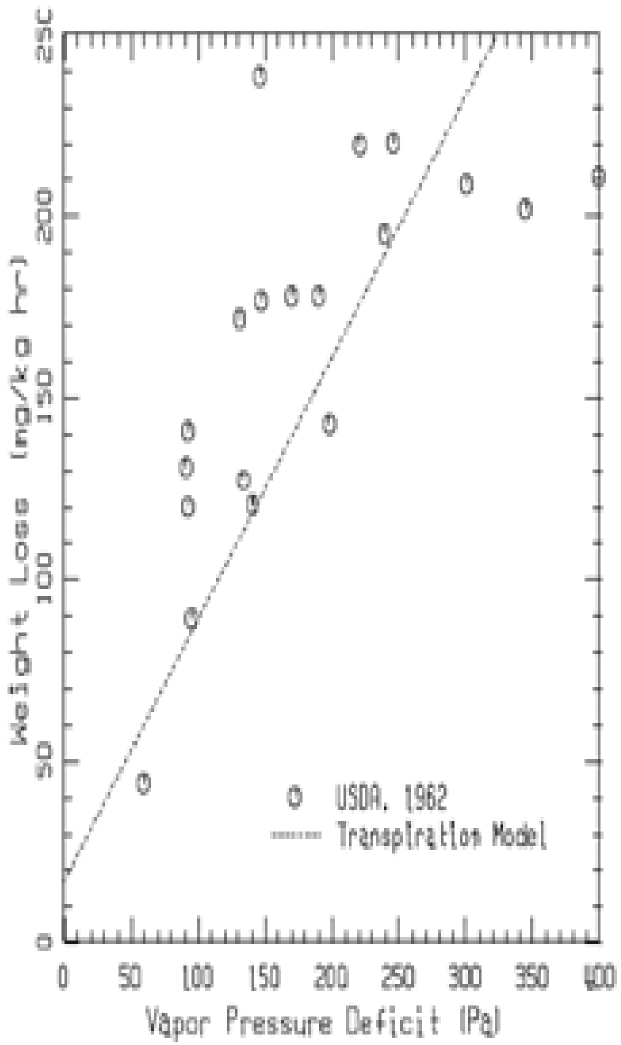
- The relative humidity

is the second most important condition the refrigeration engineer must maintain. Rapid degradation of the product can occur if the relative humidity is appreciably different from the recommended value. the relative humidifies for most fruits and vegetables are in the 90–95% range.

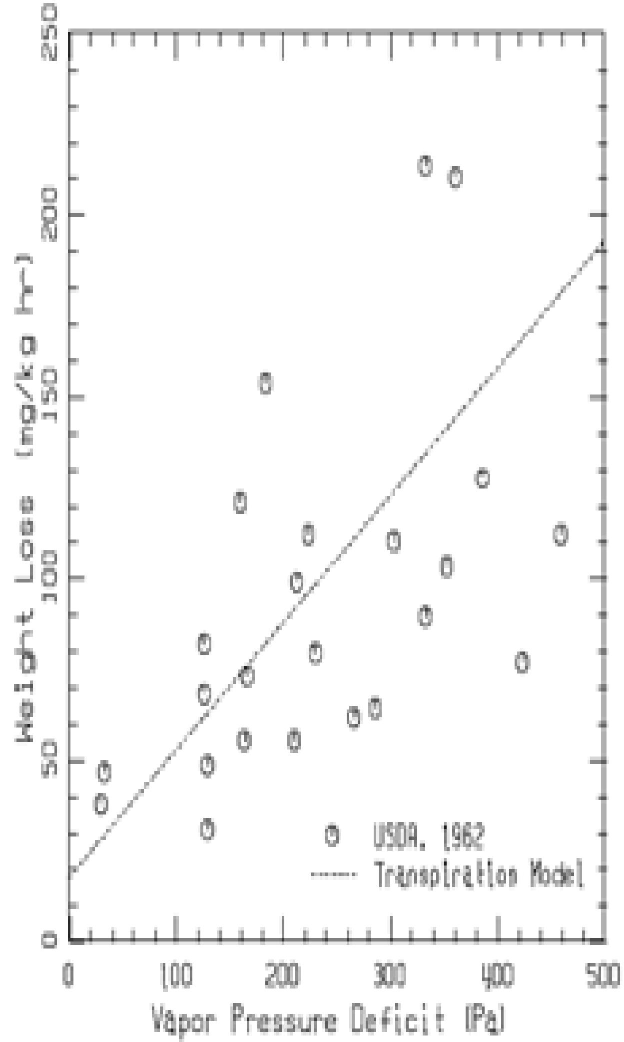
- Air temperature, air velocity over the product, and the interior dimensions and thermal characteristics of the product are the variables that determine the rate of cooling.
- A thorough knowledge of the transpiration and respiration processes will allow both the designer and operator of cold storage facilities to achieve optimum storage conditions.



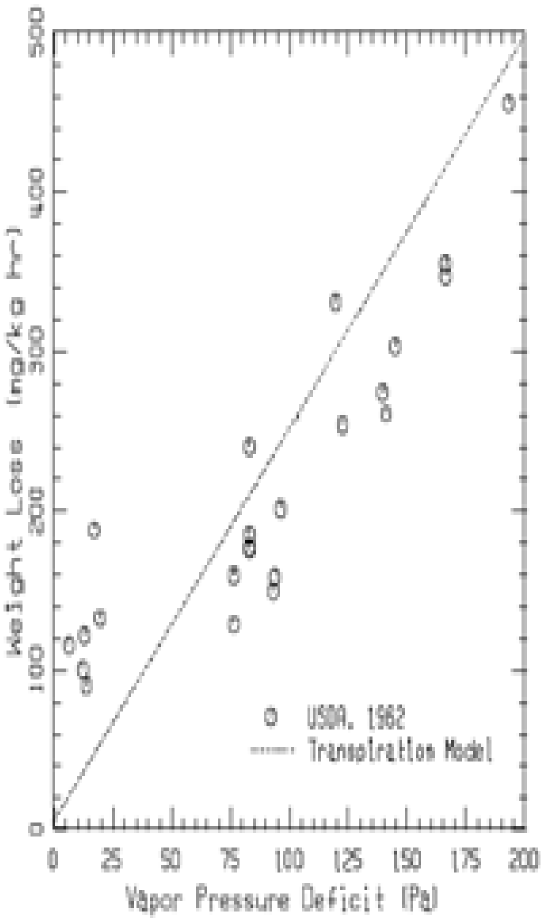
Transpiration coefficient vs. air velocity for carro



