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Managing post-harvest loss in fruits and vegetables by implementing intelligent cold chain logistics

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ABSTRACT

The article focuses on the supply chain of fresh fruits and vegetables in the Indian market and the various post-harvest losses that take place during the inefficiency of its supply chain. The concept of the cold chain is used to describe the supply chain cycles of these fragile and perishable goods through thermal and refrigerated packaging methods and the logistical planning to retain its quality and increase its life cycle. India's aggregate yield of fruits and vegetables is appreciably high but so is its post-harvest wastage. Thus, to curb this issue and make the sector more profitable, the cold chain needs to be efficiently implemented. However, the country faces various setbacks that disturbs the successful implementation of the same, such as, uneven distribution of cold storages throughout the country which ultimately disturbs the distribution channels, outdated refrigeration technology, unawareness about the system amongst the people involved throughout the chain, inconsistent power supply on which the cold storage systems depend on, and inability to invest in the system due high capital requirement. India also lags in providing technological up-gradation and implementation of modern-day tools like the intelligent container, smart warehouses, and better cold storage systems equipped with sensors that detect temperatures. The article highlights the problems in the current supply chain model and suggestions are given considering the existing successful techniques and methods which are nearly absent in the Indian supply chain. The article also highlights the wide potential of the cold chain industry which is also extensively supported by the Government of India that provides various incentives to influence the growth of the industry.

Keywords— Cold chain, Supply chain, Reefers, Multi-modal chain

1. INTRODUCTION

The fresh fruits and vegetable market in India is a big one. India is known to be an agricultural economy and it contributes a majority of the Indian GDP. The fresh fruits and vegetable industry is a big part of the agriculture industry. India has been bestowed with a wide range of climate and physio-geographical conditions, and as such, is most suitable for growing various kinds of horticultural crops such as fruits, vegetables, flowers, nuts, spices and plantation crops (Birthare, 2019). Fruits and vegetables account for nearly 90% of the total horticulture production in the country.

India is now the second-largest producer of fruits and vegetables in the world and is the leader in several horticultural crops, namely mango, banana, papaya, cashew nut, areca nut, potato, and okra (Birthare, 2019). The production has increased in recent years and it is almost twice as it was in the first decade of the 21st century. India produced 97.36 million metric tonnes of fruits and 184.39 million metric tonnes of vegetables. The area under cultivation of fruits stood at 6.5 million hectares, while vegetables were cultivated in 10.26 million hectares (Birthare, 2019).

With the increase in production, it becomes necessary to ensure what is produced in the fields reaches the market at the right time in the right condition. This is where the Supply chain comes into play. The supply chain's efficiency and effectiveness play the most important part of the success of the fresh fruits and vegetable market. In India, the Traditional Retail Model of fruits and vegetables is predominantly followed in the unorganized sector. Players involved in this model are commission agents, auctioneers, wholesalers, traditional retailers of all type of formats, family-run 'mom and pop' stores, roadside shops, pavement shops and cart vendors apart from farmers and customers. This model carries several inefficiencies with it. Cane baskets and jute or gunny bags new-age in handling vegetables. Loading and unloading are carried out manually. Vegetables are not cleaned and washed off dirt and soil. No sorting, grading, and packaging of any kind are being done. No temperature-controlled storage or warehousing is used across the chain. Information technology and advanced management techniques are not deployed (Sihariya,

Hatmode, and Nagadevara, 2013). This results in a lot of wastage of fruits and vegetables during the process of reaching the final customers. As the shelf life of these products is already less (since they are perishable), the supply chain needs to be in line with the modern technologies and methods to achieve maximum efficiency and effectiveness.

2. POST-HARVEST LOSS

India is often known as an agrarian country as agriculture is the most important sector in the economy accounting to 18% of GDP and 50% towards employment (Madhusudhan, 2015). However, the farmers in India are incurring post-harvest losses of fruits and vegetables worth Rs 92,651 crore per year (Pandey, 2018).

