Appendix 3. Literature reviews on fresh-cut products

TREATMENTS TO PRESERVE FRESH-CUT FRUIT AND VEGETABLES: A REVIEW OF RELATED LITERATURE - (UP Min)

Importance of Fresh-cut Products

Fresh-cut products are any fruit or vegetable, or combination thereof that has been physically altered from its original form, but remains fresh (International Fresh-cut Produce Association, 2002). Thus, the tissues are in a living, respiring physiological state (USFDA, 2000) They may be consisted of peeled, sliced, shredded, trimmed and/or washed fruits and vegetables (Francis et al., 2012).

The demand for convenient food products has been ever-growing in all parts of the world due to the persistent lifestyle shift of consumers from conventional home-cooking to "on-the-go" meals. Along with this, nutritional aspects of foods have also become a concern for consumers in developing countries due to growing education level (Qadri et al., 2015). Thus, market for chilled fresh-cut fruits and vegetables has witnessed dramatic growth in the recent years because of meets most of the aforementioned consumer demands (James and Ngarmsak, 2010) Fresh-cut products present the consumer with a range of options in a single package, reduce wastage by allowing consumers to procure only what is required, and allow consumers to readily assess the quality of the produce (James and Ngarmsak, 2010)

In the Philippines, some fresh-cut mixes sold in supermarkets and public markets are ingredients for traditional dishes such as, *chopsuey, pancit, pinakbet, sinigang, tinola,* and *nilaga*. The manual preparation of these dishes can be indisputably laborious. Consequently, the chore of peeling, shelling, trimming, slicing, and then combining different fresh ingredients can often discourage busy housewives from producing these healthy cuisines. This issue is addressed by fresh-cut processing by making fresh ingredients available in a ready-to-cook, easy-to-use setup with minimal waste (James and Ngarmsak, 2010).

Problems with Fresh-cut Products

Fresh-cut products have faster rate of deterioration as a result of the wounding process that they undergo (Brecht et al., 2004). Cutting and size reduction operations initiate physiological and biochemical changes such as moisture loss, browning, softening, off-flavors, acceleration respiration rate, and induced production of ethylene (Flor et al., 2007). Hence, fresh-cuts and intact produce have differences in handling and storage requirements.

A. Physiological Changes

Transient increase in ethylene production and in respiration rate are the earliest physiological responses to wounding (Brecht et al., 2004) Respiration rate is highest immediately after cutting and then declines after 3 hours of storage at 5C (Flor et al., 2001). However, the changes in respiration rate are dependent on the inherent differences among crops (Flor et al., 2007). Increased respiration rate leads to reduction of water, levels of carbohydrates, vitamins, and organic acids (James and Ngarmsak, 2010).

Softening happens alongside ethylene production because the latter increases activity of softening enzymes like polygalacturonase, alpha and beta-galactosidase

(Karahurt and Huber 2003; Watada et al., 1990). Hence, suppressing the action of ethylene may delay the softening of fresh-cuts (Flor et al., 2007).

The oxidation of phenolic compounds and loss of chlorophyll causes browning and yellowing of fresh-cut produce, respectively (Brecht et al., 2004). This discoloration primarily happens when acids and enzymes come into contact with their substrates during cell breakage brought about by wounding (Martinez and Whittaker, 1995; Heaton and Marangoni 1996; Laurila et al., 1998). Commodities with higher levels of phenolic compounds, like potato and artichoke, undergo faster browning when broken tissue is exposed to oxygen in air (Brecht et al., 2004). Phenolases such as polyphenol oxidase (PPO) and peroxidase (POD) catalyze enzymatic browning (Martinez and Whitaker, 1995: Hanson and Havir 1979). Cultivar differences among produce are also an important factor that influence susceptibility of fresh-cuts to enzymatic browning due to their varying amount of phenolics (Flor et al., 2007). Since oxidative browning at the cut surface is a limiting factor for many fresh-cut produce, stresses such as temperature, physical injury, and disease should be controlled during pre-cutting treatments (Brecht et al., 2004).

B. Microbiological Changes

Microbial contamination can happen at any point of the fresh-cut production chain. However, due to the removal of the skin and size reduction operations, exposed tissues provide readily available nutrients and greater area for microbial attack (Flor et al., 2007). Several contamination sources are soil, dust, water, and handling during pre- or postharvest stages (Eni et al., 2010). In addition, type of commodity and its inherent characteristics, such as moisture content and water activity, influence the survival and/or growth of microorganisms on fresh-cuts.

Flor et al. (2007) emphasized the impact of spoilage and pathogenic microorganisms to fresh-cut fruits and vegetables. Spoilage microorganisms can be bacteria or fungi. Although they do not cause diseases to people, they significantly affect the visual and sensory qualities of fresh-cut produce. According Qadri et al. (2015), a mold population ranging from 10^2 CFU/g on cut lettuce to 10^8 CFU/g in shredded carrots has been reported by previous literatures. On the other hand, pathogenic microorganisms such as *E. coli* O157:H7, *Salmonella* and *Listeria monocytogenes* pose a greater threat on food safety as they cause diseases and even death to people who have consumed contaminated fresh-cuts. Gram-negative rods mostly *Pseudomonas* have been reported to be the predominant group of microorganisms on fresh produce. *Enterobacteriaceae* may also be present on minimally processed products (Bennik et al., 1998). Table 1 shows a documentation of microbial populations present in fresh-cut vegetables garnered from various literatures.

Table 1. Total mesophilic and yeast and mould populations present in/on some fresh-cut vegetables (Lifted from Qadri et al., 2015)

Minimally processed vegetables	**Microbial population (Log cfu g−1)**		**References**
	Total mesophilic count	**Yeast and mold**	
Chopped lettuce	4.85	-	Odumeru et al. (1997)

Packaged salad (iceberg lettuce, carrot and red cabbage)	5.3–8.9	0.9–3.8 yeasts 0.3–2.2 molds	Hagenmeier and Baker (1998)
Carrot sticks	4.99–5.77	4.25	Garg et al. (1990)
Shredded lettuce	4.28	4.28	Delaquis, Stewart, Toivonen, and Moyls (1999)
Shredded carrots	2.9	1.1	Chervin and Boisseau (1994)
Trimmed spinach leaves	4.00	-	Izumi (1999)
Chopped bell peppers	3.5	-	Izumi (1999)
Fresh-cut mushrooms	8.3	-	Sapers and Simmons (1998)

The last two decades has witnessed a large increase of foodborne disease outbreaks that were linked to the consumption of fresh produce, especially of green leafy vegetables (Warriner et al., 2009). Data from Center for Disease Control and Prevention and other sources reported that fresh spinach grown in California was responsible for the *E. coli* O157:H7 outbreak in 26 U.S states in September 2006, which led to about 200 cases of illness and three deaths (USFDA, 2006).

