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Role of cold storage in preservation of fruits and vegetables in India

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ABSTRACT

India, one of the world's largest producers of fruits and vegetables, continues to suffer from significant post-harvest losses estimated at 20–35%, primarily due to inadequate cold chain infrastructure, poor handling, and fragmented supply chains. Cold storage infrastructure serves as a critical component in maintaining the quality, safety, and longevity of perishable commodities by regulating temperature, humidity, and atmospheric composition. This review synthesizes global and Indian cold storage trends, explains the technical functioning of refrigeration systems, evaluates economic feasibility, and highlights major gaps in existing infrastructure. India's cold storage capacity is heavily skewed toward potatoes (over 60%), revealing commodity and regional imbalance. Despite substantial governmental interventions through NHB, PMKSY, MSME, and NABARD schemes, infrastructural deficits remain—particularly in pack houses (99% gap) and reefer vehicles (84% gap). Emerging sustainable technologies, such as solar-based and biomass-driven cold storage, demonstrate promising solutions for regions with unreliable power supply. Case studies from Telangana, Gujarat, Bihar, and Karnataka show that decentralized cold storage systems significantly reduce losses, improve market timing, and enhance farmer incomes. The review concludes that strengthening cold chain infrastructure is essential for increasing farmer profitability, improving national food security, and reducing wastage within the agricultural value chain.

Keywords : Cold chain logistics, post-harvest losses, value chain, business models, drawbacks and challenges, government support

INTRODUCTION

Cold storage is widely used for handling large amounts of perishable items as they move from where they are produced to the market. Essentially, it's a key method for keeping fresh produce wholesome and extending its shelf life by carefully controlling the temperature and humidity within the storage facility. Fundamentally, a cold room is a refrigerated enclosure specifically designed for storing chilled or frozen food and other sensitive perishable goods.

Cold storage offers several significant advantages for produce. It effectively reduces the respiratory activity of fruits and vegetables, slowing down their natural degradation caused by enzymes. This process also minimizes internal water loss, preventing wilting and keeping the produce firm. Furthermore, cold storage significantly slows or even stops the growth of microorganisms that lead to decay. Importantly, it also reduces the production of ethylene, a natural agent that speeds up ripening. Beyond simply maintaining quality, cold storage provides immense marketing flexibility for farmers. It allows them to store their produce and sell it strategically when they can achieve the best market price. However, for successful storage, it's crucial to begin with a high-quality product, ensuring the produce contains no damaged or diseased units. Additionally, it is important to avoid mixing incompatible products, as certain combinations can accelerate spoilageas noted by Wankhede *et al.* (2020).

Reasons for Losses

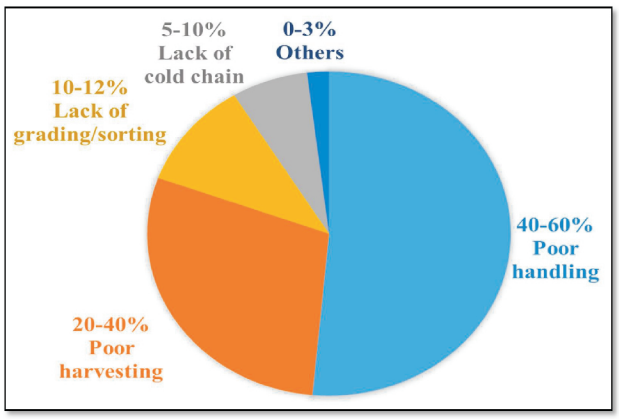


Fig.1: Reason for Losses

Significant losses of fruits and vegetables in India occur due to inadequate storage facilities, poor handling, fragmented supply chains, and extreme weather conditions. Overproduction during peak seasons often exceeds the capacity of existing storage and distribution systems, while farmers are forced to sell quickly because of price fluctuations and lack of proper storage access. Weak transportation networks, insufficient processing units, and rough handling during transit further increase spoilage. Overall, about 40–60% of losses arise from poor handling, 20–40% from improper harvesting practices, 10–12% from lack of grading and sorting, and 5–10% from gaps in the cold chain, with only 0–3% due to other minor factors. Strengthening harvesting practices, handling methods, cold-chain systems, and processing infrastructure is essential to reduce these major post-harvest losses as stated by Ranjan and Sahani (2023).