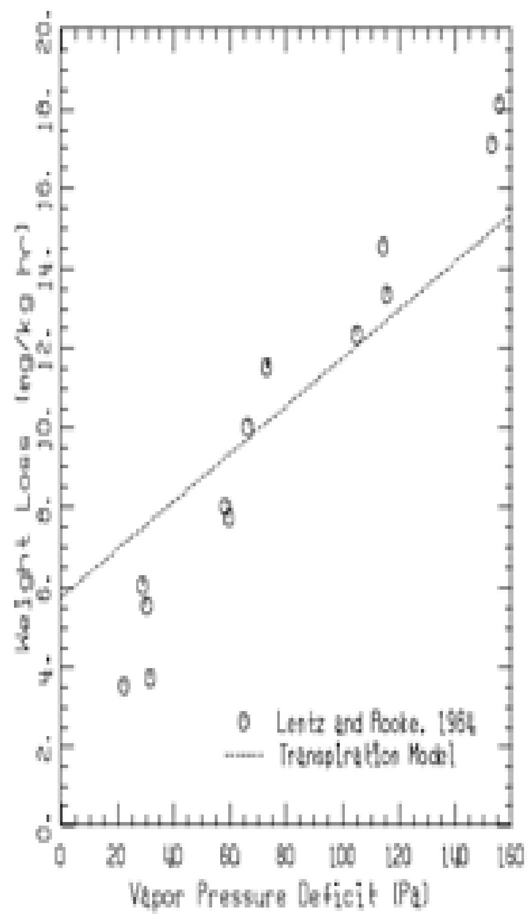
Weight loss vs. water vapor pressure deficit for lemons



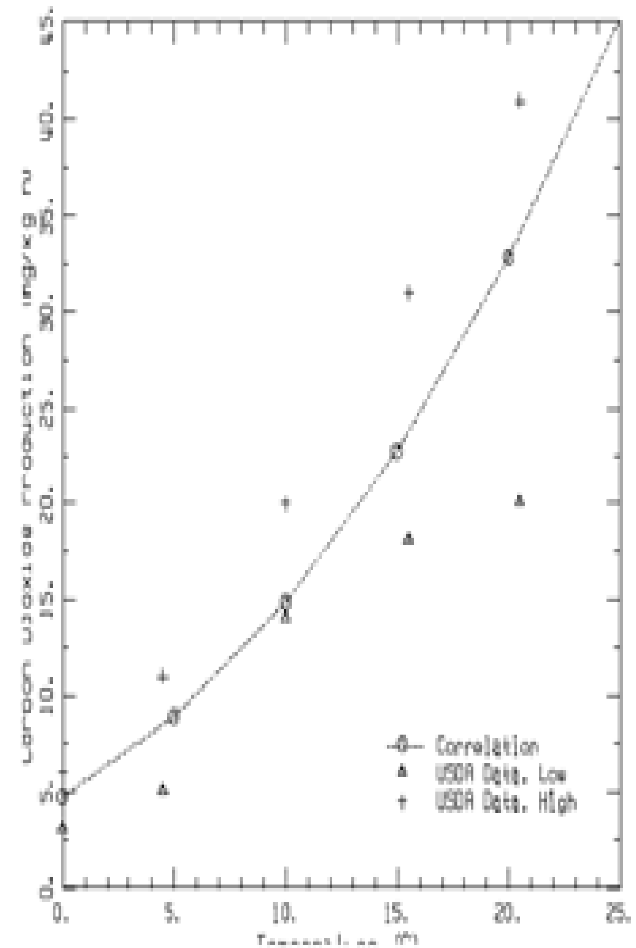
Weight loss vs. water vapor pressure deficit for oranges



Weight loss vs. water vapor pressure deficit for peaches

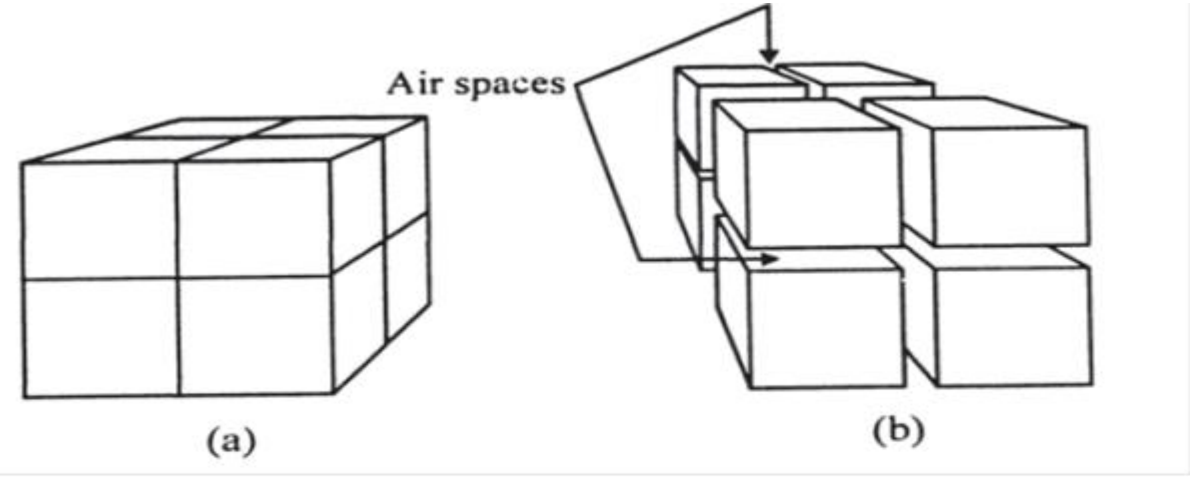


Weight loss vs. water vapor pressure deficit for apples



Carbon dioxide production vs. temperature correlation for apples.

