Low temperature methods for food preservation.

[1]Prasad V. Kengar, [2] M. S. Joshi,

[1]Department of Mechanical Engineering, Walchand College of Engineering, Sangli - 416415, Maharashtra, India

Abstract—**In Production of fruits, India stands first and in vegetables stands second having 10 and 15 percent of total global production. India have a strong and dynamic food processing sector playing a vital role in diversifying the agricultural sector, improving value addition opportunities and creating surplus food for agro-food products. Presently, approximately 2.2 per cent of fruits and vegetables are processed, even as the country ranks second in the world in terms of production. This is comparatively low when compared to other countries like Brazil (30 per cent), USA (70 per cent) and Malaysia (82 per cent). Wastage of fruits and vegetables due to poor post-harvest management and lack of cold chain facilities have been estimated to cost up to Rs 500 billion annually. The country also experiences wide fluctuations in prices of horticultural produce, particularly potatoes and onions. The cold storages will help boost exports of agricultural and allied produce, marine produce etc.**

***Index Terms*—Food processing, agro food products, horticulture.**

I. INTRODUCTION

Major vegetables grown are Potato, Onion, Tomato, Cauliflower, Cabbage, Bean, Egg Plants, Cucumber, Gherkin, Peas, Garlic and okra. The major fruits grown in India are Mangos, Grapes, Apple, Apricots, Orange, Banana Fresh, Avocados, Guava, Litchi, Papaya and Water Melons. Mango, accounts for 40 percent of the national fruit production and India is one of the leading exporters of fresh table grapes to the global MARKET. The changing food habits are discernible. There has been a positive growth in ready –to-serve beverages, fruit juices and pulps, processed fruits and vegetables products, i.e., dried or preserved and dehydrated vegetables and fruits such as sauces, preserved onions, cucumbers and gherkins, green pepper in brine, dehydrated garlic and ginger powder, dried garlic and ginger, tomato products, pickles and chutneys, processed mushrooms and truffles and curried vegetables. Nearly one third of our horticultural produce, especially fruits and vegetables are wasted, mainly on account of poor cold storage and other storage facilities.

There are some standard temperature and storage time for each food product depending on the moisture content and preservation time following table gives brief idea about that

Table no 1. Fruits and their storage temperatures.

Name of Fruit	Storage temperature(℃)	Cold Storage life (in weeks)	Remarks
Apple	0 to 3	7-26	Small fruits keep better than large ones
Apricot	-2 to 0	2-4	-
Bananas	12 to 17	2-3	-
Cherries	-2 to 0	2-3	-
Guavas	3 to 7	3-4	-
Grapes	-2 to0	4-6	Fumigation with 1-2% sulpher dioxide before storage reduces decay and storage life can be increased to 8-12 weeks
Lemon	7 to 12	9-13	Lemon for storage should be picked at the greenish yellow colour
Lime	7 to 12	4-5	-
Mangoes	1 to 7	4-6	-
Mandarin Oranges (Nagpur)	-5 to -7	9-13	Mandarin oranges can be kept satisfactorily at lower temperature if to be stored for less than 4 weeks
Oranges Malta (Punjab)	-9 to -12	13-17	Tight skinned oranges can also be kept at lower temperature if to be stored for less than 8 weeks
Pears	-2 to 0	2-4	-
Peaches	-2 to 0	2-4	-
Plums	-2 to 0	2-4	If fruit is to be stored for jam making, the storage life can be extended by another two weeks.
Pineapple	7 to 12	3-4	-

Table no. 2 gives information about Vegetables.

