

E355 : Cold Chain Management

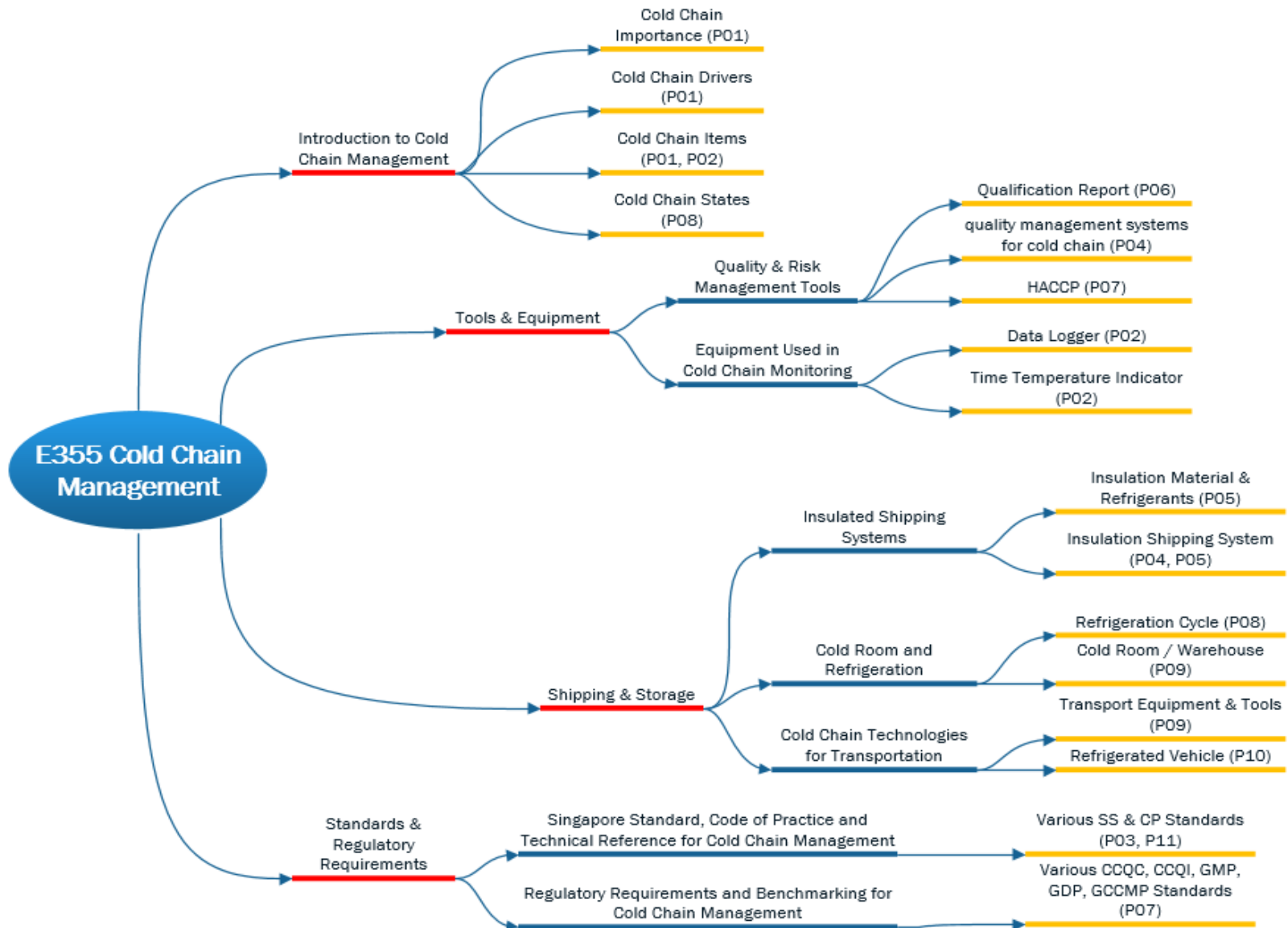
Problem 11

How do we manage these food?



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E355 Cold Chain Management - Topic Tree