For packaged products, instead of stacking the packages together, as in, much more rapid cooling results when air spaces are provided at as many surfaces as possible



Shortening the cooling time for packages by changing from (a) a compacted arrangement to (b) providing air spaces between the packages.

Shelf life of chilled processed foods: Depend on:-

– Type of food
– Degree of microbial destruction or enzyme inactivation achieved by the process
– Control of hygiene
– Barrier properties of the package
– Temperatures during production chain

It is therefore essential that good manufacturing practice (GMP) is enforced during the production of chilled foods. Details of the hygienic design of chilling plants, cleaning schedules and total quality management (TQM).

Mechanical refrigerators

Mechanical refrigerators have four basic elements:

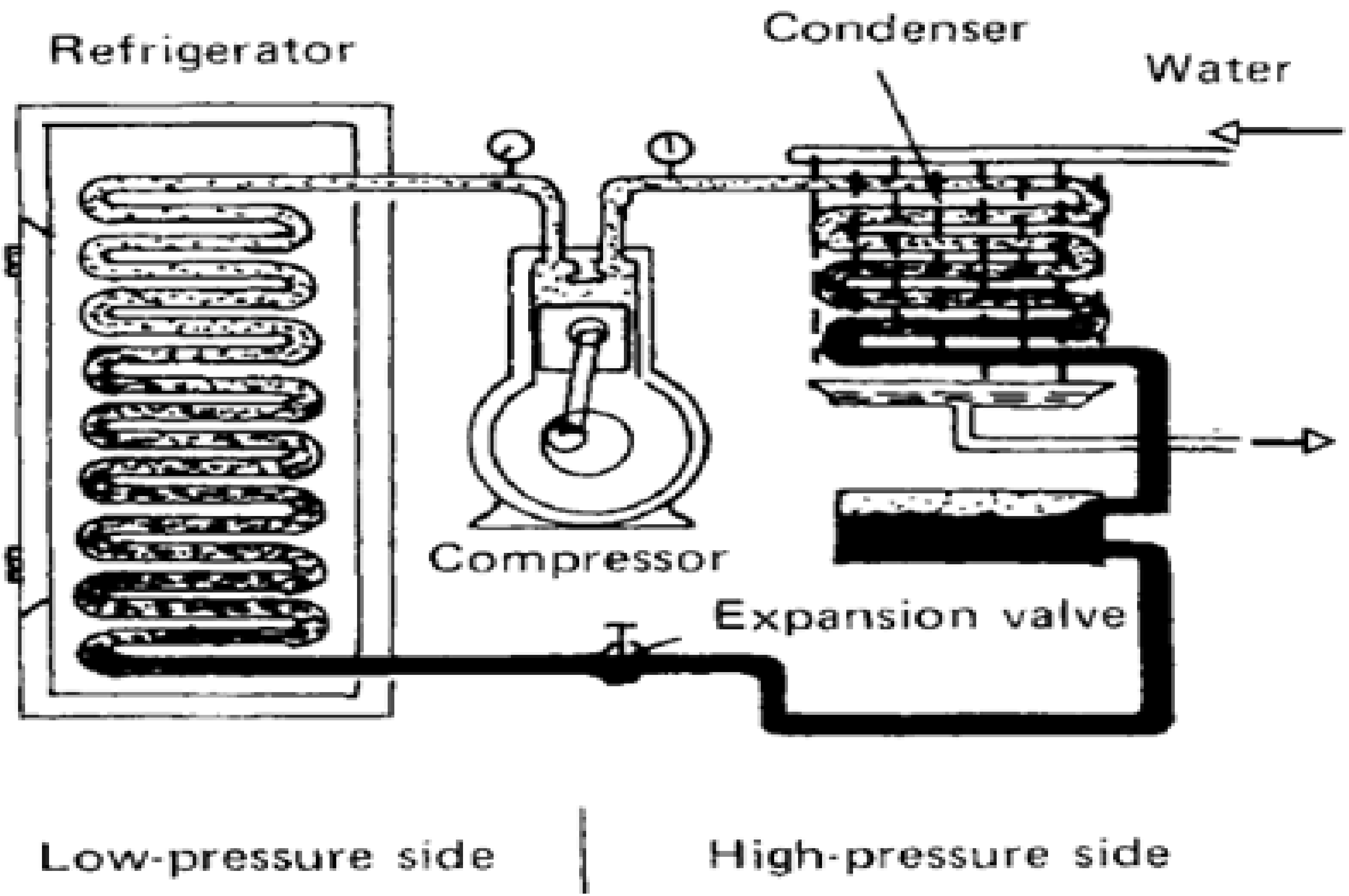
- Evaporator
- Compressor
- Condenser
- Expansion valve .

