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Strategies Used to Prolong the Shelf Life of Fresh Commodities

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Abstract

Fruits and vegetables are metabolically active, perishable fresh commodities that have a shorter shelf life. Post-harvest treatments of fresh produce are used as strategies to minimize major losses in nutritional and quality attributes. Moreover, they are crucial in terms of consumer safety. Post-harvest treatments will slow down the physiological processes in fresh fruits and vegetables such as respiration, senescence and ripening. In addition, those treatments also reduce the incidence of pathogen attacks and microbial contamination to increase the shelf life of fresh commodities. Recent studies involving postharvest treatments are reviewed, with the aim to capture the state of art on current research about strategies used to reduce postharvest losses of fruits and vegetables.

Keywords: Fresh produce; Physiological processes; Post- harvest losses; Post-harvest treatments

Introduction

Fruits and vegetables are widely used as an excellent source of micronutrients and phytochemicals. Habitual inclusion of fruits and vegetables in the diet may prevent or reduce the risk of several chronic diseases [1,2]. However, as they are perishable products that contain living tissues, the quality retention and prevention of postharvest loss during handling, storage and retailing is critical [3]. It is estimated that more than 20-22% of the total production of fruits is lost due to spoilage at various post-harvest handling stages [4].

Postharvest treatments are used to minimize the loss of fresh produce as well as to maintain the quality, thereby increase the shelf life [5]. They can be divided in to three main categories as chemical, physical and gaseous treatments. Chemical treatments include usage of hydrogen peroxide, chlorine-based solutions, peroxyacetic acid, organic acids, nitric oxide and Sulphur dioxide to retard browning reactions, inhibit ethylene bio synthesis, reduce respiration rate and water loss and reduce the incidence of postharvest diseases [6-8]. Moreover, chemical treatments can minimize the deterioration of texture and microbial growth in fresh produce [9]. Heat treatments, edible coating and irradiation are the major physical treatments used to prevent postharvest loss of fruits and vegetables. Heat treatments are used for insect infestation, disease control and to prevent chilling injuries [10,11]. Edible coatings provide a barrier for moisture and preserve color, texture and natural aroma [12,13]. Irradiation is used to inhibit sprouting of tubers, bulbs and roots [14-16].

Gaseous treatments include ozonation, 1-methyl propene, control atmospheric packaging and modified atmospheric packaging. They are also helping to maintain cell wall integrity, peel color, retard senescence, reduction in decay, slow down the respiration rate and deterioration [17-19]. This review will focus on different types of postharvest treatments, their beneficial effects and limitations in usage. It also examines the status of postharvest treatments on fresh produce.

Chemical Treatments

Antimicrobial and anti-browning agents

Magnitude of enzymatic factors and microbial growth in fruits and vegetables may have a great impact on post-harvest quality and consumer safety [20]. Post-harvest quality can be maintained by using different anti-microbial and anti-browning agents. These agents include chlorine-based solutions, hydrogen peroxide (H_2O_2), peroxyacetic acid (PAA), organic acids, and electrolyzed water [5].

Chlorine-based solutions are commonly used as a disinfectant due to its very strong oxidizing properties and cost effectiveness, but chlorine have been associated with the formation of carcinogenic compounds. In addition, Chlorine-based compounds have a limited effectiveness in the reduction of microbial load on fresh produce. However, high levels may cause taste and odour defects on treated products [9]. H_2O_2 is a compound which has bactericidal, sporicidal and inhibitory ability based on oxidation of fungi and bacteria, and it was successfully used to control vegetable pathogens during storage [21]. Treatment with H_2O_2 can extend the shelf life and reduce natural and pathogenic microbial populations in melons, oranges, apples, prunes, tomatoes, whole grapes and fresh-cut produce [22]. PAA has not reported any harmful byproducts and it is very effective in controlling E. coli O157:H7 and Listeria monocytogenes in apples, strawberries, lettuce and cantaloupe [23].