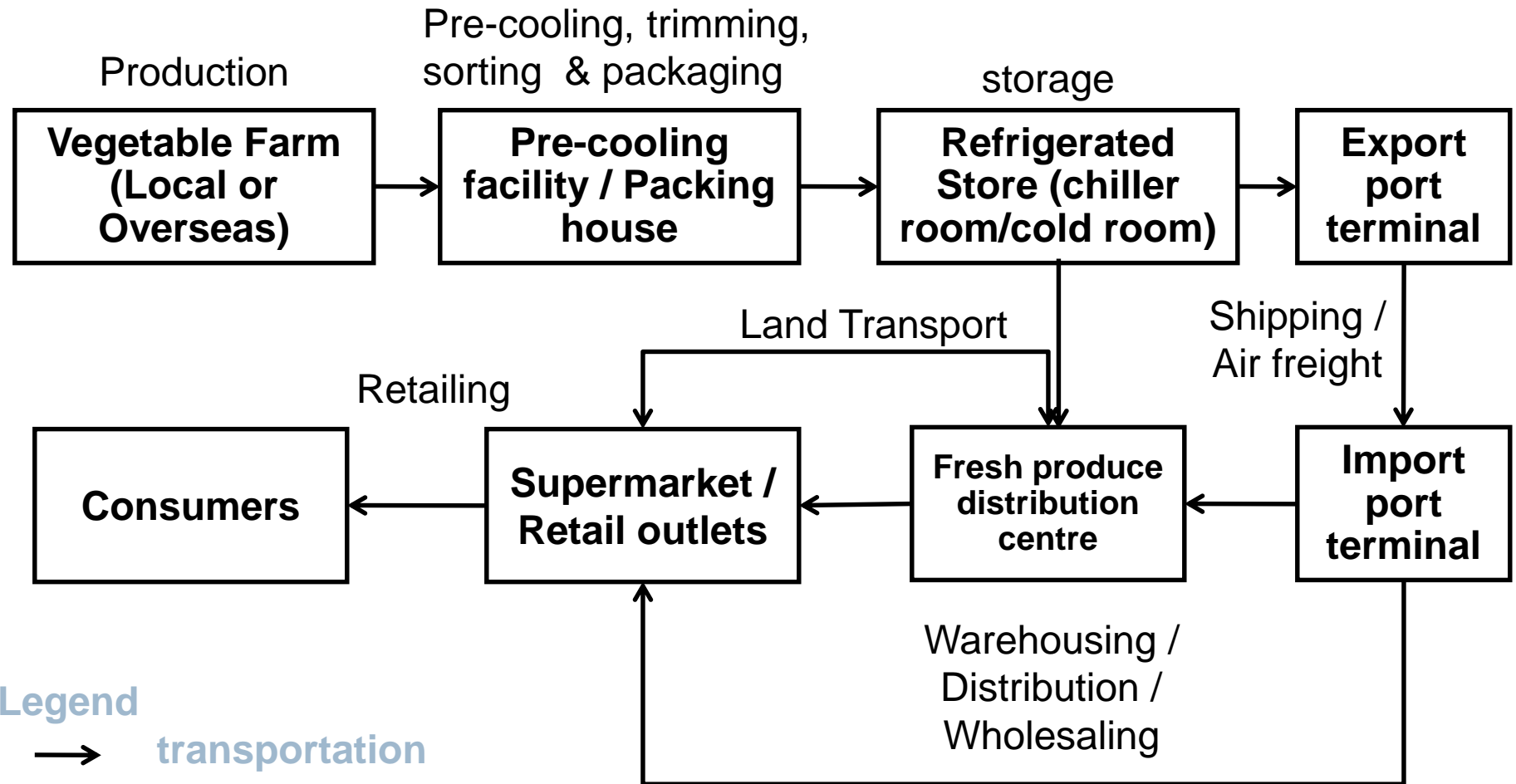


Integrated Cold Chain Management for Vegetables



- Involves different modes of transportation and multiple handling
 - challenge to effective cold chain management
- Each stage in cold chain is interdependent
- Non-compliance or abuse of stipulated required time-temperature-relative humidity controls at any stage of the chain has a cumulative “carry over” effect.
- Quality assurance system for the vegetables cold chain includes
 - Good Agricultural Practices for Vegetables Farming (GAP-VF)
 - Good Manufacturing Practices (GMP)
 - Hazard Analysis of Critical Control Point (HACCP)
- Records of Time-Temperature and Relative Humidity activity shall be maintained. Continuous temperature loggers are used to identify breaches in temperature control. Internal verification should be conducted at least on half-yearly basis.

Stages in Cold Chain Management of Vegetables



Vegetable Farms



- Vegetable farm constitutes the first stage in the chain.
- Each crate or container used for storing the harvested vegetables should be in good condition, made of plastic material, that is easily cleaned, and stackable to minimize damage and to optimize space during transportation and storage at packing house
- Use of rattan or bamboo baskets, as well as recyclable paper cartons should be avoided as stacking will lead to spoilage
- Exposure to ethylene gas and intense sunlight should be avoided. Hence vegetables should be placed under shade after harvest.
- For transport time > 2 hrs, vegetables should be put into refrigerated vehicle for transport to the packing house.
- For transport time < 2 hrs, covered vehicle could be used.



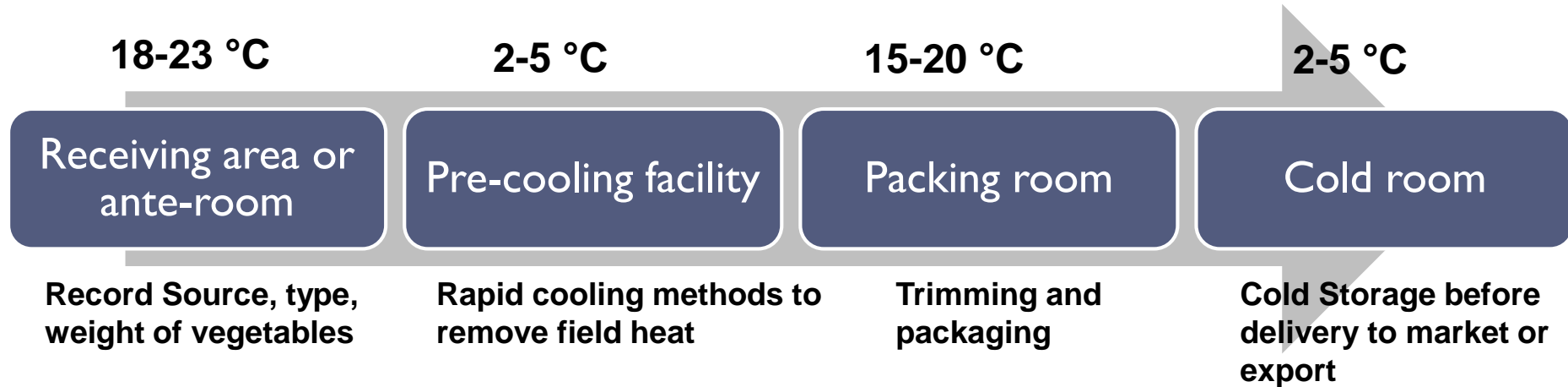
Transportation from Farm to Packing House



- Refrigerated vehicles or covered vehicles should be used to transport harvested vegetables
- Temperature of refrigerated vehicle should reach the desired holding temperature before loading vegetable
- Loading and unloading should be done within 30mins to reduce the exposure of vegetables to high ambient temperature
- Stacking of crates/ containers to facilitate circulation of cold air
- Shortest route, undulating, avoid bumpy and winding roads



Packing House



- The cold room and pre-cooling facility should have good insulation.
- Devices such as air curtains, plastic strips or sensor operated vertical curtain should be installed at the doors to reduce loss of cold air or introduction of hot air from external environment.
- Operations should adopt requirements of GMP and HACCP
- Temperature of facilities in the packing house should be monitored and recorded regularly.

