
Reconfiguring the Horticultural Value Chain: Lessons from Post-Harvest Management Models in Western India

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ABSTRACT

Post-harvest losses continue to be a persistent constraint in India's horticulture sector, particularly among smallholder farmers in Western states such as Rajasthan, Maharashtra and Gujarat. Drawing a synthesis of case studies in post-harvest management and rural infrastructure, the paper analyses operational models that integrate decentralised processing, aggregation systems, and institutional market access. The study outlines strategies that address these multidimensional losses, encompassing transport and handling inefficiencies, limited processing capacity, weak market linkages, and financial barriers to infrastructure adoption. The analysis draws on examples from producer-led enterprises and mobile processing platforms. Findings indicate that context-specific, localised models contribute to improved efficiency and resilience in horticultural supply chains. The paper situates these insights within national priorities aligned with broader goals of agricultural modernisation and inclusive rural development.

INTRODUCTION

The Indian agricultural economy comprises over 86% small and marginal farmers (Agricultural Census, 2016), suffers considerably from post-harvest losses (PHL), particularly in the fruit and vegetable sectors. Estimates from the Indian Council of Agricultural Research (ICAR) and the Central Institute of Post-Harvest Engineering and Technology (CIPHET) indicate aggregate losses for fruits and vegetables ranging from 30% to 35% (ICAR-CIPHET, 2015). This is primarily due to delayed processing, inadequate storage, and fragmented logistics. These losses, especially in perishable horticultural crops, are not confined to spoilage or reduced quantity. They also encompass various aspects: transport and handling losses, storage and shelf-life deterioration, yield diversion caused by market delays, revenue loss from forced distress sales, and value leakage due to limited access to processing or credit infrastructure.

It is observed that PHLs are not a singular metric; they occur across multiple dimensions. These include: physical degradation of produce during transport and handling; storage and shelf-life deterioration due to lack of cold chain and pre-cooling infrastructure; market-linked yield losses when crops miss their optimal selling window; and financial losses, such as distress sales caused by absence of aggregation or credit facilities (Kumar et al., 2016; Singh & Gangwar, 2021). A 2020 FAO report further highlights that post-harvest inefficiencies contribute more to farmer income volatility than productivity deficits (FAO, 2020). Collectively, these issues reflect not just technical inefficiencies but a deeper systemic vulnerability of how agricultural supply chains are designed and governed, leading to the disempowerment of producers and farmers.

Horticultural production has expanded rapidly in agro-climatically favourable regions such as Jaipur in Rajasthan, Nashik in Maharashtra, and Anand and Kheda in Gujarat, intensifying both output and vulnerabilities. These regions represent high-value production hubs for perishables such as grapes, pomegranates, tomatoes, and bananas. Despite productivity

gains, farmers in these areas experience disproportionate value loss due to weak connectivity, lack of aggregation platforms, and missing infrastructure for flexible, small-scale processing (Gulati et al., 2018). As a result, farmers are often price takers during peak seasons and are structurally excluded from downstream value addition (Pingali et al., 2017).

Contemporary literature suggests a shift from top-down, infrastructure-heavy approaches to institutionally innovative, farmer-centric models. These include mobile processing, solar drying, and farmer-owned logistics systems that build resilience and retain value close to the farm gate (World Bank, 2021; Ghosh et al., 2020). FAO and IFPRI research further argue for an integrated value chain design that promotes both quality assurance and decentralisation to reduce perishability risks in real-time (FAO, 2021).

This study investigates how alternative organisational and technological models can mitigate these losses and enhance low-cost, affordable, and scalable technologies for smallholder farmers. The aim is not to generalise from a single model, but to derive grounded insights from real-world experiments that address systemic gaps in post-harvest & supply chain management.

Multiple contrasting, but complementary, cases are examined:

Sahyadri Farms (Nashik, Maharashtra), a farmer-led, vertically integrated value chain enterprise. It reduces post-harvest losses by investing in shared infrastructure such as packhouses, pre-cooling centers, ripening chambers, and cold storage, which are linked to centralised processing and export units. It has also established a fully backward-integrated traceability system, ensured residue-free certification, and supported farmers with agronomic extension and crop planning tools. Importantly, it has developed a waste-to-value model through pulp extraction, composting, and biogas generation from discarded or sub-grade produce, turning what would have been a loss into a secondary revenue stream.

