


Minimizing postharvest food losses: a vital strategy to alleviate food insecurity and malnutrition in developing nations: a review

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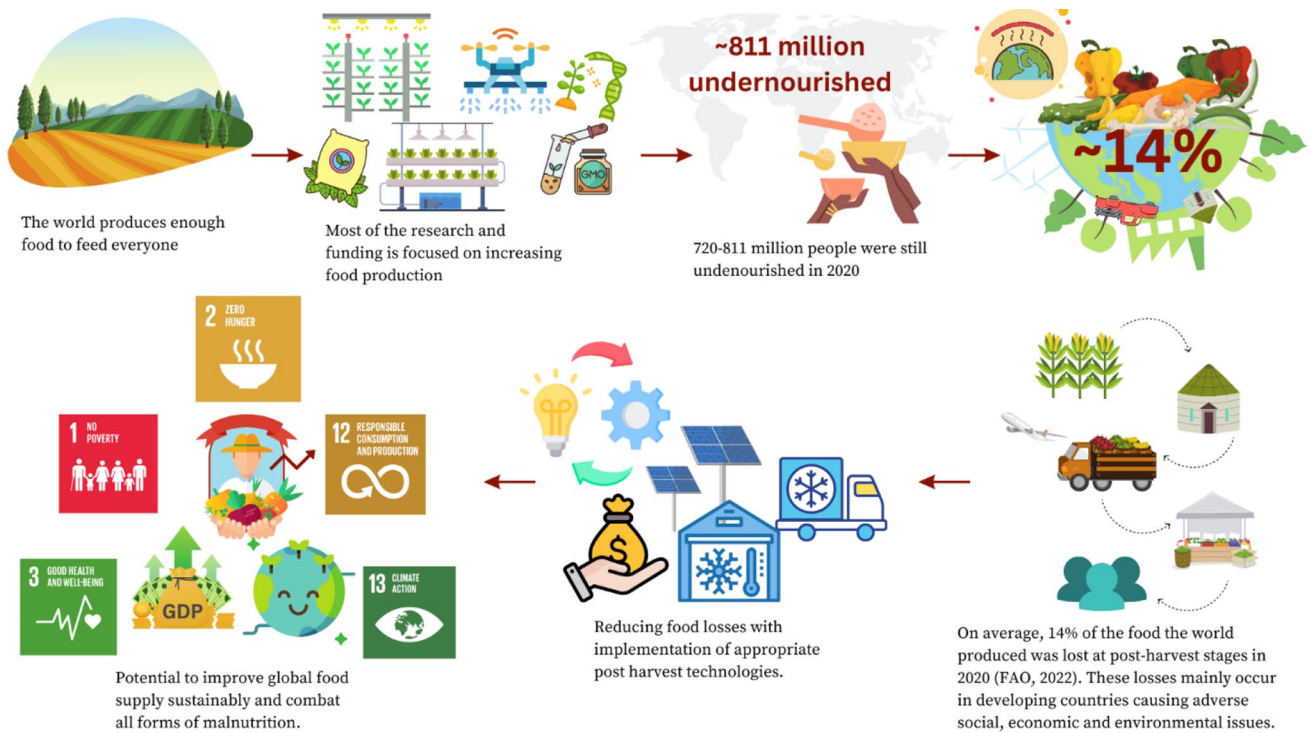
Abstract

As global food production encounters escalating challenges, postharvest losses (PHLs) emerge as a critical yet often overlooked issue. Despite considerable progress in food production, PHLs remain a significant concern, accounting for an average of 14% of food production in 2021. Against the backdrop of 811 million people facing food insecurity and the triple burden of malnutrition, it becomes increasingly evident that reducing food losses offers a sustainable solution to enhancing global food and nutritional security, particularly in developing countries. This review aims to underscore the significance of PHLs, their impact on global food security, and the current PHL scenario in developing nations. Despite the abundance of innovative technologies developed by researchers, accessibility to these technologies remains limited for farmers in many countries. The ongoing struggle and dire circumstances surrounding proper food handling in developing nations necessitate immediate action. Research efforts must focus on assessing the regional applicability, costs, and economic returns of existing technologies for mitigating PHLs. In addition to capital investments, the long-term sustainability of reducing PHLs hinges on ensuring the effective use of these technologies through education and training.

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Graphical Abstract



Keywords Postharvest management · Malnutrition · Food loss · Food insecurity · Food supply chain

1 Introduction

Since the inception of the Green Revolution in the 1950s, there has been a remarkable increase in food production driven by modern agricultural advancements, including innovations in irrigation, fertilizers, herbicides, genetically modified better-yielding grain types, and mechanized agricultural labor. This surge in agricultural productivity has been transformative for many nations, such as India and China, which have successfully averted famines by adopting advanced plant technologies like selective crop breeding [1, 2].

However, this unprecedented increase in food production has come at a cost to the environment and human health [3]. Moreover, agriculture uses an astounding 50% of the world’s habitable land [4]. Acknowledging this dilemma, researchers are developing groundbreaking technologies for sustainable food production. Promising strategies, such as organic fertilizer use, drones in farming, and vertical farming systems in urban settings [5, 6], Klauser and Pauschinger, 2021) have emerged. However, widespread adoption of these technologies, especially in underdeveloped countries, remains a distant goal.

