



# The Role of Cutting-Edge Post Harvest Management Technologies in Enhancing Shelf Life of Vegetables

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## INTRODUCTION

Important sources of vital vitamins, minerals and antioxidants include all the vegetables. In recent decades, consumers are preferring vegetables more frequently as they have become aware of their potential of preventing several non-communicable diseases. Vegetable quality is primarily determined by assessing many visible characteristics (size, shape, colour, gloss, firmness and texture), taste as well as interior aspects (chemical, physical and microbiological) that relate to sustainability, safety and nutritional qualities. Harvested produce are highly perishable and metabolically active. They lose quality as a result of ripening and senescence processes which are frequently linked to the growth of spoilage microorganisms and other undesirable phenomena. These processes need to be managed in order to maintain the produce's quality and extend its shelf life while it is being stored. Fruit and vegetable post-harvest waste has emerged as a major worldwide issue that affects both developed and developing nations. According to estimates from the Food and Agriculture Organization (FAO), post-harvest spoiling accounts for 33% of the total amount of food produced for human use. In all, 40% of losses take place in developing countries and 44% in developed countries. Fruits and vegetables are the food group with the second-highest value of losses and waste (about 22%) at all stages of the food supply chain, after roots, tubers and oil-bearing crops, according to a recent FAO analysis. This is because of their intrinsic perishability which results from their distinct morphological and physiological characteristics. Throughout the supply chain, harvesting, post-harvest handling, shipping and storage can all result in a decline in the quantity and quality of vegetables.

Improving security, advancing environmental sustainability and cutting production costs all depend on minimizing losses and waste in the vegetable industry.

The biological processes brought on by senescence and maturation can be slowed down, physiological disorders can be prevented or reduced and microbial growth and contamination can be minimized with proper post-harvest handling, which includes controlling storage time and temperature, relative humidity, chemical and/or physical treatments and packaging (i.e., a modified atmosphere). Moreover, as food globalization has advanced, the quantities of



agricultural products exchanged worldwide have typically increased as well. As a result, the transportation distance and duration have been increased, consequently, protracted exposure to sub-optimal storage conditions can result in a rapid decline in quality of the product with ensuing losses and waste. Because of these factors, extended product shelf life and improved quality control technology across greater distances have emerged as crucial concern. Nowadays, a lot of research is being done on the effects of novel physical and chemical post-harvest treatments as well as bio-control methods those are utilized to maintain the safety, nutritional value and quality of fresh food from harvest to consumer usage.

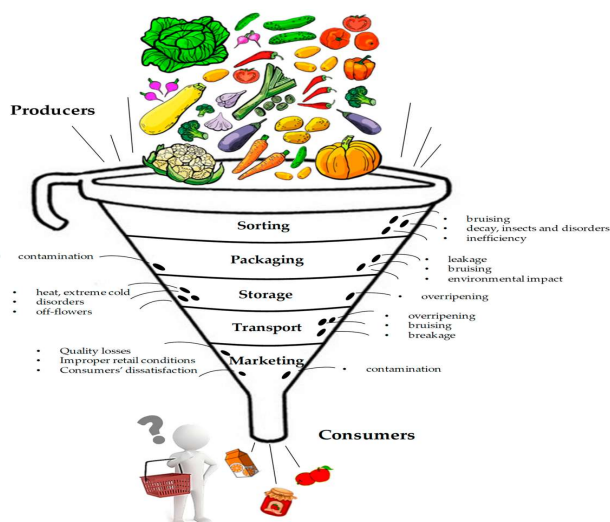


Fig: Causes of post-harvest losses along the supply chain

### Why cutting-edge methods in post harvest management?

The use of chemicals is the primary method of post-harvest disease and loss management in many countries. Although they work well, chemicals have several drawbacks:

- Detrimental to the customer
- Product residue has a negative impact on the environment
- Impact the vegetable's quality
- Unsuitable for exporting organic products
- Consumers refraining from using things that have been chemically treated

In order to manage vegetables after harvest, alternative techniques must be used, which are:

- Simple to use
- Eco-friendly, residue-free and long-lasting impact on the product
- Adequate for organic goods
- Consumers are not at risk



- GRAS stands for "Generally Recommended as Safe"

**Table: Estimated loss of vegetables, Source:- Magray et al. (2017)**

Vegetables	Loss (%)
Onion	15 – 30
Garlic	1-3
Potato	15-20
Tomato	10-20
Cabbage & Cauliflower	7-15
Brinjal	10-13
Beans and Peas	7-12
Carrot	5-9

