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A call for locally led postharvest innovation to urgently address global nutrition insecurity

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Reducing food loss and waste has recently gained significant global attention. However, prolonged underinvestment in efforts to tackle food loss and waste, particularly in horticultural crops, now demands accelerated, collaborative action. Neglecting to invest in postharvest initiatives in horticulture exacerbates global nutrition insecurity, diminishes global resilience to climate change impacts, wastes scarce resources, and sustains greenhouse gas emissions. Addressing food loss and waste involves tackling a complex array of issues throughout the food system, from upstream research and policy to downstream handling, and consumption. This complexity can make it challenging to develop effective, scalable interventions that demonstrate clear impacts in the short term. Integrating interdisciplinary perspective ensures that innovations are inclusive, scalable and context specific for sustained and measurable global impact. Locally led postharvest innovations are well suited to maximize vital opportunities for improved livelihoods, particularly for marginalized groups such as women who are heavily involved in postharvest activities globally. Establishing a global consensus on the importance of effective postharvest management is essential for improving access, affordability, and profitability in horticultural value chains. Achieving this requires innovations tailored to regional and local needs, improved postharvest systems, and capacity strengthening that simultaneously promote equity. A supportive policy framework is vital, promoting local expertise and balancing the benefits of export markets with regional consumption. We are calling for a reframing of the approach to reducing postharvest losses in horticulture crops to be an absolute necessity if we are to achieve the United Nations' Sustainable Development Goals and outline our perspective in this article in order to promote a transition in approach.

KEYWORDS

nutrition, food loss and waste, locally led, innovations, horticulture

Introduction

Reducing postharvest food losses is an essential but underfunded strategy to addressing global food and nutrition insecurity. The United Nations Sustainable Development Goal (SDG) 12.3 calls for a 50% reduction in per capita global food waste at retail and consumer levels by 2030 (United Nations, 2023). Although food loss reduction is recognized as a key component of responsible consumption, it has yet to be prioritized with the urgency required for lasting impact. In the context of horticulture, less than 5% of funding for agricultural research and extension programs globally is dedicated to postharvest management of fruit and vegetables, despite its potential to be a more sustainable approach than increased food production (Kader and Rolle, 2004). In preliminary findings from a Global Horticulture Opportunity Study led by the Feed the Future Innovation Lab for Horticulture, postharvest losses were mentioned by horticulture experts across nine countries in Africa, Asia and Central America as one of the most prominent areas in horticulture research and development that needs increased investment. Addressing postharvest losses in horticulture not only contributes to food security and year-round nutrition but also plays a role in curbing greenhouse gas emissions (FAO, 2019).

This perspective calls for postharvest management, in horticulture in particular, to become a key pillar of food systems transformation to secure improved nutrition, increase small-scale producer incomes, and reduce environmental impact. Local leadership is crucial for scaling innovations, as local expertise is critical for adapting technologies to regional crops and practices. Additionally, prioritizing marginalized communities in these efforts is essential to avoid reinforcing inequities and to empower groups across the food value chain. This includes researchers, business owners, and the women who make up a significant portion of the postharvest workforce (Nordhagen, 2021). Researchers, in particular, play a crucial role in developing and disseminating postharvest innovations, yet they often face challenges such as limited funding, restricted access to real-world implementation opportunities, and barriers in engaging with marginalized communities. Strengthening their capacity through inclusive research funding, collaborative partnerships with communities, and practical training ensures that their work leads to impactful, equitable solutions rather than remaining confined to academic spaces.

Background

It is estimated that nearly half of fruit and vegetables meant for consumption are lost, with losses by weight surpassing those of all other food types (Spang et al., 2019; FAO, 2011). This amounts to approximately \$490 billion dollars in fruit and vegetables losses annually (Ueda et al., 2022). Over a twenty-year period, from 1994 to 2014, there was no discernable decrease in losses in low- and middle-income countries (LMICs) where many small-scale producers operate (Singh et al., 2014). These losses primarily

occur before the produce reaches the consumer - not as food waste (Kader, 2005). At the farm, aggregator, and retail level, losses have remained stubbornly high since the 1970s (Kitinoja et al., 2011). There is an extreme urgency to reverse this stagnation in levels of losses. Beyond the economic costs, losses pose broader implications for food security and sustainability.