Despite already producing more than 1.5 times the food needed to feed the projected 10 billion people by 2050 [7], the Food and Agriculture Organization of the United Nations (FAO) reported a troubling increase in the number of undernourished people to 811 million in 2020 [8]. This alarming rate of undernourishment is driven primarily by factors such as poverty, social inequality, and inadequate access to healthcare and education. A critical underlying factor contributing to this high prevalence of malnutrition is the agricultural practices used in various countries [3]. Nearly 2 billion people rely on an estimated 500 million smallholder farms in developing nations for their sustenance, providing 70% of the calories produced to people in Sub-Saharan Africa and South Asia [9, 10]. However, these small-scale farmers frequently experience food and nutritional insecurity due to inadequate consumption of their own produce and limited access to other foods, leading to poor diets and malnutrition.

Traditionally, agricultural interventions have focused on boosting food production and revenues to address malnutrition and poverty [1]. While this approach remains relevant, it has become increasingly clear that food poverty often stems from access issues, including purchasing power and food affordability, rather than supply [7]. Moreover, agricultural produce undergoes several steps from harvest to the end consumer, with each stage in the food production chain requiring specific techniques and technologies to ensure the safe delivery of food for consumption.

Notably, across the food supply chain, from harvesting to consumer delivery, postharvest losses (PHL) are evident at every stage, with approximately ~14% of global food production failing to reach its intended consumers [11]. PHL are most prevalent in low- and middle-income countries (LMICs) (Fig. 1), primarily due to financial constraints, managerial limitations, and technical challenges in harvesting methods, storage and cooling facilities in adverse climatic conditions, and packaging and marketing systems [11]. The potential to combat food insecurity by tackling PHLs is too critical to ignore. A case study in Uganda reported farm-level losses of maize range from 280,000 to 420,000 tons annually, considering a conservative estimate of on-farm losses at 10 to 15% during harvesting and drying, and total annual production of 2.8 metric tons [12]. Given that maize holds a food value of 3,700 kilocalories per kilogram, PHLs in food value amount to a minimum of 1.04 trillion kilocalories. This substantial quantity could have sustained 1.14 million individuals for an entire year at a daily intake of 2500 kilocalories, representing approximately 3.4% of Uganda's population of 34 million. This example highlights the vast economic and humanitarian cost of PHLs. While the Green Revolution significantly increased crop productivity, it did not address PHLs. Today, developed countries waste around 670 million tons (Mt) of food, while developing nations lose 630 Mt of food before it even reaches consumers [13].

Adding to this complex landscape, the ongoing conflict between the Russian Federation and Ukraine, two major agricultural commodity producers with food exports totaling around 12% of total caloric commerce sold globally [15], has disrupted about one-fifth of the world's food trade. This disruption carries potential disastrous repercussions for about 50 countries, including Bangladesh, Egypt, Iran, and Turkey, which purchase most of their wheat from Russia and Ukraine. Moreover, the ongoing food price inflation triggered by disruptions in the supply chain due to the COVID-19 pandemic has exacerbated the situation. As exemplified by Sri Lanka, where food price inflation has destabilized markets and even led to government collapses [16], the repercussions are profound. In war-torn regions, where food insecurity rages and every morsel matters, minimizing PHLs becomes a vital lifeline, stretching scarce resources and feeding those ravaged by conflict.