Value Chain for Fruits and Vegetables in India

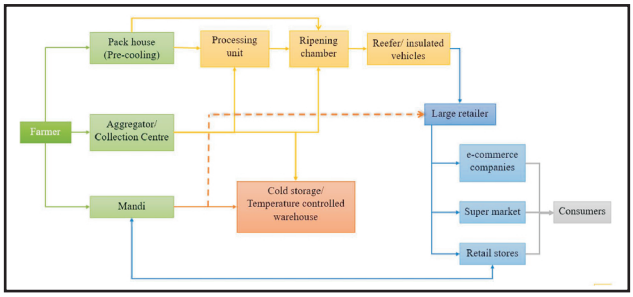


Fig.2: Value Chain for Fruits and Vegetables in India

After being harvested, produce can follow several paths. It might go to an aggregator or collection centre, or directly to a Mandi, which is a traditional wholesale market. From these initial points, different pathways emerge. Some produce goes to a pack house for pre-cooling, a crucial step to remove field heat quickly. From there, it could move to a processing unit, a ripening chamber for fruits, or directly into reefer or insulated vehicles for transport. Crucially, cold storage facilities, or temperature-controlled warehouses, act as central hubs, receiving produce from collection centres or Mandis, and then distributing it further along the chain. Ultimately, the produce makes its way to various retail channels such as large retailers, e commerce companies, supermarkets, or smaller retail stores, before finally reaching the consumers. This complex network highlights the many points where cold chain infrastructure is essential to prevent losses (*Anon*. 2023).

Global Scenario

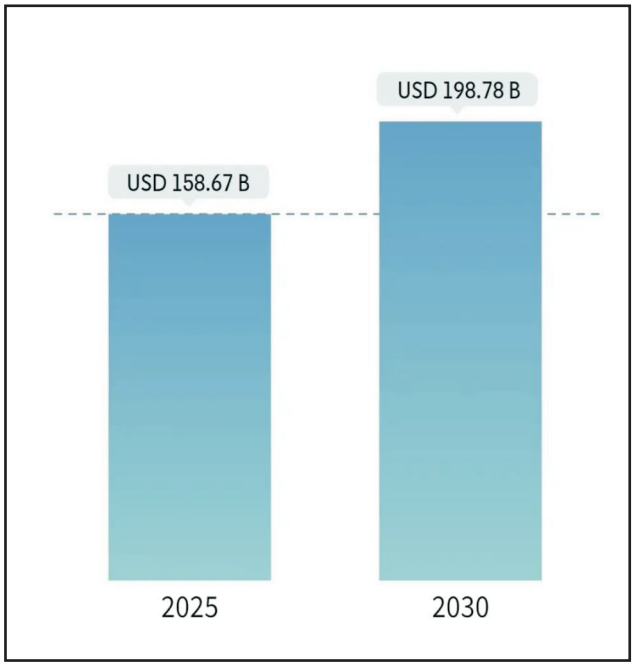


Table 1: Cold Storage Market Size in World

Study Period	2020 - 2030
Market Size (2025)	USD 158.67 Billion
Market Size (2030)	USD 198.78 Billion
CAGR (2025 - 2030)	4.61 %
Fastest Growing Market	Asia Pacific
Largest Market	North America

Fig.3: Reason for Losses

The Cold Storage Market size is estimated at USD 158.67 billionin 2025, and is expected to reach USD 198.78 billion by 2030 at a CAGR of 4.61% during the forecast period 2025-2030 (*Anon*. 2025).

