Chapter 7

Value-Added Fruit Processing for Human Health

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1. Introduction

Fruits are staple food in human diet. There has been a growing interest in the connection of fruit and vegetable consumption and improved health. Research have shown that biologically active components in plant-based foods, particularly phytochemicals such as polyphenolics and carotenoids, have important role in reducing the risks of chronic diseases, including cancer, cardiovascular disease, diabetes and Alzheimer's disease, among others. The first part of the chapter provides a brief update of the links between fruit-based antioxidants and other biologically active compounds and potential health benefits.

Fruit production is increasing globally. Despite the increasing fruit production at the global level, a significant amount of fruit produced is lost or wasted due to poor post-harvest management. The second part of the chapter provides information on current status of post-harvest losses in selected fruits and methods to prevent these losses. Therefore, processing fruits into value-added products is one of the strategies to reduce post-harvest losses and promote consumption of fruits.

Fresh-cut fruits, also called minimally processed fruits, are products that are partially prepared, maintain a fresh-like state and ready for use and eating. Recently, fresh-cut fruits have become popular because they meet the consumer demand for convenient ready-to-eat foods with fresh-like quality. However, fresh-cut fruits are more perishable than whole fruits. The third part of the chapter covers some recently developed approaches for the value addition of fresh-cut fruits with respect to the use of natural antimicrobials, anti-browning agents, edible coating, modified atmosphere packaging (MAP), 1-methylcyclopropene (1-MCP) application and vacuum impregnation (VI).

2. Fruits and human health

Consumption of fruits and vegetables is increasing because of strong evidence that many beneficial effects for human health are associated with the dietary intake of fruits and vegetables (Kaur & Kapoor 2001, Rupasinghe et al. 2012). As suggested by epidemiological studies, the consumption of fruit and vegetables may lead to prevention of many chronic diseases, including cardiovascular disease (Weichselbaum 2010, Al-Dosari et al. 2011; Thilakarathna and Rupasinghe 2012), type II diabetes (Johnston et al. 2002, Yu et al. 2012b) and some cancers (De Mejía & Prisecaru 2005, Lala et al. 2006, Sun & Liu 2008, Lippi & Targher 2011). These disease prevention effects of fruits could be due to the presence of health promoting phytochemicals such as carotenoids (Chichili et al. 2006), flavonoids (Yu et al. 2012a), other phenolic compounds (Masibo & He 2008) and vitamins (Lippi & Targher 2011, Gutierrez 2008). Furthermore, the health-protective effects may be rather produced by complex mixtures of interacting natural chemicals than a single component in these plant-derived foods (Lila 2007). Table 1 gives a summary of selected fruit-based antioxidants and other health promoting compounds for disease prevention.

3. Fruit production and post-harvest loss

3.1. Fruit production

Fruit production is increasing dramatically worldwide. According to the FAO, the total world fruit production in 2008 was 572.4 million tons, and the number climbed to 609.2 million tons in 2010 (FAO 2010). Among these fruits, thirty percent of which were tropical fruits, with water melon occupied of 59.2%, mongo and guavas of 20.5% and pineapple of 11.4% (Rawson et al. 2011).

Despite the increasing food production at the global level, about one-third of the food produced in the world is lost or wasted (Prusky 2011), among which, post-harvest stage losses and marketing stage losses are major losses.

3.2. Post-harvest loss of fruits

Despite of food production is increasing globally, a significant amount of the food for human consumption is lost or wasted, especially perishable foods such as fruits and vegetables (Prusky 2011). The amount of food lost each year is equivalent to more than half of the world's annual cereals production (2.3 billion tonnes in 2009/2010) (Gustavsson et al. 2011).

It is hard to give precise information on the amount of fruit losses generated globally, because fruit losses vary greatly among varieties, countries, and climatic regions, and there is no universally applied method for measuring losses. As a consequence, the food loss data during post-harvest are mostly estimated and the variations are from 10% to 40% (Prusky 2011). Table 2 lists some examples of post-harvest losses of selected fruits in India, Egypt and United States.