InnoFarms (Rajasthan), a decentralised, Processing-on-Wheels model developed through field trials in Anand and Kheda districts. This mobile solution includes a van equipped with units for sorting, grading, pulping, juicing, and dehydration, powered by solar-battery systems. By reaching farms directly, InnoFarms minimises losses due to transportation lag, limited aggregation infrastructure, and poor rural connectivity. Farmers can process surplus or cosmetically rejected produce on-site, convert it into intermediate or shelf-stable products, and access urban markets or bulk buyers. Trials showed that farmers gained 30–50% more revenue by converting waste into value-added pulp or dried produce.

S4S Technologies (Jalgaon and Aurangabad, Maharashtra), a woman-led enterprise using solar-conduction dryers and decentralised micro-processing units to reduce spoilage at the village level. Women entrepreneurs are trained to collect, slice, and dry surplus farm produce, especially during seasonal gluts, resulting in extended shelf life and creating rural microenterprises. S4S directly links processed goods (e.g., tomato powder, onion flakes) with B2B food processors, enabling durable market access. Its model tackles both post-harvest waste and rural underemployment through affordable, scalable technology and localised processing.

These three models differ in institutional form, i.e., centralised, mobile, and decentralised, microenterprise, respectively. However, they converge in their purpose to reduce waste, retain value, and re-empower farmers in a system otherwise designed around intermediaries. Collectively, they highlight how context-specific, technology-enabled, and institutionally inclusive solutions can address various facets of the post-harvest challenge from transport and perishability losses to market exclusion and financial inaccessibility.

Research Objectives & Methodology

This study aims to:

1. Examine how different post-harvest solutions address specific types of losses, i.e, transport, processing, financial, and storage.
2. Compare organisational models (centralised vs. decentralised) through case studies from Western states of India.
3. Discover what contributes to the success of these solutions and how they can be applied in other regions with similar farming and economic conditions.

The research follows a qualitative case study approach, using three primary cases:

- Sahyadri Farms (Nashik, Maharashtra) – a centralised, FPO-driven integrated agri-enterprise.
- InnoFarms / Processing-on-Wheels (Jaipur, Rajasthan) – a decentralised, mobile processing model targeting transport and perishability loss.
- S4S Technologies (Jalgaon & Aurangabad, Maharashtra) – provides a solar-powered dehydration and processing platform to reduce perishability and increase the storage life of farm produce.

Section 1: Transport and Handling Losses

In the context of horticultural production in Western India, transport and handling represent a critical stage of inefficiency in the post-harvest system. These losses are often the result of delayed aggregation, manual handling practices, and the absence of dedicated logistics infrastructure such as cold chain transport and pre-cooling systems. Small and marginal farmers cultivating perishable crops like tomatoes, grapes, pomegranates, and bananas frequently harvest based on the availability of transport or market opportunity rather than physiological maturity, which adversely affects quality and shelf life (FAO, 2020).

The region's logistics networks remain fragmented, particularly in districts such as Nashik, Jalgaon, and Anand. Produce typically passes through multiple intermediaries before reaching terminal markets or processing centers. During that time, it is subject to repeated manual handling, ambient heat exposure, and deterioration due to a lack of protective packaging or temperature regulation. Field-level evidence suggests that primary collection is often carried out using loose stacking in open vehicles or bags, leading to bruising and spoilage within hours of harvest (Sahyadri Farms Case, 2022; InnoFarms Case, 2021).

Institutional efforts to reduce such losses have focused on improving the design of first-mile logistics. Some producer-led enterprises have created decentralised aggregation centers equipped with sorting, grading, and pre-cooling capabilities, which are then connected to cold chain vehicles. These measures reduce the time between harvest and dispatch, while also introducing basic quality control at the point of origin. Farmers can coordinate harvesting based on scheduled pick-ups, thereby minimising post-harvest exposure and increasing the likelihood of reaching distant markets with acceptable quality (World Bank, 2021; Sahyadri Farms Case, 2022).