**Different advanced post harvest management technologies:****(1) Physical Treatments:**

- (a) Microwave:** Because heat is applied slowly and dispersed through conduction in plant tissue, heating processes like hot water and hot air treatments, high-temperature/short-time treatments and radio frequency can generally result in a decrease in the amounts of vital nutrients and flavour related compounds. Vegetables are temporarily treated using this method to control microbial growth during the limited processing of the product, reducing quality losses while also ensuring the least amount of environmental impact and the lack of residues in the treated product.
- (b) Pulsed Electric Field (PEF):** One cutting-edge technique used in food processing to lessen post-harvest waste is PEF technology, which is notable for its rapid treatment time. This non-thermal preservation technique has been gaining popularity because of its continuous functioning and low electric field needs. By providing an electric field that breaks down the food's cell membrane matrix, the method improves the food's nutritional value, safety and shelf life. PEF is frequently used in the food and beverage sector to preserve juices that have been derived from different fruits and vegetables.
- (c) High Hydrostatic Pressure:** The primary applications of high hydrostatic pressure (HHP) technology are enzyme denaturation and microbial inactivation or reduction. High pressure, which damages microbial cellular structures may have comparable effects on plant cells, hence, a thorough investigation into treatment optimization in a variety of novel systems is necessary. Numerous findings indicate that HHP has a major impact on microbial load. The effects of HHP application have been reported for



different minimally processed horticultural commodities, whole produce and juice demonstrating great efficiency in improving food safety aspects and in maintaining quality.

- (d) **Cold Plasma:** In order to manage microbial development and replace traditional sanitation treatments while maintaining the nutritional value and antioxidant content of food products, cold plasma is applied extensively in the whole and minimally processed fruit and vegetable industries. The use of plasma-activated water (PAW) has also been the subject of increased research in recent years. This method is a useful substitute for the traditional option of washing during fresh-cut processing for a number of goods since it enables the manufacturer to prevent cell damage brought on by direct exposure to cold plasma.
- (2) **Dipping and Vacuum Impregnation:** Physiological changes like enzymatic browning brought on by tissue damage and high respiration rates and physical factors like mechanical injuries and the removal of outer protective coverings, have a significant impact on the quality of fresh-cut fruit and vegetables. These changes result in shrivelling, a loss of colour and appearance, a shorter shelf life and faster weight loss. In order to preserve and improve the quality and to increase the shelf-life of these products, new food processing technologies, like dipping and vacuum impregnation techniques are being researched and used to sanitize, reduce enzymatic browning, improve texture and use nutrients to fortify fresh-cut fruit and vegetables. The process of dipping involves immersing the product either mechanically or by hand and then draining the excess solution. The elimination of cellular exudates, which can negatively impact the post harvest quality of commodities is one of the main benefits of these dipping procedures.
- (3) **Edible Active Packaging:** Natural antioxidants are incorporated into edible polymers to provide edible active packaging. By slowing down a number of natural processes, such as gaseous exchange and the rate of respiration and transpiration, edible coatings have been shown to be an effective primary packaging material for postponing the ripening process, maintaining nutritional qualities and reducing quality loss. It has recently been noted that adding active natural ingredients with antibacterial and/or antioxidant qualities might greatly increase the effectiveness of edible coatings. These so called "active" packaging materials are made to interact with food by releasing biologically active ingredients. Even without cold storage, the incorporation of active chemicals into biopolymer matrix improves the food product's oxidation stability and prevents the formation of food-borne infections, adding to its safety qualities. Carrots coated with casein and turmeric had a roughly 7-day shelf-life extension while maintaining their texture, antimicrobial qualities, and carotene content.
- (4) **Strategies of Bio-control:** In the realm of biological treatments, bio-control stands out as the primary solution among the alternative strategies. One of the more environmentally friendly postharvest methods for extending the shelf life of vegetables is bio-control, which uses certain microorganisms as control agents. The use of specific microbes that can prevent the growth of undesirable bacteria is the foundation of bio-



control. Bacteria and yeast serve as bio-control agents. Among the best antagonists for post-harvest management are the genera *Bacillus* and *Pseudomonas*. In agriculture, *Bacillus* is widely acknowledged as a biological substitute for conventional chemical fungicides and bactericides. The widespread distribution of *Pseudomonas* in the field attests to the genus' adaptability in the agricultural setting. The ability of the chosen strains to withstand harsh environmental conditions, grow quickly, control the host response, and produce lytic enzymes and antimicrobial compounds including the formation of endospores for *Bacillus* are among the various phenotypes of interest that have been extensively studied. By inoculating cells or using cell-free supernatants, all of these biomolecules have been used to extend the shelf life of fresh plant products under storage conditions. The Lactic Acid bacteria have also been successfully used in enhancing shelf life of leafy greens, lettuce, potatoes, mushrooms, tomatoes, melon, cabbage and so on.