Post-harvest loss can be explained as the decrease in the quantity and quality of produce from harvest to consumption. Quality loss occurs when the edibility, nutrient content, calorie content demerits and the product becomes unacceptable. India, being a diverse market, has a very complicated and vast supply chain for fruits and vegetables. Therefore, it can often be difficult to smoothly control the various activities in the supply chain like storage (cold storage), processing and transportation which eventually become the primary reasons for the post-harvest losses. Taking the bigger picture into consideration, farmers invest their time, money and effort into producing fruits and vegetables, but are unable to sell them completely due to post-harvest losses. According to a study done by the Department of Agriculture, Cooperation and Farmers Welfare, farmers across the country were unable to sell 40% of the fruits and vegetables that they had produced which left them with a loss of Rs 63,000 crore per annum (Pandey, 2018).

The reasons for the post-harvest loss of fruits and vegetables could be due to many factors. The first one being shelf life. Since fruits and vegetables are perishable goods, they do not last very long under all conditions after harvest as their water content decreases. Since water is crucial for the survival of plant organs, there are higher chances of tissue death in the shortage of water. This explains the reason for fruits and vegetables having a short shelf life. Secondly, fruits and vegetables need proper air supply and ventilation to survive. Lack of ventilation forces them to proceed to fermentation. Thirdly, some of the damages caused due to wrong handling while transferring and transporting goods to the market place are responsible for post-harvest losses. Finally, a few of the other factors that result in post-harvest loss are - inappropriate containers, presence of contaminants, temperature, faulty packaging, etc. (Bionovelus, 2018).

3. COLD CHAIN INDUSTRY

Supply chain management is the set of actions to efficiently integrate suppliers, manufacturers, warehouses, and stores so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, to minimize system-wide costs while satisfying service level requirements. In other words, it is the management of material, money, men, and information within and across the supply chain to maximize customer satisfaction and to get an edge over competitors (Borade and Bansod, 2007).

The supply chain for fruits and vegetables, however, require special attention due to its perishable nature with low shelf life, as well as other factors such as; fluctuations in demand, and thus, prices, and growing consciousness and concerns towards food quality and safety, which increases the demand for organic fruits and vegetables. Thus, to retain the freshness and quality, and to reduce post-harvest wastage, it is important to have an efficient cold chain implemented and managed throughout the supply chain (Lee and Kader, 2000).

Subsequently, India ranks second worldwide in farm output and is the world's largest producer of food staples, spices, select fibrous crops, seeds as well as fresh fruits and vegetables among other agricultural produce, after China. The estimated annual production of just fruits and vegetables in the country accounts for 18 percent of our agricultural output (Arora, 2018). During 2017-18, India produced 97.35 million metric tonnes of fruits and 184.39 million metric tonnes of vegetables (APEDA, 2019). However, in a country dominated by agriculture, food worth Rs 58,000 crore to Rs 92,651 crore is wasted every year (Arora, 2018). A well-planned and managed cold chain will definitely curb this issue through effective packaging, storage, temperature control, handling, and transportation. Therefore, it is the need of the hour for India to invest in cold chain infrastructure and increase the agricultural produce, reduce post-harvest wastage and lead the country towards total food security, safety, and quality, and even double the farmer's income.

The cold chain involves the transportation of temperature-sensitive products along a supply chain through thermal and refrigerated packaging methods and the logistical planning to protect the integrity of these shipments. There are several means in which cold chain products can be transported, including refrigerated trucks and railcars, refrigerated cargo ships, reefers as well as by air cargo (Rodrigue, 2017).