Vital and his team conducted an analysis of the microbial quality of bell pepper, cabbage, carrots, lettuce, and tomatoes from open air and supermarkets in National Capital Region, Laguna and Pampanga. Their study has shown high prevalence of bacterial pathogens and fecal indicator microorganisms from the various produce in both two types of markets. Furthermore, they reported that carrots had the highest microbial counts, which can be attributed to the vegetable's extensive exposure to soil. Interestingly, they also found out that open air and supermarkets had statistically similar occurrence of microbial contamination despite their operational differences (Vital et al., 2014).

The reduction of the microbial load in the final fresh-cut product is greatly affected by the efficiency of the sanitation system applied to both equipment and raw materials (Flor et al., 2007). More importantly, conditions during storage, transport, and distribution shall largely determine the degree of the consequent growth of the microorganisms that survived the sanitation process (Soliva-Fortuny and Martin-Belloso, 2003).

Extending shelf-life of fresh-cuts

Shelf-life of fruits and vegetables is defined as the period within which the product retains acceptable quality for sale to the consumer (Sousa-Gallagher and Mahajan, 2011). In addition, it must exceed minimum distribution time required from the processor to the consumer to allow a reasonable period for home storage and use (Piagentini and Güemes, 2002) Unlike other processes applied to other food products that extend shelf-life, i.e. drying and curing, fresh-cut processing of fruits and vegetables represents a paradox in food science as it tend to decrease shelf-life of the product mainly because of the wounding it undergoes (James and Ngarmsak, 2010).

A. Mechanical Approach

There are multiple strategies for maximizing quality during fresh-cut processing operations. The first one is the usage of the sharpest cutting tools and optimization of cutting shape. Several studies have shown that rate of deterioration was faster in commodities wherein dull blades were used. For instance, O'Beirne (2007) reported that slicing with blunt blade enhanced the penetration of *E. coli* and its survival in fresh carrots (James and Ngarmsak, 2010).

B. Temperature Control

Temperature control during processing and storage is also an essential factor in maintaining the quality and safety of fresh-cut products. Low temperatures are necessary to reduce respiration rates, retard microbial growth, and retard deterioration such as browning and softening in fresh-cut products. Thus, it is recommended that refrigeration should take place throughout transportation and storage, and maintained during retailing and in the home of the consumer (Sousa-Gallagher and Mahajan, 2011).

C. Physical treatments

- **Hot water treatment.** High temperature has also been used in the pre-treatment and post-cutting treatment of whole fruits and vegetables prior to fresh-cut processing in order to increase shelf-life (Lamikanra et al., 2005). It has been employed to whole, intact apples to retain firmness of some fresh-cut apple cultivars (James and Ngarmsak, 2010). A team of researchers led by Algeria (2010) reported that there was lower microbial development rates found in carrot samples pre-treated in 100°C water bath for 45 seconds. As a post-cutting treatment, a 90-second heat-shock at 45°C prevented wound-induced browning of iceberg lettuce (Saltveit, 2003). In other studies, heat shock treatments of 50°C for 90 s or 55C for 60 s both repressed the activity of phenolic compounds in wounded lettuce after three days of storage (Loaiza-Velarde et al., 1997).

- **UV-C.** UV-C at around 254 nm has benefits to fruits and vegetables because of its germicidal properties and ability to activate defense mechanisms of crops by the *de novo* synthesis of antimicrobial compounds such as phytoalexins (Rohanie and Ayoub, 2012). Thus, it is a possible alternative to chemical fungicides for the control of postharvest diseases. In a study by Rodoni and team (2012), fresh-cut green bell peppers were subjected to UV-C with dose of 20 kJ/m^2 in the inner and outer surfaces. UV-C treated samples had significantly lower incidence of shriveling, weight loss, soft rot, and fungal decay after 12 days of storage at 5°C; and lower microbial load after 7 days of storage at 5°C (Rodoni et al., 2012).

D. Chemical Post-cutting Treatments

- **Acidification.** Chemical post-cutting treatments are another approach to minimizing losses during fresh-cut processing. For instance, ascorbic acid can slow down browning because it inhibits the action of PPO in catalyzing cut-surface discoloration by reducing surface pH (James and Ngarmsak, 2010). However, this may influence the final flavors or firmness fresh-cuts. Furthermore, combinations of acids such as combination of ascorbic and citric acid may be more effective because of the acidulant/antioxidant blend of these two (James and Ngarmsak, 2010).

- **Acidified sodium hypochlorite (ASC).** Hypochlorite in sodium hypochlorite (NaClO) reacts with nitrogen-containing compounds in foods that result in potentially carcinogenic, halogenated organic compounds. This has prompted consideration of alternative disinfectants. The addition of a GRAS (Generally recognized as safe) acids to sodium chlorite ($NaClO_2$) results in active ClO_2 which is more soluble than NaClO in water, has 2.5 times greater oxidizing capacity than chlorous acid (HOCl), and does not form chlorinated organic compounds (Inatsu et al., 2005). FDA-approved concentration is 500-1200 mg/L, pH 2.5-2.9 (Code of Federal Regulation, 2000).

Specific Studies on the Improvement of Fresh-cut Processing of Different Vegetables

1. Hot water treatment

I. Post-cutting treatment in fresh-cut white cabbage (var. *capitata)* (Valencia-Chamorro et al., 2016)

i. Method

Outer leaves were removed and discarded. Cabbages were washed with tap water and excess water was drained. They were then put in a food processor to shred them into 3 mm pieces to provide a julienne cut. These were dipped (1 min) in solutions of either 1% acetic acid, mixture of 0.2% ascorbic acid and 0.5% citric acid, 0.5% potassium sobrate, or hot water (60°C for 2 min). These were compared with a control (distilled water). They were then stored in either PP or LDPE films.

