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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 Mejia & 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 watermelon occupied of 59.2%, mango 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|                        |
|          | Resveratrol      | Antioxidant, anti-inflammatory, activation of SIRT1                                   | Alzheimer’s                      | Sun et al. 2010        |
|          | Resveratrol      | Normalize iron and Ca²⁺, 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    |
### Table 2. Post-harvest losses in selected fruits

| 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      |

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.

### Table 3. Controlled atmosphere storage conditions of selected fruits

| Source | Temp (°C) | RH (%) | O₂ (%) | CO₂ (%) | 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 | DeEII & Murr 2009 |
| Apple (Gala) | 0   | N/A | 1.5-2.5 | 1.5-2.5 | 5-8 months | DeEII & Murr 2009 |
| Apple (Golden Delicious) | 0   | N/A | 1.5-2.5 | 1.5-2.5 | 5-8 months | DeEII & Murr 2009 |
| Apple (McIntosh) | 3   | N/A | 1.0-2.5 | 0.5-2.5 | 5-8 months | DeEII & Murr 2009 |

* Temp: temperature; RH: Relative humidity
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)](http://dx.doi.org/10.5772/53161) * 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, Chiabrandino & 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 (Ngarmasak 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 subject 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 been 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, spraying 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, CaCl₂   | 1.0 (w/v)         | Carrageenan       | Lee et al. 2003 |
| Fuji              | Ascorbic acid, CaCl₂   | 1.0 (w/v)         | Whey protein concentrate | Lee et al. 2003 |
| Fuji              | Ascorbic acid, CaCl₂   | 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 |
|--------------|-------------------------|------------|
| 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) | 15% Brix of grape juice, 1.6% of CaCl₂ (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 CaCl₂ (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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