Today, the use of reducing compounds, including ascorbic acid and its derivatives, cysteine and glutathione, is most effective for controlling enzymatic browning [24]. Organic acids have been applied largely to slow down enzymatic and non-enzymatic browning, deterioration of texture and microbial growth on fresh produce [25]. Chelating agents such as sorbic acid, polycarboxylic acids (citric, malic, tartaric, oxalic and succinic acids), polyphosphates (ATP and pyrophosphates), macromolecules (porphyrins, proteins) and ethylene diamine tetra-acetic acid (EDTA), which can inactivate enzymes by binding to transition metals in the metal-enzyme complex, have been used for a variety of food processing applications. Poly Phenol Oxidase (PPO) possesses copper at its active site and removal of the copper by chelation inevitably renders PPO inactive. A typical combination of

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anti-browning agents for fresh-cut products may consist of a chemical reducing agent, an acidulant and a chelating agent. However, internalization of bacteria and inaccessible sites of fruits and vegetables are the major limitations of applying anti-microbial and anti-browning agents [26].

Nitric oxide

Nitric oxide (NO) is a highly reactive and acts as a multifunctional signaling molecule in various plant physiological processes, such as fruit ripening and senescence of fruits and vegetables [27].

Postharvest application of NO is a potential new technology to reduce post-harvest losses of fruits and vegetables during handling and marketing [28]. Exogenous application of NO by gas fumigation or dipping in a solution has been demonstrated beneficial effects to reduce the production of ethylene, reduce rate of respiration and reduce ion leakage resulting from better maintenance of cellular integrity; reduction in oxidative stress through reduced lipid oxidation and enhanced activity of a range of antioxidant enzymes [29]. Successful application of NO has been reported for apple, banana, kiwifruit, mango, peach, pear, plum, strawberry, tomato, papaya, loquat, Chinese winter jujube fruit and Chinese bayberry [30]. It has found that treatments of strawberries with NO delayed the onset of senescence and extend postharvest life by inhibiting the action of ethylene [31]. NO has been combined with cold storage conditions and modified atmospheric conditions to improve the shelf life of fruits and vegetables such as Mango, green beans and broccoli [32-34].

Sulfur dioxide

SO_2 treatment is widely used due to its universal antiseptic action and economic application [26]. SO_2 technology has been tested for control of postharvest decay on fruits such as table grapes, litchi, fig, banana, lemon or apple. However, the SO_2 concentration necessary to inhibit fungal growth may induce injuries in grape fruits and stems, and sulfite residues pose a health risk for some individuals [35].

Calcium chloride

Calcium chloride is used to reduce chilling injuries, suppress senescence, enhance the storage and marketable life of fruits by maintaining their firmness and quality. Calcium application also delays aging or ripening, reduces postharvest decay, reduce the incidence of physiological disorders and increase the resistance to diseases [36]. It has been suggested that calcium treatment can increase tissue firmness and reduced the susceptibility to physiological disorders and reduced the risk of salt-related injuries in peaches [37]. The post-harvest application of $CaCl_2$ extend the storage life of pear up to 2 months, plum up to 4 weeks and apple up to 6 months at 0-2°C with excellent color and quality [36].

Gaseous Treatments

Ozone

Activated oxygen is the best available technology that can replace traditional sanitizing agents [38,39]. It is strong and ideal, germicide, sanitizer, sterilizer, anti-microbial, fungicide and deodorizer and detoxifying agent [40].

It has been reported that shelf life of fruits and vegetables can be increased when they are subjected to ozonation [41].

Ozone oxidizes the metabolic products and neutralizes the odors generated during the ripening stage in storage of fruits. This helps preserve and almost double the shelf life on fresh produce. It also enhances the taste by retaining the original flavor of the products [42]. Ozone enhances the taste of most perishables by oxidizing pesticides and by neutralizing ammonia and ethylene gases produced by ripening or decay. The reduction of ethylene gas increases the shelf life and reduces shrinkage. It changes the chemicals complex molecular structure back to its safe and original basic elements. Its use does not leave any toxic by-products or residues, does not affect healthy cells or alter its chemistry, and is non-carcinogenic. Ozone always reverts to its original form-oxygen [43].