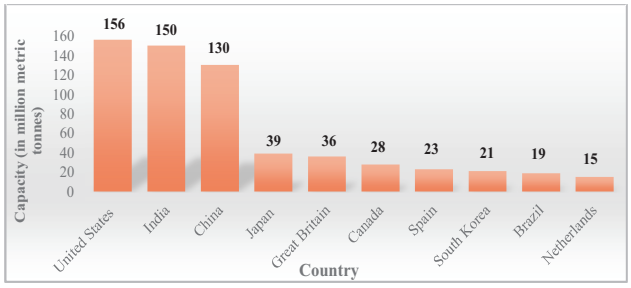


Fig.4: Distribution of Cold Storages in World

Fig 4 shows the global cold storage landscape is highly concentrated, with the United States, India, and China leading at 156, 150, and 130 million metric tonnes of capacity. Their dominance reflects their large populations, strong economies, and growing need for temperature-controlled supply chains. Beyond these top three, countries like Japan, Great Britain, and Canada have much smaller but still important cold storage systems. This gap shows uneven cold chain development worldwide, influencing food security, waste reduction, and the efficient distribution of vaccines and other sensitive products as noted by Global Cold Chain Alliance (2020).

Indian Scenario

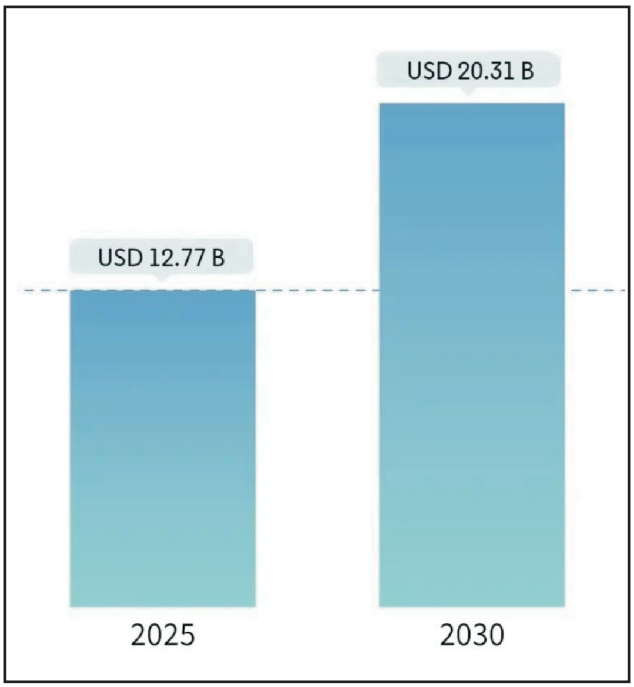


Fig.5: Indian Market Size

Table 2: Cold Storage Market Size in India

Study Period	2020 – 2030
Base Year for Estimation	2024
Market Size (2025)	USD 12.77 Billion
Market Size (2030)	USD 20.31 Billion
CAGR (2025 - 2030)	9.72 %

The India Cold Chain Logistics Market size is estimated at USD 12.77 billion in 2025 and is expected to reach USD 20.31 billion by 2030, at a CAGR of 9.72% during the forecast period 2025-2030 (*Anon*. 2025).

State Wise Number of Cold Storages

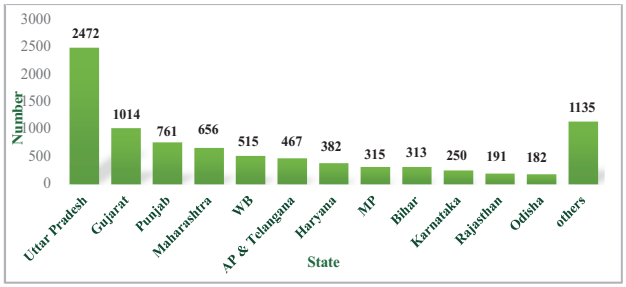


Fig 6: State Wise Number of Cold Storages

Fig 6 shows the total number of cold storages in India is 8653. Uttar Pradesh has the highest number of cold storages with 2472. It is a major producer of potatoes and other perishable crops needing cold storage. Gujarat follows with 1014 cold storages. Punjab has 761 and Maharashtra has 656. West Bengal Andhra Pradesh and Telangana Haryana Madhya Pradesh Bihar Karnataka Rajasthan and Odisha have fewer cold storages. The category labelled others represents 1135 cold storages. This chart clearly shows the distribution of cold storage facilities across various Indian states as noted by PIB (2023).

