COLD-CHAIN - A NEW TECHNOLOGY FOR AGRICULTURAL PRODUCTS PRESERVATION AND PROCESSING

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ABSTRACT

The term cold chain or cool chain denotes the series of actions and equipment applied to maintain a product within a specified low-temperature range from harvest/production to consumption. A cold chain system is a temperature controlled supply chain which ensures and extends the shelf life of products such as fresh agricultural products, seafood, frozen food, photographic film, chemicals and pharmaceutical drugs. This paper reviews the increased importance of cold chain management as a result of changing product portfolios, the requirements for Good storage and Distribution practices, current regulatory trends, quality management, risk assessment factors, and temperature monitoring. A cold chain can be managed by a quality management system. It should be analyzed, measured, controlled, documented, and validated.

Keyword: - Cold chain, Temperature monitoring, Vaccine cold chain, Refrigeration, Logistical chain

1. INTRODUCTION

A cold chain is a temperature-controlled supply chain. An unbroken cold chain is an uninterrupted series of refrigerated production, storage and distribution activities, along with associated equipment and logistics, which maintain a desired low-temperature range. It is used to preserve and to extend and ensure the shelf life of products, such as fresh agricultural produce, seafood, frozen food, photographic film, chemicals, and pharmaceutical drugs. Such products, during transport and when in transient storage, are sometimes called cool cargo. Unlike other goods or merchandise, cold chain goods are perishable and always en route towards end use or destination, even when held temporarily in cold stores and hence commonly referred to as cargo during its entire logistics cycle. The cold-chain is a logistical chain of activities involving packaging, storage and distribution of perishable food products (for example, fruits and vegetables, milk, meat and poultry, flowers, and vaccines) from point of production to point of consumption, where the inventory is maintained in predetermined environmental parameters. Typically, a cold chain is made of 4 links: pack-houses or source point, reefer transport (vehicles or mulita-modal), cold storages, ripening chambers (for some fruits) as illustrated in fig.1 Refrigeration forms an important and significant part of the food and beverage retail market. It ensure optimal preservation of perishable food. Domestic refrigeration and commercial refrigeration are the important elements of the cold chain.

2. ELEMENTS OF COLD CHAIN

A cold chain is a temperature controlled supply chain. This typically involves keeping items cold from manufacture to point-of-use. This has several elements:

Packing: Packing designed to be energy efficient and secure such as insulated shipping containers for fresh sea designed to safely endure short periods of increase temperature as a mean of risk reduction.

Monitoring: Monitoring the temperature of items throughout the supply chain with tools such as a temperature data on the cargo, it may also necessary to monitor other environment parameters such as air quality.

Transport: Cold transport such as refrigerator trucks, refrigerated boxcars, reefer ships and reefer containers.

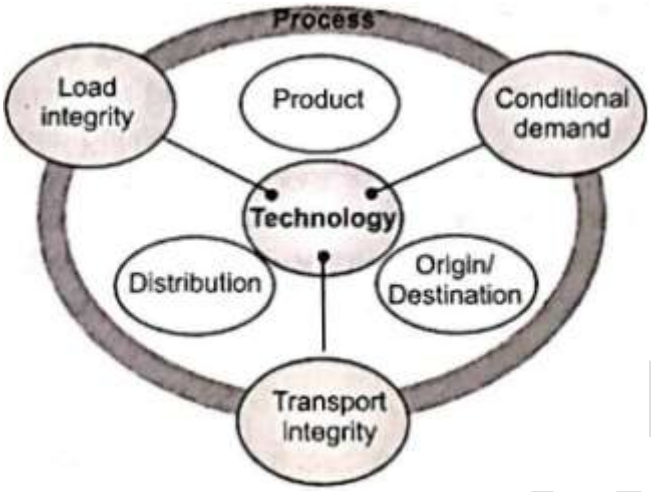

Fig -1: Elements of cold chain

Customs: A cold chain may pay particular attention to anything that can be done to reduce customs delays. This is process of controlling customs paperwork to ensure it meets all known requirements.

Storage: Cold storage facilities such as temperature controlled warehouses.

Quality Assurance: The process of quality control and managing any quality failures.

End-Customer: Delivery to end-customers and communication of storage requirements. This may involve integration processes for accepting cold deliveries.