However, Ozone should be constantly consumed and absorbed during the oxidation process. The effectiveness of ozonation can be influenced by different factors such as presence of steam and humidity level. The micro-organisms must be in a certain condition of swelling to be attacked [44].

1-Methylcyclopropene

1-methylcyclopropene (1-MCP) is a synthetic cyclic olefin which can block the access to ethylene-binding receptor there by inhibit the action of ethylene [45]. It has found that avocado treated with 1-MCP showed significantly less weight loss and retained greener color than control fruit at the full-ripe stage [46]. It can also inhibit ethylene induced ripening of avocado fruit at very low concentration by suppressing the ethylene response pathway by permanently binding to a sufficient number of ethylene receptors [47]. Treatment with 1-MCP controls the blue mold rot, postharvest pitting and effectively suppressed endogenous ethylene production in citrus fruits [48,49]. Moreover, it has increased the firmness of apple and pears [50,51].

In addition, Postharvest application of 1-MCP significantly delayed and suppressed the climacteric ethylene production of plum with reduction in the activities of ethylene [52]. However, application of 1-methylcyclopropene to permit extended storage requires prior assessment of the appropriate concentration range and storage conditions for each type of produce at maturity [53].

Modified Atmosphere Packaging (MAP)

MAP is a technique used to extend the shelf life of commodities by sealing them in polymeric film packages to modify the oxygen and carbon dioxide concentration levels within the package atmosphere [54]. Composition of the air inside the package is changed due to the respiration and transfer of gases through the package. In contrast, it creates an atmosphere richer in carbon dioxide and lower in oxygen [55]. Reduced oxygen and elevated carbon dioxide levels effectively reduce the rate of respiration of fruits and vegetables [56]. Elevated carbon dioxide levels inhibit the production of ethylene hormone and suppress plant tissue sensitivity for the effects of ripening [57].

The use of MAP also reduces the incidence of decay, compositional changes and softening of tissues [54]. Furthermore, it can retard the browning reactions and senescence thereby extends the post-harvest life [56]. MAP is widely used in the long-term storage of apple, pears, kiwi fruits, cabbage, and temporary transport of strawberries, guava, banana and tomato [58]. However, risks of developing anaerobic pathogenic flora in MAP are unknown. Most of the plastic films are undesirable for the environment [59,60].

Physical Treatments

Heat treatments

During the past few years there is a higher demand for heat treatments in post-harvest technology instead of chemicals. However, usage is limited due to the high cost [26]. Mode of action of heat treatment is to wash off the spores from the surface of the commodity. In addition, due to heat energy there is a considerable reduction of microorganisms such as bacteria and fungi. There are different types of heat treatments including hot water dip, saturated water vapor heat, hot dry air and hot water rinse with brushing [61].

Heat treatments have shown beneficial effects for insect control, prevention of fungal development, delayed ripening through inactivation of enzymes and prevention of postharvest storage disorders including chilling injury [62]. Many commodities will develop chilling injury if the temperature is too low or if the cold conditions are maintained for too long. Heat treatments have been found to delay or prevent the development of chilling injury and ripening processes. Ripening can be delayed by heat inactivation of degradative enzymes [63]. Time of the heat treatment can depend upon several factors and it can be vary from hours to days [64]. Heat treatments have been used to preserve the color of asparagus, to prevent the development of off flavors, to prevent development of overripe flavors in cantaloupe and other melons, to the longevity of grapes, plums, bean sprouts and peaches and to preserve the color of asparagus, broccoli, green beans, kiwi fruits and celery [61,64].

