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POSTHARVEST PRACTICES FOR ORGANICALLY GROWN PRODUCTS

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Summary: Quality of produce cannot be improved after harvest, only maintained. Postharvest handling depends on the specific conditions of production, season, method of handling, and distance to market. Under organic production, growers harvest and market their produce at or near the peak ripeness more commonly than in many conventional systems. Organic production often includes more specialty varieties whose shelf life and shipping traits are reduced or even inherently poor. Harvesting and handling techniques that minimize injury to the commodity, as well as increased care with field and packinghouse sanitation, (chlorine, ozone, calcium hypochlorite, sodium hypochlorite and chlorine dioxide, acetic acid, peroxyacetic acid, vinegar, ethyl alcohol, hydrogen peroxide, etc.) during postharvest processes are vital components of a postharvest management plan for organic products. Sodium carbonate, sodium bicarbonate, and physical treatments such as heat treatments (as hot water treatment or dips, short hot water rinsing and brushing or hot air) can significantly lower the disease pressure on the harvested commodities. These sanitation practices are very easy to implement in the organic food production chain. They start in the field and continue during harvesting, sorting, packing, and transportation and continue even in the consumer's home. All those treatments reduce rot development, provide quarantine security, and preserve fruit quality during cold storage and shelf life. In addition, the use chitosan, propolis, methyl jasmonate, essential oils, carnuba wax, biocontrol agents and modified atmosphere packaging can also reduce decay development during prolonged storage. All these treatments can be applied alone or in combination with each other in order to improve decay control after harvest and provide a healthy and safe product to the consumer. The aim of this chapter is to shed more light on the latest information on permitted treatments for organic products and on the possible mode-of-action of these treatments. This chapter summarizes technologies developed over the past five years that explore special physical treatments applied either directly, or in combination with other means to control rot development and insect infestation on fresh produce.

Key words: organic vegetables, fruit, postharvest treatments, storage, shelf life

INTRODUCTION

Consumption of vegetables and fruit has increased worldwide in recent years, not only because of their sensory attraction, but also for their nutritional and health benefits (Villa-Rodriguez et al., 2015). Worldwide, roughly one-third of fresh fruit and vegetables are lost because their quality has dropped below an acceptance limit and, in light of the increasing world population, this is totally unacceptable (Jedermann et al., 2015). Organic standards include a well-defined set of practices and a list of technical tools that are permitted by regulation (Ceglie et al., 2016). Most synthetic inputs are prohibited for both producing and handling agricultural and processed food products labeled as organic. Postharvest handling of organic commodities raises a number of issues both in terms of allowed procedures and of their effectiveness in maintaining quality of the produce. On the other hand, the postharvest performance of the produce obtained from specific sustainable procedures may be somewhat affected by preharvest conditions. In organic systems, many methods are used to maintain soil fertility, including addition of organic matter to the soil, which slowly release soil nutrients, in contrast to chemical fertilizers. In addition, conventional agriculture practices

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utilize the levels of pesticides that can result in disruption of phenolic metabolites that have a protective role in plant defense mechanisms. These differences may result in differences in plant composition and nutritional quality, which in turn influence storage performance of the products.

Quality for most crops cannot be improved during storage, only maintained, so the importance of the variety and preharvest factors must be taken into account. Growers usually select varieties on the basis of their marketability (visual qualities specific to the market of choice) and yield, because these factors directly affect the bottom line. However, varieties can vary greatly in storage and shelf life. The absence of postharvest chemical treatments for organic growers (Permitted substances lists National standards – Law of organic production – Zakon o organskoj proizvodnji „Sl. glasnik RS“, br. 30/2010) makes it even more important that varieties are selected with these factors in mind. Variety selection should also include resistance to postharvest diseases and physiological disorders.

One of the benefits of organic production is that it is often more common to harvest and market near or at the peak ripeness, compared to many conventional systems. However, organic production often includes more specialty varieties that have reduced or even inherently poor shelf life and shipping traits. Organic crops, however, are handled and shipped in smaller quantities since organic farms tend to produce less, and this results in higher costs. Additionally, organic farms are usually located farther from major cities, increasing the shipping cost. Conventional farmers use certain chemicals to reduce their loss of crops. For example, synthetic pesticides repel insects and antibiotics maintain the health of the livestock. Since organic farmers do not use these, their losses are higher, which costs the farmer more and increases the cost to the consumer. Additionally, without all the chemical preservatives added to conventional foods, organic foods face a shorter storage time and shelf life.