Optimum storage conditions for vegetables R.H. 85-90% except Beet root, Cabbage, Radish, Turnips and Peas where R.H. is 90-95%			
Name of Vegetables	**Storage temperature**	**Cold Storage life (in weeks)**	**Remarks**
Beans	0 to 5	2-3	Beans are liable to be sweet in storage. Need more ventilation, should be in crates and not in bags.
Beet Root	0 to 5	6-8	-
Brinjals	8 to 10	3-4	Big Brinjals keep better than small ones
Carrots	0 to 5	13-17	-
Cauliflower	2 to 5	4-6	Only firm and compact heads should be stored as loose heads shrivel badly.
Cabbage	0 to 5	9-13	Only firm and compact heads should be stored.
Onions	0 to 5	17-26	-
Potatoes	5 to 8	26-35	In cold storage potatoes become sweet due to Accumulation of sugars. This could be avoided by keeping potatoes at ordinary room temperature for 1-2 weeks before they are processed.
Raddish	0 to 5	6-8	-
Turnips	0 to 5	13-17	-
Tomatoes Ripe	8 to 13	1-1½	Tomatoes should not be stored in temperature lower than 4 because they show tendency to break down. Green but matured tomatoes can be ripened satisfactorily with the development of attractive red colour by storing at 15-21
Peas	0 to 5	2-3	Green peas loose part of their sugar content unless they are promptly cooled to 0 They also need more ventilation

Above information gives about how these products are preserved some techniques are adopt for these preservation such as vapour compression refrigeration, vacuum cooling, evaporative cooling. So these techniques used for preservation in following techniques.

II. COLD STORAGE.

Cold Storage is a special kind of room, the temperature of, which is kept very low with the help of machines and precision instruments. India is having a unique geographical position and a wide range of soil thus producing variety of fruits and vegetables like apples, grapes, oranges, potatoes, chilies, ginger, etc. Marine products are also being produced in large quantities due to large coastal areas. The present production level of fruits and vegetables is more than 100 million MT and keeping in view the growth rate of population and demand, the production of perishable commodities is increasing every year. The cold storage facilities are the prime infrastructural component for such perishable commodities. Besides the role of stabilizing market prices and evenly distributing both on demand basis and time basis, the cold storage industry renders other advantages and benefits to both the farmers and the consumers. The farmers get opportunity of producing cash crops to get remunerative prices.

The consumers get the supply of perishable commodities with lower fluctuation of prices. Commercially apples, potatoes, oranges are stored on large scale in the cold storages. Other important costly raw materials like dry fruits, chemicals, essences and processed foods like fruit juice/pulp, concentrate dairy products, frozen meat, fish and eggs are being stored in cold storages to regulate marketing channels of these products.

- **MARKET POTENTIAL**

Cold storages are essential for extending the shelf life, period of marketing, avoiding glut, reducing transport bottlenecks during peak period of production and maintenance of quality of produce. The development of cold storage industry has therefore an important role to play in reducing the wastages of the perishable commodities and thus providing remunerative prices to the growers.

- **COMMODITY STORAGE CONDITIONS**

For designing a cold storage, product storage conditions must be defined in terms of critical storage conditions of temperature, relative humidity, presence of CO_2, ethylene, air circulation, light etc. In absence of research data for Indian conditions, it is recommended to adopt commodity storage conditions as prescribed by *Commodity Storage Manual of WFLO*.

a. Temperature range: The temperature in the multi commodity cold store chambers should be kept within + 1°C of the recommend temperature of the produce being stored. For storing at temperatures close to freezing point of the commodity, for increasing storage life, even a narrow range may be needed.

b. Humidity range: The humidity (RH) is again dependent on the produce storage requirements and may vary from 95% to 98% RH in case of fresh fruits and vegetables like grapes, kiwi fruit, carrots, cabbage etc and lower in the range of 65% - 75% RH in case of onion and garlic.

c. CO_2 level – Not more than 4000 PPM during loading and 2000 PPM during holding. *(Source – Industry)* However if the cold store chambers is being used for Modified Atmosphere Storage for selective commodities like apples etc, the levels of CO 2 & O 2 should be maintained and regulated as recommended in the *Commodity Storage Manual of WFLO*.