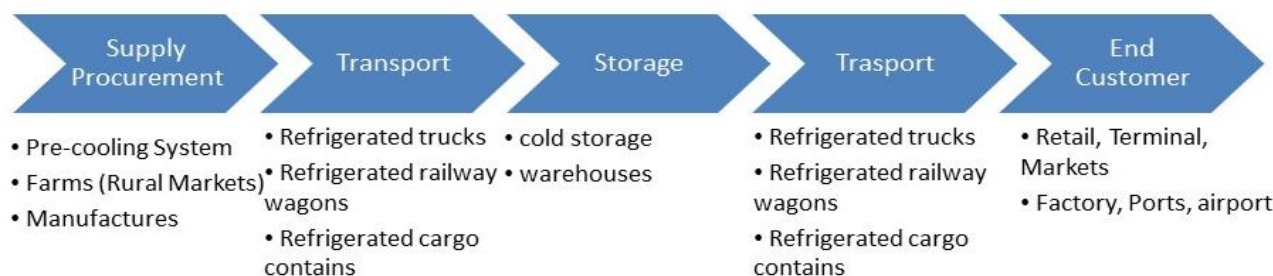


Fig. 1: Supply Chain Infrastructure

The objective of cold chain technology purpose is primarily to protect perishable goods from inclement natural conditions that affect the quality of the goods (de-la-Fuente and Ros, 2010). Thus, the origin of the cold chain is the production/manufacturing unit and the value-added products at the end for market realization. The other important purpose of cold chain solutions is to increase the life cycle of the goods and retain its nutrient quality, thus, extending the buying time to reach the customer base.

4. EXAMPLE- BALAJI AGGREGATOR'S COLD CHAIN FOR KINNOW

Balaji Aggregator, a company based at Abohar in Punjab, supplies kinnow and other fruits to local markets in Punjab, Bangalore, and Gujarat with occasional exports to Dubai, Russia, and Ukraine. Punjab is India's leading producer of kinnow with 29% of total national production (NCCD, 2016). Kinnow fruits deteriorate rapidly after harvest and require storage at 4-5 °C and RH of 85-90% to stay in best form. About 28% losses occur during transportation from Abohar to Bangalore resulting in reduction of the potential revenues for farmers, aggregators, transporters, distributors and retailers. The fruits stay for 5-7 days in ambient conditions during winter months of December and January which can be extended to 20 days when waxed or wrapped. The cold chain makes a significant increase to shelf life up to 2 months, which enables sale of kinnow off-season from March and April and even as late as May well after harvest ends in January or February.

5. TECHNOLOGY

The technology used in the supply chain of fresh fruits and vegetables plays a very important part in determining how effective the supply chain is. The old-age technologies have become obsolete now and are of minimum use. In India, infrastructure facilities such as roads are not equally developed in all regions of the country which induce inefficiency to the transportation industry. The country has diverse climatic conditions and hence during transportation, the majority of fruits and vegetables gets deteriorated due to difference in temperatures. A large chunk of fresh fruits and vegetables is lost because of inadequate post-harvest handling and lack of cold storage, processing facilities, and convenient marketing channels (Sihariya, Hatmode, and Nagadevara, 2013). The temperature of the storing pallets or boxes used for transporting the fruits and vegetables is also very important to keep in check. Different kinds of fruits and vegetables require different temperatures to remain in fresh condition. It is important to properly find out the right temperature to be maintained for a given fruit or vegetable both during the storage and transportation period. There are many new-age technological advances which meet all the before-mentioned requirements. Getting an estimate of the product shelf life is a big plus as it can help in getting to know in what time period the product should reach the shelf without getting spoilt. The Q_{10} model can serve as a starting point with only two required parameters for the initial shelf life at the reference temperature (Reiner, Nicometo, Uysal, and Lang, 2014). The temperature dependence can then be modeled by an exponential function with the Q_{10} value as the key parameter, such that, for every 10 °C increment in temperature, the product's shelf life is reduced by a factor given by the Q_{10} parameter. From a more general standpoint, the Q_{10} parameter can either be defined by the measured CO₂ rates or by measurement of a quality attribute at different temperatures (Steel, 2004).