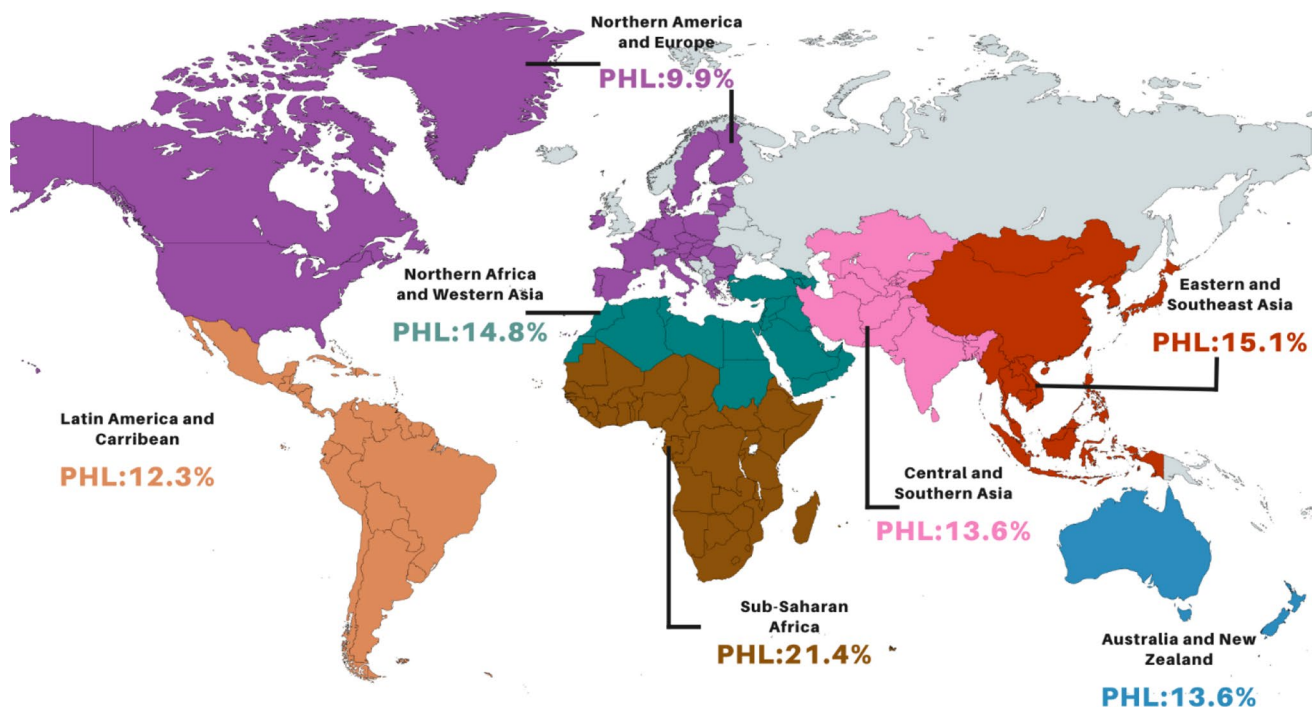


Fig. 1 Percentage of postharvest losses in different regions in 2020. (Data source: [14], Tracking progress on food and agriculture-related SDG indicators 2021: A report on the indicators under FAO custodianship. Rome. Graphic created with Canva software and mapchart.net)

Hence, this article emphasizes the critical need for enhanced postharvest management in developing nations, presenting compelling statistics, real-life case studies, policy recommendations, and ongoing initiatives. We aim to highlight how reducing PHL can lead to significant improvements in food security and sustainability.

2 Triple burden of malnutrition

Malnutrition presents a multifaceted challenge encompassing undernutrition (lack of food calories), micronutrient deficiencies, and the dual burden of obesity and overweight—a complex phenomenon often termed the ‘triple burden’ of malnutrition. This issue significantly affects individuals of all ages, particularly those in developing nations [17]. According to FAO global estimates, 190 million children under the age of five suffer from stunted growth and 47.5 million experience wasting, with 89–93% of these children likely living in LMICs [8] (Fig. 2).

Traditionally, communities in developing countries relied on diets rich in freshly harvested fruits, vegetables, and locally sourced fish. However, over time, dietary patterns in these regions have shifted towards more affordable and convenient Western diets characterized by high levels of processed foods, sugars, and saturated fats, contributing to rising rates of obesity. [18]. An estimated 2 billion individuals globally suffer from one or more micronutrient deficiencies, with iron and zinc being the most widespread [19]. These essential nutrients are abundantly available in diverse fruits and vegetables, including sweet potato, papaya, mango, and leafy vegetables. However, a significant barrier to realizing their nutritional potential lies in the prevalent issue of PHLs [20].

The Green Revolution’s focus on increasing the production of inexpensive, nutrient-poor cereals to combat malnutrition must evolve. There is a need to prioritize cultivating a wider variety of local plants, including fruits, vegetables, and underutilized crops. Equally important is ensuring the successful delivery of these nutritious commodities to consumers without losses in the supply chain due to spillage, mechanical damage, contamination, or pest attacks. A case study in Nigeria highlighted the substantial impact of farm-level losses, with even modest losses of 2% resulting in significant nutritional deficits, such as the loss of around 69,000 tons of sweet potatoes or approximately 59.34 billion kilocalories, which could have sustained 65,000 individuals for a year, assuming a daily intake of 2500 kilocalories [12].

Furthermore, various interventions have been devised to enhance the micronutrient intake of populations. For instance, an initiative involving the biofortification of maize and sweet potato with Vitamin A, iron, and zinc represents a commendable strategy to augment micronutrient intake [21]. However, inadequate storage and processing techniques