State Wise Distribution of Cold Storages Capacity

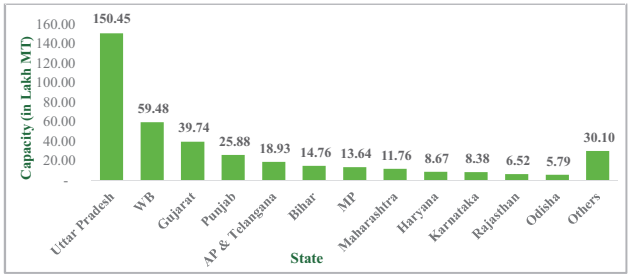


Fig 7: State Wise Distribution of Cold Storages Capacity

Uttar Pradesh having the highest capacity is likely due to its vast agricultural output especially potatoes and other vegetables that need long term storage. West Bengal also has a significant capacity probably because it is a major producer of potatoes fish and other perishable goods. Gujarat's capacity might be driven by its strong food processing industry and its role as an export hub for agricultural products. Generally, states with high production of perishable crops high population density or significant food processing industries tend to develop more cold storage capacity to prevent wastage and ensure market supply as noted by PIB (2023).

Commodity Wise Distribution of Cold Storages

The table 1 illustrates, is that cold storage in India is overwhelmingly dedicated to potatoes. Out of all the space available for keeping things cold, a huge 64% is used just for potatoes. This is because potatoes are a very important food for many people in India, and they are harvested all at once, so they need a lot of space to be stored safely so they don't spoil and can be sold throughout the year. While there are also places for fruits, vegetables, fish, and other items, potatoes are by far the biggest priority for cold storage as analysed by EDII (2017).

Table 3 : Commodity Wise Distribution of Cold Storages

Commodity	Units	Capacity (lakh tones)
Potato	**2,012**	**92.82**
Multipurpose	447	7.63
Fruits & Vegetables	198	1.07
Meat	23	0.09
Fish	360	0.73
Meat & Fish	30	0.15
Milk & Dairy Products	272	0.68
Others	101	0.36

Cold Chain Infrastructure Availability and Requirements in India

Table 2 presents required numbers created numbers and the existing gap. For Packhouses a very large 99% gap exists indicating a critical shortfall. Reefer Vehicles also show a substantial 84% gap highlighting another major area needing development. Ripening Chambers have a significant 90% gap pointing to a severe deficit. In contrast Cold Storage Hub has a minimal 2% gap showing almost full achievement. Cold Storage Bulk has a smaller 10% gap suggesting good progress. This data clearly identifies where resources are most critically needed (*Anon.*2023).

Table 4 : Cold Chain Infrastructure Availability and Requirements in India

CCI Component	Required (Nos)	Created (Nos.)	Gap
Packhouses	83,041	675	99 %
Cold Storage – Bulk	6,669	6,026	10 %
Cold Storage – Hub	231	225	2 %
Reefer Vehicle	70,035	11,000	84 %
Ripening Chambers	12,654	1,232	90 %

Types of Cold Storages

First, we have Bulk cold stores which are typically very large facilities designed for storing a single commodity or a few compatible items in huge quantities like potatoes or apples. Next are multi-purpose cold stores these facilities offer flexibility often having multiple chambers set at different temperatures to accommodate a variety of products simultaneously. Then we have Small cold stores which are generally smaller in scale perhaps used by individual businesses or for local distribution needs. Following these are Frozen food stores specifically engineered to maintain very low sub-zero temperatures ensuring the long-term preservation of 9 frozen goods like meat or processed foods. Additionally, we see Mini units or walk in cold stores these are compact modular units often found at retail outlets restaurants or for specific on-site storage. Finally Controlled atmosphere CA stores are highly specialized facilities that precisely regulate the levels of oxygen carbon dioxide and nitrogen in the storage environment which significantly extends the shelf life of fruits and vegetables. Each of these types plays a crucial role in the cold chain infrastructure as stated by Wankhede *et al.*(2020).