Source	Active component	Prevention mechanism	Disease	References
Grape	Anthocyanins	Anti-proliferative	Cancer	Lala et al. 2006
	Flavonoids	Inhibition of HNR-adduct formation	Macular degeneration and cataract	Yu et al. 2012a
	Resveratrol	Antioxidant, anti-inflammatory, activation of SIRT1	Alzheimer's	Sun et al. 2010
	Resveratrol	Normalize iron and Ca^{2+}, increase SOD activity	Cardiotoxicity	Mokni et al. 2012
	Resveratrol	Enhance insulin secretion	Diabetes	Yu et al. 2012b
Apple	Polyphenols	Antioxidant, cell cycle modulation	Cancer	Sun & Liu 2008
	Polyphenols	Antioxidant, multiple mechanisms	Cardiovascular	Weichselbaum 2010
	Phloridzin	Anti-inflammatory, bone resorption	Bone protection	Puel et al. 2005
	Polyphenols	Reduce amyloid-β formation	Alzheimer's	Chan & Shea 2009
	Phloretin-2'-*O*-Glucoside	Delay glucose absorption	Diabetes	Johnston et al. 2002
Banana	Lectins (Bioactive protein)	Cell cycle arrest, apoptosis	Cancer	De Mejía & Prisecaru 2005
	Polyphenols	Antioxidant, reduce LDL modification	cardiovascular	Yin et al. 2008
	Polyphenols	Antioxidant	Alzheimer’s	Heo et al. 2008
Pineapple	Bromelain	Proteolytic enzyme regulation	Anti-inflammatory	Hale et al. 2010
Mango	Phenolic compounds	Antioxidant, multiple mechanisms	Degenerative diseases	Masibo & He 2008

Table 1. Fruit-based health promoting compounds and postulated disease prevention

Source	Post-harvest loss %				References
	Farm	Wholesale	Retail	Total	
Grape	15.1	6.9	6.0	28.0	Kader 2010
Grape	7.3	4.2	2.9	14.4	Murthy et al. 2009
Grape	N/A	N/A	7.6	N/A	Buzby et al. 2009
Mango	15.6	8.9	5.3	29.7	Murthy et al. 2009
Mango	N/A	N/A	14.5	N/A	Buzby et al. 2009
Banana	5.5	6.7	16.7	28.8	Murthy et al. 2009
Banana	N/A	N/A	8.0	N/A	Buzby et al. 2009

Source	Post-harvest loss %				References
	Farm	**Wholesale**	**Retail**	**Total**	
Papaya	N/A	N/A	54.9	N/A	Buzby et al. 2009
Pineapple	N/A	N/A	14.6	N/A	Buzby et al. 2009
Kiwi	N/A	N/A	12.7	N/A	Buzby et al. 2009
Apple	N/A	N/A	8.6	N/A	Buzby et al. 2009
Avocado	N/A	N/A	9.3	N/A	Buzby et al. 2009
Tomato	9.0	17.9	16.3	43.2	Kader 2010

Table 2. Post-harvest losses in selected fruits

3.3. Prevention and reduction of post-harvest loss

Methods of preventing losses of fruits and vegetables could be found from papers and fact sheet written by Singh and Goswami (2006), Sonkar et al. (2008), Prusky (2011) and DeEII and Murr (2009). These methods include selection of new cultivars with firm fruits and longer postharvest life, minimizing physical damage during harvesting and postharvest handling, control and monitoring of temperature and relative humidity, use of controlled or modified atmosphere storage, use of pre- and post-harvest fungicides (hydrogen peroxide) before and after harvest and use of physical treatment such as ozonation technology. Table 3 gives examples of use of controlled atmosphere storage of selected fruits.