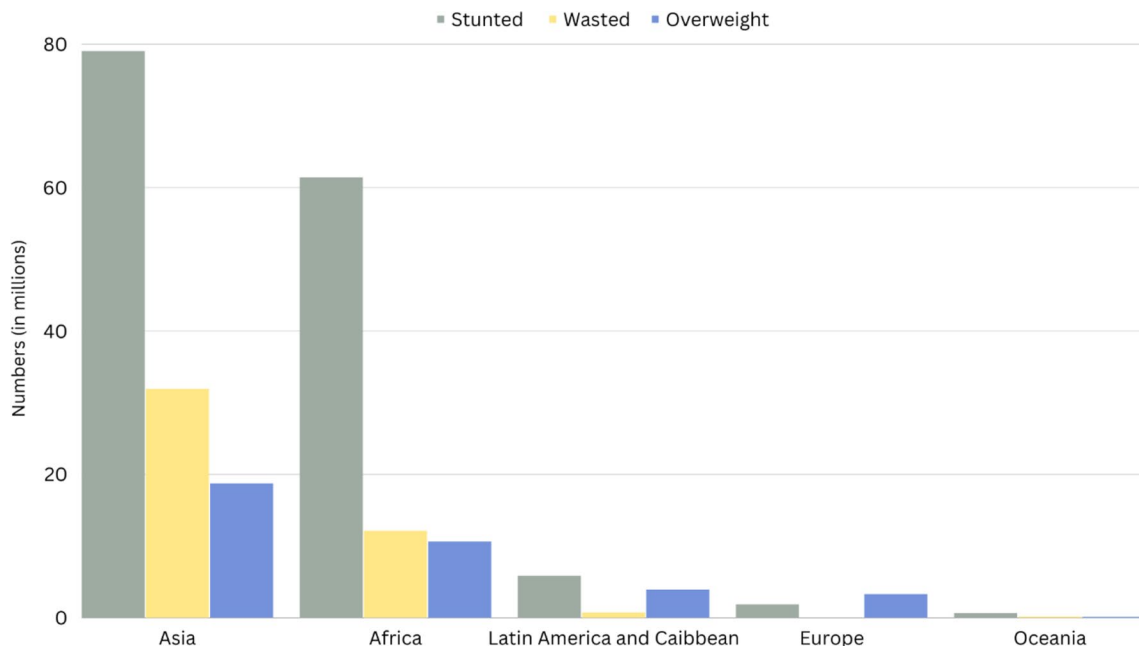


Fig. 2 Number of children under the age of five who were stunted, wasted, and overweight in 2020. (Data source: United Nations Children’s Fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/The World Bank. Levels and trends in child malnutrition: key findings of the 2021 edition of the joint child malnutrition estimates. Graph created with Canva software)

can lead to significant nutritional degradation of provitamin A carotenoids. Conventional storage methods, including ordinary sacks, granaries, and metallic silos, that primarily aim to shield grain from pests and mold have shown limited effectiveness in minimizing carotenoid losses and preserving nutritional quality, with reported losses of up to 90% over 8–12 months in controlled storage conditions.

Therefore, efforts to improve food production and implement biofortification strategies may be counterproductive if nutritious produce fails to reach consumers intact. Addressing logistical and distribution challenges is crucial to realizing the full nutritional potential of health-enhanced crops, thereby advancing nutritional goals and ensuring food security.

3 Understanding PHLs in developing countries: socioeconomic, nutritional and environmental impacts

Postharvest losses encompass the loss of edible food at any stage of the food supply chain—including production, storage, transportation, processing, and marketing—before it reaches the market [22] (Fig. 3).

The postharvest process begins at harvest, directly from the production site, where growers must decide when to harvest various fruits and vegetables to meet customer demand for desired features. Harvesting under ideal physiological conditions is crucial for obtaining high-quality characteristics such as aroma, firmness, color, flavor, and extended shelf life [23]. The correct harvesting method is crucial for avoiding mechanical damage [24]. However, common harvesting practices in many developing countries, such as handpicking fruits or using secateurs or clippers, often lead to problems such as produce dumping from picking bags and overfilling storage bins, resulting in fruit compression and bruising [25, 26]. For instance, in Ghana, once a major tomato producer in West Africa, substantial financial losses occurred due to rough handling during harvest, leading to failed tomato enterprises [27] and increased tomato imports (> 7000 metric tons from neighboring nations annually) [28]. Furthermore, farmers frequently discard their harvested crops when market prices plummet, or demand dwindles. For example, during the recent COVID-19 outbreak, > 80% of raw turmeric in Odisha, India, was discarded due to plummeting prices during the lockdown [29].

Proper storage of perishable commodities like fruits and vegetables is crucial to meet off-season demand. Most storage insects and molds develop rapidly between 20 and 35 °C, with temperature fluctuations leading to moisture accumulation and mold growth [30]. However, the lack of cold storage infrastructure, particularly in rural regions of developing