In parallel, other models aim to bypass traditional transport constraints altogether. In horticulture zones with limited access to structured logistics, mobile processing units have

been deployed to enable the stabilisation of produce near the farm. These mobile units are equipped with pulping, dehydration, and packaging systems powered by solar energy, allowing farmers to process cosmetically rejected or surplus fruits within a short window after harvest. The use of this model has been shown to reduce loss by 25–30% and increase income by creating intermediate goods with longer shelf life (InnoFarms Case, 2021; FAO, 2020).

Another approach observed in Maharashtra involves the deployment of solar-conduction dryers at the village level. These technologies allow farmers or their collectives to pre-process commodities like tomato, banana, and onion into dried formats, reducing both perishability and the urgency for same-day transport. Shelf life is extended up to 6–12 months, and transportation is consolidated to occur post-processing in bulk batches (S4S Technologies Case, 2025; NITI Aayog, 2018).

Design considerations for transport-related loss reduction vary by model. In centralised systems, success is linked to the availability of coordinated logistics networks and cold chain coverage. In decentralised systems, proximity-based stabilisation methods and reduced handling cycles are more relevant. Across both approaches, the effectiveness of interventions depends on how well they are integrated into harvesting decisions, aggregation flows, and market connectivity structures.

In summary, transport and handling losses are not isolated technical problems but are closely tied to the structure and timing of early post-harvest operations. Emerging supply chain models in Western India indicate that loss reduction can be achieved through context-specific logistics planning, localised infrastructure, and near-farm stabilisation systems customised to the perishability and aggregation profile of the crops being handled.

Section 2: Processing Capacity and Infrastructure

The development of appropriate processing infrastructure plays a central role in reducing post-harvest losses in horticultural value chains. In Western India, characterised by high-value perishable crop cultivation and a fragmented production landscape, the lack of proximate and scalable processing solutions has contributed to continued waste, particularly during seasonal gluts or delayed market access. Processing capacity, both at the primary and secondary levels, serves as a critical buffer that stabilises surplus, adds value, and improves market readiness.

Conventionally, smallholder horticulture in Maharashtra and Gujarat has relied on external procurement channels and distant processing hubs that are often inaccessible to farmers due to cost, volume, or coordination barriers. In such systems, value addition is concentrated downstream, and surplus produce that does not meet fresh market standards is typically discarded, fed to animals, or sold at distressed prices. Less than 10% of perishable produce in India's horticultural sector is processed into secondary or shelf-stable formats, leaving most of the value unrealised (FAO, 2020).

Recent models in the region have sought to improve access to processing by investing in decentralised or mobile infrastructure linked to farmer-controlled or community-based platforms. In some districts, centralised packhouses have grading lines, ripening chambers, and residue-free processing facilities. These enable basic product standardisation, certification, and preparation for retail or export supply chains. Mechanised lines and digital traceability systems also support compliance with safety and quality protocols, further improving market eligibility for value-added formats such as cut fruit, pulp, or minimally processed produce.

Complementary approaches involve the deployment of mobile or semi-mobile processing units capable of pulping, drying, or juicing produce at the village level. These platforms are

especially relevant where production is dispersed and volumes may not justify high fixed-cost infrastructure. Solar-powered units with integrated processing equipment have enabled the conversion of cosmetically rejected or surplus produce into intermediate goods such as pulp or dehydrated slices. This model has been particularly effective for tomatoes, bananas, and chikoo, among other common perishable crops in the region's agri-ecological zones.

In areas with recurring post-harvest gluts, low-cost solar dehydration technologies have also been introduced to convert excess volumes into value-added ingredients like powders and flakes. These shelf-stable forms can be stored for 6–12 months, reducing perishability risks and allowing delayed entry into markets when prices are more favorable. Institutional buyers and food processors offer procurement linkages, ensuring integration into the formal food supply chain.

