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FOOD LOSS & WASTE

The Role of Packaging in Mitigating Food Loss & Wate in North American Fresh Produce Supply Chains

When evaluating the sustainability of packaging, it is essential to understand not just the material's environmental footprint but also the role it plays in protecting food from the farm to the fork of the consumer. Food loss and waste is a significant sustainability challenge in the fresh produce sector, where an estimated 40 percent of the U.S. food supply goes uneaten each year, totaling around 60 million tons annually *(4, 5, 9)*. Fruits and vegetables are the most wasted category of food, accounting for roughly 42 percent of discarded food *(5, 9)*. Fresh fruits and vegetables are highly perishable because even after harvest, they are living, breathing organisms that continue to undergo physiological changes.

FOOD LOSS	FOOD WASTE
Edible food that is lost during production, post-harvest, processing, or distribution stages of the supply chain *(10, 25)*. Food loss occurs before it reaches retail or consumers and is often due to inefficiencies, spoilage, or infrastructure gaps. On farms, produce may be left unharvested or discarded because it does not meet cosmetic or food safety standards or because there is oversupply *(12, 15)*. During packing and transportation, spoilage can occur from mishandling, poor temperature or humidity control, or inadequate packaging *(10, 17, 22)*.	Edible food discarded at the retail and consumer level, often due to over-purchasing, cosmetic standards, or improper storage *(10, 21)*. Food waste, also referred to as "shrink," is a type of food loss that happens after food has entered markets or households *(3)*. At the retail stage, foods are often discarded if they do not meet appearance standards *(3, 5, 9, 20)*. At home, consumers may throw away food due to poor storage practices or confusion over expiration dates (*4, 5, 9, 18, 23)*.

The Role of Packaging in Food Loss and Waste

Fresh produce packaging is a critical tool in the fight against food loss and waste across the entire supply chain. In North America, packaging plays a critical role in protecting fresh produce from physical damage, contamination, and premature spoilage during handling and transportation. This protection is particularly important given the perishable nature of produce and the complexity of modern supply chains.

Beginning immediately postharvest, field containers protect delicate produce items from initial mechanical and temperature damage that can accelerate spoilage. Cooling and storage in climate controlled conditions as quickly as possible is one of the most effective practices to reduce food loss and extend shelf life. During transit and distribution, packaging is engineered to maintain the appropriate temperature and humidity, and prevent bruising, compression, and vibration damage to ensure produce arrives at the retailer intact and of a high quality.

Technologies such as Modified Atmosphere Packaging (MAP) help slow respiration and decay, extending shelf life by adjusting internal oxygen, carbon dioxide, and humidity levels *(6)*. When combined with proper postharvest handling procedures and temperature control management, MAP can positively impact the quality and shelf life of fresh produce. For example, reducing oxygen (O2) concentrations below ~10% slows respiration rates and indirectly slows the rates at which most fruits and vegetables ripen, age and decay. Additionally, reducing the O2 concentration can, in some cases, reduce oxidative browning reactions, particularly concerning in precut leafy vegetables.

MAP also increases the carbon dioxide (CO2) concentration within the packaging. When the increased CO2 dissolves on the moist surface of the produce, carbonic acid is produced, causing a drop in pH. This acidification, as well as direct antimicrobial effects, can suppress the growth of spoilage microorganisms and is essential in many types of extended shelf life packaging. Further, smart packaging, which may include sensors or indicators, provides real-time information on freshness and safety, giving retailers and consumers more confidence in the quality of the food *(8)*.

The design of packaging also influences how much food gets wasted in stores and households. If the packaging is oversized, difficult to open, or poorly resealable, it can result in portions of produce going unused and ultimately discarded *(1, 22, 25)*. Conversely, packaging that is portioned to match consumption patterns, easy to empty, and clearly labeled with storage guidance can reduce waste *(2, 22, 25)*. It is also important to have clear and consistent labeling as confusion between "best-by," "sell-by," and "use-by" dates leads to unnecessary discards, particularly in households *(22, 24, 25)*. Educational messaging on packaging can guide consumers toward proper storage and optimal use of fresh produce *(2, 22, 24, 25)*.