The concept of an intelligent container fitted with a sensor network has been put forward by several workers (Lang, Janßen, and Jedermann, 2014). An intelligent container consists of (i) a wireless sensor network for monitoring fluctuations in temperature and other parameters, (ii) a supervision unit to predict the shelf life of the transported commodities, (iii) a telematics unit for communicating with the global system for mobile communications (GSM) or satellite networks, and (iv) a remote server for web access and integration into company databases (Reiner, Nicometo, Uysal, and Lang, 2014).

Small mistakes in the packaging can also lead to temperature imbalances inside the pallet resulting in product spoilage. An analysis of the dynamic temperature inside the pallets showed that a large amount of cooling capacity is lost due to inefficient packing (Reiner, Nicometo, Uysal, and Lang, 2014). The storage areas are also a very important part.

There is a need for continuous temperature and quality supervision as due to unavoidable variations in some of the cold chain processes, time and temperature data collection, coupled with automated calculation of shelf life loss variation, will continue to generate significant process benefits in real-time while reducing the avoidable shelf life loss. In order to keep the process as efficient and effective as possible, a continuous audit, based on both current and past temperature and quality data, is necessary (Reiner, Nicometo, Uysal, and Lang, 2014).

6. INDIAN SCENARIO OF COLD CHAIN TECHNOLOGY

All these technologies are lacking in the Indian supply chain of fresh fruits and vegetables. It is very basic, traditional and, to a great extent, outdated. Though some new key players like Reliance Fresh are introducing the new age models in the supply chain of fresh fruits and vegetables (Birthare, 2019), there is still a long way to go as these retailers cater to mostly the big cities and towns with the underdeveloped parts of the country untouched. The rural areas are still technologically crippled and so are the producers of fresh fruits and vegetables in India. The cold storage facilities aren't temperature smart; the packaging processes are not scientific and have a minimum focus on maintaining the temperatures of the goods inside, and the farmers' involvement in the supply chain process is very less.

6.1 Challenges in the cold chain industry

The major challenges that the cold chain industry is facing can be summarised as:

- **Uneven distribution of cold storage facilities:** In India, out of 7645 cold storages with a capacity of 34.95 million MT in all, 72% of it is spread across Gujrat, West Bengal, and Punjab and UP. However, there are a limited number of cold storages in south India. This can cause the quality and quantity of the product to decrease if it's coming from the north due to increase in transportation time. Besides, the humid climate in the region makes the situation even worse as fruits and vegetables get damaged faster (ASSOCHAM, 2018).

- **Outdated Equipment:** The purpose of the cold chain industry is to keep the produce fresh and undamaged until it reaches the customer. However, the cold chain equipment used in transportation for many such chains is in poor condition. The refrigeration technology is outdated and the standards for food security are not met. The situation would get worsened if the lead time increases due to the long waiting time at tolls and state border regions.
- **Inability to integrate cold chain:** Warehouses are an integral part of the cold chain and the lack in its quality can immensely affect the quality of the fruit and vegetables stored in it. The inability of the warehouses to function smoothly could be because of various reasons like lack of power supply, temperature differences, cleanliness, inefficient staff, etc. A study carried out by the National Centre for Cold-Chain Development on All India Cold-chain Infrastructure capacity (Assessment of Status and Gaps) in August 2015 found that because of inadequate transport capacity and packing houses, the integration of cold chain doesn't exist (ASSOCHAM, 2018).
- **Poor logistics connectivity:** It is necessary to maintain a balance between demand and supply of the product, but due to poor logistics connectivity, various imbalances arise. Connectivity is very important in this industry, but because of lack of proper roads and highways, the villages and cities are not well connected.
- **High Fuel Cost:** As shown in the table below (ASSOCHAM, 2018), the costs of fuel in India have been rising over the years. In India, the cost of fuel is estimated to be 30% of the operating expenses of cold storages. In the supply chain, fuel is required for various purposes like transportation needs, generators used for back up during power cuts, forklifts or counterbalance trucks for loading/unloading (ASSOCHAM, 2018). Thus, the cold chain industry will be burdened due to such hikes due to large quantities of fuel required in the process.