In this perspective, we outline the broader impact of postharvest losses on nutrition and horticulture specifically, then advocate for a prioritization of efforts to reduce postharvest losses, specifically through local led strategies, in order to effectively and equitably scale postharvest innovations and practices.

Postharvest loss and nutrition security

Access to a healthy diet remains a significant challenge, with 3 billion people unable to afford the WHO-recommended 400 grams of fruits and vegetables per day (FAO et al., 2020). Diets lacking in these vital micronutrients were responsible for 26% of all deaths among adults in 2018 (Global Nutrition Report, 2021). Postharvest losses reduce access to essential nutrients in two main ways: through the outright loss of produce, and through nutrient degradation during postharvest handling. While increasing agricultural productivity has long been touted as a solution to food security, global total factor productivity (TFP) has decreased by about 21 percent since 1961, the equivalent to a loss of the last seven years of productivity growth (Ortiz-Bobea et al., 2021; International Agricultural Productivity, 2024). This underscores the need for food and nutrition security solutions beyond production increases. Furthermore, the capacity of proper horticulture postharvest management to reduce seasonal periods of nutrition scarcity in communities is not only beneficial for consumer health, but also provides economic opportunities in particular for women, and can give small-scale producers leverage in the market (The Rockefeller Foundation, 2021; Ambuko et al., 2018; FAO, 2022; Saran et al., 2012). Ultimately, the multi-faceted beneficial outcomes from improving postharvest management in horticulture crops position advances in this arena to be foundational in achieving sustainable and resilient nutrition security.

Impacts of postharvest losses in horticulture for small-scale producers

Globally, food loss between harvest and retail generates an estimated 8–10% of global greenhouse gas emissions from methane-producing spoilage in landfills (FAO, 2019). The environmental opportunity cost of food loss goes far beyond this when taking into account the use of emission-intensive production inputs, like fuel and synthetic fertilizers, as well as precious resources, like water – which are squandered when food produced is not ultimately consumed. As climate change threatens the amount and productivity of arable land, improving the efficient use of input resources and working toward a lower emission food system that can aid in curbing climate change is critical. Cutting global

postharvest losses in half is estimated to reduce greenhouse gas emissions by 5%, lower agricultural water use by 13%, reduce fertilizer use up to 15%, and reduce biodiversity loss by 33%, making it a critical entry point in mitigating the intensification of climate feedback loops (Willett et al., 2019).

For small-scale horticulture producers, postharvest losses significantly reduce the potential income benefits of horticulture. Research indicates that adopting technologies to minimize these losses can increase net returns by 5% (Balana et al., 2022). Additionally, small-scale farmers often lack adequate storage options, which forces them to sell produce immediately after harvest. This lack of leverage makes them “price-takers” (Ambuko et al., 2018), unable to negotiate favorable prices in oversupplied markets. Reducing postharvest losses would enable small-scale producers to store and sell produce at more favorable times, overcoming the challenge of rapid deterioration in fresh fruits and vegetables (Jarman et al., 2023). Additionally, opportunities in the postharvest value chain for value-addition, distribution of innovations, packaging, marketing and other entry-points also provide income generating opportunities while corresponding to a reduction in the environmental impacts of losses (Vilariño et al., 2017; McGinty, 2021). A circular bioeconomy approach further enhances these opportunities by transforming agricultural by-products and food waste into valuable inputs for other industries. For instance, vegetable trimmings and fruit peels can be used to make animal feeds, organic fertilizers, or biodegradable packaging materials. Similarly, surplus or less appealing produce can be processed into dried, frozen, or pureed products, extending shelf life and reducing postharvest waste. Strengthening market linkages for these value-added products not only increases incomes for small-scale producers and entrepreneurs but also contributes to more resource-efficient and sustainable food systems. Supporting business models that integrate circular bioeconomy principles within postharvest management can thus enhance sustainability, create employment, and drive innovation in food systems.