POSTHARVEST STORAGE

Optimal postharvest treatments for fresh produce seek to slow down the physiological processes of senescence and maturation, to reduce/inhibit development of physiological disorders, and to minimize the risk of microbial growth and contamination (Mahajan et al., 2014). Storage diseases are responsible for substantial postharvest losses. Currently, the most important means of maintaining quality and prolonging the shelf life of organic produce is low temperature storage, as organic producers have no access to chemical programs, unlike the growers and storage operators of regular crops.

Temperature is the single most important tool for maintaining postharvest quality. For products that are not field-cured or exceptionally durable, the removal of field heat as rapidly as possible is highly desirable. When harvested, a vegetable is cut off from its source of water, but it is still alive and will lose water, and therefore turgor, through respiration. Field heat can accelerate the rate of respiration and consequently also the rate of the quality loss. Proper cooling protects the quality and extends both the sensory (taste) and nutritional shelf life of the produce. The capacity to cool and store the produce gives the grower greater market flexibility (Suslow, 2000).

Other postharvest issues, which involve combined steps of unloading commodities from harvest bins, washing, and precooling, must also be evaluated in terms of adherence to the organic standards. Some operators use flotation as a way to reduce damage at the point of grading and packing. Standards for handling organic vegetables maintain the identity and integrity of organic vegetables. Vegetable packers will need to implement the procedures for handling organic vegetable to gain access to domestic and export markets for organic food. International trade in fruit and vegetables worldwide is severely constrained by quarantine and phytosanitation barriers, which were erected to prevent the spread of fungal and bacterial diseases in fresh and fresh-cut produce. Trade constraints can be removed only when an effective treatment exists for use on fresh produce after harvest (Fallik and Ilić, 2017). Entire bins are submerged in a tank of water treated with a chemical flotation aid that allows the picked product to be gently removed and separated from the container. Lignin sulfonates are allowed in certified organic handling as flotation aids for water-based unloading of field bins or other density separation applications.

SANITATION

Preventive food safety programs, sanitation of equipment and food contact surfaces, and water disinfection should be integrated into every facet of postharvest handling. For organic handlers, the nature and prior use of cooling water is a special consideration. Postharvest water cannot at any time contain prohibited substances in a dissolved form. Responsibility for this falls on the organic producer, handler, processor, and retailer. Even incidental contamination from a prohibited material would keep the product from being certified organic. Organic producers, packers, and handlers are required to keep accurate, specific records of postharvest wash or rinse treatments, identified by brand name and source (Suslow, 2000).

Food safety and decay/spoilage control are concerns for produce handlers at all scales of production. Briefly, the proper use of a disinfectant in postharvest wash and cooling water can help prevent both postharvest diseases and foodborne illnesses. Guidelines for packing fresh or minimally processed fruit and vegetables generally specify a washing or sanitizing step to remove dirt, pesticide residues, and microorganisms responsible for quality loss and decay (Sapers, 2006). However, washing procedures with water or chemical sanitizers typically result in only a 1 to 2 log_{10} decrease in microbial counts (Sapers, 2001). In addition to washing with plain water, various factors are in use to enhance the washing effect of water and to reduce more efficiently the microbial load of whole or freshly cut produce, e.g., washing with chlorine, hot water dips or rinsing and brushing, ozone, acidic electrolyzed water or H2O2 (Palou et al., 2007).

Chlorine. Chlorine is currently the predominant method used by packinghouses to sanitize water systems. The main advantages of using chlorine are that it is effective at killing a broad range of pathogens at concentrations between 100 and 200 ppm active ingredient, at pH around 7, and that it is relatively inexpensive (Sapers, 2006).