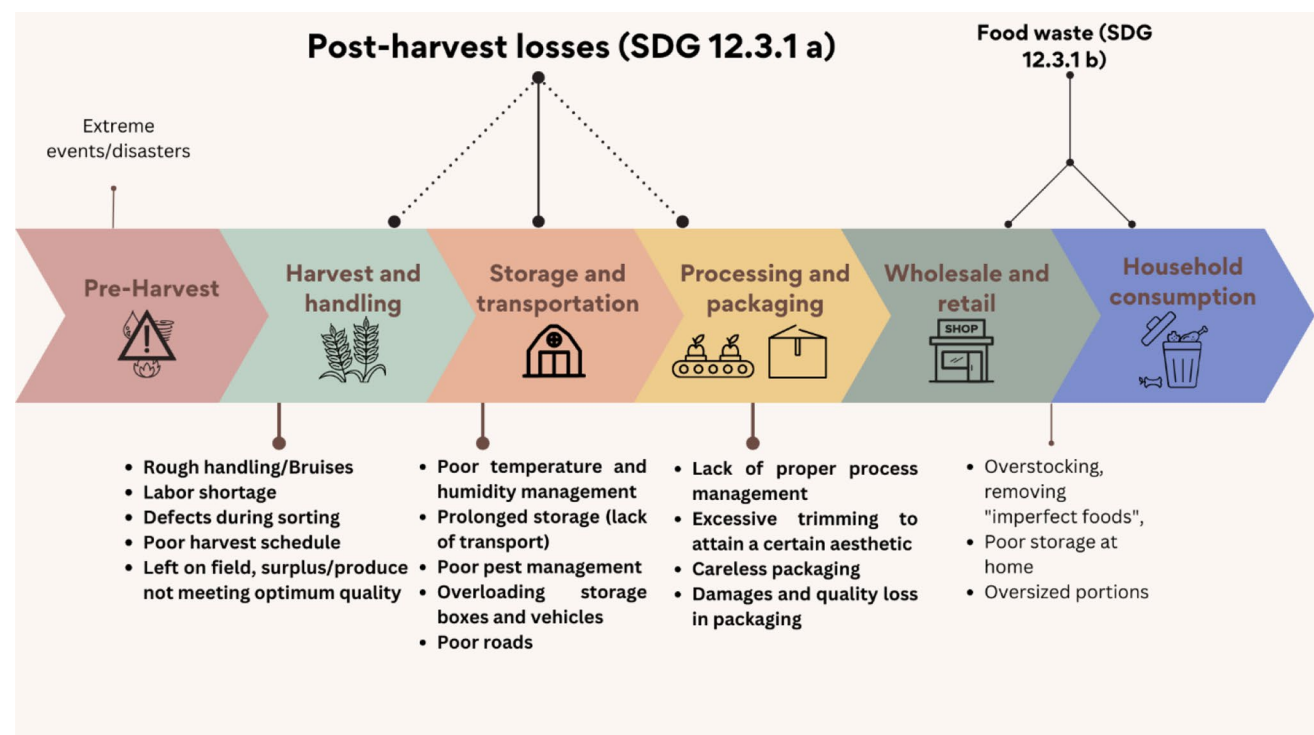
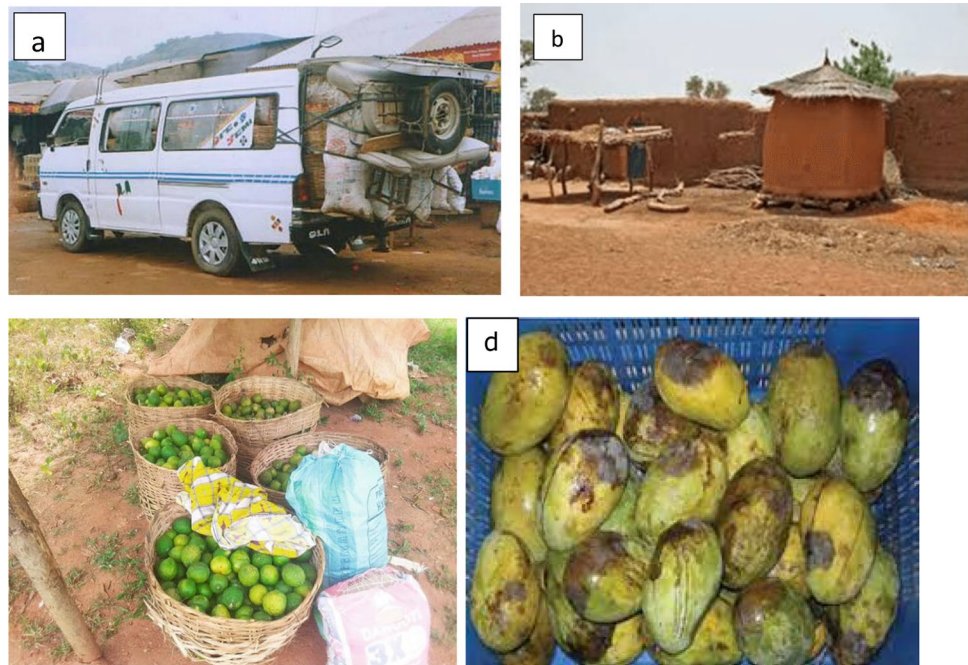


Fig. 3 Causes of food losses in the supply chain with emphasis on PHL (Credit: graphics designed with Canva software)

Fig. 4 **a** Overloaded truck with improper storage, **b** traditional granary bags used for storage in that are prone to pests and pathogens, **c** lemons stored in wicker baskets with sharp edges **d** rotting mangoes during storage in Bangladesh. Source: **a** Oluyinka et al., 2022, **b** Mofokeng, 2016 **c** Oluyinka et al., 2022, **d** Elda, FAO, 2018 [33]



nations, leads to significant food losses. For instance, in Tanzania, ~25% of fresh produce is wasted due to the absence of cooling systems [31].

Inadequate transportation and packaging methods also contribute to food losses in developing countries (Fig. 4). Fragile bamboo baskets with sharp edges, poorly maintained vehicles loaded beyond their designed capacity, the absence of refrigeration facilities, and exposure to intense heat exacerbate the vulnerability of perishable goods during transit, especially on uneven roads, leading to overripening, bruising, and microbial spoilage [25, 26, 32].

Manual processing tasks like grain threshing can lead to further losses from spilling, incomplete separation of grain from chaff, and breakage due to excessive hammering. Inadequate cleaning after threshing can increase mold development, pest infestations, and damage to processing machinery. For instance, in Pakistan, ~4% of grain is lost during threshing and winnowing [34]. Even pre-processed foods like salads and fresh juices contribute to wastage during fruit and vegetable processing [35]. A study in Brazil revealed that one market unit generated 25 tons of waste from minimally processed fruits and vegetables in a year [36].

Postharvest losses have profound socioeconomic impacts at every stage of the food supply chain, affecting farmers' financial stability, reducing income and job opportunities, exacerbating food insecurity, and destabilizing markets. For instance, in Egypt, the cost of human work due to PHLs is substantial, with an estimated 8.3 million workdays and 7.48 million work hours annually used in producing lost food [37].