Investing in resources that reduce postharvest losses

Effective postharvest management should be a central pillar of global food system reform. When prioritized, improvements in postharvest outcomes, in particular in horticulture crops, can serve as a transformative catalyst, simultaneously advancing multiple UN Sustainable Development Goals (SDGs) simultaneously, including SDGs 1 (No Poverty), 2 (Zero Hunger), 5 (Gender Equality), 8 (Decent Work and Economic Growth), 9 (Industry, Innovation, and Infrastructure), 13 (Climate Action), and 17 (Partnerships for the Goals), across various sectors (United Nations, 2023).

Preserving horticulture quality during postharvest through effective temperature management, food safety practices and other handling techniques can help reduce significant global health burdens associated with the consumption of unsafe foods (Kader, 2005; World Health Organization, 2024). Efforts to reduce

postharvest losses should prioritize the development of cold and dry chains. Cold chains, which involve refrigeration or freezing to preserve perishable items like fruits and vegetables, are essential for reducing postharvest losses. A lack of refrigeration in rural horticulture value chains can result in significant waste, particularly during the “first mile” of transport from farm to market (Lipinski et al., 2013). Cold storage, cooling facilities, and refrigerated transport are vital to address this issue, especially for small-scale producers. Policies that support cold storage interventions can help small-scale producers extend shelf life to access broader markets while reducing transport costs, thus enhancing efficiency, reducing waste, and lowering the cost of nutrient dense foods (Cooper et al., 2021). For instance, a preferential lending program in Uzbekistan, supported by international financial institutions, led to a remarkable increase in the country’s cold storage capacity, growing more than 1,000-fold in 2011 (Tracy and Taylor, 2017). Similarly, for dry chains, which focus on preventing spoilage by ensuring products remain dry and safe from contamination, government-backed initiatives that promote affordable and accessible technologies through private sector collaboration, while increasing awareness of public health risks of improperly dried products can contribute to reduced losses and better health outcomes for communities (Bradford et al., 2017). While many complex and expensive postharvest technologies are typically employed by large-scale or high-value export businesses, leaving small-scale producers at a disadvantage (Jarman et al., 2023), by supporting the development and distribution of low-cost, locally adaptable cold and dry chain solutions, local communities can significantly reduce food waste, increase shelf life, improve market access, and enhance food security.

Locally led postharvest solutions

Addressing postharvest losses in horticulture requires a shift towards locally led research, policy, and collaboration. Research in postharvest technology continues to ignore crucial, context specific topics necessary for successful scaling, including social, economic, cultural considerations, and capacity strengthening (Affognon et al., 2015). Given that effective scaling benefits from a deep understanding of local systems and socioeconomic conditions (Anadon et al., 2016; Matavel et al., 2021), locally led approaches are essential for ensuring solutions are practical, sustainable and widely adopted. Locally led approaches prioritize the leadership and expertise of local professionals in identifying and implementing solutions that fit within the social, economic, and environmental realities of their communities. These approaches go beyond technology transfer by integrating community-driven innovation, participatory research, and inclusive policy development. A locally led, globally supported model strengthens these.

Approach by placing local experts as leaders with global experts as supportive resources in a dynamic consortium whose aim is to collaboratively find context-specific solutions to postharvest losses in horticulture and improve food security for small-scale farmers in LMICs. Horticulture can be knowledge intensive, including the

postharvest handling which requires a high level of expertise. This factor, along with an understanding of the resources locally available to improve postharvest outcomes and the development of a sustaining enabling environment for the distribution and maintenance of those postharvest resources, demands local expertise to achieve optimal outcomes. However, local researchers often face challenges such as limited funding, inadequate infrastructure, and a lack of integration into global research networks. Empowering local researchers with resources, training, and leadership opportunities within interdisciplinary collaborations is essential for developing contextually appropriate and sustainable postharvest solutions.

Further, a lack of interdisciplinary cooperation to address postharvest losses in horticulture among development agencies, governments, trade associations, grower associations, researchers, and marketers negatively affects efforts to scale postharvest knowledge, practices, and technologies (Hewett, 2012; Kitinoja et al., 2011). Locally driven policy framework to address postharvest losses in horticulture crops is essential for sustained transformation. The shift in policy needs to prioritize reducing losses, and the design of that policy framework should be led by local experts who are well-versed in the factors constraining reductions and opportunities that are untapped. This local led framework for policy should additionally empower local researchers to be central in the efforts to develop contextually appropriate solutions. Furthermore, this localized approach in policy development would likely result in more sustained policy enforcement and implementation.

