



The Role of Refrigeration in Modernising INDIA'S MANDIS

A scene from Apni Mandi in Panchkula, Haryana.

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The agricultural *mandis* – primarily the fruits and vegetable wholesale markets - in most parts of the country are established and regulated traditionally under the 'Agricultural Produce Market Committee' (APMC) governed by the state APMC Act. The whole geographical area in the state is divided and declared as a market area wherein the mandis are managed by the market committees constituted by the state governments.

The APMC has been made specifically responsible for:

- the transactions taking place in the market area,
- providing market-led services to farmers,
- ensuring payment for agricultural produce sold by

farmers.

Agricultural *mandis*, which number about 7500 all over India, involve in their simplest form the buying and selling of agricultural produce. The state level APMC is intended to regulate the marketing of fruits and vegetables. The purpose of the regulation is to ensure orderly marketing to safe guard the interests of the producers and the sellers.

In olden days when the village economy was more or less self-sufficient the marketing of the agricultural produce presented no difficulty as the farmer sold his produce to the consumer on a cash or barter basis.

The transfer of produce or goods now takes place through a chain of middlemen or agencies. In the

mandis the main functionaries are the producer, the village or itinerant merchant, pre-harvest contractors, commission agents, transport agents etc. With over 184 million hectares of gross cropped area, agriculture is the key component of India's economy. Agriculture accounts for about 25 – 30% of the GDP, concerns the entire population, employs over 60% of it and therefore is the fulcrum of the Indian economy. India is one of the leading agricultural economies and will need to harness and leverage

About the Author

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this potential with a vision. The marketing system for agriculture and horticulture produce in India, however, is subject to inefficiencies due to the presence of a large number of intermediaries between the primary source (producer and growers) and the end consumers without adequate value addition at the level of middle men which has drawn the attention of the policy makers and equally the corporate institutions holding a vision for the agriculture sector.

Need for Modernised Mandis

The state owned mandis are currently characterized by a long, fragmented supply-chain resulting in high wastages in the link between the producer and the consumer leading to poor remuneration to the growers and high cost and unacceptable quality to the consumers.

In view of the thrust being given to the development of horticulture in India – cooperative and contract farming, farm training institutes, cold chain management etc. – agricultural production is likely to see a quantum jump in the times to come. These high levels of production can be sustained only through well managed post-harvest mandis. The perishable nature of the agricultural produce make the role of mandis complicated. An example of this is the varying storage condition required for different produce: mushrooms require 2°C and 90% relative humidity (RH); peas require 0-1°C and 98-100% RH; litchis require 2-6°C and 90% RH; coriander seeds require 8°C and 65% RH. Facilities for the optimal storage conditions under conventional, controlled and modified atmosphere for perishable agricultural produce is wanting in the current mandis in large measure.

Therefore the need for modernizing mandis arises to meet the following objectives:

- To link farmers to the market productively for the benefit of both farmers and consumers.
- To provide effective cold storage of perishables to enhance the operational efficiency and the shelf life.
- To provide grading and sorting lines to meet the needs of various markets.
- To provide multiple choices to the farmers and the wholesalers / purchasers through e-auctioning methods.
- To provide price-discovery mechanism of the agricultural produce by electronic display of various price points across the consumption locations.

However, there are also certain specific problems associated with the modernization, which need to be addressed and these are:

- High cost of such facilities in the mandis
- Energy intensive nature of cold storage operations
- Much needed investment which is not forthcoming

as the corporate sector prefers to focus on their core competencies instead of diversifying in this state-controlled agricultural trade

- Inadequate fiscal incentives

Concept of Agricultural Terminal Market

The National Horticulture Mission (NHM) was launched recently for the development of horticulture in India. NHM provides the concept of “a terminal market” to operate on a ‘hub and spoke’ model wherein the terminal market (hub) would be connected to a number of collection centers (spokes). This is an alternative to the existing mandis and is totally a Public-Private-Partnership (PPP) initiative, the guidelines for which are being put into place by the respective state governments. The terminal market will remain a one stop solution in terms of providing logistic support including transport services and cold storage facilities.