The success of these processing models depends not only on the availability of equipment but also on the supporting systems around aggregation, technical training, and product standardisation. Where collectives or producer organisations have coordinated processing with structured market access, outcomes have included reduced spoilage, increased price, and improved capacity to absorb production volatility.

Section 3: Market Linkage and Value Retention

In horticultural value chains, the ability to access stable and remunerative markets is essential for ensuring that post-harvest gains translate into improved farm-level incomes. However, in states like Rajasthan, Maharashtra, and Gujarat, market access often gets constrained by supply volatility, cosmetic rejection, price uncertainty, and a lack of structured procurement systems. As a result, farmers frequently engage in distress sales or face post-harvest losses due to missed market entry windows (NITI Aayog, 2018).

Traditional marketing pathways involve a high degree of intermediation, with produce moving from farm to trader to local mandi before reaching institutional or retail buyers. These elongated channels erode value at multiple points and expose perishable goods to delays and quality deterioration. Additionally, smallholder producers often lack access to quality certification, grading infrastructure, or aggregation platforms that meet the specifications of formal markets.

Recent models across Western India have adopted integrated approaches that link post-harvest infrastructure with direct market access mechanisms. In centralised systems, producer-led organisations have created pathways to B2B buyers, export channels, and modern retail by ensuring standardisation, traceability, and volume consistency. In such cases, dedicated buyer contracts, residue-free certification, and branding have enabled farmers to retain a larger share of the end-market value (Sahyadri Farms Case, 2022).

While in decentralised contexts, where institutional linkages are less developed, mobile and localised processing platforms provide access to intermediate goods buyers, including food processors and ingredient manufacturers. These formats allow value retention even when the produce is not suitable for fresh sale. Solar-dried and pulp-based products have longer

shelf lives, enabling flexible timing for market release and price optimisation (S4S Technologies Case, 2025; InnoFarms Case, 2021).

Value retention is closely linked to the ability to control both quality and timing. Models that integrate procurement, processing, and logistics under producer ownership or partnership frameworks demonstrate higher efficiency in converting harvested output into marketable value. Further, participation in structured markets also builds feedback loops for improving pre-harvest practices, crop planning, and investment in quality-enhancing inputs.

Section 4: Waste Recovery and By-Product Utilisation

A significant portion of post-harvest losses in horticulture arises not from direct spoilage alone, but from the underutilisation of produce that is cosmetically rejected, near expiry, or surplus during glut periods. In Western India, where climatic variability, fluctuating market prices, and production concentration are common, such produce is often discarded or sold at minimal value. This represents a missed opportunity for circular use and income diversification.

Traditionally, discarded produce has either been used as cattle feed or allowed to decompose, contributing to nutrient loss and localised environmental burden. However, emerging supply chain models in Maharashtra, Rajasthan, and Gujarat have introduced decentralised mechanisms to convert unusable fresh produce into valuable by-products. These include pulp, compost, biofuel, and dried food ingredients, depending on the crop type and available infrastructure.

In processing-intensive systems, rejected fruits and vegetables are redirected toward secondary processing lines. Produce that fails to meet export or retail grading standards is converted into pulp or puree and sold to institutional buyers in the beverage or food service sector. This helps in reclaiming value from volumes that would otherwise exit the chain without returns (Sahyadri Farms Case, 2022). In some instances, the residual organic waste post-processing is further utilised in anaerobic digesters to produce biogas or in vermicomposting units for biofertiliser production. Mobile and solar-based processing platforms deployed in rural clusters have enabled similar outcomes at smaller scales. Farmers can convert downgraded or oversupplied produce into dehydrated slices, powders, or pulps, which are then integrated into secondary markets. For crops like banana, chikoo, and tomato, this not only reduces perishability but also generates shelf-stable products with longer marketing potential (S4S Technologies Case, 2025; InnoFarms Case, 2021).

Section 5: Financial Barriers in Post-Harvest Management

Financial constraints remain a critical bottleneck in the adoption and scaling of post-harvest management systems, particularly in smallholder-dominated horticultural regions of the Western Indian states. These constraints affect multiple points in the value chain, from on-farm handling practices and access to cold storage, to investment in decentralised processing technologies and transport linkages. Inadequate access to affordable finance prevents producers and grassroots enterprises from adopting capital-intensive but loss-reducing infrastructure.