For optimum antimicrobial activity with a minimal concentration of applied hypochlorite, pH of water must be adjusted to between 6.5 and 7.5. At this pH range, most of chlorine is in the form of hypochlorous acid (HOCl), which delivers the highest rate of microbial kill and minimizes the release of irritating and potentially hazardous chlorine gas (Cl_2). Chlorine gas will exceed the safe levels if water is too acidic. Products used for pH adjustment also must be from a natural source, such as citric acid, sodium bicarbonate, or vinegar.

However, chlorine is corrosive to equipment and pH must be monitored and adjusted often to maintain chlorine in its active form. Continual addition of chlorine without changing the water can result in accumulation of high salt concentrations that may injure some produce. Further, chlorine can react with organic matter to form small amounts of different trihalomethanesđ (THMs) that are thought to be carcinogenic. However, the relative risks from chlorine-generated THMs on the surface of fresh horticultural produce are extremely low (Sapers, 2006).

Food-grade hydrogen peroxide (0.5 to 1%) and peroxyacetic acid are additional options. In general, peroxyaceti acid (PAA) has good efficacy in water dump tanks and water flume sanitation applications. PAA has

very good performance, compared to chlorine and ozone, in removing and controlling microbial biofilms (tightly adhering slime) in dump tanks and flumes.

Cleaners, sanitizers, and disinfectants

Disinfecting agents (ethanol, acetic acid, electrolyzed oxidizing water) have been used for fruit surface sterilization, mainly when the process of washing is included in postharvest fruit packaging. Acetic acid was successfully used as fumigant to control postharvest decay (Sholberg et al., 1996), as well as ethanol (Mlikota Gabler et al., 2005). The application of electrolyzed oxidizing water is effective in disinfection of water used in packinghouses operations and has shown to decrease conidia contamination of different pathogens, including *B. cinerea* (Guentzel et al., 2010).

Table 1. Substances for water disinfection and cleaning of equipment and facilities for organic products

Chlorine	***Acids***	***Other***
sodium chloride	acetic acid	ozone
sodium hypochlorite	citric acid	hydrogen peroxide
calcium hypochlorite	peroxyacetic acid	alcohol *(ethyl)*
calcium oxide	peroctanic acid	potassium permanganate
		caustic soda

Klaiber et al. (2005) studied the application of cold and warm tap water with and without chlorination (200 mg L^{-1}) as a postharvest sanitation program. Other options are acetic acid, hydrogen peroxide and ozone. Stabilized hydrogen peroxide (Tsunami® 100) or a yeast commercial product (Shemer™) are usually applied as postharvest treatments in Israel (Eshel et al., 2009). Also, hitosan coatings delay microbial spoilage and exhibit positive effects on the colour and texture of carrots during long storage (Leceta et al., 2015).

There are three additional postharvest treatments that may be used on produce:

Carbon dioxide – permitted for postharvest use in modified – and controlled – atmosphere storage and packaging. For crops that tolerate treatment with elevated CO2 (15%), suppression of decay and control of insect pests can be achieved.

Fumigants – allowed if materials are naturally occurring forms (e.g., heat-vaporized acetic acid). Materials must be from a natural source.

Wax – must not contain any prohibited synthetic substances. Acceptable sources include carnuba or wood-extracted wax. Products that are coated with approved wax must be so indicated on the shipping container.

POSTHARVEST TREATMENTS

A new worldwide trend to explore alternative, non-chemical compounds that control postharvest diseases, giving priority to decay-preventing methods with a minimal impact on human health and environment has emerged (Mari et al., 2007). These compounds, such as carbonate and bicarbonate salts, chitosan, ethanol, essential oil, and many more, are known as GRAS compounds for many applications, and have been applied for organic products.

Carbonate and bicarbonate salts

Sodium carbonate, sodium bicarbonate, potassium carbonate, potassium bicarbonate, and ammonium bicarbonate are common food additives for leavening, pH control, taste, texture modification, and spoilage control, and they inhibit various plant pathogens (Smilanick et al., 2006; El-Mougy and Abdel-Kader, 2009). All these compounds are fungistatic rather than fungicidal. The effective concentrations vary from 0.5% to 3%. Higher concentration may increase phytotoxicity damage (Fallik et al., 1997). The direct and indirect effects of bicarbonate salts on microorganisms are in part because of the reduction of fungal cell turgor pressure, which resulted in collapsed and shrinkable hyphae and spores, and therefore the inability of the fungi to sporulate. It is also possible that the bicarbonate ion increases the fungal cell membrane permeability to ionic species, which could result in a decrease in turgor pressure in the fungus (Fallik et al., 1997).