Tests conducted were color, weight loss, CO_2 concentration, pH, TSS, microbiological analyses and sensory evaluation. These parameters were analyzed on the 6^{th} and 12^{th} day of storage.

ii. Results

a. Color – Heat-treated samples had the highest browning index
b. Weight loss – Heat-treated samples had the lowest weight loss
c. CO_2 concentration – Heat-treated samples had the lowest CO_2 concentration
d. Firmness – Heat-treated samples had higher firmness which could be the activation of endogenous calcium brought by heat.
e. pH – All treated samples had lower pH than the control.
f. TSS – Heat-treated samples had the lowest TSS after 6 days of storage.
g. Microbiological analyses – All samples treated had microbial load that was within the permitted range after 12 days of storage.
h. Sensory evaluation – Panelists reported presence of off-flavor in heat-treated samples.

II. Post-cutting treatment in fresh-cut iceberg lettuce (Murata et al., 2014)

i. Method

Uninjured leaves were removed and 2 x 4 cm midrib segments were cut starting from the base of the leaf. Cut lettuce was then soaked in 1.5 L warm water (50°C for 90 s) and then cooled by cold water at 4°C. These were wrapped in clear plastic film and were stored at 4°C for 6 days.

Tests conducted were evaluation of browning, polyphenol determination, ascorbic acid and total vitamin c determination, enzyme extraction and assay, sensory analysis, and total bacterial count.

ii. Results

a. Browning – The cut lettuce hardly turned brown for 6 days of storage

b. PAL (Phenylalanine ammonia lyase) activity – Heat-shock treatment inhibited induction of PAL by cutting
c. Polyphenols – Polyphenol content in heat-shocked lettuce was significantly lower than in the control lettuce
d. Change in Vitamin C content – Control samples had higher vitamin c and ascorbic acid content but they were not significantly different with that of the heat-shocked lettuce.
e. Sensory evaluation – Appearance of the control lettuce was significantly inferior to that of the heat-shocked lettuce. No significant differences were detected in the aroma, crispness and flavor or taste.
f. Microbiological analyses – No significant difference was detected in the total bacterial count during 6 days of storage. But at 12 days of storage, heat-shocked lettuce had higher count which could be due to cell death promoted by heat-shock treatment.

III. <u>Pre-cutting treatment in fresh-cut green bell peppers (var. 'Festos')</u> (Sgroppo and Pereyra, 2009)

i. Method

Peppers were washed in running water and immersed for 40 s in 100 ppm sodium hypochlorite solution. Heat treatments used were 55°C and 60°C for 180 s. Fruits were then deseeded and cut manually with sharp knives in 0.4 x 6 cm pieces, rinsed with distilled water and drained. 150 g were packaged in polystyrene trays and covered with self-adhering polyvinyl chloride film. They were stored at either 4°C or 10°C.

Tests conducted were total phenols, quercetin content, ascorbic acid content, antioxidant capacity, sensory evaluation, microbial analysis, titratable acidity, sugar content, and chlorophyll content.

ii. Results

a. Total phenols – Non-treated peppers had higher elevation in phenols at the beginning of storage. Phenol contents of heat-treated fresh-cut peppers had the same trend at 4°C and 10°C storage.
b. Total quercetin – At 4°C, no significant differences were detected among the different samples. At 10°C, higher losses were recorded in all samples.
c. Ascorbic acid – No significant differences were observed between the two heat-treated samples after 15 days at 4°C. Control peppers had the lowest ascorbic contents, it decreased by 28% at 10°C and 16% at 4°C.
d. Antioxidant capacity – At 4°C, no significant difference was recorded in all fresh-cut peppers (treated and untreated). At 10°C, all samples had losses but the highest loss was recorded in the untreated peppers.
e. Sensory evaluation – Heat-treated peppers had significantly higher attribute scores than control peppers at both storage temperatures (except for color). Fresh-cut peppers stored at 10°C lost their quality faster.

f. Microbial analysis - After heat treatment, there were no differences in total counts between control and heat treated peppers, and at the end of storage, mesophilic bacteria and yeast and mold counts were under tolerance limit of 108CFU/g at both storage temperatures
g. Titratable acidity – untreated peppers showed 20% increase at 8 days. No significant difference was recorded between the two heat-treated samples.
h. Sugar – At 4°C, heat treatment did not have an effect on sugar content. At 10°C, sugar contents dropped but untreated samples had more noticeable decrease (28%) at 8 storage days.
i. Chlorophyll content – No effect was found at 4°C storage. Heat-treated samples had higher chlorophyll loss than the untreated samples at 10°C

2. Citric acid

I. Post-cutting treatment in fresh-cut Chinese cabbage (Kim and Klieber, 1997)

i. Method

Whole chinese cabbage was trimmed, washed with tap water, and washed with chlorinated water at 4°C. After a series of drying and washing, they were separated into different treatments for 3 min at 4°C: Citric acid, ascorbic acid and calcium chloride (all at concentration of 10 g/L). After centrifuge draining, they were packed in 50 µm LDPE disinfected by 700 mL/L ethanol. They were stored in 0°C and 5°C.

Chilling injury, pH and taste were the parameters analyzed

ii. Results

a. Chilling injury – This was not evident during storage of minimally processed Chinese cabbage at either 0°C or 5°C.
b. Overall quality – At 0°C, shelf-life was not extended by various dips, but citric acid and calcium chloride resulted in a significantly better quality. Black specks were reduced by citric acid at both temperatures. Its shelf-life at 5°C was extended by 4 days to 14 days by using citric acid.
c. pH – Samples treated in citric acid showed slight reduction of pH
d. Taste – No significant difference was detected between the control and citric acid treated-samples.

3. Acidified sodium chlorite (ASC)

I. As pre-cutting (but post-peeling) treatment in fresh-cut zucchinis, cucumbers, green bell peppers, potatoes, sweet potatoes, carrots and radishes (Sun et al., 2012)

i. *Method*

Fruits underwent peeling and three washing steps. The primary step was washing with tap water (10C) for 3 min, followed by washing with sanitizier solutions (10C) for 5 min either 100 mg/L sodium hypocholite or 500 mg/L Acidified sodium chlorite (ASC). ASC was prepared by mixing sodium chlorite and citric acid at 50:50 (w/w) ratio. Last washing step used tap water for 5 min to reduce chlorine odor at ratio 1:10 (w/v). They were then sliced automatically using a vegetable slicer.