Recommended Temperature and Humidity for Cold Storage

Table 3 highlights the precise storage conditions needed for various commodities to maximize their shelf life. It shows that different items require very specific temperatures ranging from 0 degrees Celsius for carrots and onions to warmer temperatures for tomatoes and sweet potatoes. Relative humidity also varies for optimal preservation like the lower humidity for onions compared to most other produce. Understanding these tailored conditions for temperature and humidity is essential because they directly determine how long each commodity can remain fresh from a few weeks for delicate items to several months for more robust produce like potatoes or apples noted by FAO (2023).

Commodity	Storage temperature (°C)	Relative humidity (%)	Shelf life
Potato (white)	5-10	93	2-5 months
Potato (Sweet)	12-16	85-90	**4-6 months**
Carrot	**0**	90-95	2-5 months
Onion	**0**	**65-70**	**1-8 months**
Tomato	12-20	85-90	1-3 weeks
Cauliflowers	**0**	90-95	2-4 weeks
Apples	1-4.4	85-90	**3-8 months**
Mango	12	85-90	2-3 weeks
Pineapple	7-12.5	85-90	2-4 weeks
Avocado	4.4-12.5	85-90	2-4 weeks

COLD STORAGE BUSINESS MODELS

1. **Third Party Services Model**

- **Storage Based Model:** Now let us discuss the Storage Based Model as shown on this slide. A cold room is a specialized storage facility designed to hold large quantities of products for a longer duration at a lower temperature. To achieve this extended storage life and maintain product quality specific storage conditions are crucial. These conditions primarily involve precise control of both temperature and humidity once the crop has been cooled to its ideal storage temperature. For instance, fresh fruits and vegetables specifically require low temperatures typically ranging from 0 to 13 degrees Celsius and high relative humidity between 80 to 95 percent. These conditions are vital to lower their respiration slow down metabolic processes and reduce transpiration rates ensuring they remain fresh for as long as possible as noted by Wankhede *et al.* (2020).
- **Value Added Services Model:** This particular model functions as a highly specialized and customer specific service provider. Under this model various value-added services are provided. These include activities such as sorting grading customized

packaging labelling transportation and even customer care services. This approach allows third-party logistics or 3PL providers to manage larger segments of their client's supply chains. By offering these comprehensive services 3PL providers gain a significant competitive advantage within the industry as stated by Juma and Basheer (2023).

- **Public Private Partnership Model:** This model represents a cooperative arrangement that unites both the public and private sectors under a single umbrella aiming to fulfil a common objective. It is understood that Cold Chain Supply Management can be most effectively developed and operated through this PPP approach by connecting all small stakeholders within an organized framework. The Government of India has recognized the crucial need for strengthening the Cold Chain Supply across the country. Furthermore, the Public Private Partnership model especially when combined with Viability Gap Funding is considered a suitable method to attract significant large-scale investments from the private sector into the cold chain. A prime example of this model in action is seen in the development of Mega Food Parks. This collaboration fosters growth and efficiency in vital sectors noted by Kendurkar and Tiwari (2017).

2. **On Farm Cold Storage Model:** This innovative system is also known as a Zero Energy Cooling Chamber. It functions by maintaining its internal temperature and relative humidity primarily through an evaporative cooling mechanism. A key benefit of this model is its ability to efficiently remove field heat from freshly harvested fruits and vegetables directly at the farm site. This method is notable for being both efficient and highly cost effective. Ultimately the On-farm Cold Storage Model empowers farmers allowing them to delay selling their produce until market prices are more favourable stated by Patel *et al.*(2022).
3. **Owned or Private Cold Storage:** These facilities are specifically owned and operated by large food producers or retailers for their exclusive use. They are frequently situated close to the company's manufacturing facility which enhances both convenience and operational efficiency. The primary purpose of these private cold stores is to hold both raw materials and processed produce belonging to the owning company or retailer. A practical example of this model includes FPO-managed storage facilities specifically for commodities like mangoes or potatoes ensuring controlled conditions for their own products noted by Juma and Basheer (2023).