For small and marginal farmers, the most immediate financial challenge is the inability to absorb the upfront costs of storage, sorting, or drying equipment. Credit access in the post-harvest phase is limited, as most institutional lending remains focused on input provisioning or pre-harvest production cycles. Post-harvest infrastructure, especially decentralised systems such as dryers or mobile units, often fall outside formal lending categories or require collateral that smallholders cannot provide (World Bank, 2021).

In farmer-led enterprises, the financial viability of establishing common facilities such as pre-cooling centers, packhouses, or food processing units relies on collective investment, grant-based support, or hybrid public-private financing. Without external de-risking mechanisms, such capital investments remain out of reach for most producer groups. In some documented cases, phased development supported by government subsidies, export incentives, or institutional buyer linkages has enabled gradual infrastructure build-up.

Decentralised processing solutions introduced in Gujarat and Rajasthan have attempted to address this gap by designing low-cost, modular units operable by local entrepreneurs or women's self-help groups. Yet even these systems face barriers related to working capital, input aggregation, and equipment maintenance. Where no minimum procurement

agreements exist, the risk of underutilisation makes such investments unattractive to local actors.

At the enterprise level, emerging agri-tech firms and FPOs face challenges in scaling their operations because of limited access to growth-stage capital. Debt-financed models often struggle with delayed cash flows and seasonal revenues, while equity models face valuation constraints in semi-formal rural markets. Financial institutions continue to perceive decentralised post-harvest enterprises as high-risk, limiting innovation diffusion and private sector participation in infrastructure delivery (NITI Aayog, 2018).

Table 1: Comparative Supply-Chain Measures to Reduce Post-Harvest Loss

Dimension of Post-Harvest Loss	Sahyadri Farms Response	InnoFarms Response	S4S Technologies Response
Transport & handling losses	Centralised aggregation, farmer collection centers, cold chain trucks	Mobile units eliminate transport delays by processing near farms	Localised pre-processing stations reduce the need for long-distance transport
Processing capacity	On-site packhouse, pulp unit, grading lines, and processing for multiple commodities	Mobile van with pulping, drying, and packaging; solar-powered	Solar-powered dehydration units (off-grid), scalable micro-processing at the village level

Market linkage	B2B, retail, and export markets with quality certification and traceability	Bulk buyers, regional B2B processors, and local institutions	B2B supply to food processors and institutional buyers for powders and flakes
Financial barriers	Shared infrastructure under FPO; equity participation model	Low capital requirement due to mobile unit; pay-per-use model	Low-cost drying tech with buy-back assurance lowers entry barriers
Shelf-life & perishability	Pre-cooling, cold storage, ripening chambers, and residue-free certification	Processing on-site extends shelf life via pulp and dried products	Solar drying enhances shelf life significantly (6–12 months), reducing glut-related waste
Value recovery from surplus/waste	Pulping, composting, and biogas generation from non-grade produce	Converts cosmetically rejected produce into intermediate goods	Converts near-expiry produce into shelf-stable commercial products

Conclusion

The success of post-harvest solutions in Western India hinges on their alignment with local production scales, perishability profiles, and market dynamics. Key enabling factors include decentralised infrastructure close to farm-gates, integration with producer collectives, and context-adapted technologies such as solar drying and mobile processing units. These models succeed by reducing handling time, stabilising surplus, and enabling value retention through intermediate goods.

Critically, the presence of institutional partnerships, scheduled procurement, and basic quality standardisation further enhances viability. Financial de-risking mechanisms such as subsidies, grants, government schemes supporting FPOs, or anchor buyer contracts play a pivotal role in scaling adoption.

Regions with similar smallholder-driven horticulture, seasonal gluts, and weak cold chain infrastructure can adopt these models by fostering community-led platforms, ensuring modular and low-cost technologies, and integrating market linkages into the design. Replication requires adaptive planning that considers local crop portfolios, infrastructure gaps, and producer capabilities, supported by targeted policy and financing frameworks.

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