Source	Temp (ºC)	RH (%)	O_2 (%)	CO_2 (%)	Storage life	References
Grape	0-5	90-95	5-10	15-20	> two weeks	Singh and Goswami 2006
Mango	10-15	90	3-7	5-8	> two weeks	Singh & Goswami 2006
Banana	12-16	90	2-5	2-5	> two weeks	Singh & Goswami 2006
Papaya	10-15	90	2-5	5-8	> two weeks	Singh & Goswami 2006
Pineapple	8-13	90	2-5	5-10	> two weeks	Singh & Goswami 2006
Kiwi	0-5	90	1-2	3-5	> two weeks	Singh & Goswami 2006
Avocado	5-13	90	2-5	3-10	> two weeks	Singh & Goswami 2006
Apple (Empire)	1-2	N/A	1.5-2.5	1.5-2.0	5-8 months	DeEll & Murr 2009
Apple (Gala)	0	N/A	1.5-2.5	1.5-2.5	5-8 months	DeEll & Murr 2009
Apple (Golden Delicious)	0	N/A	1.5-2.5	1.5-2.5	5-8 months	DeEll & Murr 2009
Apple (McIntosh)	3	N/A	1.0-2.5	0.5-2.5	5-8 months	DeEll & Murr 2009

* Temp: temperature; RH: Relative humidity

Table 3. Controlled atmosphere storage conditions of selected fruits

4. Fruit processing and preservation

Processed fruit products generally include minimally processed fruit products such as fresh-cut fruit, fermented fruit products such as cider, wine and vinegar, traditional thermally processed fruit products such as jam, jelly, juice and beverage, novel non-thermal processed fruit products such as juice and beverage, etc. A comprehensive review has been given by the same authors on novel non-thermal processed fruit product preservation including juices and beverages (Rupasinghe & Yu 2012). At the same time, fresh-cut fruit stands out to be a promising food that meets the demand of consumers for convenient and ready-to-eat fruits with a fresh-like quality. In this case, this part of the chapter would give emphasis on fresh-cut fruit processing and preservation.

4.1. Fresh-cut fruit processing

The sales of fresh-cut produce have grown from approximately $5 billion in 1994 to $10–12 billion in 2005, which is about 10% of total produce sales (Rupasinghe et al. 2005). Fresh-cut fruits and vegetables are products that are partially prepared, maintain a fresh-like state and no additional preparation is necessary for use and eating (Watada & Qi 1999). Figure 1 shows the flowchart of fresh-cut fruit processing. It generally includes washing, and/or peeling, cutting, and/or slicing or wedging and packaging. Dipping solutions or edible coating materials could be applied during dipping or coating process.

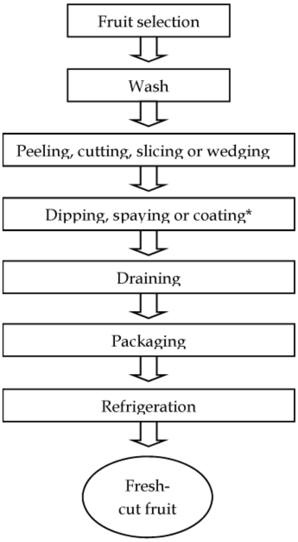

Figure 1. Major steps for fresh-cut fruit processing (revised from Corbo et al. 2010) * During this process, natural preservatives or edible coating materials could be applied

4.2. Fresh-cut fruit preservation

Fresh-cut fruits are more perishable than whole fruits, because the tissue integrity of fruits is more easily altered during processing. Post-cut quality of fresh-cut fruits suffers from wound induced biochemical and physiological changes such as water loss, accelerated respiration and cut-surface browning as well as microbiological spoilage (Kader 2002, Chiabrando & Giacalone 2012). Therefore, preservation of fresh-cut fruits needs combinative efforts of antimicrobial agents, anti-browning substances as well as packaging strategies. A detailed review was given by Oms-Oliu et al. (2010) about recent approaches for preserving quality of fresh-cut fruits.