Recommended Storage Conditions for Leafy Vegetables



Names		Storage temperature (°C)	Relative humidity (%)	Ethylene ⁱ⁾ production	Ethylene ⁱⁱ⁾ sensitivity	Approximate storage-life
Common	Scientific					
Bayam (Amaranth)	<i>Amaranthus gangeticus</i>	10 - 12	90 - 95	VL	M	5 - 7 days
Bai cai	<i>Brassica campestris</i>	2 - 5	90 - 95	VL	H	5 - 7 days
Cai xin	<i>Brassica chinensis</i> var. <i>parachinensis</i>	2 - 5	90 - 95	VL	H	5 - 7 days
Celery	<i>Apium graveolens</i> var. <i>Dulce</i>	2 - 5	90 - 95	VL	M	1 - 2 weeks
Chinese cabbage; (Pak choy)	<i>Brassica campestris</i> L. (Chinensis group)	2 - 5	90 - 95	VL	M-H	5 - 7 days
Gailan (Chinese kale)	<i>Brassica alboglabra</i>	2 - 5	90 - 95	VL	H	5 - 7 days
Iceberg lettuce	<i>Lactuca sativa</i> L., var <i>capitata</i>	2 - 5	90 - 95	VL	H	1 - 2 weeks
Kang kong	<i>Ipomoea aquatic</i>	10 - 12	90 - 95	VL	M	5 - 7 days

Recommended Storage Conditions for Leafy Vegetables



Names		Storage temperature (°C)	Relative humidity (%)	Ethylene ⁱ⁾ production	Ethylene ⁱⁱ⁾ sensitivity	Approximate storage-life
Common	Scientific					
Romaine lettuce	<i>L. sativa, var longifolia</i>	2 - 5	90 - 95	VL	H	1 - 2 weeks
Spinach	<i>Spinacia oleracea</i>	2 - 5	90 - 95	VL	H	10 - 14 days
Watercress; garden cress	<i>Lepidium sativum</i> ; <i>Nasturtium officinales</i>	0 - 2	95 - 98	VL	H	2 - 3 weeks
Xiao bai cai	<i>Brassica chinensis</i>	2 - 5	90 - 95	VL	H	5 - 7 days

ⁱ⁾ Ethylene production rate:

VL = very low (<0.1 µL/kg-hr at 20°C)

L = low (0.1-1.0 µL/kg-hr)

M = moderate (1.0-10.0 µL/kg-hr)

H = high (10-100 µL/kg-hr)

VH = very high (>100 µL/kg-hr)

ⁱⁱ⁾ Ethylene sensitivity :

L = low sensitivity

M = moderate sensitivity

H = high sensitivity

Recommended Storage Conditions for Headed Vegetables



Names		Storage temperature (°C)	Relative humidity (%)	Ethylene ⁱ⁾ production	Ethylene ⁱⁱ⁾ sensitivity	Approximate storage-life
Common	Scientific					
Broccoli	<i>B. oleracea</i> var. <i>Italica</i>	0 - 5	95 - 98	VL	H	10 - 14 days
Cauliflower	<i>Brassica oleracea</i> var. <i>Botrytis</i>	0 - 2	95 - 98	VL	H	3 - 4 weeks
Round cabbage	<i>Brassica oleracea</i> var. <i>capitata</i>	5 - 7	90 - 95	VL	H	10 - 14 days
Long cabbage, Wongbok	<i>Brassica campestris</i> var. <i>Pekinensis</i>	5 - 7	90 - 95	VL	H	10 - 14 days

ⁱ⁾Ethylene production rate:

VL = very low (<0.1 µL/kg-hr at 20°C)

L = low (0.1-1.0 µL/kg-hr)

M = moderate (1.0-10.0 µL/kg-hr)

H = high (10-100 µL/kg-hr)

VH = very high (>100 µL/kg-hr)

ⁱⁱ⁾Ethylene sensitivity :

L = low sensitivity

M = moderate sensitivity

H = high sensitivity

Recommended Storage Conditions for Fruited Vegetables (1)



Names		Storage temperature (°C)	Relative humidity (%)	Ethylene ⁱ⁾ production	Ethylene ⁱⁱ⁾ sensitivity	Approximate storage-life
Common	Scientific					
Bell pepper, Paprika, capsicum	<i>Capsicum annuum</i>	5 - 7	90 - 95	L	L	2 - 3 weeks
Bitter melon; Bitter gourd	<i>Momordica charantia</i>	10 - 12	85 - 90	L	M	10 - 14 days
Chayote	<i>Sechium edule</i>	7 - 10	90 - 95	L	M	10 - 14 days
Cucumber	<i>Cucumis sativus</i>	10 - 15	90 - 95	L	H	1 - 2 weeks
Corn	<i>Zea mays</i>	0 - 2	95 - 98	VL	L	2 - 3 weeks
Eggplant, Brinjal	<i>Solanum melongena</i>	10 - 12	90 - 95	L	M	1 - 2 weeks
Chilli	<i>Capsicum annuum</i> and <i>C. frutescens</i>	5 - 8	90 - 95	L	M	3 - 6 weeks
Long bean; Yard-long	<i>Vigna sesquipedalis</i>	4 - 7	90 - 95	L	M	7 - 10 days
Luffa; Chinese okra	<i>Luffa acutangula</i>	10 - 12	90 - 95	L	M	12 - 14 days

Recommended Storage Conditions for Fruited Vegetables (2)