DRAWBACKS AND CHALLENGES

- **Sprout induction:** Certain produce, such as potatoes, can prematurely sprout when stored in cold conditions. This sprouting can degrade the quality of the vegetable, making it less suitable for consumption or processing. It indicates that the cold temperature, while intended to preserve, has triggered an undesirable physiological response.
- **Shrinkage:** Produce in cold storage can lose significant moisture, leading to a reduction in its size and weight. This dehydration causes wilting and shrivelling, impacting the visual appeal and market value of items like lettuce. Proper humidity control is crucial to mitigate this loss.
- **Tissue softening:** For some fruits and vegetables, prolonged cold storage can lead to a breakdown of their cellular structure. This results in the produce becoming soft, mushy, or mealy, compromising its desired texture and freshness. Apples are a common example where this deterioration in texture can occur.
- **Freezing injury:** If cold storage temperatures drop below the freezing point of the produce, ice crystals form within the plant tissues. These ice crystals physically damage cell membranes and walls, leading to irreversible injury. Upon thawing, the affected areas appear water-soaked, discoloured, and often completely broken down.
- **Chilling injury:** This physiological disorder occurs when chilling-sensitive produce is stored at low, but non-freezing, temperatures for an extended period. Symptoms vary but can include surface pitting, internal browning, dullness, or a failure to ripen properly, as the produce's natural metabolic processes are disrupted. It often makes the produce more susceptible to decay.
- **Off colour development:** Many fruits and vegetables exhibit undesirable colour changes when exposed to inappropriate cold storage temperatures. For example, bananas stored below their optimal temperature will develop dull, dark, or mottled peels instead of ripening to a vibrant yellow. This discoloration significantly reduces their marketability and consumer acceptance as stated by Patel *et al.* (2022).

CHALLENGES FOR THE FARMERS

- **Lack of awareness of post-harvest cooling benefits:** Many farmers are not fully informed about how proper cooling after harvest can significantly extend the shelf life and quality of their produce. This unawareness prevents them from realizing the potential for reduced spoilage and higher market prices.
- **Lack of knowledge about Government Policies:** Farmers often lack information regarding government schemes, subsidies, or support programs aimed at promoting cold chain infrastructure. This knowledge gap means they miss opportunities to access financial aid or technical assistance for improving their post-harvest practices.
- **High investment cost:** The initial capital required to establish personal cooling facilities or even to access centralized cold storage is often prohibitive for most farmers. This significant upfront expenditure acts as a major barrier to adopting modern post-harvest preservation techniques.
- **Uneven power supply:** Farmers in many regions contend with unreliable electricity, characterized by frequent outages and voltage fluctuations. Such an erratic power supply makes it extremely difficult to consistently operate any cooling equipment needed for preservation.
- **Lack of connectivity to access consumer markets:** Farmers frequently face challenges due to poor transportation infrastructure and limited direct links to final consumer markets. This isolation often forces them to sell produce quickly at lower prices, even when cold storage could offer better returns (*Anon.*2023).

CHALLENGES FOR THE COLD STORAGE OPERATORS

- **Delayed & complex process to claiming subsidies:** Cold storage operators often encounter bureaucratic and time-consuming procedures when applying for and receiving government subsidies. This complexity and delay can significantly strain their cash flow and deter further investment in expansion or upgrades.
- **Lack of skilled manpower:** Operating and maintaining modern cold storage facilities requires specialized technical expertise in refrigeration and inventory management. There is often a shortage of adequately trained personnel, leading to operational inefficiencies and increased risk of equipment failure.
- **Irregular power supply:** Cold storage units require a continuous and stable electricity supply to maintain precise temperatures. Frequent power outages or fluctuations can lead to energy waste, equipment damage, and critical spoilage of stored goods.
- **High cost of power:** Even with a reliable supply, the electricity tariffs for cold storage operations are frequently very high due to their energy-intensive nature. This elevated cost of power significantly inflates operational expenses, directly impacting the profitability of the business and the affordability of services.
- **Uneven demand distribution:** The demand for cold storage services fluctuates considerably throughout the year, driven by seasonal harvests and market cycles. This inconsistency leads to periods of both overcapacity and under-utilization, making it difficult to maintain consistent revenue and operational efficiency.
- **Questionable viability due to seasonal changes in production:** The economic sustainability of cold storage facilities is heavily dependent on the highly seasonal nature of agricultural output. During off-peak seasons, facilities may sit idle or underutilized, making it challenging to ensure long-term profitability and a stable business model (*Anon.*2023).