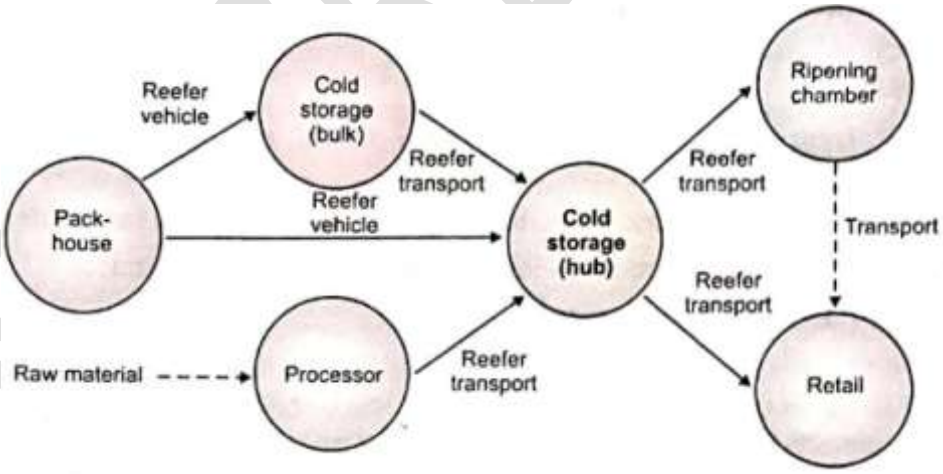

Fig -2: Schematic depiction of the flow of produce in a typical cold chain

3. TEMPERATURE REQUIREMENTS OF DIFFERENT KINDS OF PRODUCTS

Frozen (< -18°C): Ice cream, frozen meats (fish, poultry, livestock), frozen ingredients, some frozen processed commodities.

Chilled (0-10°C): Fresh fruits and vegetables, fresh meats, milk, butter, confectionary, some pharmaceuticals.

Mild chilled (10-20°C): Fresh fruits and vegetables, chocolates and seeds and some milk products.

Normal (> 20°C): Whole onion, dehydrated foods, pickle, jams and oils and extracts.

4. COLD-CHAIN AND REFRIGERATION COMPONENTS

4.1 Pack-house

The pack-house is the entry point into the cold-chain. Pack-houses are used to pre-condition the produce for market connectivity and typically serve a range of operations like sorting, grading, washing, drying, weighing, packaging, pre-cooling and staging. The Government has exempted preconditioning services from Goods and Services Tax (GST) to incentivize the development of pack-houses. The precooling units and staging chambers require energy intensive cooling. Precooling of the produce rapidly for packaging and thereby prepare the loads for subsequent travel in the cold chain. Depending on the produce, the pre-cooling process could be by forced-air cooling, hydro cooling, vacuum cooling, and room cooling or top-icing. A cold staging unit is an insulated and refrigerated chamber which serves as a transient staging space and is a necessary attachment to a pre-cooling unit. A staging room frees the pre-cooler chamber to operate for sequential batches of freshly harvested produce. The country presently has approximately 500 pack-houses (per inputs received from NCCD, Agricultural and Processed Food Products Export Development Authority (APEDA), National Horticulture Board (NHB) and other cold-chain industry experts) but growth in the creation of pack-houses is expected in the next 10-20 years, primarily driven by the Doubling Farmers' Income (DFI) mission.

4.2 Reefer Transport

A reefer transport unit can be a road vehicle or reefer container, with a fixed insulated body equipped with active refrigeration. There are very small numbers of reefer containers in the country. Over 95% of current existing reefer vehicles are used mainly for carrying frozen products. A typical reefer unit is considered with a holding capacity of 10 MT and is equipped with a refrigeration unit of 3.6-5 kW cooling capacity. However, a variety of sizes are in operation, of smaller and larger capacity. There are presently about 13,000-14,000 reefer vehicles as per the industry information. The number of reefer vehicles is likely to witness a high growth of 20-25% CAGR in the next 10 years while it is expected that the growth in the subsequent decade will be significantly less. Refrigeration systems using CO as a refrigerant and liquid-air based cooling systems are some of the emerging technologies for this sub-sector and are yet to be mainstreamed. Vapor Absorption Refrigeration (VAR) systems are sustainable option wherein waste heat from the prime mover can be utilized.