In addition to causing economic losses, PHLs result in the depletion of vital nutrients throughout the supply chain. The absence of proper storage infrastructure leads to the gradual degradation of nutrients in food over time [30]. For instance, traditional sun-drying methods accelerate the degradation of heat-sensitive vitamins like vitamin C in fruits and vegetables [38]. A Nigerian study examined the impact of sun drying without the preliminary steps of blanching and sulfiting, revealing significant losses of ascorbic acid, ranging from 46.5% in okra, 69.67% in sweet pepper, and 74% in tomato [39].

While a growing body of literature has quantified food losses at various supply chain stages, nutritional postharvest losses (NPHLs) remain relatively underexplored. Among the limited available studies, one investigation conducted in Sub-Saharan Africa focusing on sweet potato, maize, and cowpea revealed that white maize losses translated into carbohydrate losses of 17–25% and protein losses of 22–25% in Zimbabwe, with significant implications for vulnerable groups such as children and pregnant women [40]. In the same study, PHLs in Ugandan sweet potato affected 3.3% of the population's nutritional requirements. Despite sweet potato being a significant carbohydrate source, these losses raised concerns about nutrient availability for vulnerable groups, potentially leaving around 70,000 individuals (1.7% of the population) facing daily nutritional deficits in terms of carbohydrates and energy [40].

A study on the Zambian bean value chain conducted over three months revealed significant nutrient losses, including 1,128 g protein, 2,468 g carbohydrates, and 345 mg iron, during postharvest handling [41]. Had these lost beans been consumed, the protein losses alone could have fulfilled the Recommended Daily Allowances (RDAs) for 98 children and 27 adults. Furthermore, the carbohydrate and iron losses could have met the RDA for 21 adults. Effectively addressing these nutritional losses requires the first crucial step of collecting accurate evidence through refined measurement techniques capable of discerning the types and extents of nutrient losses. The existing research gap partly arises from the limited and expensive methods for accurately assessing these losses. Nevertheless, a thorough examination of nutrient losses would yield robust data-driven insights, enabling the formulation of impactful policies, interventions, and initiatives aimed at curtailing losses and enhancing overall nutritional value.

In addition to causing nutritional deficits, PHLs also adversely impact the environment. Mitigating agriculture's environmental impact is crucial to embracing a circular economy [42]. A circular economy in agriculture is a system where farms strive to operate as closed-loop systems, minimizing waste by reusing resources and converting byproducts from one process into inputs for another. Thus, reducing food loss and maximizing the utilization of agricultural waste are essential components of implementing a circular agriculture model. Currently, the agricultural sector contributes over 26% of global greenhouse gas emissions, uses 70% of the world's freshwater, and occupies half of the global land [43, 44]. Food production is closely linked to synthetic fertilizers, containing finite resources like phosphorous. Kumm et al. [45] revealed that about a quarter of the produced food supply (614 kcal/cap/day) is lost within the food supply chain. Lost and wasted food represents a significant share of resources, accounting for 24% of total freshwater used, 23% of global cropland area, and 23% of global fertilizer consumption. Per capita resource usage for food losses is highest in North Africa and West-Central Asia (freshwater and cropland) and North America and Oceania (fertilizers), while Sub-Saharan Africa (freshwater and fertilizers) and Industrialized Asia (cropland) demonstrate the smallest per capita resource usage. Relative to total food production, South and Southeast Asia experiences the least food supply and resource losses. If global food supply losses could match the lowest loss and waste percentages observed in any region throughout the supply chain, we could potentially halve food supply losses, providing enough food to feed approximately one billion more people [40].

Unused food occupies approximately 1.4 billion hectares of land or nearly 30% of the world's agricultural land area. With a billion malnourished individuals and escalating pressure on finite natural resources, it becomes crucial to comprehend the actual loss of kilocalories within the food supply chain [45]. Similar to the research on NPHLs, studies determining how many resources could be conserved by minimizing PHLs are also essential. By focusing on reducing post-farmgate food losses—during storage, transportation, processing, and distribution—we can significantly decrease environmental impacts and improve the efficiency and sustainability of food systems.

4 Technological advancements

Postharvest science is continuously evolving, with researchers identifying new strategies and technologies to minimize food losses across every stage of the supply chain [46]. Recent technological advancements include machine vision, 3D imaging, light and aroma sensing, and soft robotics, which enable the precise identification of fruit maturity for optimal picking [47]. Moreover, modern packaging and storage techniques can prolong the shelf life of food, prevent microbiological deterioration, and preserve freshness. These approaches encompass various methods such as the use of chemicals like 1-methyl cyclopropane (MCP) to inhibit ethylene production in fruits and vegetables, modified atmosphere packaging, controlled atmosphere storage (including hypobaric or low-pressure storage), and vacuum cooling and hydro cooling to remove field heat from harvested produce [48]. Other innovations for minimizing food losses include essential oils for disease management [49, 50], edible films like chitosan derived from crustacean waste [51], novel silk-based active and intelligent packaging [52], electronic nose technology for early detection of postharvest diseases [53, 54] and light-emitting diodes for preservation (Thilini Deepashika [55]). Moreover, innovations like low-cost energy-saving cooling systems (e.g., evaporative coolers) are gaining traction to help small holder farmers in many parts of the world [56]. Furthermore, nanotechnologies, including nanopackaging and disease biocontrol with nanomaterials, integrated into these approaches can overcome challenges in sustainable postharvest management [57, 58]. Such innovative technologies hold great potential to reduce food losses at various stages of the supply chain and can be tailored to the specific needs of different regions. However,

despite these remarkable scientific breakthroughs, countries like India [59], Bangladesh [60], Sri Lanka [61], Rwanda, and Tanzania [62], continue to experience horticultural production losses ranging from 30 to 80%. These figures underscore the importance of not only developing new technologies but also ensuring their widespread adoption and accessibility, particularly in regions where food losses remain a significant challenge.