GOVERNMENT SUPPORT

Pradhan Mantri Kisan SAMPADA Yojana

The Ministry of Food Processing Industries (MOFPI) operates the Pradhan Mantri Kisan SAMPADA Yojana (PMKSY), an overarching scheme designed for agro-marine processing and the development of agro-processing clusters. A key component within PMKSY, established in 2008, focuses on developing Integrated Cold Chain, Value Addition, and Preservation Infrastructure. Under this specific component, the ministry offers a grant-in-aid of 40% of the project's capital cost for developments in general areas. This grant increases to 50% for projects located in North Eastern states, Hilly States, and Scheduled Areas, with a maximum grant ceiling of Rs. 10 crores for any project. Furthermore, eligibility criteria include a net worth requirement for applicants: their combined net worth must be at least 1.5 times the sought grant-in-aid for projects in general areas. This requirement is relaxed for proposals from North Eastern areas, or those submitted by Scheduled Caste/Scheduled Tribe (SC/ST) farmers, Farmer Producer Organizations (FPOs), or Self-Help Groups (SHGs), where

the net worth needs to be at least equal to the grants-in-aid sought. This scheme, as sourced from MOFPI in 2018, aims to bolster food processing infrastructure and reduce post-harvest losses across Indiaaccording to MOFPI (2018).

Credit Linked Capital Subsidy and Technology Up-gradation Scheme

The Ministry of Micro, Small and Medium Enterprises (MSME) offers the Credit Linked Capital Subsidy and Technology Up-gradation Scheme (CLCS-TUS), which was introduced in 2000. This scheme's primary objective is to facilitate technology up-gradation for Micro, Small, and Medium Enterprises by providing a 15% capital subsidy on institutional finance that they secure. A key aspect of the scheme is the specified ceiling limit for the amount of loan or institutional finance eligible for this subsidy, which is Rs. 1.00 crore. Furthermore, to specifically support marginalized communities and promote inclusive growth, an additional 10% subsidy is provided to SC/ST MSMEs. This additional benefit is channelled through the National SC/ST Hub (NSSH) in accordance with the guidelines of the SCLCSS (likely a related scheme or component). This information is sourced from MSME in 2013, highlighting the government's sustained efforts to modernize and empower the MSME sectoraccording to MSME (2013).

Scheme for Infrastructure Development

The Agricultural and Processing Food Products Export Development Authority (APEDA) introduced a "Scheme for Infrastructure Development" in 2014, aimed at bolstering the infrastructure necessary for agricultural and processed food exports. Under this scheme, financial assistance is provided at various rates depending on the nature of the project. Generally, assistance is offered up to 40% of the project cost, with a maximum ceiling of Rs. 200 lakhs. For cold storage facilities specifically, if they are established by Central and State government institutions, the assistance is significantly higher, covering up to 90% of the approved cost, subject to a ceiling of Rs. 600 lakhs. Additionally, the scheme also supports the acquisition of equipment by providing assistance up to 25% of the equipment's cost, with a maximum limit of Rs. 10.00 lakh per beneficiary. This information is based on APEDA's guidelines from 2014, reflecting their commitment to enhancing export capabilities through infrastructural supportaccording to APEDA (2014).