d. Loading Rate- Generally the refrigeration system capacity is based on 4% to 5% loading rates of the total cold store capacity. The loading pattern is also a design consideration for sizing the storage chamber capacity for optimal utilization and performance. **In case separate pre-cooling chambers** are provided in the multi commodity storage facility, the load per batch is to be considered along-with initial and final desired product temperature, pull down rate etc while sizing the pre-cooling chambers and the refrigeration requirements.

e. Pre-cooling Time- 4-6 hours for pre-cooling to 7/8 th cooling time as recommended for majority of fresh fruits and vegetables. However, in case of fresh produce like carrots, apples etc meant for long/medium term storage, which are directly cooled and stored in the cold rooms, the cooling period, can be up-to 20 hrs per day and should meet the requirements specified in the commodity storage manuals.

f. Air Circulation- Multi Commodity stores should be design to provide an air flow of 170 CMH per metric ton of product, based on maximum amount of product that can be stored in each chamber. This is essential for rapid cooling of the produce. However the system should be designed to reduce air flow to 34 to 68 CMH per metric ton of product after the produce has reached the storage temperature. This is achieved by variable frequency drive and control system to automatically maintain the temperature variation within each chamber at less than + 1ºC throughout the storage period. In case the fresh produce is pre-cooled in a separate pre-cooling chamber before loading and storage in the main cold store chambers, the air flow requirements may range from 67 CMH to 100 CMH.

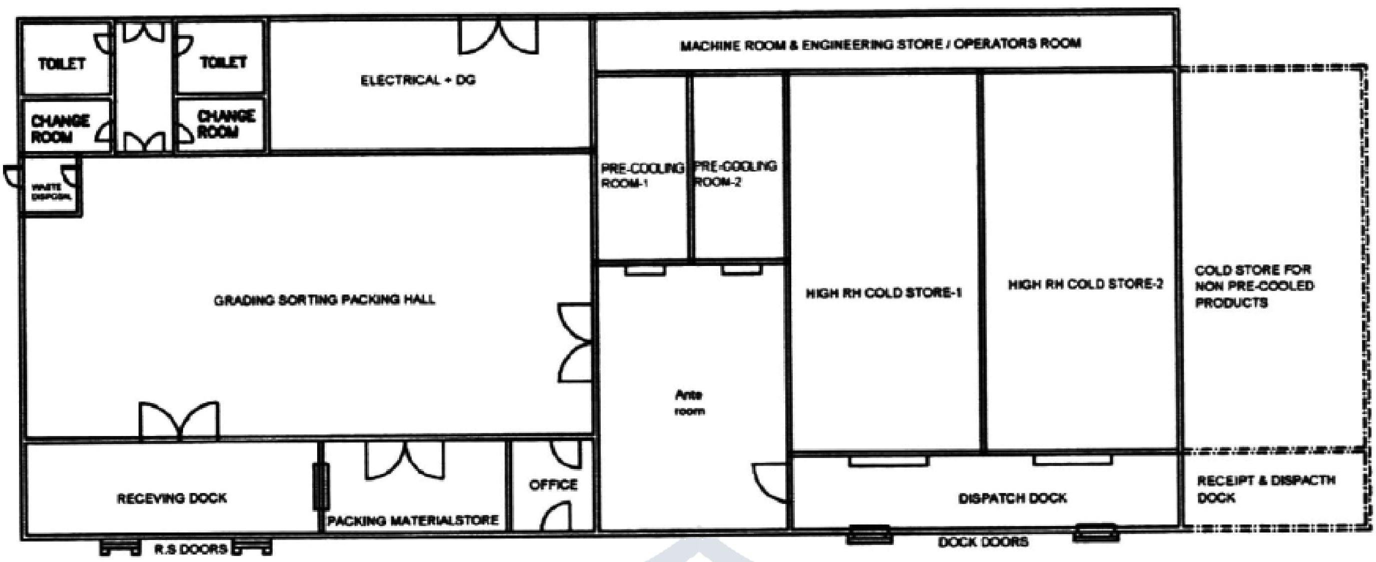
g. Stacking – During room cooling, cold air from the coils flows past the produce stored in crates/ pallet racks/bins thereby removing the product heat. For best result the pallets/crates/ boxes/ bins should be stacked so that the moving air can contact all the container surfaces for adequate heat exchange. It is therefore recommended that such multi commodity cold store chambers / facility are designed for storage in PVC crates, bins and ventilated card board boxes stacked in pallet frames. However Commodities which do not require rapid cooling like onion, garlic, potatoes etc may be stored in jute / nylon net bags, stacked in pallet frame. The pallets are required to be handled with fork lift / Stackers. Generally steel pallet frame are of size 1200mm x 1000 mm x 1600 mm high suitable for holding crates and boxes and can be easily stacked up to 4 high. Sometimes pallets frame of size 1300mm x 1000mm x 1800mm are preferred for storing in 50 kg bag of potatoes / onion/ garlic for optimal utilization. Generally each pallet frame can hold up to 1000 kg produce