Color, Polyphenol oxidase activity, and microbial load were the tests conducted.

ii. *Results*

a. Color – ASC-treated potatoes and sweet potatoes had lower a* and L* values during storage at 10C.
b. PPO activity - The PPO activities of the potatoes and sweet potatoes washed with ASC were lower than those washed with NaClO during the storage period at 10C. The PPO activity of potatoes washed with ASC was maintained up to 3 days in this study.
c. Microbial load – ASC-treated samples had lower aerobic plate count and coliform count than those washed with NaClO at 10C storage. More significant washing effects due to ASC on coliform count were observed in radishes, zucchini and green bell peppers. There was also higher reduction of microbial load in root vegetables than in fruit vegetables.

II. <u>As post-cutting treatment in controlling *E. coli* O157:H7 and natural microflora of fresh-cut cilantro</u> (Allende et al., 2009)

i. *Method*

Fresh cilantro leaves were cut into approximately 1 cm segments using a sharp knife, put into mesh bags, inoculated with *E. coli* O157:H7 by immersing in the inoculum solution, and washed with the different solutions for 1 min:

- Sodium hypochlorite – 0.2 g/L of free chlorine (pH = 6.5)
- 0.1 g/L acidified sodium chlorite SANOVA®
- 0.25 g/L acidified sodium chlorite SANOVA®
- 0.5 g/L acidified sodium chlorite SANOVA®
- 1 g/L acidified sodium chlorite SANOVA®
- 6 g/L citric acid
- 1 g/L sodium chlorite

Microbial load (aerobic bacteria, *E. coli*, and yeasts and molds) were analyzed

ii. *Results*

Low concentrations of ASC (0.25 and 0.5 g/L) were still able to reduce microbial load even if they are below the FDA-recommended range (0.5-1.2 g/L).

a. Aerobic bacteria – 0.25, 0.5, and 1 g/L ASC-treated samples had significantly higher reduction compared to that of sodium hypochlorite and citric acid

b. E. coli – 0.5 and 1 g/L ASC-treated samples had the highest reduction and were significantly different from that of sodium hypochlorite, citric acid, and the other ASC concentrations
c. Yeast and molds - 0.25, 0.5, and 1 g/L ASC-treated samples had significantly higher reduction compared to that of sodium hypochlorite and citric acid.

III. <u>As post-cutting treatment in controlling *E. coli* O157:H7 on fresh-cut Chinese cabbage</u> (Inatsu et al., 2005)

i. *Method*

The leaves were cut into 3 x 3 cm pieces using a sterile knife. They were then dipped into 1200 mL of *E. coli* inoculum for 10 min. After air drying, leaves were mixed well in a plastic bag, stored at 10C and used within 24 h. 100 g of inoculated leaves were mixed with 1000 mL of the wash solutions for 15 min at room temperature. Chlorite wash solutions used had different organic acids—citric, succinic, malic, tartaric, acetic, and lactic acid (0.5 g/L sodium chlorite and 5 mM acid). The effect of sonication and heating was also determined in this study.

ii. *Results*

a. Use of different organic acids – no significant difference was observed in the reduction of *E. coli* in the solutions with different acids. There was about 3 log reduction of load using 0.5 g/L sodium chlorite and 5 mM organic acid compared to only about 1 log reduction using distilled water.
b. Effect of sonication – No difference
c. Effect of heat – Washing solutions at 50C had significantly lower *E. coli* load but it caused softening of leaves.

4. UV-C

I. <u>As post-cutting treatment in fresh-cut green bell pepper</u> (Rodoni et al., 2012)

i. Method

Fruits were treated with chlorinated water for 3 min and were cut into 5 cm x 1 cm sticks. UV-C dose selection was done by comparing the deterioration index (DI) of different doses: 0, 2, 10, and 20 kj/m^2. Selected dose was 20 kj/m^2 applied to inner and outer surface and this was compared to the control (0). They were stored for 12 days at 5°C.

Decay and dehydration, weight loss, extractable juice, respiration rate, electrolyte leakage, texture, color, sugars and acidity, antioxidant capacity against DPPH· and ABTS radicals$\cdot^{+}$, molds and bacteria, and water-soluble pectin were the parameters analyzed.

ii. Results

a. Weight loss – Weight loss increased during storage in both control and treated fruit but irradiated samples had lower weight loss. At 5°C, weight loss was 11.8% in control and 3.6% in UV-treated samples after 12 days.
b. Dehydration and decay – 3% of UV-treated samples and 20% of the control showed dehydration borders after 7 days of storage. No chilling injury was observef during the 12 days storage at 5°C. After 7 days at 5°C, no soft rots were detected in all samples but after 12 days, its incidence increased rapidly in the control. UV-C reduced incidence of fungal decay and soft rots significantly.
c. Extractable juice Electrolyte leakage – Control fruit had higher extractable juice and juice exudates.
d. Respiration rate – No differences in respiration rate before storage were found between control and treated samples. At end of storage, UV-treated samples had respiration rate 20% lower than control samples.
e. Color, sugar, acidity, and antioxidant capacity – No differences in color and sugar content were detected between control and treated fruit. Only slight reduction in acidity was observed in UV-treated samples. UV-treated fruit did not show differences in antioxidant capacity compared to the control.
f. Microbial counts – Reductions in bacterial and fungal count were immediately detected after UV-C exposure. Irradiated samples had lower counts at 7 days at 5°C. At the end of the storage period, the log CFU/kg for molds and mesophilic bacteria were similar in control and UV-C-treated peppers, despite the great difference of decay. This suggests that decrease in decay could be a result of the beneficial physiological responses of the fruit to UV.
g. Texture and water-soluble pectin – UV-C exposure significantly delayed loss of rigidity and tissue pectin solubilization. The delay in softening and the higher resistance to deformation, together with the lower solubilization of pectin, juice extractability, and electrolyte leakage in UV-C-exposed fruit, suggest a better maintenance of tissue integrity.

II. <u>As pre-cutting treatment in shredded carrots</u> (Alegria et al., 2012)

i. Method

Whole peeled carrots were placed in a single layer on the illumination area (lamps were 15 cm above the illumination area) and rotated manually (180°) to ensure even exposure to UV. Treatment time was 2 min at each carrot hemisphere and the applied UV-C dose was calculated from a mean of 10 readings (0.78±0.36 kJ/ m^2). Whole peeled carrots were then held at 5°C for 24 h until shredding operations. Shredded carrots were packed in 125-g portion using 35 µm bioriented polypropylene. These were heat sealed and stored at 5°C. Control samples were treated with chlorine.