The terminal market would integrate farmers through their collection centers on one end and on the other end would provide forward linkage to wholesalers, distribution centers, retail cash and carry stores, food processing units and exporters.

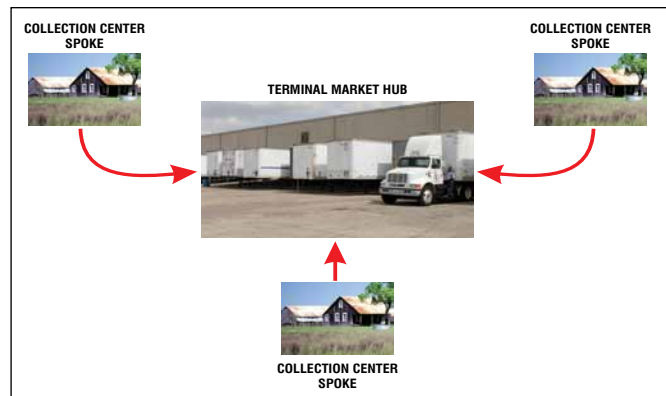


Figure 1 : An indicative picture of Hub & Spoke model of Terminal Market.

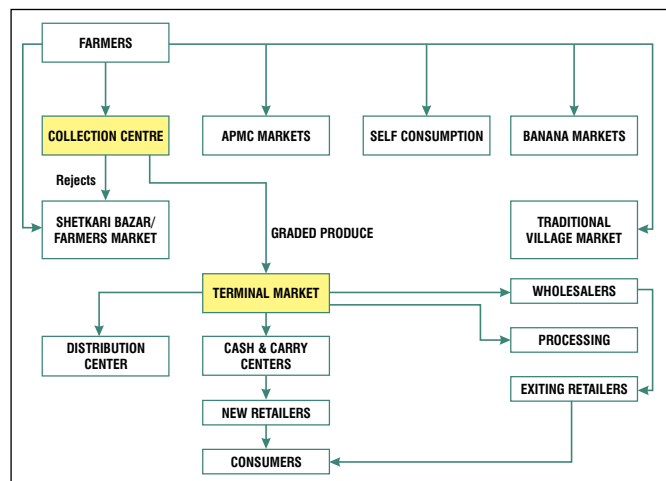


Figure 2 : Farm-to-fork flow diagram with a Terminal Market.

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Producers, farmers and their associations and the other market functionaries from any part of the country may use the infrastructure / facility of the terminal market directly or indirectly. The terminal market will be set up in those states that undertake reforms in their laws dealing with agricultural marketing to provide direct marketing and permit setting up of markets in private and cooperative sectors.

Modernization of the Existing Mandis

Let us understand the needs of various stake holders in the operation of the mandis:

Farmer

- Better price realization
- Protection from illegal market practices

Service Provider

- Economic volumes
- Appropriate service charges

Trader / Wholesaler

- Transparency in operation
- Consistency in quality
- Better delivery mechanism

Customer

- Availability of produce
- Quality and price concerns addressed

Whether the state governments opt for “PPP model of terminal markets” or “state owned mandis”, the development of agricultural marketing will largely depend on the modernization of such trading houses. All mandis need to be modernized to provide the following infrastructure for meeting the growing demands from retail outlets, food processing units and export houses:

Storage of Produce

- Pre-cooling chambers
- Short term cold storages
- Long term cold storages
- Ripening chambers
- State of the art testing/certification laboratory

Material Handling

- Electronic grading and sorting lines
- Packing lines
- Dock shelters
- Dock levelers
- Fork lift truck

Trading

- Electronic display board and live auction
- Platform for electronic trading
- Automated total business process
- Transactional banking solutions / ATM
- Multi purpose information kiosks - health services, incentive to growers etc.
- Commodity exchange node

- Tie up with major food chains

Retailing

- Provision for cash and carry stores for small time traders.
- Small retail outlets for consumers

Others

- Weather insurance, personal life insurance, accident insurance
- Rest rooms for farmers, drivers and exporters
- Hotel and social infrastructure

Refrigeration Needs in Mandis

The mandis form an important link in the overall cold chain of agricultural marketing. This is illustrated simply in Figure 3.