4.2.1. Antimicrobial agent

During the preparatory steps of fresh-cut fruit processing, the natural protection of fruit is removed and chances of contamination may increase. Damage of tissues allows the growth and fermentation of some species of yeasts such as *Saccharomyces cerevisiae* and the attack by pathogenic microorganisms such as *Listeria monocytogenes*, *Salmonella* spp., *Staphylococcus aureus* and *Escherichia coli* O157:H7 (Martin-Belloso et al. 2006). Therefore, the searching for methods to retard microbial growth is of great interest to researchers and fresh-cut industry.

Traditionally, the most commonly used antimicrobials are potassium sorbate and sodium benzoate. However, consumer demand for natural origin, safe and environmental friendly food preservatives is increasing. Natural antimicrobials such as organic acids, herb leaves extracts and oils, chitozan and *bacteriocins* have shown feasibility for use in some food products including fresh-cut fruits (Gould 2001, Corbo et al. 2009). Some of them have been considered as Generally Recognized As Safe (GRAS) additives in foods. Selected natural antimicrobials and their status for GRAS additives are listed in Table 4.

Cinnamon as an antimicrobial agent has been investigated in fresh-cut apple slices (Muthuswamy et al. 2008). Ethanol extract of cinnamon bark (1% to 2% w/v) and cinnamic aldehyde (2 mM) could reduce *E. coli* O157:H7 and *L. innocua in vitro*. Ethanol extract of cinnamon bark (1% w/v) reduced significantly the aerobic growth of bacteria inoculated in fresh-cut apples during storage at 6°C up to 12 days. It was also found that cinnamic aldehyde has greater antimicrobial activity than potassium sorbate (Muthuswamy et al. 2008).

Carvacrol and cinnamic acid could delay microbial spoilage of fresh-cut melon and kiwifruit. Dipping of fresh-cut kiwifruit in carvacrol solutions at up to 15 mM reduced total viable counts from 6.6 to less than 2 *log* CFU/g for 21 days of storage at 4°C. Also, treatment with 1 mM of carvacrol or cinnamic acid reduced viable counts on kiwifruit by 4 and 1.5 *log* CFU/g for 5 days of storage at 4°C and 8°C, respectively (Roller & Seedhar 2002).

Vanillin was also proved to be a practical preservative for processing fresh-cut mango and apples under refrigerated conditions. Fresh-cut mango slices were dipped for 1 min in solutions containing 80 mM vanillin before being packaged. Results indicated that treatment with 80 mM vanillin significantly delayed ($P < 0.05$) the development of total aerobic bacteria and yeast and mold populations of fresh-cut mangoes stored at 5 and 10 ∘C for up to 14 and 7 d, respectively (Ngarmsak et al. 2006). Also, a dip of 12 mM vanillin incorporated with a commercial anti-browning dipping solution (calcium ascorbate, NatureSeal™) inhibited the total aerobic microbial growth by 37% and 66% in fresh-cut 'Empire' and 'Crispin' apples, respectively, during storage at 4 °C for 19 days. Furthermore, vanillin (12 mM) did not influence the control of enzymatic browning and softening by NatureSeal (Rupasinghe et al. 2006).

Name	Origin	GRAS status
Rosemary	Plant	Yes
Cinnamon	Plant	Yes
Cinnamic acid	Plant	Yes
Clove	Plant	Yes
Lactoperoxidase	Animal	No
Lemon (peel, balm, grass)	Plant	Yes
Lime	Plant	Yes
Nisin	Microorganism	Yes
Chitozan	Animal	No
Carvacrol	Plant	Yes
Citric acid	Plant	Yes
Ascorbic acid	Plant	Yes
Vanillin	Plant	Yes

* Revised from USFDA (2006): Food Additive Status List

Table 4. Selected natural antimicrobial agents and their status for GRAS additives*