Table 1: Diesel price hike as per Indian Oil Corporation website (ASSOCHAM, 2018)

Year	January 01, 2016	January 02, 2017	January 01, 2018	May 11, 2018	CAGR %
Delhi	45.03	57.82	59.7	65.93	13.55
Kolkata	48.8	60.06	62.36	68.63	12.04
Mumbai	52.16	63.61	63.35	70.2	10.41
Chennai	46.25	59.47	62.9	69.56	14.57

- **Inconsistent Power supply:** Consistent supply of power is a factor that the cold storage sector is heavily dependent on. Without steady power, the refrigerators won't be able to maintain the required temperature at all times which can demean the quality and quantity of fruits and vegetables. Various cities in India face power cuts which result in an increase in capital investments made to invest in power backups (table 2).

Table 2: Percent electricity deficiency States/Union Territories (ASSOCHAM, 2018)

State/ Union Territory	% of Electricity Deficiency	No of cold storage	Capacity
Assam	24.7	36	157906
Jharkhand	14.9	58	236680
Jammu and Kashmir	13.6	38	112516
Bihar	12.7	306	1415595
Kerala	10.4	198	80405
Haryana	10.2	338	749830
Manipur	10.1	2	5500
Chandigarh	6.4	7	12462
Karnataka	5.4	198	560178
Punjab	5.2	660	2155704
Andhra Pradesh and Telengana	3.9	442	1782561
Arunachal Pradesh	3.4	2	6000
Uttarakhand	3.3	46	160419
Puducherry	1.3	3	85
Total		2334	7458841

- **Insufficient Awareness:** Human resource plays a critical role in cold chain and mistakes/mishandlings done by the handlers lead to losses. From harvesting the produce to packaging to loading, humans are the ones who supervise the entire process. Many a time the minimal knowledge that the workers about temperature-sensitive products can result in the fruits and vegetables losing its quality due to over packing/under packing, incorrectly regulated temperature in the warehouses, etc.

6.2 Current scenario of the cold chain industry in India

Cold stores are like the heart of a cold chain. According to the Directorate of Marketing and Inspection (DMI) up to 2009, National Horticulture Board (NHB), National Horticulture Mission (NHM) and Ministry of Food Processing Industries (MoFPI) as on 31.03.2017, there are 7645 cold storages with a capacity of 34.95 million MT in the country in the following agency wise distribution:

Table 3: Number of cold storages and capacity in MT as on 31.03.2017 (ASSOCHAM, 2018)

Cold Storages up to 2009		Cold storages from 2009-10 to 2016-17						Total	
		NHB		NHM		MoFPI			
Nos.	Capacity (MT)	Nos.	Capacity (MT)	Nos.	Capacity (MT)	Nos.	Capacity (MT)	Nos.	Capacity (MT)
5381	24450652	886	4567886	1142	5170946	236	767507	7645	34956991

The above figure shows how the number of cold storages has increased from 5381 in 2009 to 7645 in 2017. The distribution of Indian cold storages is uneven as more than 70% of cold storage capacity is concentrated in the states of West Bengal, UP, Punjab, and Gujarat which makes the situation more complex in south India. This sector has witnessed a certain amount of development over the years however there is scope for much more. Many of the Indian cold storages are operating on the old methods in spite of the changes that have occurred in the sector worldwide. Technological improvements require huge capital investments which India has currently not undertaken to a great extent (ASSOCHAM, 2018).