Color, total phenolic content, total carotenoid content, peroxidase activity, headspace analysis, and total mesophilic aerobic bacterial count were the analyses done.

ii. Results

a. Color – no significance
b. Total phenolic content – UV treated samples had generally higher TPC than control.
c. Total carotenoid content – UV treated samples had the highest loss of carotenoid compared to the intact carrots right after processing. During storage, it exhibited a consistent increase in carotenoid compared with control.
d. Peroxidase activity – UV treated samples had lower peroxidase activity than the control throughout the storage.
e. Headspace analysis – UV treated samples had lower metabolic rates than the control
f. Total mesophilic aerobic count – UV treatment achieved a 1.7 log cycle reduction in the initial microbial load which means that it is as effective as chlorine decontamination (1.9 log cycle).

III. As post-cutting treatment in carambola slices (Moreno et al., 2017)

i. Method

Carambola fruit were washed with chlorinated water for 3 min and cut transversally to main axis into 5 mm slices. UV-C dosage selection was done by subjecting carambola slices under UV-C lamps at 30 cm with irradiation doses of 6, 10 or 12.5 kJ/ m^2 measured with a digital radiometer. They were then stored at 4°C for 21 days.
Selected UV dose was 12.5 kJ/ m^2. Control and UV samples were covered with perforated PVC film and stored at 4°C for 0, 7, 14, 21 days.

Deterioration index, weight loss, electrolyte leakage, soluble solids content, pH and acidity, color, microbiological counts, phenolic compounds, enzyme activities (PPO, POD, PAL) were the parameters analyzed.

ii. Results

a. Deterioration index, weight loss, electrolyte leakage – UV treated samples maintained acceptable quality throughout the storage period and showed significantly lower weight loss and electrolyte leakage compared with the control.
b. Microbiological count – UV treated samples had significantly lower microbial load (aerobic bacteria and yeasts and molds) than the control after 7 and 14 days.
c. pH, acidity, soluble solids and titratable acidity – No differences between control and UV samples
d. Color – After irradiation, carambola slices showed lower lightness and hue values than control.
e. Phenolic content – No variation in total phenolic content was detected immediately after UV treatment, but there was a gradual increase in TPC after 14 and 21 days of storage, whereas in control, there was none.

f. PAL (phenylalanine-ammonia lyase) activity – Activity decreased in all samples throughout storage
g. POD (peroxidase) activity – This was transiently inhibited by the UV treatment but in increased during storage
h. PPO (polyphenol oxidase) activity – This was dramatically inhibited by the UV treatment.

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TREATMENTS TO PRESERVE FRESH-CUT FRUIT AND VEGETABLES: A REVIEW OF RELATED LITERATURE - (VSU)

Introduction to fresh-cut

Fresh-cut products pertain to lightly processed or minimally processed vegetables or fruits. The production involved peeling, trimming, deseeding and cutting of vegetable and/or fruit into small serving-size and are ready to eat or to cook in the case of vegetables (Saltveit 1996). International Fresh-Cut Produce Association (IFPA) also simply defined fresh-cut fruit and vegetables as products minimally processed that are only washed, cut, mixed and packed.

During 2003, fresh-cut products boomed particularly in the US wherein its sales increased upto +25% from $12 billion and even in European countries marked a record on the rising of the industry (Nicola 2006). Today, fresh-cut vegetables and fruits is a global trend (James et al., 2010; International Tropical Fruits Network). The lifestyle of the people for the past decades had been very different and dynamic. This does not only include people in developed countries but even also in developing ones such as the Philippines including those in rural areas.

The demand for easier-to-prepare fresh vegetables, the recognition of the nutritive importance of fresh vegetables to a healthy diet, and the consumption of more meals away from home all combine to make the demand for fresh-cut vegetables likely increased (Saltveit, 1996). Among these, convenience and health awareness of people are main reasons of the increased of sale of fresh-cut vegetables and fruits (Raegert, 2004).

In the Philippine local market, fresh-cut products are from different vegetables that are mixed which include pinakbet, chopsuey and sari-sari. These are mainly cut in the morning and expected to be sold before the end of the day. If unsold, these are considered as wastes. In the case of the fruits like jackfruit and watermelon, they are relatively bulky and cannot be consumed at one sitting by most families (Rattanapanone et. al., 2000). Both fresh-cut vegetables and fruits are displayed at open-air and ambient condition without considering other means of storing the produce. However, supermarket displays are also available for some vegetables and even for fruits (http://www.searca.org/phocadownload/ADSS_2011/adss-institutional-markets-for-fresh-vegetables-concepcion-2011-mar-02) that are mostly stored in refrigerated of low storage condition with some packaging materials. Procurement from either market mainly saves time for meal preparations as people omit the activities involved in fresh-cut production. Moreover, in the advent of technology, some entrepreneurs offer online shopping and offer fresh-cut products especially within the city of Manila.

Problems with fresh-cut

Browning sensitive – Browning or discolouration of cut surface is the main concern in fresh-cut products. The processes involved in fresh-cut production (Fig. 1) contribute the immediate physical effects of wounding tissue, such as what occurs during peeling or size reduction operations that cause mechanical stress to the tissue, phenolic metabolism which in turn leads to the formation of undesirable brown pigments, remove the protective epidermal layer, accumulate surface moisture and expose tissue to contaminants which consequently shortens the storage life (James and Ngarmsak, 2010; Saltveit 1996).

Microbial-sensitive – Criteria of quality attributes such as appearance, texture, flavour and nutritional value on fresh vegetables and fruits have been traditional. Commonly, cut vegetables are washed and sanitized to reduce microorganisms that affect the quality and the safety of fresh-cut products. However, oftentimes this technique does not guarantee food safety and longer shelflife. Nowadays, key players in the supply chain from farm to consumers had also increased their concern for food safety. Though in the Philippines there are no cases reported on outbreaks of foodborne diseases, many studies had reported on the risk of consuming minimally produced fresh food mainly eaten raw. *Listeria monocytogenes*, *Salmonella enteritidis* phage, and *Escherichia coli* O157:H7 and O104:H4 are major pathogens.Incidence of microbial contamination among local markets and supermarkets are likely similar (Acedo et. al, 2013; Valida et. al., 2015; Mahajan et. al, 2014; Vital et.al. 2014).