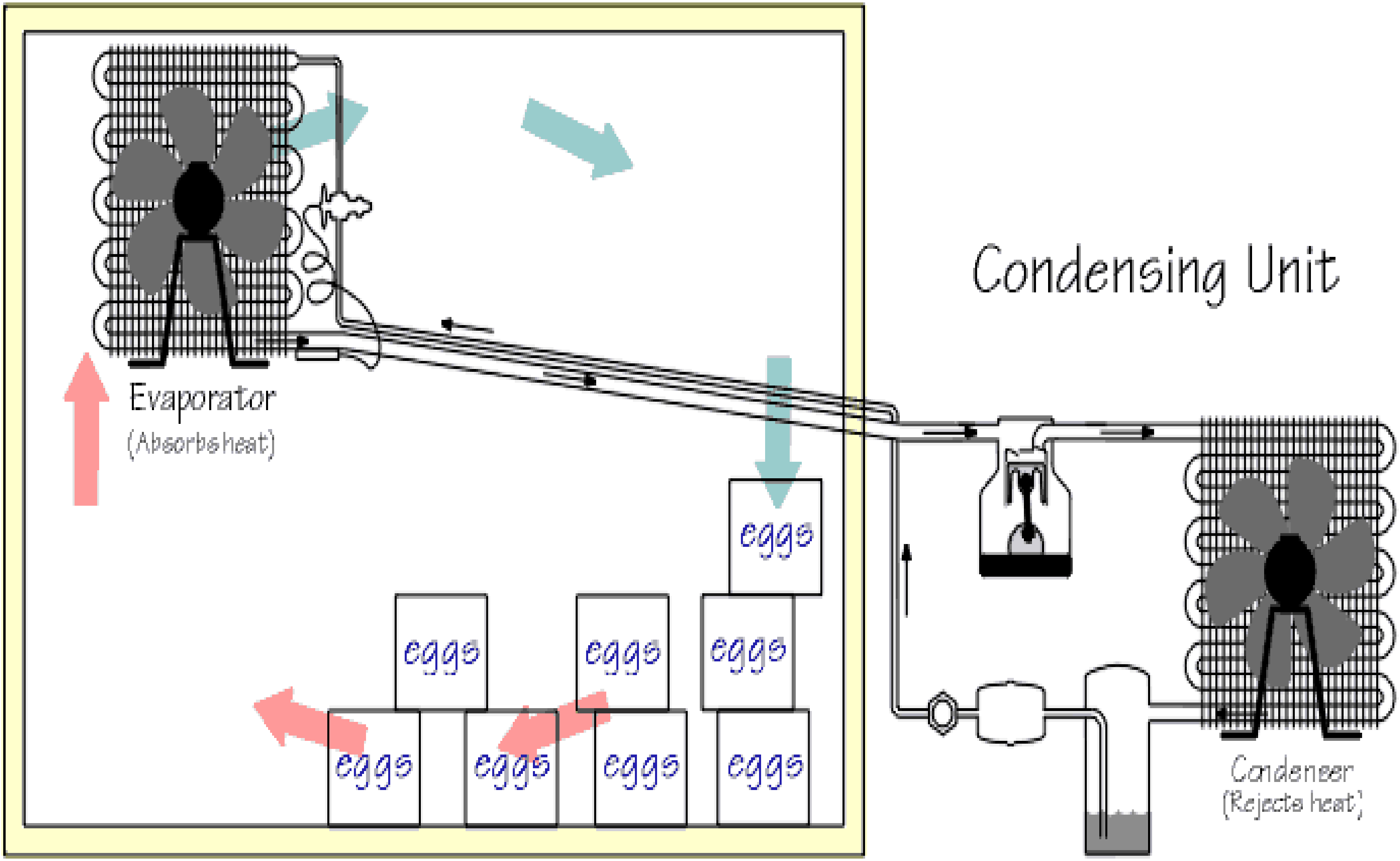
Components of refrigerators are frequently constructed from copper as the low thermal conductivity allows high rates of heat transfer and high thermal efficiencies

A refrigerant circulates between the four elements of the refrigerator changing state from liquid to gas, and back to liquid as follows:

- In the evaporator the liquid refrigerant evaporates under reduced pressure, and in doing so absorbs latent heat of vaporization and cools the freezing medium. This is the most important part of the refrigerator; the remaining equipment is used to recycle the refrigerant.
- Refrigerant vapour passes from the evaporator to the compressor where the pressure is increased.
- The vapour then passes to the condenser where the high pressure is maintained and the vapour is condensed.
- The liquid passes through the expansion valve where the pressure is reduced to restart the refrigeration cycle.

Mechanical (compression–expansion) refrigerator




Condensing Unit
Evaporator
(Absorbs heat)
eggs
eggs
eggs
eggs
eggs
eggs
eggs
eggs
Condenser
(Rejects heat)

The important properties of refrigerants are as follows:

- a low boiling point and high latent heat of vaporisation
- a dense vapour to reduce the size of the compressor
- low toxicity and non-flammable
- low miscibility with oil in the compressor
- low cost.

Chilling medium may be

Air

water

Metal surfaces.

- Air chillers (e.g. blast chillers)

– Use forced convection to circulate air at 4ºC at high speed (4 ms^{-1})

_ Reduce boundary films thickness to increase rate of heat transfer.

– Also used in refrigerated vehicles, but food should be adequately chilled when loaded on to the vehicle

Eutectic plate systems

Another type of cooling _ refrigerated vehicles, esp. for local distribution.

- Salt solutions (e.g. KCl. NaCl, or NH_4Cl) are frozen to their eutectic temperature (from -3 to - 21ºC)
- air is circulated across the plates, to absorb heat from the vehicle trailer.

- plates are regenerated by re-freezing in an external freezer

Other methods of cooling

- Vacuum cooled.

The food is placed in a large vacuum chamber and the pressure is reduced to approximately 0.5 kPa. Cooling takes place as moisture evaporates from the surface (a reduction of approximately 5ºC for each reduction of 1% in moisture content).

Cryogenic chilling

- A cryogen is a refrigerant that changes phase by absorbing latent heat to cool the food.

Cryogenic chillers use **solid carbon dioxide, liquid carbon dioxide or liquid nitrogen.**

Solid carbon dioxide removes latent heat of sublimation (352 kJ kg^{-1} at -78ºC)

liquid cryogens remove latent heat of vaporisation (358 kJ kg^{-1} at -196ºC for liquid Nitrogen; liquid carbon dioxide has a similar latent heat to the solid).

Solid carbon dioxide can be used in the form of 'dry-ice' pellets, or liquid carbon dioxide can be injected into air to produce fine particles of solid carbon dioxide 'snow', which rapidly sublime to gas.

