Version: December 2025

FOOD SAFETY

The Role of Packaging in Mitigating Food Safety Risks in North American Fresh Produce Supply Chains

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Packaging plays a significant role in enabling the global trade systems the world relies upon. The fresh produce industry is no exception. Packaging within the food industry, for produce or otherwise, is carefully developed to ensure the quality of the food is preserved, the package materials are not known to pose a food safety risk, critical consumer handling and nutritional information are communicated to consumers, and food waste and environmental impacts are minimized *(1, 9, 15, 16, 27)*. This paper highlights the role of packaging in mitigating food safety risks in North American fresh produce supply chains.

Food safety and quality are often misrepresented as being synonymous and used interchangeably, but they are distinct concepts representing different measurements of a product. Food safety addresses the hazards and associated human health risks a product, package, or system may pose and focuses on mitigating those risks *(1)*.

No product is risk- free, but packaging designed to help mitigate food safety risks is an important component of the overall safety of the food system *(19)*. Quality, for our discussion, consists of a product's attributes which makes it appealing to consumers. This includes specific parameters like color, size, Brix, shelf-life, price, etc. *(4, 23)*.

Functionality

Packaging can range from a simple bag to retain the product for a period of time, to a complex modified atmosphere packaging (MAP) tasked with maintaining the ideal conditions for shelf life, food safety, or product protection *(9, 13, 14, 18)*. Fresh produce packaging can provide the functionality of mitigating the food safety risks and quality degradation of fresh produce *(5)*.

Displays of bulk ready-to-eat produce may elevate food safety risks from increased exposure to airborne hazards and from human handling and contact with shopping carts, conveyers, scales, etc. *(2, 3, 10, 29)*. Open displays of bulk product also complicate temperature control, traceability, and lot separation (*5*, *36*). Containers may also include materials that may be hard to clean and/or require a cleaning and sanitation infrastructure that is not readily present in all areas of the supply chain (*21*). For example, fiber cartons can absorb water and support microbial growth; reusable plastic crates generally collect organic material, have numerous surface area/harborage points for ventilation, and are difficult to properly clean and sanitize (*21*, *26*, *31*).

Customers may also provide their own reuseable containers (e.g., for self-serve salad bars), which may introduce human pathogens into the retail environment and purchased products if the container is not sanitary. In fresh-cut produce items, packaging can provide MAP to control gas exchange (i.e., oxygen and carbon dioxide levels), slowing both microbial growth and spoilage *(9, 13, 14, 18, 30)*. However, improperly designed MAP can exacerbate food safety issues *(14*).

Fresh produce packaging can mitigate food safety risks via:

Protection

Packaging can form a non-permeable barrier which prevents the entry of water, human pathogens (e.g., bacteria, viruses, protozoa), and other potential hazards thus reducing the food safety risks to the product *(5)*.

Most fresh produce items continue to respire once packaged, and a solid, non-permeable barrier can be utilized in very specific situations *(14)*. However, primary packaging, when it forms a continuous, unbroken barrier around a product, may lead to anaerobic conditions (i.e., low or no oxygen) and

higher food safety risks from anaerobic human pathogens (e.g., *Clostridium botulinum*) *(14)*. Therefore specific gas transmission technologies are utilized in combination with continuous barrier packaging.

Solid barriers make excellent matrices for the application of labels or laser printed information like traceability codes, best before dates and UPC bar *(5)*. As products are transported through a packinghouse or a facility, the solid barrier helps to reduce the risk of microbial, chemical or physical hazards from contaminating the product *(19)*. Continuous packaging, clamshells in particular, allow for secure packing into master cases thus reducing quality defects, which may occur because of shaking or jostling during transportation *(5, 19, 32, 33)*.

Packaging can also protect against bruising and plant damage. These physical injuries, in some studies, have been associated with an increased ability for human pathogens to survive/grow on plant tissue *(6, 20, 32)*.

Tamper-resistance and traceability

Packaging can prevent tampering, reduces ability for cross-contamination, and provides space for labeling with lot codes and PLUs *(19)*. With enhanced ability to trace product, recalls can be more targeted and precise, faster, and help support improved consumer confidence in the food supply *(5)*.

Cross-contamination prevention

Packaging also plays a crucial role in protecting fresh fruits and vegetables by forming solid, tamper-resistant barriers that reduce contamination risks during handling, transport, and storage *(5, 33)*.

Key areas where packaging can prevent cross-contamination include:

TRANSPORTATION

Without primary packaging, some susceptible items (e.g., leafy greens) will be more vulnerable to contamination during transit; this is especially true if the cleanliness of refrigerated trailers and cooler units is not well-managed and operators do not conduct environmental monitoring to verify the sanitary condition *(33, 36)*. Cooler units have been found to aerosolize microbial pathogens, and historically, the trucking industry's food safety management plans and expertise has not been fully developed *(33)*.

LOADING

Reusable totes are often used to move product around during processing, and also for shipping *(5)*. These reusable totes, unless specifically vented, can have ventilation issues and often are difficult to clean/sanitize. Appropriate cleaning/sanitation measures are needed throughout the supply chain to ensure their proper condition and use (i.e., reduce the contamination risk of food-contact surfaces and foods) *(31)*.

RETAIL

Consumer handling of produce may introduce microbial/chemical contaminants *(2, 3, 7, 28)*. Further, fresh produce displays at retail contain harborage points that can cross-contaminate produce from display materials and/or other produce (e.g., cantaloupe of mixed origin in a display) *(29, 36)*.

CONSUMER

Packaging choices have historically been considered as a decision within the production and food supply chain. However, packaging's role does not end at the retailer but extends to ensure food safety within the consumer's home as well. In many cases, home storage practices may introduce opportunities for or increase the likelihood of cross-contamination from adjacent raw meats and poultry *(8, 34)*. Packaging allows for fresh produce items to remain more protected in consumers' homes where food safety knowledge may be limited *(22, 24, 35)*.

Opportunities for Innovation

The fresh produce industry has put substantial resources and effort into supplying consumers with safe, high-quality fresh produce products and restricting the use of packaging will limit the ability to continue doing so. Further, new packaging material and technologies must be explored without taking potential solutions off the table. For example, innovation will be slowed if materials such as plastic are no longer available. Innovative packaging solutions may include incorporation of antimicrobial agents and inclusion of human pathogen detection technologies (i.e., smart packaging) *(12, 19, 26, 32)*.

Whole produce packaging

The use of PLU stickers on these items have improved quick origin tracking during recalls *(17)*. Additionally, if bulk produce is shipped without packaging, careful attention to food safety practices and systems is needed to ensure that shipping containers, whether constructed of wood, corrugated cardboard, or plastic, have hygienic design to support adequate cleaning and sanitation and prevent the harboring of human pathogens and cross-contamination of fresh produce crops *(11, 16, 23)*.

Fresh produce packaging serves a critical role in maintaining both the safety and quality of fresh produce throughout the supply chain, from production and transport to retail and consumer handling. While packaging can take many forms, packaging can provide important functionality roles such as contamination prevention, tamper resistance, traceability, and protection against physical damage. These functions not only help preserve the freshness and appeal of produce but most importantly, play a key role in mitigating food safety risks. As the industry continues to evolve, continued innovation in packaging will ensure that food safety, sustainability, and quality remain top priorities in a global food system.

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SPPA

SUSTAINABLE PRODUCE PACKAGING ALIGNMENT