Names		Storage temperature (°C)	Relative humidity (%)	Ethylene ⁱ⁾ production	Ethylene ⁱⁱ⁾ sensitivity	Approximate storage-life
Common	Scientific					
Tomato, mature-green	<i>Lycopersicon esculentum</i>	10 - 13	90 - 95	VL	H	1 - 2 weeks
Winter melon	<i>Cucumis melo</i> L. group <i>indorus</i>	12 - 16	90 - 95	L	M	2 - 3 weeks
Snow, snap and Sugar peas	<i>Pisum sativum</i>	0 - 2	95 - 98	VL	M	1 - 2 weeks
Pumpkin	<i>Cucurbita maxima</i>	10 - 13	50 - 70	L	M	2 - 3 months
Tomato, firm ripe	<i>Lycopersicon esculentum</i>	8 - 10	85 - 90	H	L	8 - 10 days

Recommended Storage Conditions for Herbs



Names		Storage temperature (°C)	Relative humidity (%)	Ethylene ¹⁾ production	Ethylene ¹⁾ sensitivity	Approximate storage-life
Common	Scientific					
Anise; Fennel	<i>Foeniculum vulgare</i>	4 - 8	90 - 95	L	H	7 - 10 days
Arugula; rocket	<i>Eruca vesicaria</i>	4 - 8	90 - 95	VL	H	7 - 10 days
Basil	<i>Ocimum basilicum</i>	15 - 18	90 - 95	VL	H	7 - 10 days
Chinese parsley (Coriander)	<i>Coriandrum sativum</i>	4 - 8	90 - 95	VL	H	7 - 10 days
Chives	<i>Allium schoenoprasum</i>	4 - 8	90 - 95	L	H	7 - 10 days
Dill	<i>Anethum graveolens</i>	4 - 8	90 - 95	VL	H	7 - 10 days
Green/ Spring onions	<i>Allium fistulosum/ cepa</i>	0 - 2	90 - 95	L	H	7 - 10 days
Leaf mint (Peppermint)	<i>Mentha piperita</i>	4 - 8	90 - 95	L	H	7 - 10 days
Sage	<i>Salvia officinalis</i>	15 - 18	90 - 95	L	H	7 - 10 days
Thyme	<i>Thymus vulgaris</i>	4 - 8	90 - 95	L	H	7 - 10 days

Ante-Room



- Ante-room (receiving area) is where vegetables are being unloaded from refrigerated vehicle, before being transferred to the pre-cooling facility
 - It should be maintained at (18-23°C)
 - It should not be left in ante room for more than 3hrs
 - Farm without temperature controlled ante-room should be received at a sheltered area and not be held there for more than 30 min

Pre-Cooling Facility



- Pre-cooling is very important step in cold chain management.
 - Temperature of facility should be kept at 2- 5°C
 - Field heat of freshly harvested vegetables is rapidly removed using rapid cooling methods before packing or storage
 - Rapid cooling after harvest is known to extend the shelf life of fresh vegetables and maintain freshness and quality of vegetables
 - Pre-cooling facility should be accessible only to workers responsible for loading and unloading of vegetables. This is to minimise the fluctuations on temperature and relative humidity in the room during pre-cooling process.
 - Maintain regularly – clean and good working conditions

Pre-Cooling Methods



- **Room cooling:** Vegetables, either packed in cartons or in bulk boxes, are placed in a cold room and cool as air circulates around the room. E.g. Pumpkin, Chives, Thyme. (slowest way ranging from 4hrs to 20 hrs)
- **Forced-air cooling:** Fans Used in conjunction with a cooling room, forced-air cooling is effective for most packaged produces. E.g. Bitter gourd, Okra (ranging from 1 hr to 10 hrs)
- **Hydro cooling:** Use on most products that are not sensitive to wetting. It involves removing heat with cold running water. E.g. Watercress, Corn
- **Top or liquid icing (Contact icing):** Suitable for dense or high-respiration produce such as broccoli, peas in pod, corn. A layer of crushed ice is placed directly on top of the produce by machine or hand.
- **Vacuum cooling:** Produce is enclosed in a chamber in which a vacuum is created. Water within the plant evaporates and removes heat from the tissues. E.g. Green Onions, Cabbage, Lettuce (Most efficient method for leafy vegetables)



Pre-Cooling Methods Comparison



Variable	Pre-cooling method				
	Room	Forced-air	Hydro	Ice	Vacuum
Cooling time (h)	4 - 20	1.0 – 10	0.1 – 1.0	0.1 – 0.3	0.3 – 0.5
Product moisture loss (%)	1	2	0	0	3
Capital cost	Low	Medium	Medium	Medium	High
Energy efficiency (energy cost/ kg veg)	Low	Medium	High	Medium	Medium



Forced Air Cooling



Front View of Forced Air Cooling Unit – pre-cooling loads of Strawberries



Multiple Forced Air Cooling Units in a Common Room

Contact Icing



Ice Completely Envelops Broccoli

Hydro Cooling



Bulk baby carrot hydrocooler



Belt conveyor unit handles individual cartons or bulk product



12 pallet front loaded system

Packing Room



- Packing Room where vegetables are trimmed, sorted, graded and packed
 - Temperature maintained at 15-20°C to preserve the benefits of pre-cooling and conducive for human work
 - Relative humidity between 80% and 95% during operation
 - Processing time per batch should not exceed 1hr
 - Only relevant quantities of vegetables should be taken out just before packing to ensure vegetables are not exposed to packing room temperature for more than 30min.
 - Temperature and relative humidity within the packing room should be recorded and maintained at least twice daily
 - Air conditioner, fans and blowers and equipment used such as weighing balances and tools should be maintained regularly.