- A recent advance in the use of carbon dioxide snow for chilled and frozen distribution of foods.
- Liquid nitrogen is used in both freezing and chilling operations.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Methods for Pre-Cooling Produce

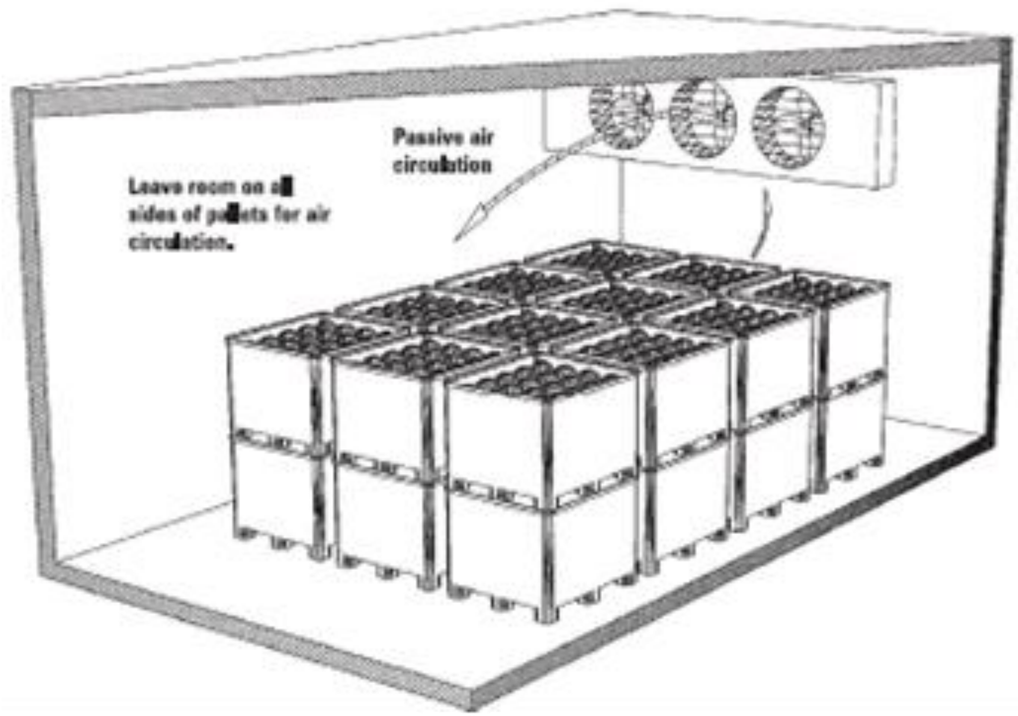
Pre-cooling rapidly lowers the temperature of freshly harvested produce and is done immediately following harvest to minimize spoilage.

There are five principal methods of pre-cooling fresh produce:

- Room cooling
- Forced-air cooling
- Hydro-cooling
- Ice cooling
- Vacuum cooling

Room cooling

- Room cooling is one method used for produce sensitive to free moisture or surface moisture.
- Because this type of cooling is slow, room cooling is only appropriate for very small amounts of produce or produce that does not deteriorate rapidly



Forced-air cooling

- Forced air cooling is used mainly for bulk produce and palletized produce. It is the most versatile and widely used of all cooling methods.

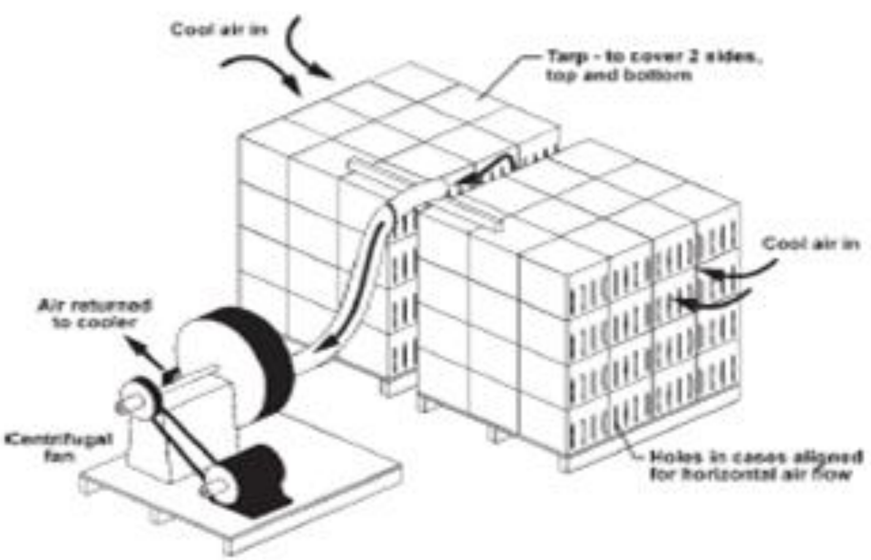


Figure B. Forced horizontal air flow.