Edible coatings

Edible coatings are thin layer of material which provides a barrier to moisture, oxygen and solute movement for the food. It can be a complete food coating or can be disposed as a continuous layer between food components [12]. Polysaccharides, lipid-based substances and protein films are commonly used as edible coatings [65]. Edible coatings provide a barrier to moisture and minimize the loss of moisture during storage. They can also act as a gas barrier and slow down the respiration, senescence and enzymatic oxidation [66,67]. In addition, edible coatings help to preserves color, texture and volatile compounds of fresh fruits and vegetables. It also maintains the structural integrity and protects against mechanical damages [13].

However, thick coating on fruits and vegetables surface becomes an undesirable barrier between the external and internal atmosphere and restricts exchange of respiratory gases (CO_2 and O_2). It may result in anaerobic respiration, which produces much more carbon dioxide, acetaldehyde and ethanol. The acetaldehyde and ethanol results in fermentation and give off-flavor to the product, which are detrimental to the perceived quality [68].

The edible coatings that have been used in different types of fruits and vegetables are summarized in Table 1.

Coating Material	Purpose	Fruit/Vegetable	References
Chitosan: Methyl Cellulose	Antimicrobial, Antioxidant properties, Gas Barrier properties	Strawberries Apple, pear, pomegranate	[12,68,69]
Mixture of sucrose fatty acid esters, sodium carboxy methyl cellulose, and mono and diglycerides	Retard ripening, reduce weight loss and chlorophyll loss	Mango	[70]
	Retention of firmness, green skin color, and titrable acidity	Pear	[69]
Chitosan, Twin 80	Reduce ethylene production and delay ripening as indicated by high content of titrable acidity	Pear	[71]
Polyvinyl alcohol, starch and Surfactant	Reduce the rate of physiological processes and delay ripening	Fruits	[69]
Alovera gel	Improve the keeping quality and extend the shelf life	Mushroom	[66]
Cellulose and glycerol	Reduce the rate of physiological processes	Carrot	[72]
Bees wax, sunflower oil, tamarind seed powder and tween 80	Reduce the rate of Physiological process and extend shelf life	Guava	[73]

Table 1: Different types of edible coatings used in research studies.

Irradiation

Food irradiation is a process of exposing the produce to speed particles or rays for improving the shelf life [15,74]. It is also serve as a quarantine treatment for many fruits and vegetables [75]. However, all fruits and vegetables are not appropriate for irradiation including cucumbers, grapes, and some tomatoes as they are sensitive to radiation [76].

Irradiation can be used on alone or in combination with other methods to improve the microbiological safety and extend shelf life [77]. Dose of application on fruit products are limited by their impact on quality [78]. The maximum doses which can be applied on fruits and vegetables range between 1 and 2 kGy. However, these maximum values depend on the type of products and might modify with new, resistant cultivars [79]. Most studies indicated that, the irradiation of fresh fruits led to a reduction in firmness. Irradiation can be recommended for sprouting inhibition (in the range of 50-200 Gy) and disinfestations purposes (at doses like those used for other dry foods) in sprouting foods such as potatoes, garlic, onions and yams [75].

In contrast, people are very confused to distinguish irradiated foods from radioactive foods. Irradiation process is not possible to induce radioactivity in the food by using gamma rays or electron beams up to 10 MeV [80]. Moreover, heterocyclic ring compounds and carcinogenic aromatic produced during thermal processing of food at high temperatures were not identified in irradiated foods [74].

Future Research Needs

There are wide ranges of chemical, gaseous and physical treatments to reduce the post-harvest losses but, future research based on postharvest technology should be carried out to improve the efficacy of treatments as well as to address the safety issues. Although there are different physical, chemical and gaseous treatments are available, their effectiveness should be investigated extensively.

Emerging technologies and techniques such as using nano-materials for edible coating, using nano packaging materials with ethylene binders and cold plasma technology should be combined with other chemical and gas treatments to optimize the beneficial effects. However, more detailed studies are essential to evaluate the effect of novel treatments on fresh produce.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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