Cold Room



- Cold room, where vegetables are stored before being transported out of the packing house
 - Uniform Temperature between 2-5°C
 - Containers of vegetables should be stacked on pallets with adequate space in between pallets, and between the cold room walls and ceiling of the cold room so as to ensure efficient air circulation.
 - Ethylene producing vegetables and ethylene sensitive vegetables should be stored separately
 - Vegetables should be discharged from the cold room in FIFO basis
 - Temperature in cold room should be monitored and recorded at several points at regular intervals at least twice daily.
 - A schedule of defrosting should be maintained and the operator of the premises should ensure workers adhere to it.

Interfacing Transportation Modes



- Supply of vegetables to Singapore's domestic market is dependent on overseas sources. Very small amount is produced locally.
- Smooth interfacing of transportation modes is crucial in maintaining the integrity of cold chain irrespective of land, sea or air transportation modes
- The transportation mode links the vegetable farms, packing house, and distribution center with the retail outlets
- Continuous temperature control and insulation in the course of conveyance (Temperature profiling to be recorded and available of inspection)
 - Land – Refrigerated Vehicles and reefer containers
 - Sea – Reefer Containers or Reefer Vessels
 - Air – ULD on Aeroplanes

Interfacing Transportation Modes



- Refrigerated vehicles with suitable cooling and insulation should be used to carry the vegetables at the required temperature
- Operating temperature of refrigerated delivery vehicle shall be 2-5 °C, temperature of the chiller store should be maintained at 2-5°C
- During unloading, the temperature should not exceed 15°C
- Refrigerated vehicle should be insulated and equipped with adequate refrigeration capacity and air delivery system to continuously maintain the temperature of vegetables.
- Regular checks of temperature at refrigerated vehicle is necessary

Vegetables Supply From Farm to Distribution Centre



Harvesting

Pre-cooling

Packing

Transfer to Reefer

Stored in Reefer

Transport to DC



Milk and Dairy Products



- Highly perishable food
- Requires specific range of storage temperature to extend product shelf life
- High in nutrients which is available for growth of other pathogens, food spoilage and poisoning organism if no proper temperature control exist



Singapore Standard SS 621: 2016



- ▶ Code of practice for cold chain management of milk and dairy products
- ▶ First published as CP95, 2002 and re-designated as SS621, 2016
- ▶ Approved by Food Standards Committee on 4 December 2016
- ▶ The objectives of this standard are to establish and provide benchmarks for the management of temperature profiles in the links of the cold chain for milk and dairy products manufactured under hygienic and sanitary conditions. It also aims to uphold the safety, quality and wholesomeness of these products, safeguard public health, provide protection for consumers and reduce unnecessary food waste.



- Provide guidelines on Critical Temperatures to be maintained throughout supply chain from manufacturing plant, warehouse, delivery trucks to retail outlets.

Item Categories	Critical Temperature (°C)
Chilled milk & dairy products e.g. pasteurised milk	+4 °C or below
Acidic milk/fermented drinks	+10 °C or below
Frozen dairy products e.g. Ice cream	-18 ° C or below

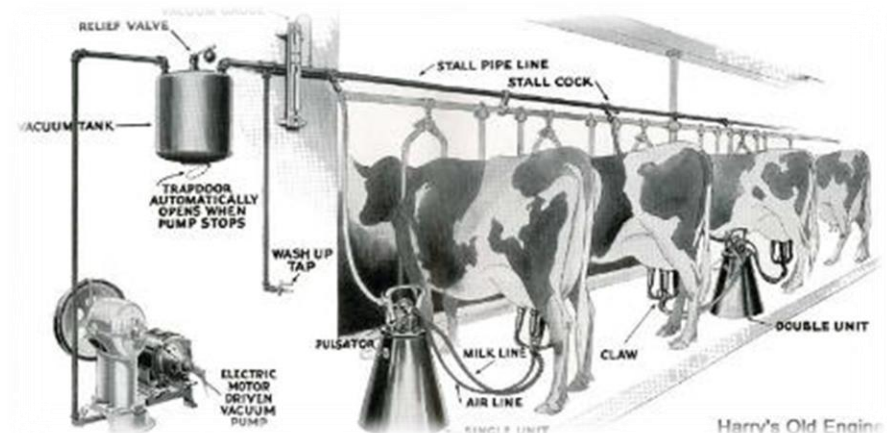
Supply Chain for Milk and Dairy Products



Production of Raw Milk



- First link in cold chain management of milk
- Originate from disease-free cows
- Hygienic operations
- Devoid of chemicals and microbial contaminations
- Breaches in this practice: deleterious effect of subsequent links
- Inspection and certification of dairy farms by AVA



Milking & Chilling of Milk in Farm Bulk Tank



- Upon completion of milking, content will be transferred to a bulk milk holding tank and chilled
- Tank must be pre-cooled to $+5^{\circ}\text{C}$ or below
- First milking transferred must be cooled to $+10^{\circ}\text{C}$ or below within 1 hour, and maintained between $+1^{\circ}\text{C}$ and $+4^{\circ}\text{C}$ within 3.5 hours after milking
- Subsequent milking should not cause the blend temperature to rise above $+10^{\circ}\text{C}$, and be cooled between $+1^{\circ}\text{C}$ and $+4^{\circ}\text{C}$ within 1 hour
- Milk must be emptied from tank once every 2 days