Essential oils

Recent exploitation of natural products to control biological spoilage and extend the storage life of perishables has received more and more attention. Particularly, natural pesticides based on plant-essential oils as alternative crop protectors are gaining support (Mari et al., 2007). Antimicrobial properties of essential oils from various plant species have been proved to affect and arrest fungal development in vitro and in vivo in various horticultural commodities (Antunes and Cavaco, 2010).

The antimicrobial activity of essential oils (EOs) against important plant pathogens, as well as food spoilage organisms, has been studied extensively. Recently, there has been a renewed interest in the application of these substances to control plant pathogens and postharvest diseases in particular (Arras and Usai, 2001). The role played by these substances in the plant has not been fully elucidated; however, it is likely that most of them are involved in chemical defence mechanisms against phytopathogenic microorganisms. Among the many EOs tested *in vitro* and *in vivo* against postharvest pathogens, those from plants of the genus *Thymus* have been particularly active.

Thyme EOs have been tested on *P. italicum*, *P. digitatum*, *B. cinerea*, *Alternaria citri*, *A. alternata*, *Fusarium oxysporum*, and *R. stolonifer* (Reddy *et al*., 1998; Arras and Usai, 2001); With *T. vulgaris* extracts, *B. cinerea* and *R. stolonifer* were inhibited by more than 50% (Reddy *et al*., 1998). On strawberries, *T. vulgaris* EO reduced decay due to *B. cinerea* and *R. stolonifer* by up to 76% (Reddy *et al*., 1998). Generally, the fungicidal activity of EOs observed *in vitro* was not reproduced *in vivo* or *in situ* because of the volatile nature of the constituents. Thymol, carvacrol and linalool were the active agents in *T. vulgaris* (Reddy *et al*., 1998). The EO of oregano (*Origanum* spp.) containing thymol and carvacrol was reported as very active *in vitro* against several mycotoxigenic fungi (Lambert *et al*., 2001) and against some disease agents.

However, essential oils are often fungistatic rather than fungicidal. This means that they stop the growth of the fungi while they are exposed to the oil, but once the oil is removed the fungi can continue to grow. Essential oils can be applied as dips, but more studies report their use as vapors, because of their benefit in preventing tainting of the product. Essential oils have been shown to reduce sprouting and pathogen viability in potatoes and can be applied to certified organic crops. Monthly thermal fogging with mint oil inhibited sprouting for 9 months in all treated cultivars. In nontreated tubers, sprout weight was more than 4% of tuber weight. Moreover, thermal fogging after sprouting stopped sprout elongation. Treated tubers lost only 3% of their weight compared to more than 7% in nontreated tubers. Two days exposure of *Rhizoctonia solani* mycelia and sclerotia to the mint oil vapor controlled up to 100% of the propagules in vitro (Eshel et al., 2009a).

Heat treatments

Pre-storage heat treatments (HT) are known for many years to be effective in managing postharvest diseases and physiological disorders. These treatments are completely safe for humans and the environment (residue-free and environment-friendly) and of feasible use without registration rules (Usall et al., 2016). These treatments can also enhance fresh produce resistance to environmental stress and help preserve fruit and vegetables quality during prolonged storage and extended shelf life (Fallik, 2010; Sivakumar and Fallik, 2013; Sui et al., 2016). However, heat techniques expose fruit and vegetables to the hazard of physiological disorders (Mittler et al., 2012). These physiological disorders can be affected by a large number of parameters, such as the initial quality of their fruit, their physiological stage of maturity, and their exposure to physical and chemical agents in the orchard (Woolf and Ferguson, 2000; Rodoni et al., 2016). In addition, incidence of damage increased with increasing temperature and treatment duration, and with increasing length of time in cold storage (Sivakumar and Fallik, 2013).