g. Ventilation requirements in the cold store chambers- it may range between 2 to 6 air changes per day to maintain CO 2 less than 4000 ppm .

h. Lighting Condition- Dark

i. Application of Smart Fresh

- **Typical Layouts of Multi Commodity Cold Store Facilities**
  Typical Multi Commodity Cold Store with provision of separate pre-cooling rooms and high humidity cold stores



- **TYPICAL CONFIGURATION.**

Multi Commodity cold stores will have multiple chambers each having capacity of 30 MT to 1250 MT, anti rooms, docking area, grading/sorting area, grading /sorting line, crates/ palletized storage System & material handling system packing material store, machine room, toilets and changing room, waste disposal, electrical room etc. The facility must be sized to handle peak amount of product. The floor area of each chamber can be calculated based on volume and weight of the produce in crates / pallets, its stackable height and considering floor area for aisle, fork lift maneuvering and staging. The maximum storage height is limited by stack ability of bin or / and fork lift reach.

- **Thermal Insulation:**

It is recommended that appropriate BIS standards are adopted for selection of design parameters (IS 661:2000) and method of application of thermal insulation **(IS 661 & 13205).** For fresh F & V stored at + 0 o C , it is recommended to design thermal insulation for (- 4 o C to + 2 o C) temperature condition to have lower heat load.

- **Materials of thermal insulation and its application:**

Cold chambers have to be insulated on walls, ceilings / roofs & floors with proper insulating material of adequate thickness, with provision for vapour barrier on outer side & proper cladding/ cover on inner side. The commonly used insulation materials are:

a) Expanded polystyrene
b) Rigid Polyurethane foam
c) Rigid phenolic foam
d) Mineral wool / glass wool
e) Extruded polystyrene

The ancillary materials to be used include:

a) Vapour barrier e.g. aluminum foil, polyurethane sheet, with bitumen / cold mastic adhesives
b) Teakwood batten pegs, Tees etc.
c) G.S. sheet runners (avoid wooden batten runners)

- **For Conventional Insulation**

Walls & Ceiling

1. Primer Coat followed by two layers of bitumen
2. Fixing aluminium foil min. 50 microns
3. Fixing wooden pegs at suitable intervals
4. Fixing two layers of insulation with staggered joints
5. Fixing G.S sheet runners over the pegs in longitudinal & lateral directions
6. Fixing profiled & pre-coated g.s. sheets, 0.5 / 0.6 mm thick over the runners with proper finishing of joints. Alternatively FRP sheets can be used.

Floor

1. Laying of polythene sheet, min. 250 microns, as vapour barrier
2. Fixing insulation slabs in two layers with bitumen as adhesive for the first layer
3. Covering with tar felt
4. Laying PCC / tremix of 75 mm / 100 mm thickness

- **For Insulated Panel Structure**

Walls & Ceiling

1. Perimeter of the plinth to be in level for panel installation
2. Panels to have cam lock or tongue and grove joints
3. Sheet metal flashing to be provided on all concrete / wall ceiling joints internally & externally. PVC coving or concrete curbing to be provided on wall - floor joints.