Sustainability initiatives for fresh produce packaging have traditionally focused on the environmental costs of material production and disposal. However, when food loss is factored into environmental costs, the results often show that preventing waste yields far greater environmental benefits than minimizing packaging material alone *(13, 16, 22, 25)*. Studies show that the greenhouse gas emissions, water, and land resources used to grow and transport wasted food are often much higher than the impacts of the packaging itself *(11, 12, 16)*. This shows that reducing food waste often provides greater environmental benefits than simply minimizing packaging materials. In other words, the assumption that "less packaging is always better" is misleading. Sustainable packaging is not just about using less of certain types of materials; it is about designing packaging that effectively protects food from damage and spoilage while also being material efficient.

Looking Forward

To maximize packaging's role in preventing food loss and waste, industry and policymakers should encourage the use of advanced technologies such as MAP and smart packaging. Life-cycle assessments should also be updated to consider the benefits of avoiding food waste, not just the environmental cost to produce and dispose of the packaging itself *(7, 11, 16)*. Designers should focus on creating packaging that is user-friendly, easy to reseal, and portioned to match real consumption patterns *(1, 2, 22)*. Packaging can also serve as a communication tool by providing clear labeling and simple storage tips that help consumers use food more efficiently *(24, 25)*.

At the same time, packaging strategies should align with the Golden Design Rules developed by the Consumer Goods Forum *(19)*. These rules provide a set of global design principles aimed at reducing unnecessary packaging, eliminating problematic materials, and increasing recyclability. For example, the Golden Design Rules emphasize minimizing headspace and excess plastic overwrap, standardizing on-pack recycling instructions, and improving recyclability of PET, HDPE, and flexible plastics *(19)*. These design standards allow companies to ensure packaging prevents food waste while advancing circular economy goals.

Finally, collaboration across the supply chain can ensure that growers, distributors, retailers, and consumers all benefit from packaging that supports both sustainability and food protection *(11, 14, 22)*. For produce growers, it recommended to actively engage with waste management providers to understand the regional sorting capabilities and contamination challenges. Retailers are encouraged to coordinate with stakeholders on best practices and current availability of technology using LCA data or food loss and waste reduction targets. For policy makers and regulators, adopting a standardized labeling system can provide clear, instruction-based disposal information to consumers.

Packaging is not a complete solution to food loss and waste in the fresh produce sector, but it is an essential part of it. By integrating food protection into sustainability strategies, the industry can reduce food waste, improve supply chain efficiency, and make nutritious produce more accessible to consumers. In this way, well-designed packaging delivers environmental and social benefits that extend far beyond the package itself.

References

1. Brennan, L., C. Francis, E. L. Jenkins, B. Schivinski, M. Jackson, E. Florence, L. Parker, S. Langley, S. Lockrey, K. Verghese, N. T. Phan-Le, A. Hill, and M. Ryder. 2023. Consumer perceptions of food packaging in its role in fighting Food waste. Sustainability. 15:1917.

2. Brennan, L., S. Langley, K. Verghese, S. Lockrey, M. Ryder, C. Francis, N. T. Phan-Le, and A. Hill. 2021. The role of packaging in fighting food waste: A systematised review of consumer perceptions of packaging. J Clean Prod. 281:125276.

3. Buzby, J., J. T. Bentley, B. Padera, J. Campuzano, and C. Ammon. 2016. Updated supermarket shrink estimates for fresh foods and their implications for ERS loss-adjusted food availability data. Economic Information Bulletin No. 155. Available at: https://www.ers.usda.gov/publications/pub-details?pubid=44103. Accessed 16 October 2025.

4. Buzby, J. C., and J. Hyman. 2012. Total and per capita value of food loss in the United States. Food Policy. 37:561–570.

5. Buzby, J. C., H. F. Wells, and J. Hyman. 2014. The estimated amount, value, and calories of postharvest food losses at the retail and consumer levels in the United States. The Estimated Amount, Value, and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States | Economic Research Service. Accessed 16 October 2025.

6. Caleb, O. J., P. V. Mahajan, F. A. J. Al-Said, and U. L. Opara. 2013. Modified atmosphere packaging technology of fresh and fresh-cut produce and the microbial consequences - a review. Food Bioproc Tech. 6:303–329.

7. Conte, A., G. M. Cappelletti, G. M. Nicoletti, C. Russo, and M. A. Del Nobile. 2015. Environmental implications of food loss probability in packaging design. Food Research International. 78:11–

8. Du, L., X. Huang, Z. Li, Z. Qin, N. Zhang, X. Zhai, J. Shi, J. Zhang, T. Shen, R. Zhang, and Y. Wang. 2025. Application of smart packaging in fruit and vegetable preservation: A review. Foods. 14:447.