Postharvest treatments for fresh produce seek to slow down the physiological processes of senescence and maturation, to reduce/inhibit development of physiological disorders, and to minimize the risk of microbial growth and contamination (Mahajan et al., 2014). Hot water treatments (HWTs), among various other nonchemical approaches, have been reported to be effective in managing several postharvest diseases and physiological disorders (Fallik, 2010). Amongst these treatments there are various physical treatments, such as hot-water treatment or dips, short hot-water rinsing and brushing, and hot-air or steam treatments. These methods enable fruit to retain their quality during prolonged cold storage and shelf life, reduce rot development, and provide quarantine security against invasive pests (Sivakumar and Fallik, 2013; Mahajan et al., 2014).

Many studies have reported that physical treatments are effective against postharvest rot development (Fallik, 2010; Sivakumar and Fallik, 2013). Therefore, the aim of this chapter is to summarize recently accumulated information regarding hot-water treatments, applied either separately or in combination with other means, to control rot development and/or insect infestation on fresh-harvested produce, and to elucidate possible mode(s) of action of these treatments.

Heat treatment can directly control decay development by decay causing agents that are found on the fresh produce skin or within 2-3 layers of the cuticle. But heat treatment can also control decay development indirectly by inducing defense mechanisms and triggers physiological and pathological responses that allow fresh produce to withstand stressful conditions during storage and to reduce rot development (Fallik, 2010). Decay causing agents are considerably varied in their sensitivity to pre-storage treatments of high temperatures (Sivakumar and Fallik, 2013). Pathogen kill is not always proportional to the temperature-time product of the treatment, although reports have indicated a linear relationship between the logarithm of the decimal reduction time and the temperature of the heat treatment. The vegetative cells and conidia of most fungi are inactivated when exposed to 60°C for 5 to 10 min *in vitro*. Spore germination and germ tube elongation were found to be more sensitive to heat treatments than dormant spores, which are unaffected by hot water (Sivakumar and Fallik, 2013). Fruit responses to heat treatment depend on their stage of the maturity at harvest, fruit size and weight, the cultivar, heat temperature and duration and mode of heat application. On the other hand, the physiological and pathological responses of different fresh produce cultivars to heat treatments can vary by the season and growing condition and location and pre-storage practices (Fallik, 2010). Heat treatments can be applied alone, or in combination with other means to control decay development on fresh fruit and vegetables.

Table 2: The beneficiary and the disadvantage of the various physical treatments on selected fresh-harvested fresh produce (HWD – hot water dip; HWRB – hot water rinsing and brushing; HA – hot air)

Crop	Physical treatment	Beneficiary	Disadvantage	Reference
Broccoli	HWD	50°C, 3 min		Perini et al., 2016
Pepper	HWD	45°C, 3 min		Rodoni et al., 2016
	HWD		55°C, 5 min	Rodoni et al., 2016
Spinach	HWD		>45°C, 60 s	Gomez et al., 2008
	HWD		>50°C, 30 s	Glowacz et al., 2013
Strawberry	HWD		45°C, >5 min	Caleb et al., 2016
Tomato	HWD	40°C, 30 min		Pinheiro et al., 2015
	HA	38°C, 12 h		Wei et al., 2016
	HWRB	52 °C, 15 sec		Ilić and Fallik, 2005
	HWD	50 °C, 1 min		
Melon	HWRB	60 °C, 15 sec		Ilić and Fallik, 2007
Rocket	HWD		>50°C	Koukounaras et al., 2009

Hot water treatments may benefit the treated fresh-harvested produce, but inappropriate heat exposure can cause severe internal and external damage. Tolerance to heat treatment is influenced by the cultivar, harvest maturity, fruit size, mineral nutrition deficiency of the orchard, growing conditions, and handling between the harvest and the treatment (Sivakumar and Fallik, 2013). Therefore, a hot water treatment that shows very successful decay management and fruit quality maintenance in one cultivar and/or in a particular country might have severely limited commercial potential for postharvest decay and quality management in a different country and/or with a different cultivar.

Heat and coating

Edible coatings provide a promising approach for extending the shelf life of organic products. Edible coatings protect products from mechanical and microbial damage, inhibit deterioration and prevent the escape of favorable volatiles. They are based on natural, biodegradable and edible materials and therefore satisfy the environmental concerns and respond to customer demands for safe and healthy food (Shiekh et al., 2013).