4.3 Cold Storage

A typical cold storage facility comprises a highly insulated and refrigerated warehouse designed to store perishable products to essentially maintain the temperature and humidity parameters, which were initiated at the pack-house (for example, vegetables) or during manufacturing (egg, ice-cream).Based on the type of product and holding duration, NCCD has categorized cold storages in two categories, i.e. bulk cold storage and hub storage. Bulk cold storage is an environment controlled warehousing space with multiple chambers intended for bulk storage of perishable produce and is often viewed as an independent refrigerated warehouse, and not part of an integrated cold-chain. The space is designed for long-term storage of a specific produce to build an inventory buffer which will serve to smoothen episodic production try stabilizing and sustaining the supply lines. These are normally constructed in areas dose to producing areas to facilitate quick access to farmers, for a selective set of crops. Per NCCD, the average holding capacity of a bulk cold storage is about 5000 MT. Majority of these facilities store bulk produce like potatoes and chilies. Hub cold storage (hub), is an environment-controlled warehousing space functioning as a distribution hub located close to

consumption centers and form an integral part of the cold-chain. It is designed for short-term handling and cross docking of produce, to serve as *a* distribution logistics platform at the last mile. These hubs cold storage provide a platform to manage distribution and delivery activities and are vital to integrated logistics for various products with shorter marketing cycles. The country presently has around 35 million MT of cold storage capacity (as per Directorate of Marketing and Inspection (DMI), Ministry of Food Processing Industries (MOFPI), National Horticulture Mission (NHM), NHB and NCCD), which caters to roughly 85% of the demand. The existing capacities can also be expected to service larger volume of goods as operations get modernized to optimize on higher rotation of goods from the same space. Cold storage cooling requirements are largely met by vapor compression units using ammonia. The cooling capacity of a cold storage varies between 200-400 kW. A typical cold storage unit runs for 16 to 18 hours per day on grid power. Diesel powered generators are also used across the country and are estimated to meet-up to 10-15% of energy consumption for cold storage operations.

The energy performance of cold storages can be optimized by using improved insulation; variable frequency drives (VFDs), efficient compressors, automation and programmable logic controller (PLC) and retrofitting and retro-commissioning practices.

4.4 Ripening Chamber

Ripening chambers are a front-end facility in the cold-chain, used for the controlled and hygienic ripening of certain fresh produce. In India, these are used extensively for ripening bananas and climacteric fruits like mangoes and papayas on commercial scale. The chambers may also be used for avocadoes, tomatoes, pears, and for de-greening purposes with some citrus fruit a ripening unit usually has 4 compartments, each of around 10 MT capacity. Controlled temperatures of 1520^0C with elevated humidity levels is typically maintained refrigeration unit A facility could be in multiples of these units. There are presently about 1000 ripening chambers, which serve around 9% of the current requirement as per assessments carried out by NCCD. Experts predict that there will be a significant growth in ripening chambers (around 9000 units) in the next decade while the subsequent decade would witness a marginal growth. The government has taken special steps to promote modern ripening units so as to eradicate harmful ripening practices, such as use of calcium carbide for ripening.

4.5 Domestic Refrigeration

Domestic refrigerators are commonly used in households, commercial setups like retail outlets, offices, hotels, and hospitals for storage of perishable food, medicines, vaccines, etc. These are two types, viz., frost-free (FF) and direct-cool (DC). The production of DC and FF refrigerators has grown at CAGR of 6% and 1% respectively since 2011(BEE) in the country. DC refrigerators dominate the market with around 80% share of the total production from 2011 to 2017 and this trend is likely to continue in the next decade. Based on these historical trends, it is estimated that domestic refrigerator production/sales are expected to at a steady rate of 5-6%. BEE star-rating has been made mandatory for FF refrigerators since 2009 and for DC refrigerators since 2016. The BEE labelling is progressively moving towards higher energy efficiency in this sector.

4.6 Commercial Refrigeration

Commercial refrigeration equipment covers equipment of different capacities: deep freezers (glass top or hard top) (<1 kW), visi-coolers (<1 kW), remote condensing units (1-20 kW), water coolers

(>2 kW), super markets (60-100 kW) and hyper markets (100-200 kW) systems. Remote condenser units could either be display type employed by large retail shops or non-display for storage of additional refrigerated goods. Non-display units have racks of condensing units placed in a small machine room away from the display area. Centralized systems (where compressor racks are installed in a machine room and involve lengthy piping) used in supermarkets and hypermarkets are not very prevalent, but upcoming. The main factors for growth in this commercial refrigeration sector will be commercial space growth, cold chain, GDP growth and technological changes in the future. Per RAMA, the market size of deep freezers, visi-coolers, remote condensing units and waters coolers in 2017-18 is estimated to be around 0.6 million units, 0.3 million units, 0.04 million units and 0.2 million units, respectively. Described below are three other important extensions of the cold-chain and refrigeration infrastructure in India:

4.7 Cold-chain for vaccine management

The purpose of the vaccine cold-chain is to maintain product quality from the time of manufacture until the point of administration by ensuring that vaccines are stored and transported within World Health Organization (WHO)-recommended temperature ranges. The vaccine cold-chain system equipment can be broadly classified under storage and transportation. The storage facilities include walk-in cooler/freezer, deep freezer and ice-lined refrigerator. Solar integrated refrigerant drives have also been a promising vaccine storage facility. Transportation infrastructure consists of refrigerated vaccine van, insulated vaccine van, cold box and vaccine carriers. With the advent of newer technologies in temperature monitoring, cold chain storage and transportation equipment especially using green energy, stock and inventory management, there is a high potential to improve the existing system. India hopes to reach at least 90% full immunization coverage over the next five years, and it is critical to strengthen the vaccine cold-chain in the country. India's Universal Immunization Program is one of the largest in the world and caters to 26 million infants and 30 million pregnant women, saving 2.5 million lives each year. The effectiveness of the program depends largely on a functional end-to-end Immunization Supply Chain system. Immunization supply chain plays a pivotal role in ensuring the uninterrupted availability of quality vaccines from the level of the manufacturer to that of the beneficiary.

4.8 Milk Chillers

Milk chillers are used in the milk chilling centers and dairy plants. Most of the chilling centers are located in remote villages to collect the milk from various local areas. The transportation of fresh milk from farms to cooling centers and processing units may take some time. The milk should be chilled within three to four hours of collection otherwise leads to spoilage. Per Balance50Refrigerant Demand in Cold-chain &Refrigeration, the installed capacity of milk chillers was around 0.4 million tonnes of refrigeration (TR) in 2015 and the market is expected to grow at a CAGR of 10%. Ammonia is the widely adopted refrigerant in the dairy sector. Intervention like precooling of warm fresh milk using water will reduce the cooling, refrigerant requirement and energy consumption in the refrigeration system.

4.9 Industrial Refrigeration

Industrial refrigeration encompasses the cooling systems for production of food, drink, chemicals, pharmaceuticals and other products. This sector also includes systems for controlling air temperature in production factories, computer centers and other process areas. Industrial refrigeration

usually uses systems with cooling capacity 10kW to few MW, typically at -50°C to +20°C evaporating temperatures.

5. THE FUTURE OF COLD-CHAIN AND REFRIGERATION

The waste cold from India's projected LNG imports in 2022 could fuel over half a million liquid air refrigeration units. NCCD is exploring the potential liquid air based cold chains by recovering stranded cold from LNG re-gasification. An analysis - in a report for the NCCD by the energy consultancy E4 tech — shows that a typical LNG terminal re-gasifying 7,100 tons of LNG/day can produce enough liquid nitrogen to provide the cooling for almost 1,100 chilled and frozen refrigerated trucks operating around the clock; and peak time cooling (three hours a day) for 7.5 million cubic meters of chilled and frozen buildings. Dearman, a UK-based technology company, has developed engines that use liquid air/ liquid nitrogen to deliver zero-emission power and cooling. Such engine and cooling systems in reefer transport can be highly efficient with zero polluting emissions. This technology will reduce fuel costs (refrigeration alone consumes as much as 20% of truck's fuel). Magnetic Refrigeration System (MRS): Magnetic refrigeration is based on the Magneto caloric Effect (MCE). MRS offers the following advantages over compressor-based refrigeration systems: High Coefficient of Performance (COP) reduces energy consumption by up to 40% No compressor/refrigerant gas used, instead water-based coolant liquid used: eliminates harmful emissions. No gas leakage: reinforced safety and eliminates refrigeration technologies: Stirling cycle refrigeration, Acoustic refrigeration, Electro caloric refrigeration, Magnetic refrigeration, Optical cooling, Thermionic refrigeration etc.

CONCLUSIONS

Cold chain supply chain is the network of facilities and distribution options that performs the usual functions of a standard supply chain cycle but with temperature and humidity control throughout the supply chain stages and entities. Some of the managerial implications identified from this study are:

• Cold Supply chain is applicable in so many industries like: Agricultural products, Food manufacturing, Chemicals industries, Medical vaccines and drugs.

• Cold supply chain has major benefits on the industries that use it like: Valuable extension to the product shelf life, Gives the ability to access overseas markets, Gives the ability to meet the huge local demand.

• Cold supply chain implementation has some costs and concerns like: The use of non-environmental gas compounds, Frosting, Safety concerns, Continuous Control and monitoring of temperatures.

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