9. Gunders, D., J. Bloom, J. Berkenkamp, D. Hoover, A. Spacht, and M. Mourad. 2017. Wasted: How America is losing up to 40 percent of its food from farm to fork to landfill. Natural Resources Defense Council. Available at: https://www.nrdc.org/resources/wasted-how-america-losing-40-percent-its-food-farm-fork-landfill. Accessed 14 October 2025.

10. Hanson, C., and P. Mitchell. 2017. The business case for reducing food loss and waste. Available at: https://champions123.org/publication/business-case-reducing-food-loss-and-waste. Accessed 16 October 2025.

11. Hemachandra, S., M. Hadjikakou, and S. Pettigrew. 2024. A scoping review of food packaging life cycle assessments that account for packaging-related food waste. International Journal of Life Cycle Assessment. 29:1899–1915.

12. Minor, T., G. Astill, S. R. Skorbiansky, S. Thornsbury, J. Buzby, C. Hitaj, L. Kantor, F. Kuchler, B. Ellison, A. Mishra, T. Richards, B. Roe, and N. Wilson. 2020. Economic Drivers of Food Loss at the Farm and Pre-Retail Sectors: A Look at the Produce Supply Chain in the United States | Economic Research Service. U.S. Department of Agriculture, Economic Research Service. Available at: https://www.ers.usda.gov/publications/pub-details?pubid=95778. Accessed 16 October 2025.

References

13. Molina-Besch, K., F. Wikström, and H. Williams. 2019. The environmental impact of packaging in food supply chains—does life cycle assessment of food provide the full picture? International Journal of Life Cycle Assessment. 24:37–50.

14. Molina-Besch, K., F. Wikström, and H. Williams. 2019. The environmental impact of packaging in food supply chains—does life cycle assessment of food provide the full picture? International Journal of Life Cycle Assessment. 24:37–50.

15. O'connor, J., S. Skeaff, P. Bremer, G. Lucci, and M. Mirosa. 2023. A critical review of on-farm food loss and waste: future research and policy recommendations. Renewable Agriculture and Food Systems. 38:e24.

16. Qin, Y., and A. Horvath. 2022. What contributes more to life-cycle greenhouse gas emissions of farm produce: Production, transportation, packaging, or food loss? Resour Conserv Recycl. 176:105945.

17. Schudel, S., K. Shoji, C. Shrivastava, D. Onwude, and T. Defraeye. 2023. Solution roadmap to reduce food loss along your postharvest supply chain from farm to retail. Food Packag Shelf Life. 36:101057.

18. Stancu, V., P. Haugaard, and L. Lähteenmäki. 2016. Determinants of consumer food waste behaviour: Two routes to food waste. Appetite. 96:7–17.

19. The Consumer Goods Forum. Plastic packaging design: CGF golden design rules. Available at: https://www.theconsumergoodsforum.com/planet/plastic-waste/key-projects/packaging-design/. Accessed 15 October 2025.

20. Todd, E. C. D., and D. Faour-Klingbeil. 2024. Impact of food waste on society, specifically at retail and foodservice levels in developed and developing countries. Foods. 13:2098.

21. Uhlig, E., A. Sadzik, M. Strenger, A.-M. Schneider, and M. Schmid. 2025. Food wastage along the global food supply chain and the impact of food packaging. Journal of Consumer Protection and Food Safety. 20:5–17.

22. Verghese, K., H. Lewis, S. Lockrey, and H. Williams. 2015. Packaging's role in minimizing food loss and waste across the supply chain. Packaging Technology and Science. 28:603–620.

23. Williams, H., F. Wikström, T. Otterbring, M. Löfgren, and A. Gustafsson. 2012. Reasons for household food waste with special attention to packaging. J Clean Prod. 24:141–148.

24. Wilson, N. L. W., B. J. Rickard, R. Saputo, and S. T. Ho. 2017. Food waste: The role of date labels, package size, and product category. Food Qual Prefer. 55:35–44.

25. Wohner, B., E. Pauer, V. Heinrich, and M. Tacker. 2019. Packaging-related food losses and waste: An overview of drivers and issues. Sustainability. 11:264.

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