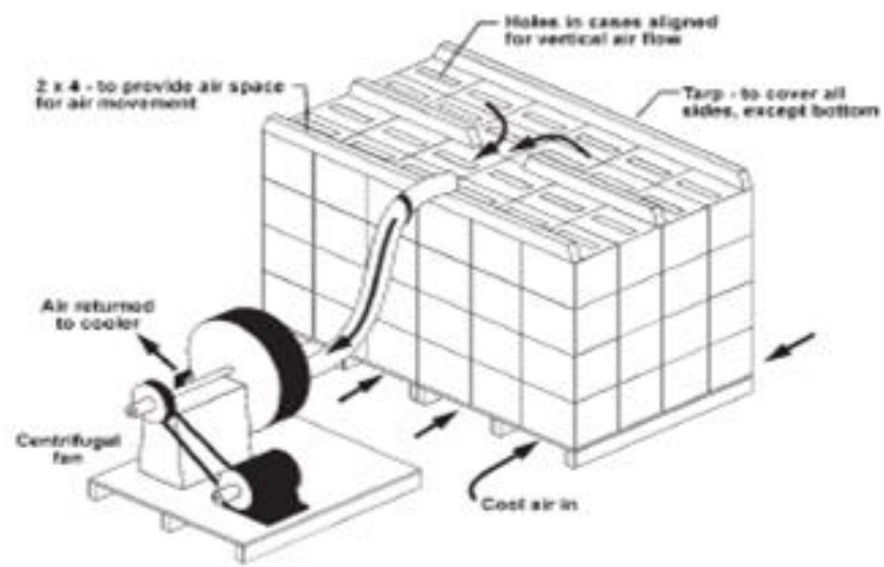
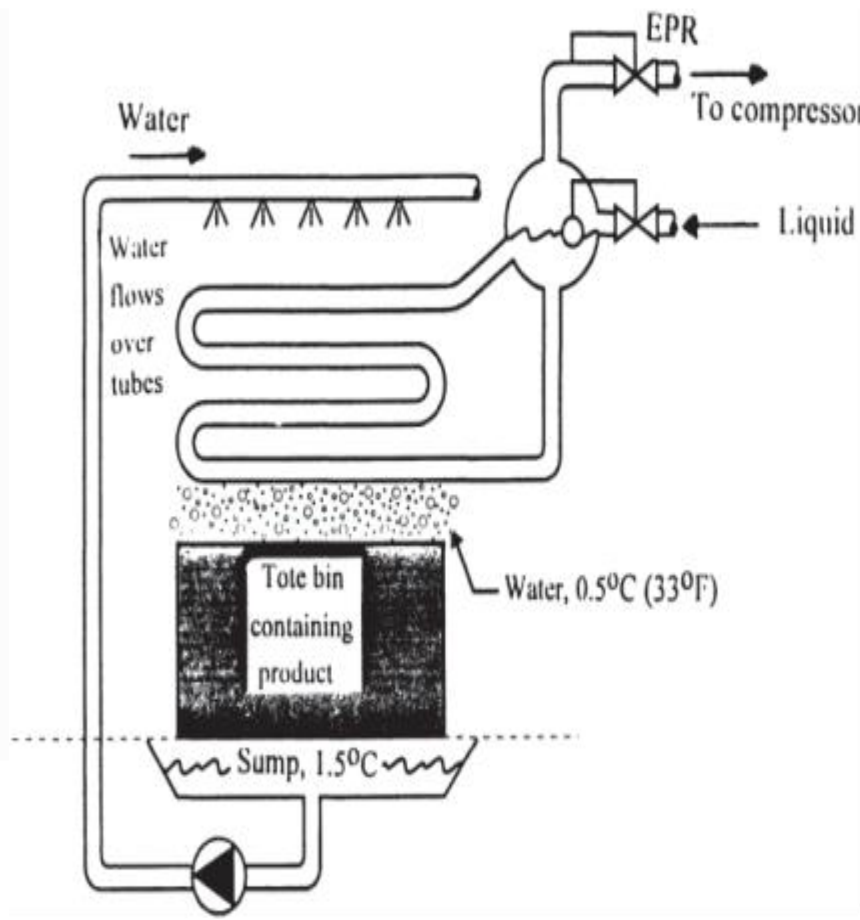


Figure C. Forced vertical air flow.

Hydro-cooling

- In hydrocooling, cold water is used to pre-cool produce. Produce may be immersed in a tank of circulating cold water or as in other techniques, cold water is sprinkled or sprayed over the produce. The equipment used for hydrocooling is often equipped with a water chiller.

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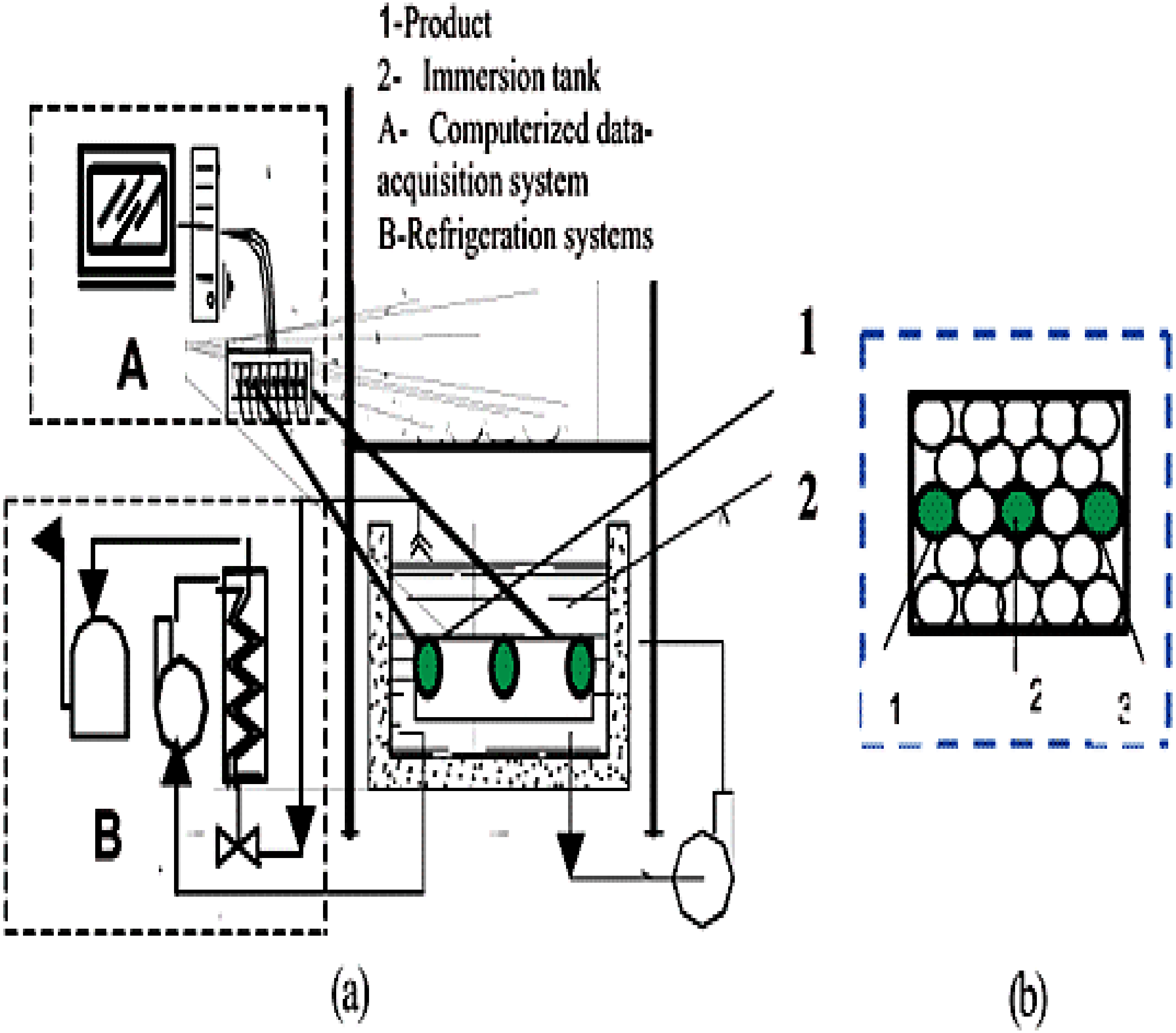