Milking & Chilling of Milk in Farm Bulk Tank

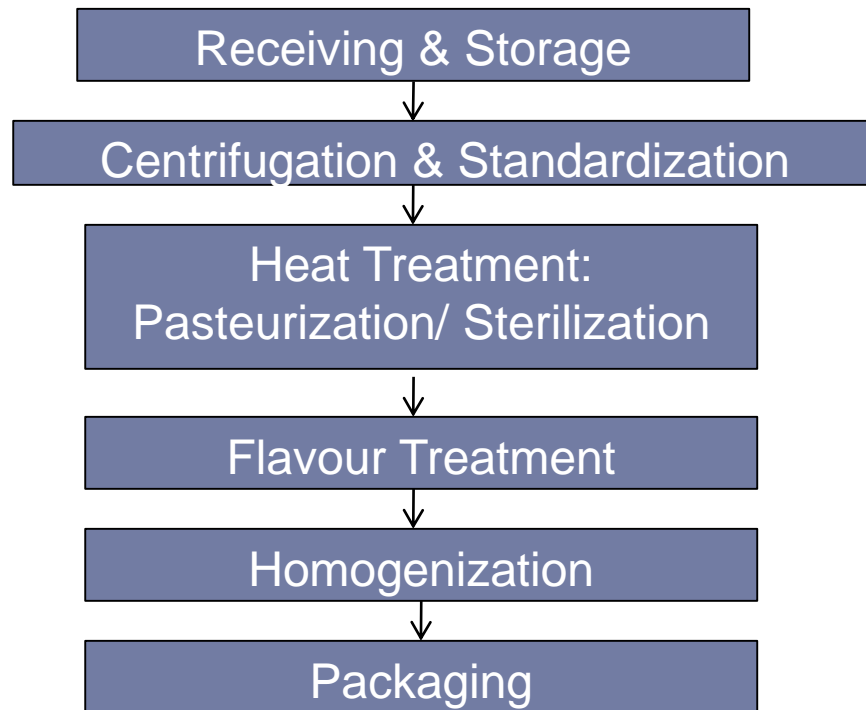


- Tank shall be cleaned with good hygienic practice and sanitized with approved sanitizing agents
- Tank capacity to hold milk equivalent to a minimum of 2.5 days of milk production by the herd of cows during its peak production period
- Tank dedicated to storage and chilling of milk only
- Equipped with gauge to determine volume of milk
- 3 hourly temperature recordings of the contents based on the thermometer installed on tank

Processing Dairy Plant



- Second link in the management of cold chain
- Receives and stores raw milk or farm-separated cream by insulated transport tanks



Chilling of Raw Milk in Dairy Plant Storage Tank

- Storage tanks pre-cooled to $+4^{\circ}\text{C}$ or below
- Raw milk maintained at $+4^{\circ}\text{C}$ or below until ready for heat-processing
- If milk temperature rise above $+4^{\circ}\text{C}$, it must be processed within 2 hours or disposed off
- Temperature should be recorded every 3 hours
- If raw milk delivered to plant exceeds $+5^{\circ}\text{C}$, reject!
- Raw milk delivered shall not exceed 3 days following milk extraction
- Storage tanks shall be emptied at least once in 72 hrs and sanitized

Pre-storage Handling of Pasteurised Milk in Dairy Manufacturing Plant



- The respective pre- and post-packaging temperature of:
 - Pasteurised milk: $< +4^{\circ}\text{C}$
 - Pasteurised liquid cream: $+8^{\circ}\text{C}$ and $+4^{\circ}\text{C}$
 - Fermented milk or drink: $< +10^{\circ}\text{C}$ and $+4^{\circ}\text{C}$
 - Ice-cream: Post packaging below -18°C , preferably -23°C
 - Others: $< +7^{\circ}\text{C}$ and $+4^{\circ}\text{C}$



Storage Rooms in Dairy Plants



- Equipped with chillers and freezer rooms for proper maintenance of temperature and humidity levels of different milk products with adequate air circulation
- To uphold product quality prior to distribution to wholesale/supermarket/retail outlets
- No product shall be placed directly on floors or exposed to foreign odours or conditions such as drippings to prevent condensation which may result in damage of package and ultimately the product
- First in, first out stock rotation, and check for marked dates and spoilages or other quality defects
- Recommendation of HACCP in dairy plants



Retail Outlets



- Third link in cold chain management
- Premises to be annually inspected and certified fit by NEA for sale of milk
- Hygiene regulations to be complied by personnel engaged in the handling of the products
- Specific cleaning schedules for the display cabinets which should be tidily maintained and kept clean at all times
- Regular inspections on the adequacy of the storage, cleaning, sanitary, and removal of damaged packages and deteriorated products



Reception and Storage of Milk



- Supermarkets should assign an area for unloading of food especially for milk and dairy products that can achieve the optimal hygienic conditions yet permit verification of documents and temperature profile
- Operating temperature of refrigerated delivery vehicle shall be 0 to +4°C for chilled products, -23 to -18°C for frozen products and +10°C for fermented milk or drink
- Random product temperature should be monitored
- Unloading from refrigerated trucks should preferably not be more than 30min
- Milk should never be stored with wrapped or unwrapped raw food



