# Field to Fork: Navigating Food Security via Post Harvest & Supply Chain Management

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In a world grappling with the dual challenge of a growing population and the need to ensure food security, post harvest and supply chain (PHSC) management stand as critical areas of focus. The Food and Agriculture Organization (FAO) estimates that nearly one-third of food produced for human consumption is lost or wasted globally, amounting to approximately 1.3 billion tons per year. Efficient PHSC are essential to mitigate these losses, enhance food security, and ensure sustainable agricultural practices. Journey of farm produce from harvest to the consumer's table is a multifaceted and complex one, where the supply chain network needs to be seamlessly connected to ensure that no time is lost in the process because it leads to wastage of perishables. This short article explores emerging prospects towards smarter versions of PHSC management, emphasizing efficiency, value addition, and traceability as key factors in securing food supply. Key elements and related optimizations are pinpointed along with ways to harness benefits of smart tools and technologies to overcome the challenge of wastes & wastage of food encompassing its qualitative as well as quantitative portraits at global scale.

## IMPORTANCE OF POST HARVEST MANAGEMENT (PHM)

PHM involves processes that maintain the quality and extend the shelf life of agricultural products after harvest. Effective postharvest handling can significantly reduce food losses, a crucial factor in food security. The Food and Agriculture Organization (FAO) reports that about one-third of the food produced for human consumption is lost or wasted globally. In countries like India, these losses are mainly due to poor postharvest practices. Proper PHM includes timely and efficient harvesting, cooling, storage, processing, packaging, and transportation. For example, cooling harvested fruits and vegetables immediately can slow respiration rates and delay spoilage. Modern storage facilities with controlled atmospheres can further extend the shelf life of perishables, reducing waste and ensuring food reaches consumers in optimal condition.

**Enhancing the Supply Chain for Efficiency :** Unlike other segment s the supply chain in farming sector, happens to be highly complex network involving multiple stakeholders, including

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farmers, processors, distributors, retailers, consumers; and all under highly uncertain and uneven situations. An efficient supply chain always ensures that produce moves swiftly from farms to consumers, reducing transit time and minimizing losses. Advanced technologies such as the Internet of Things (IoT), block chain, and artificial intelligence (AI) can revolutionize the supply chain, by monitoring/managing produce conditions during transportation & storage, providing real-time data, and offering a transparent & immutable ledger for tracking the journey of produce from farm to fork, building trust and accountability among stakeholders.

**Value Addition:** It remains a giant intrusion beyond mere "Basic Produce" to transform raw farming products into more valuable goods, increasing their shelf life, reducing waste, and enhancing marketability. Activities such as canning, freezing, drying, and packaging can significantly reduce wastage and provide consumers with convenient, long-lasting products. Value-added products open new markets for farmers and boost their incomes. By investing in small-scale processing units and training farmers in value addition techniques, rural communities can create sustainable livelihoods while contributing to food security.