4.2.2. Anti-browning agents

Enzymatic browning is also a major concern on the extension of shelf-life of fresh-cut fruit (Oms-Oliu et al. 2010). It is caused by the enzymatic oxidation of phenols to quinones by enzymes, typically polyphenoloxidases, in the presence of oxygen. Quinones are then subjected to further reactions, leading to the formation of browning pigments (Ozoglu & Bayindirli 2002, Jeon & Zhao 2005). Traditionally, sulfites have been used for browning prevention. However, their use on fresh-cut fruit and vegetables was banned in 1986 by the FDA owing to their potential hazards to health (Buta et al. 1999). Therefore, various alternative substances, such as honey, citric acid, ascorbic acid, calcium chloride, calcium lactate and calcium ascorbate, among others, have being used to retard browning in fresh-cut fruit (Jeon & Zhao 2005, Oms-Oliu et al. 2010). These anti-browning products are not often used alone because it is difficult to achieve efficient browning inhibition, and combination of them would give preferable results. Table 5 gives examples of anti-browning treatment on fresh-cut Apples.

Examples of anti-browning treatment on other fresh-cut fruits including banana, kiwifruits, mango, among others could be found in Table 3 in Oms-Oliu et al. (2010)'s paper.

Cultivar of apple	Anti-browning agent	Storage conditions	References
Gala	10% honey solution with vacuum impregnating	3°C for 14 days	Jeon & Zhao (2005)
Granny Smith	1% w/v of citric acid/CaCl2 and 1% of ascorbic acid/CaCl2	4°C for 5 days	Chiabrando & Giacalone (2012)
Granny Smith	0.05% w/v of sodium chlorite and 1% of calcium propionate	10°C for 14 days	Guan & Fan (2010)
Golden Delicious	1% w/v of citric acid/CaCl2 and 1% of ascorbic acid/CaCl2	4°C for 5 days	Chiabrando & Giacalone (2012)
Golden Delicious	80 mg/L acidic electrolyzed water (AEW) followed by 5%calcium ascorbate	4°C for 11 days	Wang et al. (2007)
Granny Smith	1% w/v of citric acid/CaCl2 and 1% of ascorbic acid/CaCl2	4°C for 5 days	Chiabrando & Giacalone (2012)
Red Delicious	300 mg /L sodium chlorite (SC) and 300 mg /L citric acid	5°C for 14 days	Luo et al. (2011)
Scarlet Spur	1% w/v of citric acid/CaCl2 and 1% of ascorbic acid/CaCl2	4°C for 5 days	Chiabrando & Giacalone (2012)

Table 5. Examples of anti-browning treatments assessed on fresh-cut fruits

4.2.3. Edible coating

The incorporation of antimicrobial and anti-browning agents to fresh-cut fruits could be done by dipping, spaying or edible coating treatment. Dipping or spraying aqueous solutions to fruit pieces containing antimicrobial agents, antioxidants, calcium salts or functional ingredients such as minerals and vitamins are widely used to improve quality of fresh-cut fruit. However, the effectiveness of these compounds could be better improved with their incorporation into edible coatings. The application of edible coatings to deliver active ingredients is one of the recent progresses made for shelf-life extension of fresh-cut fruits. Detailed information on edible coating for fresh-cut fruits could be found in review papers from Vargas et al. (2008), Rojas-Graü et al. (2009) and Valencia-Chamorro et al. (2011).

Edible coatings may be defined as a thin layer of material that covers the surface of the food and can be eaten as a part of the whole product. Therefore, the composition of edible coatings has to be food grade or GRAS. Furthermore, the coating materials need to be transparent, odourless, permeable for water vapour and selectively permeable to gases and volatile compounds (Kester & Fennema 1986).