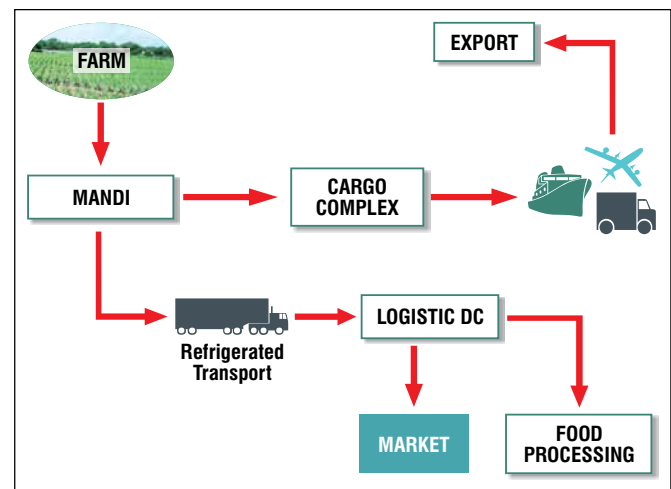


Figure 3 : Commodity flow in a cold chain process.

Cold storages in mandis for perishables (fruits and vegetables) are a pre-requisite for the following reasons:

- Deterioration of produce will largely depend on temperature post harvest stage
- Shelf life could be enhanced for the perishables through proper temperature and humidity control
- Too low a temperature will cause chill injury to the produce.
- To maintain the appearance in terms of color, size etc.
- To eliminate biological contamination - moulds can be formed if not stored properly.

Pre-Cooling Chambers



Figure 4 : Pre-cooler unit.

Pre cooling is a process of rapid removal of heat from freshly harvested produce to minimize enzymatic and other processes which cause deterioration.

It is a key component in the preservation of quality for the perishable

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fresh produce in the post harvest system. This process is typically done before the produce is put into a regular cold storage.

Pre-cooling chambers are basically rooms in the shape of a cubic box made with prefab PUF insulated panels with pre-cooling refrigeration units to ensure the desired pull down time for maintaining the acceptable temperature and humidity conditions.

Forced air cooling is the most widely acceptable method and is commonly used for many fruits and vegetables. 'Hydro cooling' uses water as the cooling medium and is less popular than fast air cooling since some produce does not tolerate water content. Most cold storages for pre cooling use the vapor compression cycle. The key design constraint for the produce storages is to uniformly maintain desired temperature and humidity. Uniform temperature is maintained by having adequate refrigeration capacity, uniform air distribution, minimizing temperature difference between the evaporator coil and the air temperature. High humidity is needed to reduce product moisture loss. Most fresh produce requires 85-95% relative humidity but a few dried commodities need a lower humidity.

In a pre-cooling system, location of pre-cooling unit in the room is very important. Even stacking of the product plays an important role in the circulation of air. Products should be stored in such a way that return air passage is created in front of pre-cooler fan. The supply air from top of the unit will pick up the heat from the produce and return by the air passage created in front of the unit between rows of the produce. Pre-cooling units should be installed on a raised PCC platform of minimum 100mm height. There should be a gap of 150mm between rear wall and the pre-cooler unit.

Short Term / Long Term Cold Storages

Short term / long term cold storages are basically rooms in the shape of a cubic box made with prefab PUF insulated panels with refrigeration units to maintain desired temperature and humidity conditions.

Ripening Chambers

Ripening is a process of converting the starch to sugar. Ripening chambers are fast becoming a major investment for most agro-based industries in India. Incorporated as part of a cold storage facility, ripening chambers ensure that fruits are ripened systematically to the right level of consistency, color, taste and flavor and thereby allowing fruit to match the best quality standards of any market from across the world.

Ripening chambers are basically rooms in the shape of a cubic box made with prefab PUF insulated panels with refrigeration units, humidifiers, ethylene gas emission and CO₂ exhaust systems to maintain the desired temperature,

humidity, ethylene and CO₂ conditions.