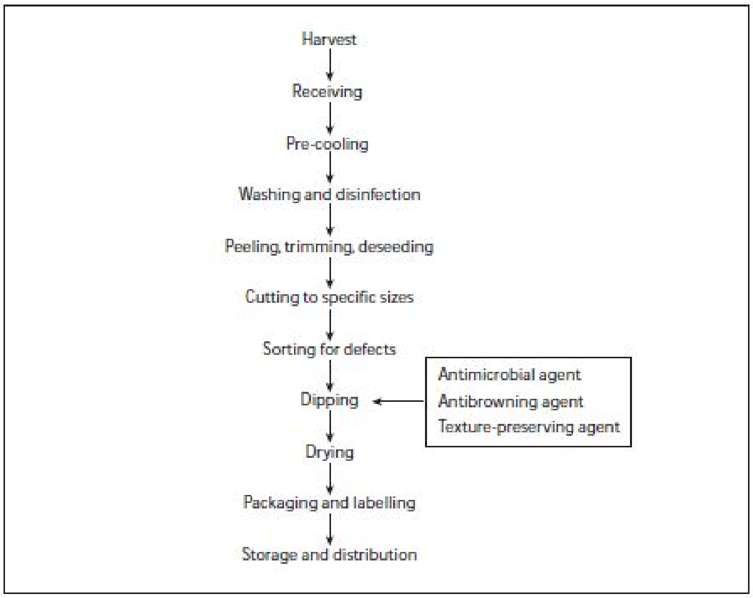

Figure 1. Typical fresh-cut process flow chart for fruits, vegetables and root crops (James and Ngarmsak, 2010)

Some methods in extending shelf-life of fresh-cut vegetables and fruits

With the acceptance of the consumers on the trend in fresh-cut, there is a real need to find methods or even new methods for extending the shelflife of fresh-cut vegetables and fruits.

Physical treatments

Heat treatment

- It has been studied as an alternative to chemical treatments for harvested fresh fruit vegetable
- Heat treatment include hot water dip (HWD), saturated water vapour heat, hot dry air and hot water rinse (HWR) with brushing
- This is applied to firm potatoes, tomatoes, carrots and strawberries; to preserve the colour of asparagus, broccoli, green beans, kiwi fruits, celery and lettuce; to prevent development of overripe flavours in cantaloupe and other melons; and to generally add to the longevity of grapes, plums, bean sprouts and peaches, among others

    - Heat shock by using hot water washing at temperatures ranging from 37 to 55◦C for 30 s to 3 min can improve the postharvest quality of spinach, rocket leaves, apples and mandarin fruit.
- Hong *et al*. suggested that the combination of *Bacillus amyloliquefaciens* HF-01, sodium bicarbonate and hot water could be a promising method for the control of postharvest decay on citrus while maintaining fruit quality after harvest.
- HW treatments are alternative to fungicide applications in commercial scale and in Germany HWD has been used in the storage of organic apples
- Hot water treatment for 10 min best reduced browning, but only when treated potato tubers were stored intact for 1 day at 20 8C before cutting, as indicated by discoloration scores and changes in L*, a*, and H values, which were significantly different from either the control or the other HW treatments. Severe browning that developed in control slices during storage was associated with significant increases of 25% and 71% in phenolic content and antioxidant capacity, respectively. On the other hand, phenolic synthesis increased by only 6.25% to 13.2% in HW-treated slices during storage and polyphenoloxidase (PPO) activity was 24% to 31% lower compared with the activity before storage. Immersing potato tubers in 55 8C water for 10 to 20 min followed by storage at 20 8C for 1 day before processing reduced but did not prevent browning of peeled slices in terms of color changes and discoloration score. There was no significant correlation between browning and phenolic content or PPO activity (Tsouvaltzis et. al., 2011).
- Hot water (45 °C for 10 min., 55 °C for 12 sec.) preceding the short-term storage of fresh-cut pepper fruit 'Blondy F1' and 'Yecla F1' significantly reduced the content of bioactive compounds and antioxidant properties. Treatment with water at 55 °C for 12 sec. caused lower losses in content of bioactive compounds and antioxidant and antiradical activity than the treatment with water at 45 °C for 10 min (Szwejda-Grzybowska 2016).

Edible coating (EC)

- Edible coatings are thin layers of external coatings applied to the surface of fresh produce that it enhances the waxy cuticle or as replacements for natural barriers where the produce cuticle has been removed.
- It is composed of hydrophobic groups, such as lipid-based waxes; hydrocolloid/hydrophilic groups, such as polysaccharide or protein-based materials; or an integration of both groups in order to improve the functionality of the coating have shown desirable attributes on fresh produce with good barrier properties, without residual odour or taste and efficient antimicrobial activity (e.g. chitosan, Aloe vera, polyvinyl acetate, mineral oils, cellulose and protein based EC.
- Natural antimicrobial agents derived from fruits, medicinal crops, and shells have also been investigated as preservatives (Kim et al., 2011). Aloevera coating was reported by to be effective than pectin for jackfruit. Less amount of ascorbic acid was loss, as well as, weight loss during storage and shelflife was extended upto 7 days (Teja 2016). Soy protein coatings in reducing oxidative browning and moisture loss of cut apples and potatoes during their storage at 4°C was effective which was also true to fresh-cut apples, carrots and potatoes with a pectin/whey protein film containing the enzyme transglutaminase. There was markedly decrease of water loss and to counteract the microbial growth during their storage at 4°C for 10 days (Porta 2013).

Table 1. Summary of edible coating(s) used on fresh/fresh-cut fruit and vegetables.

coating material	purpose of coating
guar gum; pea / potato starch ± potassium sorbate	antimicrobial
candelilla wax-based	antimicrobial; antioxidant; quality
soya bean gum; jojoba wax; glycerol and arabic gum	overall quality
Shellac ± Aloe vera gel	keeping quality
soy protein; carboxymethyl cellulose	antioxidant; H_2O barrier
chitosan; zein	antioxidant; H_2O barrier
beeswax; coconut and sunflower oil	antimicrobial; antioxidant; quality
pectin base; alginate; carboxymethyl cellulose	antioxidant; H_2O barrier
chitosan; methyl cellulose	antimicrobial; antioxidant; O_2 / CO_2 / H_2O barrier
soy protein; carboxymethyl cellulose	antioxidant; H_2O barrier
pectin base	overall quality
Aloe vera gel	overall quality
agar; chitosan; acetic acid (combined)	antimicrobial; O_2 / CO_2 barrier
whey protein; rice bran oil	H_2O barrier; overall quality
chitosan	overall quality
sucrose-polyester based	H_2O barrier; antioxidant activity
alginate and gellan based	O_2 / CO_2 / H_2O barrier