Ingredients that can be used to form edible coatings include polysaccharides such as cellulose, starch, alginate, chitosan, pectin, carrageenan, gum Arabic, guar gum and xanthan gum, proteins such as zein, gluten, soy, whey protein, lipids such as beeswax, lecithin, cocoa butter and fatty acids (Vargas et al. 2008). Examples of edible coating treatment on fresh-cut apples are listed in Table 6.

Cultivar of apple	Functional ingredients	Concentration (%)	Coating materials	References
Gala	N/A	N/A	Cassava starch, glycerol, carnauba wax, stearic acid	Chiumarelli & Hubinger 2012
Gala	N/A	N/A	Chitosan	Wu et al. 2005
Fuji	Oregano oil	0.1 – 0.5 (v/v)	Apple puree, alginate	Rojas-Graü et al. 2007
Fuji	Lemongrass	1.0 – 1.5 (v/v)	Apple puree, alginate	Rojas-Graü et al. 2007
Fuji	Vanillin	0.3 – 0.6 (v/v)	Apple puree, alginate	Rojas-Graü et al. 2007
Fuji	Cinnamon	0.7 (v/v)	Alginate	Raybaudi-Massilia et al. 2008
Fuji	Clove	0.7 (v/v)	Alginate	Raybaudi-Massilia et al. 2008
Fuji	Lemongrass	0.7 (v/v)	Alginate	Raybaudi-Massilia et al. 2008
Fuji	Cinnamaldehyde	0.5 (v/v)	Alginate	Raybaudi-Massilia et al. 2008
Fuji	Citral	0.5 (v/v)	Alginate	Raybaudi-Massilia et al. 2008
Fuji	Ascorbic acid, $CaCl_2$	1.0 (w/v)	Carrageenan	Lee et al. 2003
Fuji	Ascorbic acid, $CaCl_2$	1.0 (w/v)	Whey protein concentrate	Lee et al. 2003
Fuji	Ascorbic acid, $CaCl_2$	1.0 (w/v)	Whey protein concentrate	Lee et al. 2003
Golden Delicious	Ascorbic acid	0.5-1.0 (w/v)	Whey protein concentrate, beeswax	Perez-Gago et al. 2006
Golden Delicious	Cysteine	0.1-0.5 (w/v)	Whey protein concentrate, beeswax	Perez-Gago et al. 2006
Granny Smith	Ascorbic acid, citric acid	0.5 (w/v)	Pectin, apple purée	McHugh & Senesi 2000

Table 6. Examples of edible coating treatment on fresh-cut apples

4.2.4. Modified atmosphere packaging (MAP) and 1-methylcyclopropene (1-MCP)

The respiration rate of fresh-cut fruits is greater than that of intact fruits (Kader 1986). The increased respiration rate can induce the ethylene synthesis, increase enzymatic activity, promote oxidation of phenolic compounds and microbial growth, and therefore contributes to quality losses such as color and firmness. In this case, the control of respiration is essential for maintaining quality and prolonging the shelf life of fresh-cut fruits (Rocha & Morais 2003).

Modified atmosphere packaging (MAP) is a technology which offers the optimum gas conditions around the product by adjusting the barrier properties of the packaging film (Simpson and Carevi 2004). Various approaches to prolong the shelf life of fresh-cut products, such as edible coatings and refrigeration could be applied in combination with MAP (Rupasinghe 2005).

1-Methylcyclopropene (1-MCP) may retard or inhibit the generation of ethylene, the natural ripening hormone which is undesirable in terms of storage of certain fruits. Therefore, 1-MCP is becoming a commercial tool (SmartFresh, AgroFresh Inc., Philadelphia) for extending the shelf-life and quality of certain fruits and plant products (Rupasinghe et al. 2005). 1-MCP can be applied immediately after harvest (Aguayo et al. 2006; Mao & Fei 2007), just before fresh-cut processing or at both steps (Calderón-López et al. 2005; Vilas-Boas & Kader 2007). However, treatment of intact fruit with 1-MCP before fresh-cut processing is easier and more convenient than after processing. Moreover, the increase in ethylene production promoted by peeling, slicing or wedging could be prevented by the pre-use of 1-MCP (Rupasinghe et al., 2005).