Banana is a produce harvested throughout the year and consumed in all parts of the country. Chilling injury is an important disorder for bananas. Optimum temperature for storage of green bananas is 13.3 to 14.4°C with a relative humidity of about 90 to 95%. Bananas are sensitive to physiological levels of ethylene, oxygen and CO₂ levels. Ethylene gas emission systems are safe, fast and precise in the ripening process. They also offer flexibility of ripening more than one fruit at the same time by maintaining different conditions in different chambers. Standard ethylene cylinders for the gas emission system are designed with 5% ethylene and 95% nitrogen mixed.

Ethylene can promote ripening in tomatoes, banana, mango, pineapple, dates, papaya etc. It is clear that ethylene is a ripening hormone, a chemical substance produced by fruits with a specific biological phenomenon. External injection of ethylene is only a facilitator in the normal process of ripening of any fruit. In this process, it is possible to achieve a uniform quality of the ripened fruit, easy to be transported and marketable.

Choice of Refrigerant

Since refrigeration plays a key role of in the modernization of mandis, the selection of refrigerant and the process of cooling needs a close evaluation.

Designing of the refrigeration system intended for a mandi cold storage has to essentially provide *safety, economy and reliability*. The design of such cold storages is a specialized function since it involves an understanding of the thermo physical properties of the produce as they are perishable in nature; human traffic which is large in nature due to various trading activities and hence must be addressed by an experienced refrigeration design engineer.

Safety

In any system, design safety is paramount. Safety is critical in the design, construction and the operation of a refrigeration system. Refrigeration system safety standards must meet ASHRAE 15 (Safety Standards) which specifies the safe design, construction, installation and operation



Figure 5 : A banana ripening chamber.

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of refrigeration systems by establishing safeguards for life, health and property. This includes occupancy classification, restriction on refrigerant use, installation restrictions etc.

HCFC-22 refrigerant is most commonly used today in cold storages as it is absolutely safe, odor-free and non-toxic. However, under the terms of the Montreal Protocol its production and consumption has to be substantially phased out in a developing country like India by 2030. HFC-404a is one of several retrofit refrigerants available for replacing HCFC-22.

Ammonia is one of the oldest refrigerants which has been in use for decades owing to its advantages like no ozone depletion potential, no global warming potential, low cost etc. However, an ammonia system has several inherent drawbacks in terms of safety which were overlooked in the past due to cost considerations. India is still at a primitive stage of a cold chain without adequate legislation and laws governing cold storage safety, food safety of stored items etc.

The department of health services in several countries stipulates guidelines for food exposed to ammonia leaks which is not in existence in this country. While there are measures to monitor and control ammonia leaks, the following health hazards owing to ammonia exposure cannot be overlooked:

- Inhalation – the most common way for ammonia to enter the body is through the respiratory system. Symptoms of ammonia inhalation can include coughing, bronchitis, air way obstruction in the throat, accumulation of fluid in the lungs, chest pain, impaired vision, headache and dizziness.
- Contact with the skin – Ammonia can irritate the skin and cause chemical burns ranging from mild to severe depending on the concentration. Ammonia vapor can also cause redness in the skin, blisters, tissue death or severe burns.
- Contact with the eyes – Ammonia, even at low concentrations can irritate the eyes and cause burning, swelling and sometimes lead to blindness.
- Ingestion can cause medium burning in the mouth and throat leading to severe pain in the mouth, chest and abdomen with swallowing difficulty.

It is therefore not advisable to use ammonia as a refrigerant in a crowded place like mandis due to its toxic nature.

Economy

Well designed systems are expected to provide lowest life cycle cost with maximum energy efficiency with a special consideration for low maintenance. The primary selection of a refrigeration system with R-22, R-404A or ammonia refrigerant, direct expansion or liquid circulation systems,

should be determined by the life cycle cost analysis in the context of cold storages in mandis. Pre-cooling chambers will require higher refrigeration capacity to enable pull down of the temperature within a pre-determined time. However, other cold storages are intended to maintain the level of temperature pulled down in the pre-cooling chamber and require relatively lower refrigeration capacity. Further, loading and offloading pattern of the cold storage will substantially alter the life cycle cost, particularly in terms of its revenue expenditure.

Reliability

Reliability of the refrigeration system for a cold storage depends on several factors such as adequate design and selection of the refrigeration plant, its installation by experienced personnel, thorough testing before handing over to the operators and imparting training to the maintenance staff. A stock of essential spare parts and refrigerant must also be available at the site.