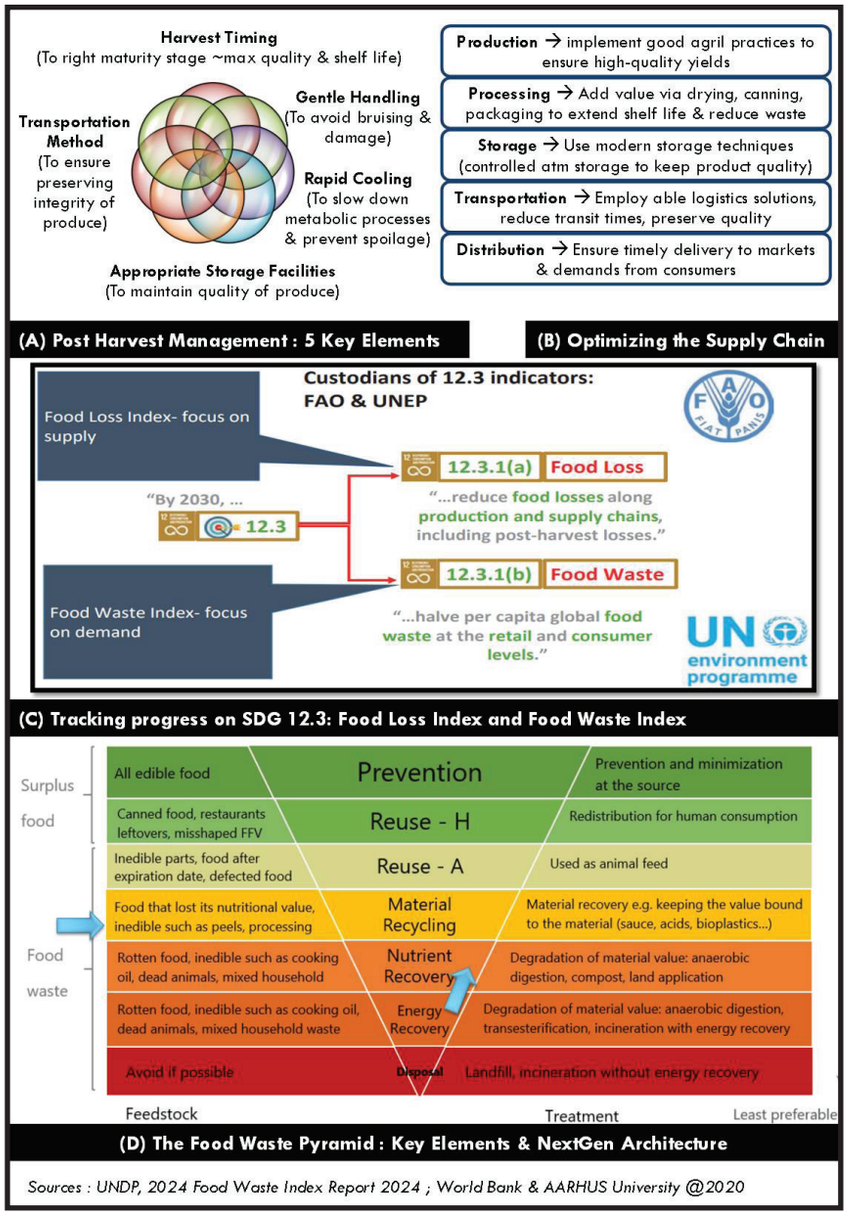


*Fig-1 Pictorial Views on Key Elements of PHSC Management & Food Loss/Wastage Indexes*

## ENTIRE TRACEABILITY: ENSURING PRECISION AND BUILDING TRUST

Traceability in the agricultural supply chain is emerging as another innovative interference; which indeed means, tracking the movement of produce from farm to consumer. It provides many advantages like; (1) Consumer confidence via necessary information to assure their food's safety and quality, even the origin of food from and how it has been handled; (2) Traceability systems hold all stakeholders in the supply chain accountable for their actions, to deal and trace back the issues like contamination/ spoilage allowing for prompt corrective actions; and (3) It facilitates compliance to regulatory bodies with food safety standards. Modern traceability solutions leverage technologies like block chain, providing a tamper-proof record of every transaction & movement in the supply chain, which in turn builds better level of consumer loyalty and trust.

## HARNESSING ROBOTICS FOR ENHANCED PHSC

In recent times, integration of robotics in PHSC presents another transformative opportunity to enhance quality, safety, and efficiency. The demands on the food system necessitate innovative solutions to optimize processes, reduce waste, manage labor shortages, and ensure food safety. Smart technologies (materials science, artificial intelligence, sensors) are revolutionizing the sphere of

opportunities in food sector, where robotic advancements are most recent options. It offers a range of standard applications, from efficient storage and retrieval to automated inventory management and safety improvements. To attain smarter PHSC, robotics can enhance variety of its key stages like quality control, sorting after harvest, storage, picking & packing, grading, sorting, packaging, palletizing, and also managing storage & material flow through mobile robots. These robots may also facilitate real-time monitoring of product quality & storage conditions, automate inventory management, optimize space utilization etc., ensuring the integrity of fresh produce from farm to fork. For NextGen PHSC experts below given viewpoints have their own significance,

• **Quality Management and Loss Reduction:** Fresh farming produce is often highly perishable, and significant food loss occurs at various stages of the supply chain (even >30% before reaching retail). Effective realizations of its 5 key elements (Fig-1 A&B) via standard operating procedures, grading, sorting, and optimized transport and storage conditions, is emerging as need of hour. Robotics may plays a vital role by providing precise, consistent handling and monitoring throughout such supply chain.

• **Robotic Grasping & Manipulation:** Though smarter robots are increasingly becoming essential in fresh food handling/processing, still the traditional industrial robots too perform repetitive tasks (picking, moving, stacking, palletizing) quite effectively at lesser costs. In recent times concept of collaborative robots (cobots), is also flourishing where robots work alongside humans in shared workspaces. Cobots are often equipped with sensors and safety features, making them flexible & safe for various tasks. Primary challenge in handling fresh produce is managing their complex, varied characteristics without causing

damage or spreading pathogens. Down-scaled indexes on food waste and food loss and also a globally adopted architecture of key food loss pyramid (Fig 1 C &D) could be better understood with such grasping & manipulations.

• **Innovations in Grasping Solutions:** Robotic handling of fresh products involves both contact-based (electric, pneumatic, hydraulic, multi-body grippers) and air-based mechanisms (suction cups, levitation grippers). Soft end-effectors, made from advanced materials, are becoming commercially viable, providing flexible, hygienic solutions for delicate fresh produce. These innovations ensure minimal damage and contamination, preserving quality at both individual and batch levels.

• **Robotic Navigation and Autonomous Mobile Robots (AMRs):** AMRs offers enhanced post-harvest logistics by optimizing transportation and material flows. These robots can autonomously navigate warehouses, manage inventory, and perform tasks such as storage and retrieval, monitoring, and quality checks. They react to their surroundings, follow designated paths, navigate around obstacles, and handle varying payloads.

• **Quality-Sensitive Warehouse Automation:** Managing perishable products in warehouses requires complex inventory systems, considering factors like product perishability, quality-driven demand forecasting, and sustainability. Their transportation capabilities allow them to move products based on quality assessments, ensuring optimal storage and handling conditions

## CONCLUSION

In conclusion, effectively navigating food security through robust post-harvest and supply chain management is crucial to mitigating global food waste and loss, as underscored by international food waste and food loss indexes reflected herein. By implementing strategic practices from field to fork, we can enhance food availability, sustainability, and resilience, ensuring a more secure future for global agriculture. The journey of farm produce from harvest to the consumer's table is fraught with challenges that require concerted efforts to overcome the newer issues by prioritizing postharvest management & enhancing supply chain efficiency to ensure farm-to-fork traceability, and thus reduce food losses and improve food security.