Warehouse Infrastructure Fund

The National Bank for Agriculture and Rural Development (NABARD) offer the Warehouse Infrastructure Fund (WIF), which was established in 2014 to provide financial support for the development of warehousing infrastructure. Under this fund, specific terms are outlined for different types of beneficiaries. For State or Central Government-Owned Assisted Entities and Corporations, NABARD provides a loan covering 95% of the Total Financial Outlay (TFO) with a repayment term of 7 years. In contrast, Private Companies and individual entrepreneurs are eligible for a loan covering 75% of the TFO, with a more flexible repayment period ranging from 7 to 15 years. The interest rate on these loans is not fixed but varies based on the credit rating of the borrower, although it is subject to a minimum Prime Lending Rate of 9.25%. This information, sourced from NABARD in 2023, indicates the ongoing relevance and updated guidelines of the WIFaccording to NABARD (2023).

Steps to Avail Benefits

To avail benefits, the initial step involves the creation of a comprehensive detailed project report (DPR) which thoroughly outlines the proposed project. This DPR is then submitted to nationalized banks for a loan application, as many government schemes are credit-linked, requiring bank financing alongside the subsidy. Upon receiving the loan sanction from the bank, a subsidy application is prepared, encompassing both the DPR and the bank's loan sanction datasheet. These documents are subsequently submitted to the relevant departmental office in the applicant's region for initial scrutiny and verification.

Following the regional office's review, the project is presented to the State-level Executive Committee (SLEC) for their recommendation for implementation, ensuring alignment with state-level objectives. Subsequently, the project undergoes technical compliance vetting by a state project appraisal committee, which assesses its engineering and operational soundness. The project then moves to a central project appraisal committee (PAC), which reviews it from a national perspective, ensuring consistency and adherence to broader guidelines. The final step in this multi-tiered process is the official sanction of the subsidy under the sponsored scheme, leading to the disbursement of funds typically to the beneficiary's loan account according to CPPR(2020).

Solar Based Cold Storage

A solar-based cold storage system harnesses solar energy to provide sustainable and cost-effective refrigeration for perishable goods. The system primarily consists of rooftop-mounted solar panels that convert sunlight into Direct Current (DC) electricity. This DC power is then transformed into usable Alternating Current (AC) by an inverter, which drives the refrigeration unit. A crucial component is the thermal energy storage (TES) system, often utilizing Phase Change Materials (PCMs), which stores "cold" generated during peak solar hours. This stored thermal energy is then released to maintain the cold room's temperature during periods of low or no sunlight, ensuring continuous

operation without constant reliance on solar input or extensive battery banks. The system also includes a well-insulated cold room to minimize heat gain and can incorporate a small battery backup for auxiliary loads like lighting and controls.

The advantages of solar-based cold storage are significant, particularly in agricultural regions and areas with unreliable grid access. It offers substantial reductions in electricity costs, contributes to environmental sustainability by using clean energy, and provides independence from the conventional power grid, thereby minimizing post-harvest losses due to power outages. While the initial investment can be higher than traditional systems, long-term operational savings and reduced spoilage often provide a strong return on investment. The inclusion of thermal energy storage further enhances the system's reliability and reduces the maintenance associated with large electrical battery banks, making it a robust solution for preserving produce and extending shelf-life as noted by Choudhury *et al.* (2024).

CONCLUSION

Cold storage units are paramount for ensuring food security, significantly reducing waste, and extending the shelf life of fruits and vegetables. By storing their produce in cold storage, farmers are empowered to obtain better prices, avoiding immediate distress sales. Effective collaboration between farmers, policymakers, organizations, and researchers is vital to foster a sustainable and resilient agricultural sector. The utilization of solar panels as an energy source is crucial, as it mitigates the risk of inadequate power supply and reduces electricity management costs. Furthermore, biomass-based cold storage offers another eco-friendly solution, providing consistent cooling independent of electrical grid fluctuations. To encourage the establishment of such vital infrastructure, the government is actively providing financial assistance through various schemes.

CONFLICT OF INTEREST

"The authors certify that they have no affiliation with or involvement in any organisation or entity with any financial interest or non-financial interest in the subject matter or materials discussed in manuscript."

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