7. POTENTIAL OF COLD CHAIN

Cold chain industry in India is expected to grow at a compound annual growth rate of 19% from 2017-2022 and the market has already reached Rs 624 billion in 2017 (Penumarthi, 2017). The supply base of the industry also comprises only 10% of organized players, thus marking it to be a less competitive industry. Cold storage capacity in India is expected to grow at 13% per annum on a sustained basis for the next four years with the organised market growing at a faster pace of 20% (Penumarthi, 2017). India also witnesses growth in organized food retail and processed food sector which increases the need and demand for cold chain facilities. Even though India is currently lagging at popularising the usage of the cold chain, there is a lot of scope for improvement with the help of technology and operational level changes/advances that can be implemented throughout the system. The Government of India has taken several initiatives to improve the sector by permitting 100% FDI and investing 15 Billion USD in cold storage infrastructure to encourage the growth in the sector. Thus, with the government also taking initiatives to induce the growth of the sector, it serves as an opportunity for retailers to invest in long term gains over the current low operating cost model.

8. SUGGESTIONS

- (a) The cold storage facilities need to be temperature smart so that they can adjust according to the requirements of the fruits and vegetable pallets. Most of the time the cold storages are too cold which also ends up spoiling the goods stored in them. The temperature needs to be neither too much cold nor too less.
- (b) The technologies such as the Intelligent Container, the Q₁₀ method which is absent from the Indian supply chain industry shall be used. The supply chain gives too less focus on the shelf life of the various fruits and vegetables which leads to the goods being on the shelves in bad quality and end up not being bought by customers.
- (c) The farmers need to be involved much more in the supply chain. They need to be equipped with modern tools. Involving them in the supply chain can result in the production of goods of better quality using the latest technologies. Also, they can be made a part of the inventory management so that the excess inventory can be stored by them only and supplies later as per demand. Besides this, all supply chain stakeholders must make efforts to promote human resource development for all levels of cold chain: farm-gate aggregation, pre-cooling, storage, transportation, handling, packaging, etc.
- (d) Use of RFIDs on the pallets as sensors to monitor the temperature inside shall be made common. These sensors will help in detecting the temperature inside the pallet and it can be adjusted accordingly afterward to meet the requirements of the fruits or vegetables kept inside. Using this we can prevent the spoilage of goods inside the pallets. Also, they can be used to keep track of the inventory in warehouses.
- (e) The cold chain industry primarily uses refrigerators and coolers to maintain the temperature in the warehouses and vehicles used for transportation. These refrigerators emit greenhouse gases that cause global warming. Since the cold chain is a large industry and the impact, they make on the global CO₂ level is large. Therefore, they must try to use equipment that is greenhouse safe and does not harm the environment like the traditional ones. This solution doesn't solve a problem that pertains only to the cold chain sector but it can contribute to a major global issue.
- (f) Attempts must be made to develop multi-modal chain links through railways and highways, aimed at fast track green corridor for perishables.

9. CONCLUSION

Even though India is the second-largest producer of fruits and vegetables in the world, a large portion of the produce gets wasted due to the lack of a proper cold chain to retain its quality and increase the life cycle of the goods, and most importantly, reduce the post-harvest losses. The gap between cold storage infrastructure and national perishable is leading to approximately 40 percent wastage of the total yield. Thus, it is the need of the hour to implement an efficient cold chain to make India a leading global food supplier. A lot of technological upgradations need to be done in the current supply chain system. Modern-day tools like the intelligent container, smart warehouses and better cold storage systems which are equipped with technology like sensors (to detect temperatures) need to be made an integral part of the supply chain. If these improvements are made in the supply chain it will help in preventing a lot of the post-harvest losses. According to the current scenario of cold chain industry in India, the country is failing in producing an efficient cold chain due to various factors such as, uneven distribution of cold storages throughout the country which ultimately disturbs the distribution channels, outdated refrigeration technology, unawareness about the system amongst the people involved throughout the chain, inconsistent power supply on which the cold storage systems depend on, and inability to invest in the system due high capital requirement.

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