4.2.5. Vacuum impregnation

Osmotic treatments have been traditionally used as a pre-treatment step in freezing, canning and frying to improve the quality of the final produce (Alzamora et al., 2000). Among developments in osmotic treatments of fruit products, vacuum impregnation (VI) may be the latest (Zhao & Xie 2004). The VI technique is performed by applying a vacuum pressure in a tank or oven containing the immersed product for a short time and then restoring the atmospheric pressure with the product remains immersed (Martínez-Monzó et al., 1998). The process of VI is a hydrodynamic mass transfer process based on an exchange between internal gas or liquid and an external liquid phase (Zhao & Xie, 2004). VI technique could be used to develop novel minimally processed fruit products with value-addition since nutritional and bioactive ingredients could be incorporated into the fruit based products during VI process (Xie & Zhao, 2003; Guillemin et al., 2008, Rößle 2011) and which gives a bright future for VI application in fresh-cut fruits. Table 7 gives examples of VI treatment on fresh-cut fruits.

Type of fruit	VI treatment conditions				References
	VI solution	VI pressure (mmHg)	VI time (min)	Restoration Time (min)	
Apple (Gala)	20% (w/w) of HFCS, Ca, Zn	50	15	30	Xie & Zhao 2003
Apple (Gala)	10% (w/w) of honey	75	15	30	Jeon & Zhao 2005
Strawberry	8ºBrix of glucose solution	37.5	5	5	Castelló et al. 2006
Apple (Empire)	15ºBrix of grape juice, 1.6% of $CaCl_2$ (w/v), 0.05% of NaCl (w/v), 0.1% of vitamin E (v/v)	152.4	10	22	Joshi et al. 2010
Apple (Empire)	20-40 % (v/v) of maple syrup, 1.6% of $CaCl_2$ (w/v), 0.05% of NaCl (w/v)	152	10	22	Joshi et al. 2011
Apple (Granny Smith)	50% (v/v) of honey	525	10	10	Rößle et al. 2011

HFCS: High fructose corn syrup

Table 7. Examples of VI treatment conditions on fresh-cut fruits or value-added products

5. Conclusion

Fruits are not only consumed as stable food but also provide desirable health benefits beyond their basic nutrition. However, the quantitative and qualitative losses of fruits are significant during post-harvest, marketing, processing and storage. Prevention of these losses during post-harvest management could be done by multiple steps and methods such as controlled or modified atmosphere packaging and application of ozonation technology.

On the other hand, promotion of minimally processed fruit products such as fresh-cut fruit into the commercial market is a practical, economical, and consumer and environmental friendly approach compared with traditional processing methods. However, fresh-cut fruits are more perishable than whole fruits in terms of biochemical and physiological changes such as water loss, accelerated respiration and cut-surface browning as well as microbiological spoilage. Therefore, preservation of fresh-cut fruits needs combinative efforts of antimicrobial agents, anti-browning substances as well as packaging strategies.

Natural or GRAS additives have been the popular ingredients used as antimicrobial agents and anti-browning agents, or bioactive ingredients. The incorporation of antimicrobial and anti-browning agents to fresh-cut fruits could be done by dipping, spaying or edible coating treatment. The application of edible coatings to deliver active ingredients is one of the recent progresses made for shelf-life extension of fresh-cut fruits. It could be used in combination with modified atmosphere packaging (MAP), 1-methylcyclopropene (1-MCP) and refrigeration for better results.

In addition for edible coating, vacuum impregnation (VI) may be another practical approach for incorporation of health promoting natural ingredients into fresh-cut fruits. VI technique could be used to develop novel minimally processed fruit products with value-addition through incorporation of nutritional and bioactive ingredients.

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