(5) **Emerging Techniques:**

- (a) **Essential Oils:** Essential oils are essentially secondary metabolites of plants that are made up of volatile and complicated molecules. Any part of the plant, including the buds, flowers, leaves, stems, branches, seeds, fruits, roots, wood or bark, can provide essential oils, which are abundant in plants that emit powerful scents and odours. The glandular trichome is a specialized plant organ that is known to manufacture and exude essential oils. Furthermore, a variety of biological activities, including antibacterial, antifungal and antioxidant properties are frequently linked to the chemical contents produced in the glandular trichomes. By preventing microbial development and possibly increasing shelf life, essential oil coatings on vegetables provide a natural means of enhancing preservation and enhancing food safety. These coverings are frequently made as nano-emulsions.
- (b) **Waxing:** It is described as the process of adding to or replacing the natural wax covering on the surface of fruits or vegetables by artificially applying a very thin layer of wax, oil or another substance. There are tiny cuts and blemishes on the exterior surface of the vegetable those can be covered with wax. All vegetables, with the exception of those that are underground, have a naturally occurring waxy coating. Washing helps to eliminate some of this coating. Waxing typically lowers transpiration and respiration rates, prevents microbial infection and increases shelf life.
- (c) **Ultrasound Technology:** Ultrasound technology is becoming more and more popular as a promising way to preserve food products made from vegetables. Its benefits include reducing flavour loss, conserving energy, improving consistency, increasing production, lowering physical and chemical dangers, improving produce quality and being ecologically friendly. Ultrasonic power, a form of vibrational energy, powers ultrasound technologies. During the course of treatment, a transducer transforms electrical energy into acoustic energy, producing this energy. Direct exposure or the use of devices like a sonotrode or an ultrasonic water bath can maximize the use of ultrasonic energy in food processing activities. Ultrasonic energy has been successfully applied in the inactivation



of enzymes and the extraction of essential oils in contemporary food and beverage preservation systems.

- (d) **Ozone Treatments:** Due to the unique advantages of the technology, such as its multifunctional qualities and the quick dissolution of the used ozone gas, ozone treatments have become a prominent use in the food processing sector. Nevertheless, there are issues with ozone therapies in spite of their benefits. In food processing, ozone gas's usage as a sanitizer may be restricted by its reactive nature and product quality levels. Depending on the ozone dosage, the chemical makeup of the food and the particular treatment circumstances, the sensory qualities of treated meals may alter. Ozone reactions can also cause food to oxidize, which can result in oxidative spoiling, discoloration, unpleasant smells, and changes in flavour.

### Conclusion:

Vegetable waste after harvest is a major worldwide problem that impacts both developed and developing nations. Several tactics have been used in the agriculture industry over time to reduce this waste. Maintaining the quality and quantity of vegetables in agricultural techniques requires early and efficient steps including sorting, grading and field heat removal. Technologies like vacuum impregnation, dipping and edible active packaging should be used when producers want to improve the nutritional value and maintain the quality of fresh vegetables. The combination of additional procedures among those listed may have a good impact on the products' quality and safety. In order to meet consumer demands, the agriculture industry has innovated by implementing these technologies. Cost analysis, however, is required to confirm the true applicability. The field will be more successful in the future when it comes to the qualitative and quantitative measures of food commodities because of the steady advancement of cutting-edge technologies used in the contemporary agriculture sector. Considering all of those advanced options, the preservation and packaging sector is leading the way in new solutions and material and technological developments that will aid in future evolutions and the occasional breaking down of barriers.

### References:

- Palumbo M, Attolico G, Capozzi V, Cozzolino R, Corvino A, de Chiara MLV, Pace B, Pelosi S, Ricci I, Romaniello R, *et al.* 2022. Emerging Postharvest Technologies to Enhance the Shelf-Life of Fruit and Vegetables: An Overview. *Foods*. **11**(23):3925. <https://doi.org/10.3390/foods11233925>
- Rajapakshe P, Rathnasinghe N, Guruge K, Nilmini R, Jayasinghe R, Karunaratne V, Wijesena R and Priyadarshana G. 2025. Strategies to minimize post-harvest waste of fruits and vegetables: Current solutions and future perspectives, *Journal of Future Foods*, <https://doi.org/10.1016/j.jfutfo.2025.04.013>
- Reachana N and Mardy S. 2024. The Critical Role of Post Harvest Handling in Vegetables, *Jurnal Semesta Ilmu Manajemen dan Ekonomi (J-SIME)*, Vol. 1 No. 2 Desember, <https://jurnalpustakacendekia.com/index.php/J-SIME>