Scaling postharvest innovations for equitable outcomes

Inclusive scaling of innovations is necessary to achieve long term positive impact in food security and social development. Adopting new innovations poses numerous challenges for small-scale producers, since access to capital, natural and technical resources, information, infrastructure, as well as community and institutional networks varies greatly among regions, communities, and individuals. Limited or inequitable access to resources can produce inequities in adoption and further marginalized groups who are already at a disadvantage, creating unintended negative consequences of innovation scaling and adoption (McGuire et al., 2023). A specific gap exists in postharvest literature, which widely lacks gender informed research, despite women being the backbone of much of the small-scale postharvest handling, processing, and marketing in low income countries (Affognon et al., 2015). Inclusive scaling plans that focus on the needs and constraints of women and other marginalized groups can enhance economic opportunity, women's empowerment, and household nutrition. For instance, one solar dryer scaling program specifically targeting women in India increased their income, increased their respect in their community, and produced a 36% increase in their dietary diversity (Nagwekar et al., 2020).

Discussion

High levels of postharvest losses, especially in horticultural commodities undermine efforts of achieving global food security, nutrition and environmental sustainability (FAO, 2019). These losses not only waste production resources but also exacerbate hunger with more than 820 million people in the world going hungry every day. Although many countries have taken positive steps towards addressing food loss and waste, it has not been enough to achieve a significant and lasting impact. While there is increased recognition in global dialogues on the importance of reducing food loss and waste with different initiatives launched, most of these efforts face substantial funding gaps within a sustainable food systems framework. Now, more than ever, there is urgency for collaborative efforts and significant resources directed towards reducing food loss and waste not only for immediate food security but for improved community nutrition and increased incomes in the long-term. However, these outcomes will only happen if postharvest management is prioritized and integrated in broader national and global food system strategies.

Most agricultural investments continue to prioritize staple crops leaving horticultural value chains under resourced (Haddad et al., 2016). This focus on staple crops, while critical to deliver macronutrients and stabilize political economies, overlooks the unique contributions of more perishable crops to nutrition, such as fruits and vegetables and legumes. Postharvest management is not just about wastage issues, it is also about resource conservation, climate change mitigation, and increasing the availability of healthy food (FAO, 2019).

A pipeline of postharvest innovations, advanced by local experts, designed for small-scale farmers is critical. These innovations would increase accessibility, year-round, to nutritious horticulture crops at the community-level and benefit women who are often the suppliers of horticultural produce to local markets but often lack access to technologies to reduce significant postharvest losses.

To achieve meaningful change in the adoption of any postharvest innovations, a locally led, inclusive, and community-driven approach is essential. Shifting from a “one-size-fits-all” model to one that focuses on locally led solutions and prioritizes marginalized groups such as women and youth can transform the adoption of postharvest innovations. If these groups are equitably engaged in locally led postharvest management efforts, they would benefit from new sources of income, jobs, and positions of authority which would have a lasting impact and create local ownership. Ensuring that postharvest strategies are designed, implemented, and scaled through locally led approaches will create more sustainable and contextually appropriate solutions that drive systemic change in food systems.

Conclusion

There is an urgent need for interdisciplinary, locally led collaborations to develop affordable and scalable solutions aimed at reducing food loss and waste for enhanced global food security.

In developing innovations, locally-led and inclusive approaches are vital throughout the development and scaling of technologies and practices. Regional and local academia, research institutes, private entities, and of course stakeholders directly in the value chain, including producers, should be pillars of locally led efforts to drive positive changes in postharvest outcomes for horticulture commodities to strengthen global food systems.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author contributions

PY: Writing – original draft, Writing – review & editing. AJ: Writing – original draft, Writing – review & editing. KB: Writing – original draft, Writing – review & editing. KG: Writing – original draft, Writing – review & editing. HH: Writing – original draft, Writing – review & editing. MK: Writing – original draft, Writing – review & editing. EM: Writing – original draft, Writing – review & editing.

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Conflict of interest

EM was CEO of the company, Responsible Innovations.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The author(s) declare that no Generative AI was used in the creation of this manuscript.

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