Mahajan et. al, 2014

Cutting

- Some mechanics of cutting and further processing were found to have insightful effects on the browning process in eggplant. It was significantly inhibited by cutting using a sharp blade (thickness, 0.04 mm) and immediate dipping in water for 10 min, followed by ambient air-drying and packaging. Scanning electron and fluorescence microscopic examinations showed that sharp blade cutting caused less physical injury and cell death, resulting in reduced discharge of phenolics and polyphenol oxidase activity further resulted to lesser browning. For commercial acceptability of the technique, storage studies were performed at ambient, 10 and 4 °C, which indicated that fine cut samples could be stored up to 5, 12, and 16 days at these temperatures, respectively, with organoleptically acceptable scores (Mishra, 2012).

Chemical treatments

Antimicrobial and anti-browning agents

- Chemical-based agents include chlorine-based solutions, peroxyacetic acid (PAA), organic acids, hydrogen peroxide (H_2O_2) and electrolysed water

- Legally, agricultural chlorine is commercially available in three forms that have been approved for use by the U.S. Environmental Protection Agency (EPA) and by individual states.

  Chlorine gas (Cl_2) - the least expensive but most demanding source of chlorine from a safety and monitoring standpoint.

Calcium hypochlorite ($CaCl_2O_2$) - the most common source of chlorine used for disinfection of produce and produce process water; beyond disinfection benefits, is reported to improve the shelf-life and disease resistance of fruits and vegetables by adding calcium to the cell wall.

Sodium hypochlorite (NaOCl) - the source of chlorine commonly used in small-scale operations. It is generally used in concentrations of 5.25 percent or 12.75 percent a.i. in liquid form, because the solid forms readily absorb water from air and release chlorine gas. It has been one of the commonly used disinfectants for fresh produce, due to its very strong oxidizing properties and cost effectiveness [20]. However, its efficacy as an antimicrobial agent is dependent on the levels of chlorine and at high levels may cause taste and odour defects on treated products.

Chlorine-based compounds have been conveyed to have partial effectiveness in the reductions of microbial load on fresh produce. However, chlorine has been associated with the possible formation of carcinogenic chlorinated compounds and this may lead to new regulatory restrictions in the EU (Suslow). In addition, the dynamic balance of the two forms of hypochlorite in water changes dramatically between pH 6.5 and 8.0. The faster acting antimicrobial form, HOCl, exists as 95 to 80% of the “free chlorine” detected with the paper test strips at pH 6.5 to 7.0.

- 15 g/L calcium ascorbate and 25 mg/L sodium chlorite on fresh-cut apples exhibited less colour change and browning reaction than did the apples in the control group. L* values of the untreated samples and the distilled water samples were lower compared to the Calcium ascorbate and Sodium chlorite samples by 5.4 and 5.0 units, respectively, after six days at 4°C packed in a polypropylene tray (14 x 19 x 5 cm), sealed using top heating with polypropylene film (anti-fog type) (Valida et. al 2016).

- The effect of antioxidants controlling enzymatic browning of eggplants was studied in extract and fresh-cut tissue. Initially, the effect of ascorbic acid (AA), citric acid (CA), peracetic acid (PA), calcium chloride, cyclodextrin, cysteine (Cys), hexametaphosphate and 4-hexylresorcinol (Hexyl) at different concentrations was studied in extracts and precipitates of eggplant. Cys and Hexyl were effective at 10 mM in both the extract and pellet. Higher concentrations were needed to have an effective control of enzymatic browning in samples treated with AA (20 mM), CA (50 mM) and PA (50 mM). Next, the application of AA, CA, PA, Cys and Hexyl at different concentrations was studied on fresh-cut eggplant tissues during storage at 5C. Cys was effective as antioxidant, extending the shelf life till 9 days of storage at 5C when applied at a concentration of 1%. Tissue browning increased as AA and Hexyl concentrations increased (Ghidelli, 2014).

- The effect of a wide range of antioxidants reducing enzymatic browning of fresh-cut eggplants was studied by Pérez-Gago et. al., (2010). Fresh-cut eggplants were dipped in ascorbic acid (AA), citric acid (CA), peracetic acid (PA), cysteine (Cys) and 4-hexylresorcinol (4-HR) at different concentrations. Colour and sensory evaluation were performed during storage at 5°C. Among the antioxidants studied, AA and Cys most effectively reduced browning, whereas the rest of the antioxidants caused tissue damage, which translated in higher browning than control samples. AA was effective in a range of concentrations from 0.35% to 0.88%, whereas concentrations above 1.5%

induced higher browning than observed in control samples. Effective Cys concentrations ranged from 0.1% to 1%. Cys effectiveness increased with the concentration. The loss of effectiveness was earlier in the AA than in the Cys treatments. The limit of marketability for samples dipped in 0.88% AA and in 0.5% Cys and stored at 5°C was 2 and 9 days, respectively. After 9 d of storage at 5°C, samples dipped in 1% Cys were still evaluated as very good. Cys has a potential as antioxidant to control enzymatic browning of fresh-cut eggplants.

- Agar et. al (1999), reported that fresh-cut kiwifruit slices had a shelf-life of 9-12 days if treated with 1% CaCl2 or 2% Ca lactate, and stored at 0-2°C and >90% relative humidity in an C_2H_4-free atmosphere of 2 to 4 kPa O_2 and/or 5 to 10 kPa CO_2. Calcium lactate had higher antimicrobial activity than ascorbic acid or chlorine. Calcium lactate and ascorbic
acid had no adverse effect on product quality.

Gaseous treatments

1-Methylcyclopropene

- The fruits were washed then sanitized by soaking in 200 ppm chlorine solution for 2 minutes. The solution for washing was prepared by mixing 15 mL 5.25% hypochlorite in 1 gallon water. The fruits were air dried, sliced to remove the cheeks, and sliced further to produce 1 inch strips of mango slices which were removed by scooping them from the peel. The fresh-cuts were directly packed into previously sanitized and dried PET trays at 150 g per pack. The packs were then overwrapped with LDPE clingwrap film. 1-MCP was prepared by weighing the calculated amount of 1-MCP powder (AnSIPTM, 0.43% 1-MCP) to prepare 1 uL L-11-MCP gas. The powder was weighed into an evacuated 1L volumetric flask and added with a few drops of water to dissolve the powder. The 1-MCP gas prepared was injected using disposable plastic syringe into the packs at a concentration of 1 uL L-1 based on the volume of the empty tray. The holes made by injection were resealed using tape. Samples were then stored at 5oC and monitored for quality parameters during storage (Castillo-Israel 2015).