Heat-treated (HT) at 38°C for 4 days, apples cv. Gala were coated with 1% chitosan (CTS) (HT+CTS) complete controlled *P. expansum* and *Botrytis cinerea* and showed the lowest respiration rate, ethylene evolution, malondialdehyde and membrane leakage, and the highest firmness and consumer acceptance among the treatments, after 8 weeks at 0°C and 7 days of shelf life (Shao et al., 2012). However, application of the heat-treatment after CTS coating (CTS + HT) did not reduce decay development. Therefore, the order where such technologies are applied should be considered beforehand, in order to control decay development.

Edible coatings based on natural materials form a promising safe and healthy tool for extending the shelf life of fresh agricultural products (Poverenov et al., 2014). For the first time, a composite chitosan–gelatin (CH–GL) coating was applied to peppers following HWRB treatment at 55°C for 15 s, and its effects on fruit quality and storability were examined. The composite CH–GL coating was associated with a 50% decrease in microbial decay, significantly enhanced fruit texture, and extensions of possible cold storage and fruit shelf life periods by up to 21 and 14 days, respectively, without impairment of the respiration or nutritional content of the fruit (Poverenov et al., 2014).

Heat and biocontrol

Progress in biological control, especially in the postharvest application of antagonists, may be attributed to the uniqueness and relative simplicity of the postharvest system. Wounds made during harvesting and fruit handling can be protected from wound invading pathogens with a single postharvest application of the antagonist directly to wounds, using existing delivery systems (drenches, on-line sprayers, on-line dips). The main strategy used to suppress postharvest fruit decay is the postharvest application of antagonists to prevent pathogens from infecting fruit wounds after harvest, but postharvest decay can also be suppressed by field application of biocontrol agents (Manso and Nunes, 2011). Since the antagonists are applied to fresh-harvested produce, they must meet strict requirements for human safety. Various mechanisms of the biocontrol agents have been described, including antibiosis, production of lytic enzymes, parasitism, induced resistance, and competition for limiting nutrients and space (Droby et al., 2009).

Microbial biocontrol agents have shown great potential as an alternative to synthetic fungicides for the control of postharvest decay of fruit and vegetables. Utilization of antagonist microorganisms appears to be a promising technology; and while some antagonist-based products are commercially available, others are currently at various stages of development (Droby et al. 2009). Only a few commercial products are available, such as Biosave™ (*Pseudomonas syringae*, Jet harvest solutions, USA), Shemer™ (*Metschnikowia fructicola*, Bayer Crop Science, AG), Candifruit™ (*Candida sake* CPA-1, Spicam-Inagra, Spain), Pantovital™ (*Pantoea agglomerans*, Biodurcal S.L., Spain), Serenade™ (*Bacillussubtilis*, AgraQuest, USA) and Boniprotect™ (*Aureobasidium Pullulans*, Bio-protect, Germany) (Manso and Nunes, 2011).

Biological control of crown rot disease was analyzed using an integrated approach combining hot water treatment and *Trichoderma harzianum* strain DGA01, a fungal antagonist. Zhao et al. (2010) tested the effectiveness of heat treatment (hot air at 38°C for 24 h) and *Pichia guilliermondii*, either alone or combined, to combat postharvest fungal spoilage in cherry tomato fruit. *In vitro* experiments demonstrated that heat treatment at 38°C significantly inhibited mycelial growth of three different pathogens (*Botrytis cinerea, Alternaria alternata* and *Rhizopus stolonifer* Ehrenb). Furthermore, a combination of heat treatment, followed by the application of *P. guilliermondii* (H+P), provided the best efficacy in preventing fungal spoilage in cherry tomato.

Microbial biocontrol agents have shown great potential as an alternative to synthetic fungicides for controlling postharvest decay of fruit and vegetables, and some antagonist-based products are already commercially available (Droby et al., 2009). Hong et al. (2014) suggested that the combination of *Bacillus amyloliquefaciens* HF-01, 2% sodium bicarbonate and hot water, at 45°C for 2 min, could serve as a promising means for controlling postharvest decay while maintaining postharvest fruit quality.