Display of Milk and Dairy Products

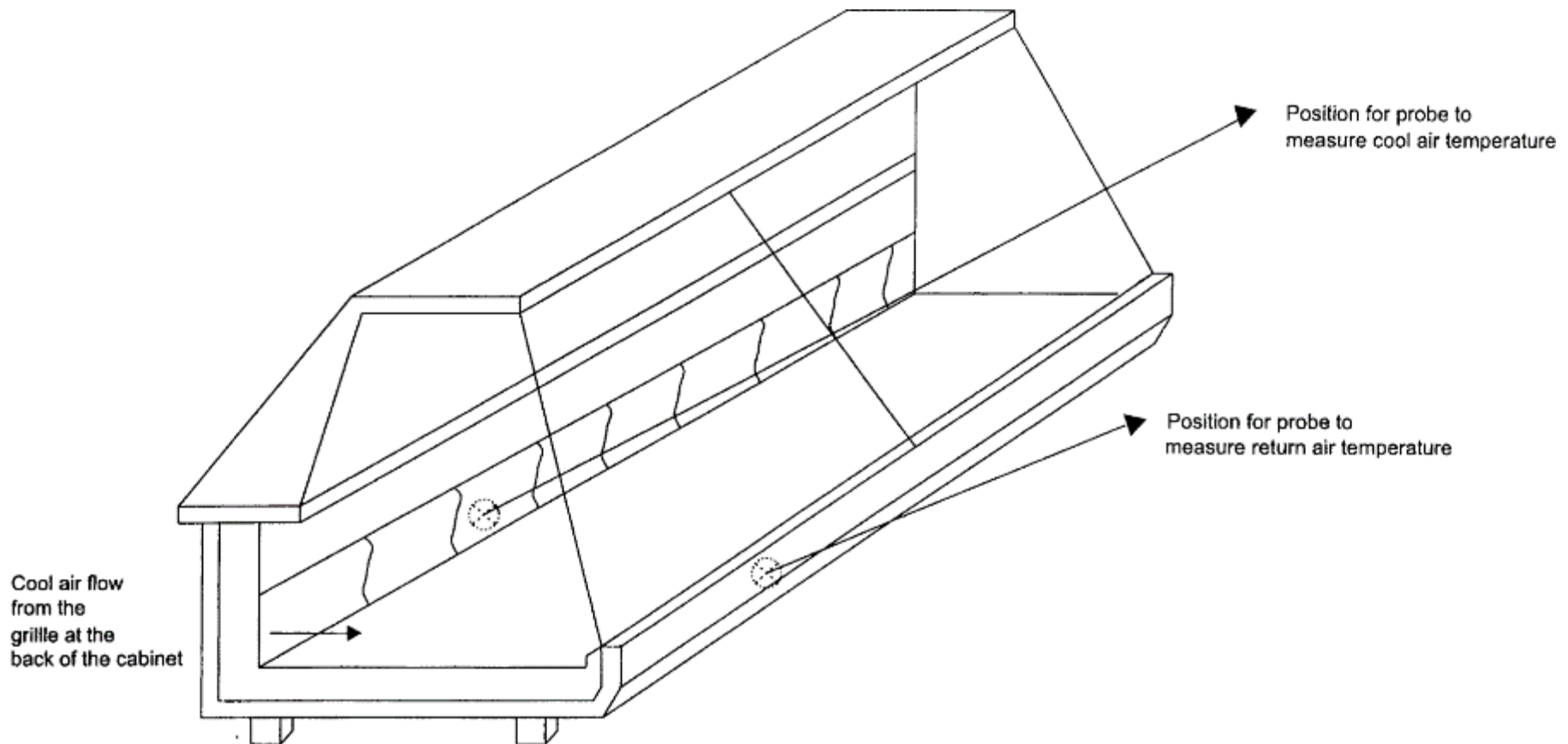


- Temperature in open multi-deck display or serve-over display cabinet shall be maintained at 0 to +5°C. Chilled cabinets of vertical design with hinged glass/plastic door shall be 0 to +4 °C.
- Temperature in horizontal, open freezer display cabinet or “island freezer” shall be maintained at or below -15°C. However temperature for frozen cabinets of vertical design with hinged glass/plastic doors shall be maintained at -23°C to -18°C.
- A temperature sensor should be placed against the centre of the air discharge opening at a position 1m in, from the left-hand end of the display; and another placed into the cabinet front grill inside edge, 1m from left hand end
- Record thermometer readings of display cabinets at regular intervals
- Night covers are recommended for open display cabinets
- Loading should be confined to the recommended load line by manufacturers
- Load new stocks of milk and dairy products at the back of the display cabinet or beneath existing stocks with reduced shelf-life