4. Horizontal Tie bracings to be provided between vertical wall panels & external columns, to take care of wind loads
5. Adequate numbers of Pressure relief ports to be provided on all chambers with electrical connection
6. Insulated doors shall be suitable for panel mounting

III. Vacuum cooling:

Vacuum cooling is the quickest and most cost-efficient cooling system for vegetables, fruits, flowers & more. The vacuum cooling technology, which can strongly improve your product quality and at the same time reduce your cooling costs, is now becoming an acceptable investment for almost all vegetable growers**!**

The technology is based on the phenomenon that water starts boiling at lower temperatures as the pressure decreases. In the vacuum cooler the pressure is reduced to a level where water starts boiling at 2 ^{0}C. The boiling process takes away heat from the product. As an effect, products can be cooled down through and through to 1 or 2 ^{0}C within 20 – 30 minutes. Even (micro-perforated) packed products can easily be cooled this way! The quick and uniform cooling (the surface and core of the vegetable reach exact the same temperature after vacuum cooling!) results in a substantially longer shelf life of your produce. At the same time you can save on energy costs, as the vacuum cooling process is much more (cost) effective than traditional cooling technologies.

- **Vacuum cooling of Fruit & Vegetables**

Leafy vegetables like (iceberg) lettuce, spinach etc are very suitable to be vacuum cooled. The process also works perfectly for field-packed leafy produce; as long as (micro) perforated film is being used. For more "solid" vegetables ranging from (Chinese) cabbage and broccoli to carrots the cooling down process might take (considerable) more time, but the result in shelf life increase can be more than substantial. For fruits (like strawberries) and mushrooms, it is most important that the produce is cooled down very shortly after harvesting. Also here, vacuum cooling has great advantages in comparison to conventional cooling.

- **Vacuum cooling of Flowers**

The vacuum cooling of fresh cut flowers is also a successful application. Special systems adapted to processing aircraft containers have been made successfully in the past.

- **Vacuum cooling of pre-cooked food**

For pre-cooked convenience food special (stainless steel) vacuum cooling systems are needed in order to preserve quality and taste as well as to save time between the processing and the-ready-to ship time.