5 Challenges and opportunities

5.1 Technology and capacity building

The potential of postharvest technologies is vast, but their widespread adoption in developing nations faces several challenges, including limited farmer access, research gaps, and inadequate infrastructure and resources. Policy interventions are crucial to bridging this gap. Funding schemes should prioritize research collaborations with farmers, consider market viability, and focus on low-cost, adaptable technologies. Bridging the gap between laboratory findings and practical application would ensure that postharvest technologies meet local needs and are more likely to be adopted on a large scale [63]. Financial assistance from international organizations and developed countries can assist with infrastructure and tool costs, but effective use requires proper training and sustainable support systems [64].

Simple yet valuable changes are often overlooked in developing countries, such as avoiding overloading trucks, ensuring proper ventilation, reducing the overuse of treatments like over-waxing and hot-water dips for insect control, and refraining from using unlicensed pesticides [65]. Techniques like cushioning storage boxes or lining rough containers with inexpensive fiberboard can minimize bruises and abrasions during transport. Extension services can provide educational programs to raise awareness of these issues, but ongoing support is needed to reduce food losses sustainably [63].

Building capacity in postharvest research is critical for developing countries and can be achieved through internships, staff training, laboratory upgrades, improved access to information, and mentoring. Collaboration among experts from various fields, including horticulturists, plant pathologists, economists, engineers, food technologists, and consumer scientists, is vital for creating successful research and extension programs [63, 66].

Additionally, midstream agents within the food supply chain, including aggregators, wholesalers, processors, and transportation providers [67], are essential intermediaries between farmers and consumers. However, they can inadvertently contribute to PHLs due to various factors:

(1) Profit maximization—midstream agents, like any business, prioritize profit, which can lead to prioritizing speed and efficiency over proper handling and storage practices, sometimes resulting in bruised and perishable produce reaching consumers faster but with shorter shelf lives [68], (2) Meeting quality standards—retailers often establish stringent quality standards regarding appearance and size, and midstream agents may feel compelled to adhere strictly to these standards, even if the produce is still edible, leading to unnecessary losses; (3) Limited capacity and infrastructure—small-scale or poorly equipped midstream agents may lack the necessary storage facilities, refrigerated transport, or trained personnel to handle perishables effectively, contributing to spoilage and wastage [69], (4) Information asymmetry—a lack of transparency and communication between farmers and midstream agents can lead to misunderstandings and inefficiencies in the supply chain. For example, farmers may not receive adequate information about desired product specifications, leading to produce being rejected or discarded unnecessarily due to mismatched expectations [70].

Understanding the motives of midstream agents and their impact on PHLs is essential for developing targeted interventions to minimize losses in the overall food supply chain. Strategies promoting collaboration for solutions and sustainable practices among midstream agents can contribute to reducing PHLs.

5.2 Research priorities and policy suggestions

Addressing PHLs requires a multifaceted approach that includes refining research priorities and implementing effective policies. Firstly, there is a need to refine specifications and guidelines for managing various cultivars of each commodity produced in different regions. This involves understanding the postharvest physiology and implementing best management practices for indigenous crops grown in developing nations [71]. Tailoring interventions to local conditions and demands can optimize resource allocation and reduce losses. For example, in the small South Pacific

Fig. 5 **a** ‘Sabzikothi’ storage design, **b** Farmers in India using ‘Sabzikothi’ for selling their produce (Source: saptkrishi.com)

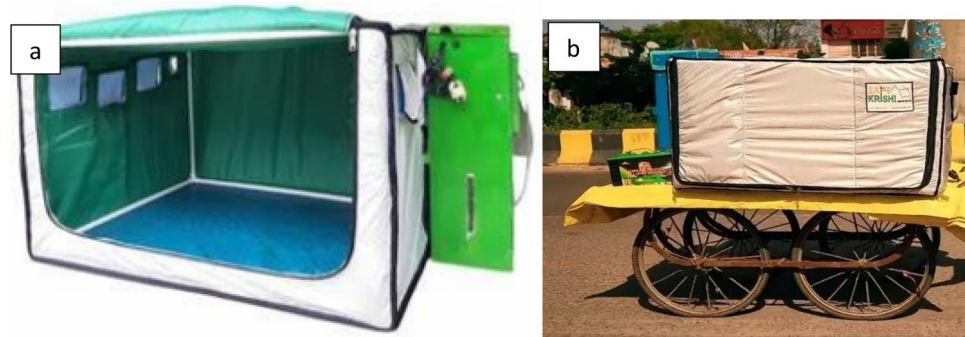


Fig. 6 Walk-in cold rooms in Nigeria (Source: coldhubs.com)



Island of Fiji, where harvested produce typically travels short distances (usually < 50 km) and involves small quantities [72], interventions like chemical-based approaches to reduce the prevalence of postharvest infections may be more economically viable than introducing costly postharvest handling facilities.