Display Cabinet & Temperature Sensor



- For serve-over cabinet

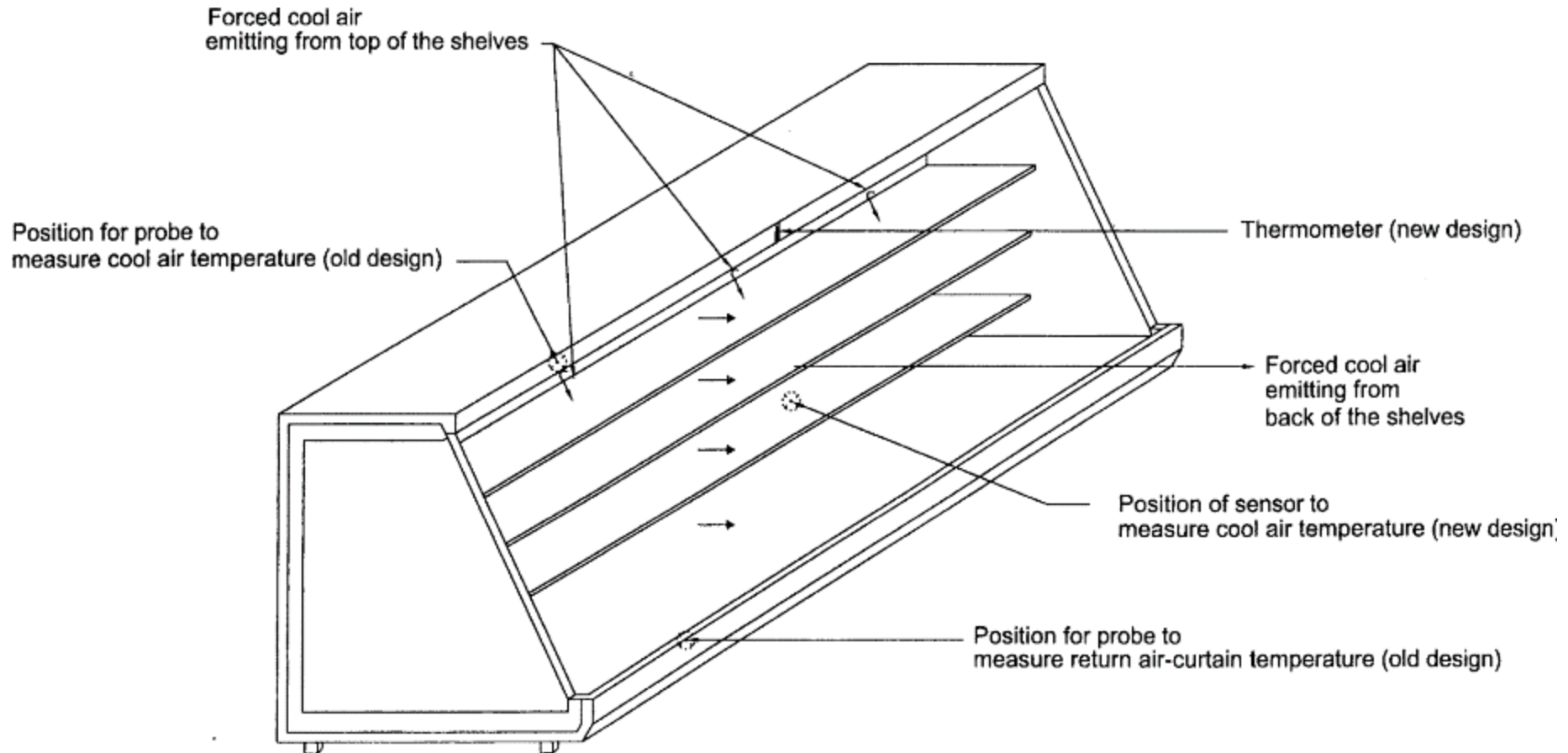


Source : Singapore Standard CP95 :2002, Code of practice for Cold Chain Management – Milk and dairy product

Display Cabinet & Temperature Sensor

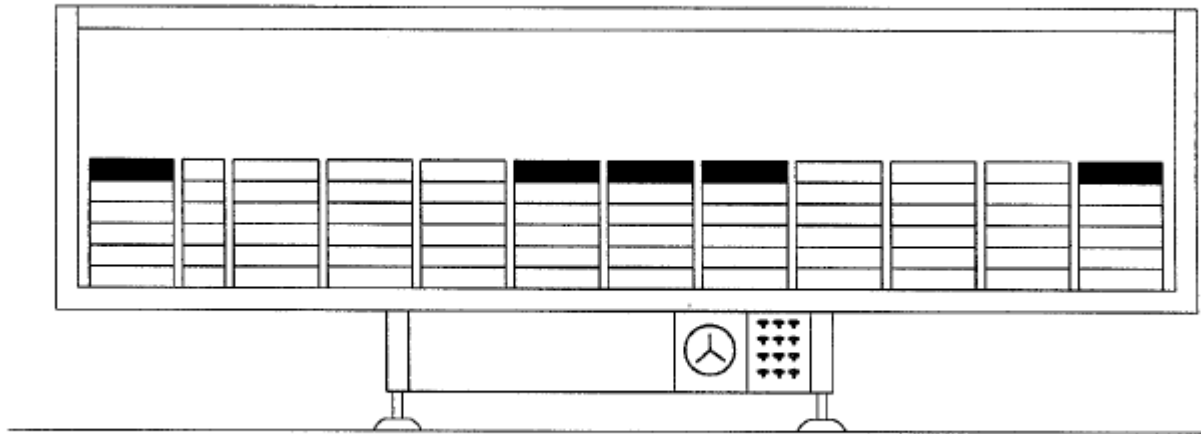


- For multi-deck cabinet

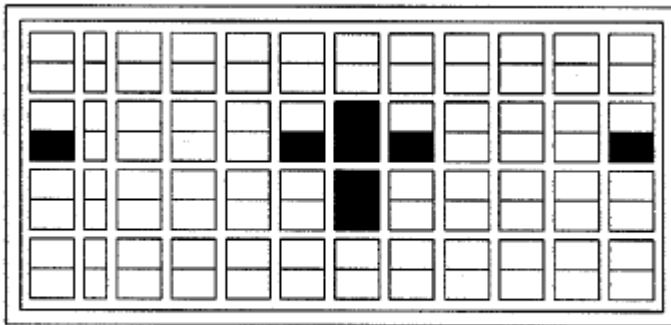


Source : Singapore Standard CP95 :2002, Code of practice for Cold Chain Management – Milk and dairy product

Horizontal, open frozen food display cabinet “Island Freezer”



Longitudinal cross-section



View from above

Source : Singapore Standard CP95 :2002, Code of practice for Cold Chain Management – Milk and dairy product

Examples of chilled cabinets



Chilled cabinet: Multi-deck display



Chilled cabinet with hinged glass doors

Examples of frozen cabinets



Frozen cabinets of vertical design with hinged glass doors



Island Freezer

Consumers



- Consumer is the final link of the Cold Chain
- Proper handling and observance of the recommended temperature is important
- Milk and dairy products should be last in the shopping list and to be picked up just before payment
- Storage of these products in insulating boxes or bags especially in the presence of frozen coolant blocks is highly desirable especially if immediate direct transfer of these products to the home refrigerator is not possible
- Perishable items should be returned to original designated site if purchase aborted; under no circumstances should they be placed in non-refrigerated shelves

Today's Problem



- Every link in the Cold Chain Management of Milk and Dairy products, Vegetables and Frozen fish and seafood is interdependent and vital and equally important
- Non-compliance or abuse in any link has a cumulative 'carry-over' effect
- Proper management provides the essence for upholding the freshness, safety of consumers and preserves the nutritional and sensory qualities of vegetables & milk and dairy products
- Thus, significant advantages can be derived through the adoption of SS585:2013 and SS621:2016

Learning Objectives



- ▶ Interpret the Singapore Standard SS585: 2013 for Cold Chain Management of Vegetables
- ▶ Determine the location of temperature loggers to measure cold chain of vegetables
- ▶ Interpret the Singapore Standard SS621:2016 Code of Practice for Cold Chain Management of Milk and Dairy Products