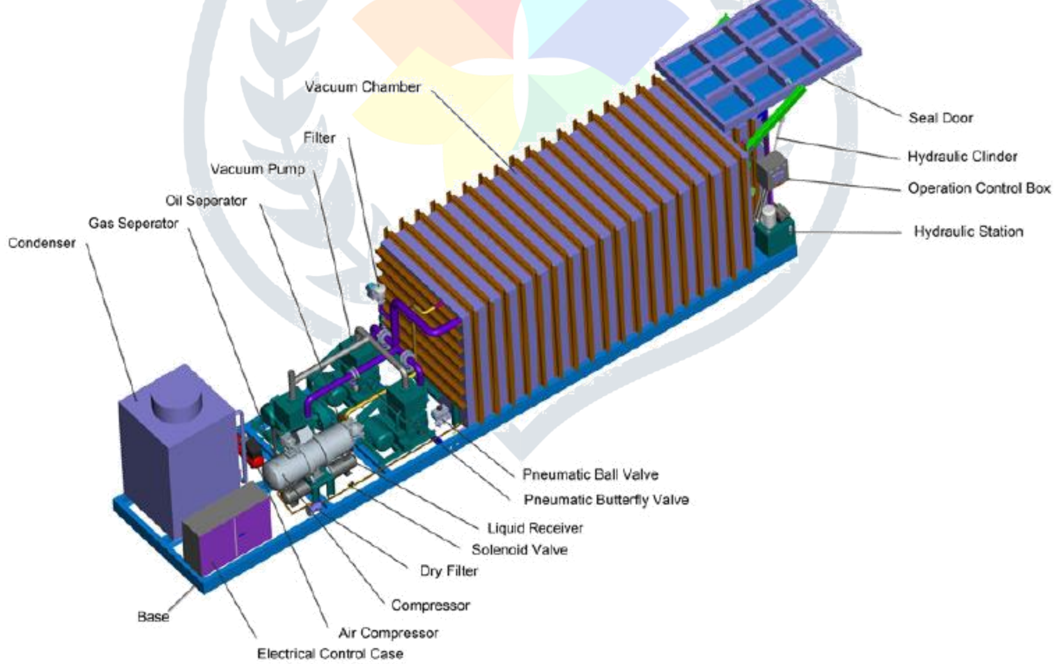


Fig. No.1. Basic vacuum technique

- **Advantages and disadvantages of vacuum cooling**

The major advantage of vacuum cooling is the fast cooling rate, compared with conventional cooling methods. For example, experimental results of cooling vegetables show that average cooling rate achieved by vacuum cooling is 0.5°C/min, which is 60 times that of slow air cooling. For the slow air cooling, the heat generated by respiration may result in the vegetables still being above cold-store temperature 24 h after loading (Longmore, 1973). A uniform and rapid cooling can be achieved for an individual food body and a package of foods by vacuum cooling if the porosity is uniformly distributed within the food body and package. For example, for vacuum cooling of packaged moisture foods, no matter where the individual food body may be located in a package or bulk container, a uniform temperature distribution can be achieved as a result of the cooling effect directly comes from water evaporation in local pores. However, for the cold store cooling, the cooling rates for individual food body may vary between 0.05 and 3C/h depending on the type of container and location of the product in a stack or pallet load. If the air blast cooling at a temperature below freezing point of water is used, the outer surfaces of the product will be damaged due to freezing whilst the inside is still cooled inadequately.

Vacuum cooling has the lowest energy cost per unit of cooled product compared with air cooling and hydro cooling . This is because there is no need to move the cooling medium through the system and the vacuum minimizes heat transfer from the environment. For vacuum cooling of one ton of lettuce, the energy consumption is about 0.56 kWh to reduce 1 °C, compared with 3.7 kWh to reduce 1 °C for hydro-cooling. If the driving energy is electrical energy, for pre-cooling vegetables and fruits, the COE (ratio of heat removed from the product over driving energy) of the vacuum cooling unit is 2.65, compared with 0.52 for forced air cooling systems and 1.20 for hydro-coolers. However, the COE varies between different coolers of the same type. There are two main factors affecting the COE, which are the type of product to be cooled and the load of product within the cooling chamber. Furthermore, vacuum cooler is very sanitary because air goes into the container only when the container is opened to release the vacuum. Almost any type of package is suitable for vacuum cooling provided that the package containing the product is porous or has breathing holes or spaces. The precise temperature control can also be achieved during the vacuum cooling process. The temperature of the products can be brought within 1–3° C by controlling the absolute pressure. Vacuum cooling also has its disadvantages. For example, vacuum cooling can not replace established freezing techniques . Furthermore, weight loss occurs during vacuum cooling. The weight loss of vegetables is about 3–4% of the weight before vacuum cooling but similar losses may be experienced in cold store cooling.

REFERNCES:

[1] A.D. Althouse, C.H. Turnquist, A.F Bracciano, "Modern Refrigeration and Air Conditioning", Goodheart-Willcox Publisher, 2010

[2] Arora C. P., "Refrigeration and Air conditioning", Tata McGraw Hill Private Limited, 3rd Edition, 2008.

[3] Vacuum cooling manual.

[4] Fennema O.R..(1982).Principles of Food Science. Part II. Physical Methods of Food Preservation. Marcel Dekker, New York and Basel.

[5] Jacek Kondratowicz, Paulius Matusevi, "Use of Low Temperatures For Food Preservation", ISSN 1392-2130. VETERINARIJA IR ZOOTECHNIKA. T. 17 (39). 2002