Both reciprocating and screw compressors are commonly used depending on the cooling capacity of the cold storage. Hermetic reciprocating are the common choice upto 10 HP, while semi-hermetic reciprocating compressors are used above 10 HP and upto 40 HP and semi-hermetic screw compressors are used above 40 HP. This is a broad generalization and there are exceptions in many instances.

Redundancy must be incorporated in the system design and selection of refrigeration equipment so that in the event of a mechanical or electrical failure of an operating compressor, a standby takes over without any loss of cooling capacity and spoilage of the stored fruits and vegetables. Rack systems, in which three or four compressors, either reciprocating or screw are mounted on a steel base or rack, connected in parallel, with one standby compressor, are often used in large cold storages to handle capacity variations required as well as redundancy.

Indirect Cooling

Quite often there is a requirement for cooling a large number of rooms to maintain identical or almost similar temperatures such as in a terminal market or a large refrigerated warehouse in which individual coldrooms are rented out by the month to traders storing food products for daily sale to retailers in a large city.

Instead of running long copper liquid and suction refrigerant lines carrying HCFC-22 from the direct expansion condensing units to the evaporators in each coldroom and taking the risk of refrigerant leakages, which are expensive to repair and lead to a long down time, a central fluid chiller chills a brine solution of water and say, ethylene glycol, which is then pumped to the individual cooling units in each coldroom. Temperatures

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Figure 6 : An air cooled brine chiller.

are maintained by individual room thermostats and brine flow control valves.

Such a system of cooling is referred to as an “indirect cooling” system since the refrigerant first cools the brine which then cools the air in the coldroom. The advantage of such a system is that the refrigerant is confined to the chiller in a remote plant room, repairs do not interfere with the coldrooms where food is stored and the distribution piping carrying the brine is ordinary steel piping instead of expensive copper tubing. Any leakage in the brine piping is cheaper to repair and the cost of topping up the leaked brine is low. *Figure 6* shows a standard factory fabricated air-cooled brine chiller installed in a plant room using HCFC-22 refrigerant.

Indirect cooling systems are ideal for cold storages in large mandis for the following reasons:

- The brine solution and the HCFC refrigerant are both non-toxic in nature and will have no adverse effect in case of leakage on the high floating population.
- The refrigerant is limited to the plant room and in the event of leakage it is not exposed to the stored food items
- With the large volume of chilled brine in the system, short-interval power failures will not materially affect the temperatures in the coldrooms.
- The brine chiller is not affected by the load fluctuations in individual coldrooms
- The running cost can be better managed under various load conditions
- Possibility of remote monitoring will help reasonable uptime of the cold storage facility.

Conclusion

Post harvest loss of fruits and vegetables due to inadequate cold storage facilities at the mandi level will certainly pave the way to arrest the “supply side constraint” benefiting both the farmers and the consumers. Now that both the policy makers in the

states and corporate business houses involved in the procurement, distribution and marketing of fruits and vegetables are equally interested, not only in improving the lot of the farmers but their own business as well, chances are bright that we would soon see modernized mandis and terminal markets in most parts of the country. The refrigeration industry is ready to play its role in this very important national activity.

Consulting Editor's note

Winds of change are sweeping across India's agricultural sector. No where is this more apparent than in the case of fresh vegetables and fruits grown by farmers and sold by intermediaries in the mandis. Large chains of organized retailers are putting pressure on the state governments to permit them to buy direct from the farmers, help them to improve yields using modern techniques, eliminate the middlemen and sell cheaper to the consumers. Several states have amended the old APMC Act and some states have already started installing cold storage facilities in the mandis to help the farmers reduce food spoilage and obtain better prices.

The author of this article is currently involved in the installation of cold storages in 9 mandis in Haryana: Punchkula, Abub Shaher, Shahbad, Panipat, Gurgaon, Abusher, Pheowa, Narnaul and Sonepat. The project value is Rs 14 crores and calls for 13,000 m² of PUF insulated 100 mm panels, 72 unit coolers and 56 condensing units. No doubt other states are also experimenting with similar facilities and the trickle of orders for refrigerated storage will soon grow into a flood. ❖

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