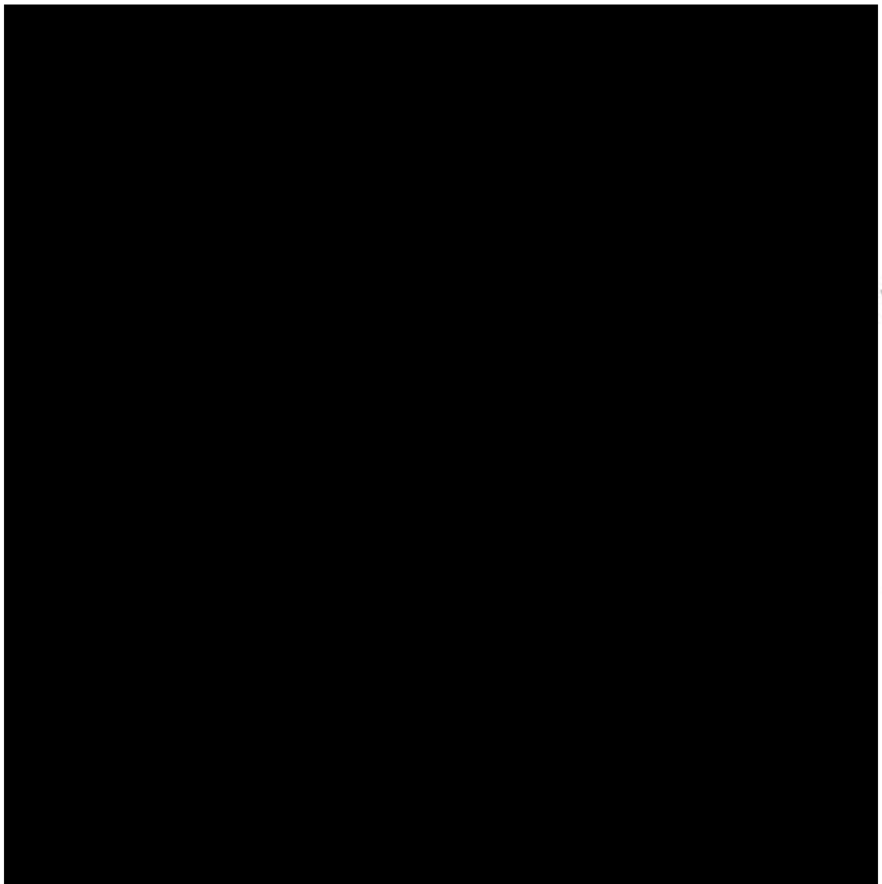
Figure 2 - a) Elements comprising the immersion refrigeration system. b) Position in the fruits where temperature was measured.