Table 3. Commercial biopesticide for some vegetable application

Commercial biopesticide	***Fungi***	***Vegetable***
Extract grapefruit	*Fusarium roseum*	Melon
Phenethyl caffeic acid (CAPE)	*Alternaria alternata*	Tomato
Benzil-isothiocianate	*Alternaria alternata*	Tomato
ITCs mixture	*Alternaria alternata*	Pepper

In the field, yeasts and bacteria are exposed to a wide array of stressful environmental conditions and their viability and effectiveness are challenged by high temperature, freeze/spray drying (desiccation), and oxidative stress. Combination of yeast and bacteria with other antimicrobial compounds could be an effective method for improving biocontrol performance. Combinations of salts, such as bicarbonates (Droby et al., 2003), and natural compounds, such as chitosan (Sivakumar et al., 2005), have reported to improve the performance of biocontrol agents. The use of organic and inorganic salts before harvest has been increasingly popular in several organic crops (Nigro et al., 2006; Feliziani et al., 2013).

MODIFIED ATMOSPHERE PACKAGING (MAP)

Modified atmosphere packaging (MAP) is a technique used for prolonging the shelf-life period of fresh or minimally processed foods (Aharoni et al., 2007). In this preservation technique, the air surrounding the food in the package is changed to another composition. In this way, the initial fresh state of the product may be prolonged. It is the shelf life of perishable products of fruit and vegetables that will be prolonged with MAP, since it slows the natural deterioration of the product. MAP is used with various types of products, where the mixture of gases in the package depends on the type of product, packaging materials and storage temperature. It is often desirable to generate an atmosphere low in O_2 and/or high in CO_2 to influence the metabolism of the product being packaged, or the activity of decay-causing organisms to increase storability and/ or shelf life (Fonseca et al., 2000). For some products, modifying both O_2 and CO_2 may be desirable, and indeed, altering the O_2 level automatically alters CO_2 level. In addition to atmosphere modification, MAP vastly improves moisture retention, which can have a greater influence on preserving quality than O_2 and CO_2 levels. Furthermore, packaging isolates the product from the external environment and helps to ensure conditions that, if not sterile, at least reduce exposure to pathogens and contaminants. If the permeability (for O_2 and CO_2) of the packaging film is adapted to the product respiration, an equilibrium modified atmosphere will establish in the package and the shelf life of the product will increase. Successful applications include broccoli florets, cauliflower florets, carrots, baby carrots, peeled garlic and fresh herbs (Aharoni et al., 2007).

Specialized films that create *modified atmospheres* (MA) when sealed as a bag or pouch are available for many produce items that have well-characterized tolerances for low oxygen and elevated carbon dioxide. Not all commodities benefit from MA. Packing design and packaging can also be designed to minimize water loss. To minimize condensation inside the bag and reduce the risk of microbial growth, the bags may be vented, microperforated, or made of material permeable to water vapor. Barriers to water loss may also function as barriers to cooling, and packing systems should be carefully selected for the specific application while bearing this in mind. Packaging materials, storage or transport containers, or bins that contain synthetic fungicides, preservatives, or fumigants (or any bag or container that has previously been in contact with any prohibited substance) are not allowed for organic postharvest handling (Suslow, 2000).

CONCLUSION

This review represents a small contribution to the wider picture of the quality of vegetable produce resulting from different systems of production. Organic production systems have the objective of including a rational use of natural resources with high quality and shelf life performance. More in-depth analyses may relate the organic vs. conventional comparison to the more general issue of pre-harvest effects on postharvest performance of crops. In this respect, the balance between primary and secondary metabolic pathways seem to be an important aspect resulting from the complex interaction of genotype, environment, and agricultural practices, which lead to differences in quality and postharvest performance of fresh vegetables. The organic sector, which emphasizes sustainability and is dedicated to minimizing waste, can benefit significantly from this environmentally-friendly technology. The ability to preserve crops longer than low temperature alone will allow and the reduced economic losses arising from postharvest losses could encourage growers to increase production of their crops and serve expanded and farther markets, leading to improved profitability of the sector. In addition, there is also a potential to enhance health-promoting phyto-compounds in the treated produce that could lead to increased consumer demand for organic produce. The proposed technology can also be beneficial to the regular fresh produce sector, which is also seeking alternative approaches to chemicals to control storage diseases.

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