Secondly, each nation should establish a system similar to the African Postharvest Losses Information System [73] to collect, analyze, and disseminate comprehensive data on PHLs, including nutritional losses. This data is crucial for a holistic understanding of the impact of PHLs on food security and public health. Identifying critical points and crops in the postharvest chain will help prioritize interventions for maximum effectiveness. Thirdly, accurate data on PHLs, resource depletion, and carbon footprint strengthen the case for policy changes, resource allocation, and investment in infrastructure and technology to reduce losses. Policymakers can use this information to track progress and measure the effectiveness of implemented interventions, ensuring that resources are directed to areas with the most significant potential benefit [70].

Moreover, strategies to reduce PHLs are pivotal in addressing the triple burden of malnutrition in developing countries [74]. Such interventions dovetail with COP28's recent emphasis on sustainable food systems, recognizing PHL reduction as a pillar of resilience.

6 Ongoing and successful campaigns

Several ongoing campaigns and initiatives are tackling PHLs and contributing to achieving Sustainable Development Goal (SDG) 12.3, which aims to reduce food loss and waste by 50% per capita by 2030 [75]. One such initiative is the '123 Pledge,' established during COP27, which promotes environmental sustainability and aligns with the food security and nutrition goals at the core of SDGs 1, 2, 3, and 13 [76]. National and international legal frameworks and policies have been implemented to reduce PHLs, with organizations like the World Food Programme actively contributing by enhancing storage facilities using hermetic bags and educating farmers on best postharvest management practices, resulting in a 98% reduction in PHLs in countries like Ethiopia and Uganda (innovation.wfp.org) [77]. The Rockefeller Foundation's YieldWise initiative [78], launched in 2016, is accelerating the adoption of postharvest technologies and practices while supporting the scaling up of effective interventions. This initiative has invested in improving postharvest infrastructure,

including cold storage facilities and transportation networks, resulting in a 20–30% reduction in PHLs in East Africa (rockefellerfoundation.org/initiative/yieldwise).

Encouraging student projects and startups also plays a crucial role in addressing PHLs, as seen in success stories like ‘Sabjikothi’/Preservator, developed by students from the Indian Institute of Technology Kanpur (Fig. 5). This low-cost (< USD120.8 for setup), eco-friendly, and microclimate-based solution extends the shelf life of various horticultural products by up to 40 days. It operates on a 20-W solar panel, consumes just 1 L of water per day, requires no further maintenance or chemicals, and can store up to 500 kg of produce (csrbox.org; Saptkrishi.com [79]) [80]. Social ventures like ColdHubs in Nigeria, which provide solar-powered walk-in cold rooms to extend the shelf life of fresh produce and provide job opportunities for women, are also making significant strides in reducing PHLs (Fig. 6) [31].

Additionally, the Warehouse Receipt System (WRS), implemented by TechnoServe in Africa [81], involves the issuance of receipts to farmers or commodity producers when they deposit their harvest in a certified warehouse. These receipts can be used as collateral to access credit or sell the stored commodities when market conditions are favorable. The WRS effectively reduces PHLs by providing secure crop storage, improves market access by fostering farmer associations, and empowers farmers to access credit and negotiate favorable prices for their produce, thus stimulating rural economies, creating job opportunities, and fostering increased local spending.

Other notable organizations like the Syngenta Foundation for Sustainable Agriculture, International Maize and Wheat Improvement Center (CIMMYT), International Potato Center (CIP), and International Rice Research Institute (IRRI) are also dedicated to reducing PHLs, increasing farmer incomes, and enhancing food security in Africa and Asia. These efforts are crucial for ensuring sustainable food supplies and supporting the livelihoods of smallholder farmers and communities in these regions.

7 Conclusion

Addressing PHLs is paramount due to its far-reaching economic, environmental, and nutritional implications. Numerous studies, particularly in Sub-Saharan African and Asian countries, underscore the urgency of addressing this issue. Investing in postharvest technologies and education is crucial, particularly in areas like the South Pacific islands, the Middle East, and North Africa, where PHL rates are notably high. Prioritizing funding for postharvest research and extension is more beneficial for reducing food insecurity than merely increasing production and land area under cultivation. Each region has unique criteria dictating the suitability of postharvest technologies for implementation, considering economic factors, farmer and community acceptance, and geographical conditions. Therefore, strategies must be tailored accordingly to identify logical solutions and determine which technologies to invest in.

Establishing postharvest working groups at the national level can foster dialogue among stakeholders involved in postharvest technology research and outreach, facilitating effective collaboration. Future research efforts should expand the current knowledge base while remaining adaptable, practical, and suitable for small-scale producers. Assessing the return on investment for each chosen postharvest technology and conducting local PHL and NPHL assessments are essential to identify priority areas for intervention.

Reducing PHLs is not only a standalone goal but also a means to accomplish other sustainable development targets such as enhancing food security and nutrition. Increasing awareness and access to locally sourced, nutrient-dense foods can promote self-sufficiency, particularly during conflicts and pandemics, while addressing malnutrition in all its forms. By collectively addressing PHLs, nations can make significant strides toward achieving a more sustainable, food-secure, and nutritionally sound future for their populations.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests Authors have declared that they have no competing interests.

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