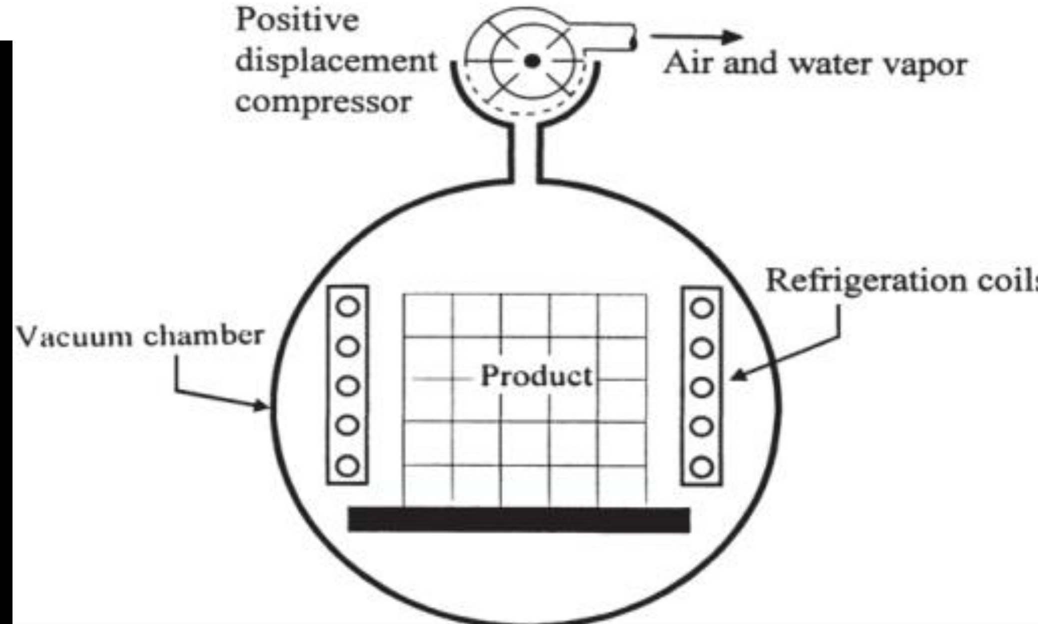
Ice cooling

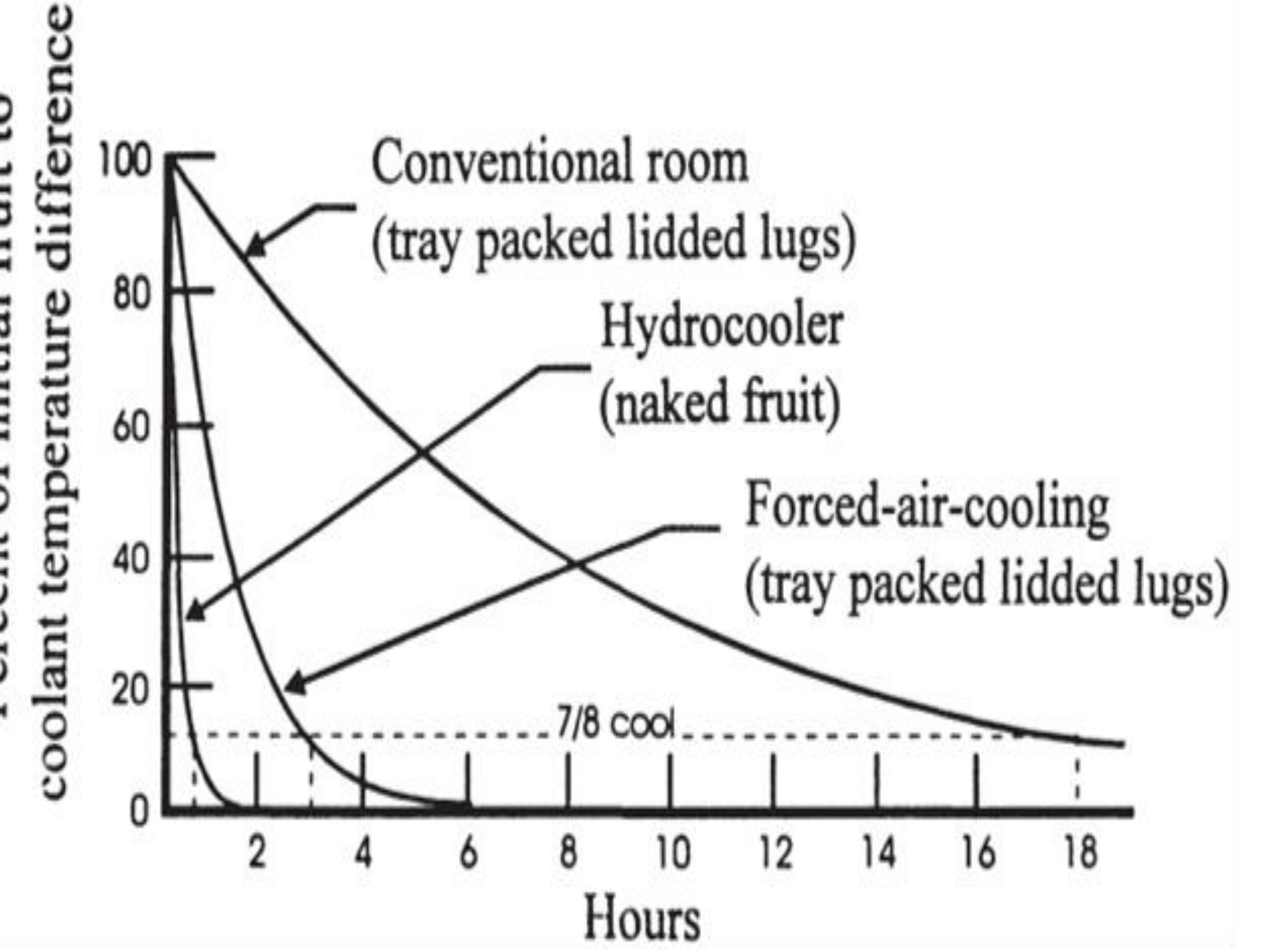
- In ice cooling, crushed or fine granular ice is used to cool the produce. The ice is either packed around produce in cartons or sacks, or it is made into a slurry with water and injected into waxed cartons packed with produce. The ice then fills the voids around the produce

Vacuum cooling

- In vacuum cooling, containers of produce are put in a vacuum chamber. Air is drawn out of the chamber creating a high vacuum. Under the high vacuum, the boiling temperature of water is substantially lowered






coolant temperature difference
100
80
60
40
20
0
Conventional room
(tray packed lidded lugs)
Hydrocooler
(naked fruit)
Forced-air-cooling
(tray packed lidded lugs)
7/8 cool
2
4
6
8
10
12
14
16
18
Hours

Chill storage

- Once a product has been chilled, the temperature must be maintained by refrigerated storage. Chill stores are normally cooled by circulation of cold air produced by mechanical refrigeration units, and foods may be stored on pallets, racks, or in the case of carcass meats, hung from hooks. Transport of foods into and out of stores may be done manually using pallet trucks, by forklift truck or by computer-controlled

Superchilling

Superchilling is one of the method that can be used to maintain food products at a low temperature. Generally, superchilling is positioned between freezing and refrigeration (conventional chilling), where the surrounding temperature is set below the initial freezing point. It is a process by which the temperature of a food product is lowered to -1 to -4 °C, by means of slurry ice or in superchilled chambers without ice.

Definitions of superchilling

Superchilling is that where temperature of food is maintained below 0°C but ice crystals are not generated. (Ando et al. 2004)

Superchilling is defined as a technology where food is stored just below the initial freezing temperature. (Beaufort et al. 2009)