Modified atmosphere packaging

- Millan (1997), reported that quality deteriorated in the sliced ripe jackfruit due mainly to decay during storage at ambient (27.03-30.70°C and 78.57-90.67% RH). Deteriorative changes were retarded by refrigerated storage (7.97-14.75°C and 53.42-66.36% RH) and use of unperforated 0.05mm thick PEB as MA chamber in which shelf life correspondingly increased. Aside from storage, samples with Sodium hypochlorite (NaOCl) at 0.5 to 1% reduced decay of the sliced ripe fruit and further prolonged shelf life of room-stored MA fruits. Activated carbon 0.05-0.1% was as efficient as potassium permanganate in scrubbing ethylene during MA holding of ripe fruit but shelf life was not improved.The chemical and sensory quality attributes were not adversely affected by the treatments, except that refrigerated storage generally reduced the eating quality of the fruits.

- Fresh-cut jackfruit soaked to pretreatment solutions (0.04374% w/v NaOCl, 0.74% CaCl2 and 0.65% ascorbic acid) for 2 minutes and packed in respective containers with different Vacuum packaging: polyethylene bags with 0.003 mm thickness, vacuumed for 25 seconds and sealed at medium heat for 3 seconds and conventional packaging: plastic tray and cling wrap; Treatments 1, 3, 5, and 7 were stored at the refrigerator (crisper) (4-6°C), and (2, 4, 6, and 8) stored at ambient temperature (30 °C) (Fig 2.) showed promising results. Deseeded products have much faster deterioration compared to treatments with seeds. Jackfruits stored in chilling (4-6°C) condition exhibited lesser variation in TSS, pH, browning and firmness during the storage period compared to those stored at ambient temperature. Jackfruits packed in vacuum have slower deterioration compared to treatments which are conventionally packed. Those packed in vacuum have slower deterioration compared to treatments which are conventionally packed (Galvez, et. al. 2017).

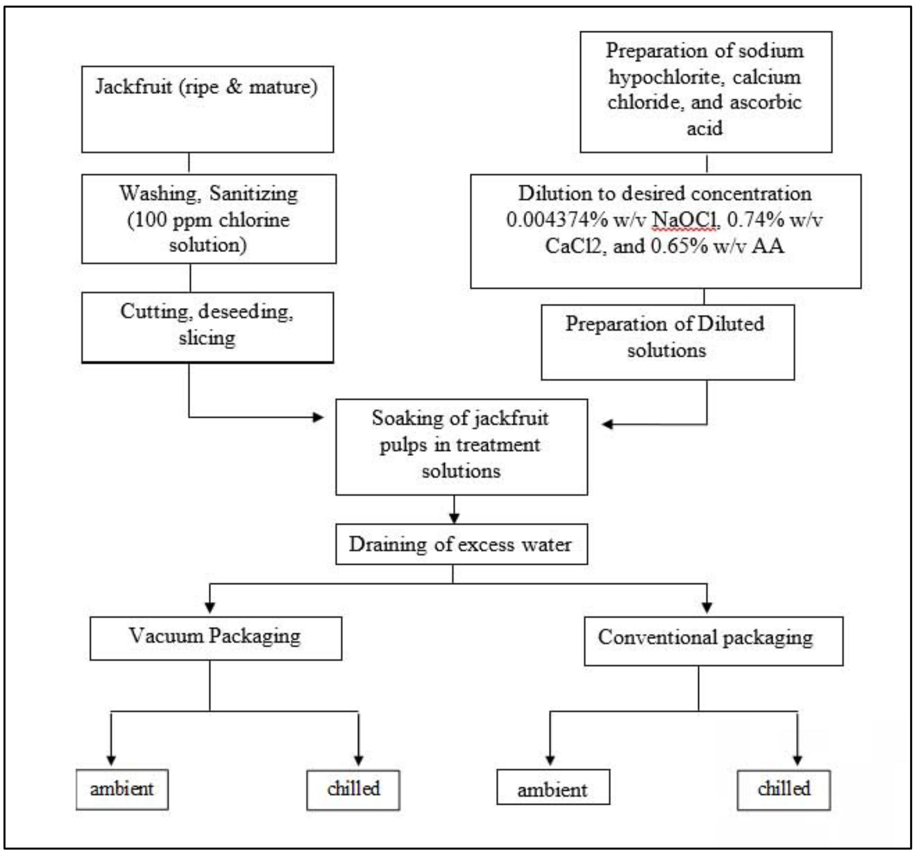

Figure 2. Process flow for fresh-cut jackfruit preparation (Galvez, et. al. 2017).

Combined Treatments

- Previously mentioned treatments are adopted and it most likely some are not of just sole treatment but in combinations instead. Moreover, more effective preservation of fresh-cut products can be achieved through combined treatments. Ascorbic acid and calcium chloride combination is a common treatment in discolouration prevention of apple (Table 2). Browning in potato was also treated with different anti-browning agent combinations (Table 3) (Garcia and Barett undated).

Table 2. Effect of treatments with ascorbic acid (AA) and Calcium chloride on the prevention of discoloration in apple slices.

Treatment*	Loss of Reflectance (%) compared to freshly sliced apples var. Newton Pippin	var. Golden Delicious
Control – water dip	62.5	60.5
0.05% $CaCl_2$	24.8	58.9
0.1% $CaCl_2$	23.3	51.2
0.5% AA	57.9	59.2
0.5% AA + 0.05% $CaCl_2$	26.9	48.0
0.5% AA + 0.1% $CaCl_2$	24.2	25.6
1% AA	25.5	45.6
1% AA + 0.05% $CaCl_2$	20.5	39.2
1% AA + 0.1% $CaCl_2$	4.2	17.0

Three minute dip in 1L of antibrowning solution, followed by 1 min draining and packaging in plastic bags prior to storage at ~1°C for 11 weeks.
(Adapted from Ponting *et al.*, 1972).

Table 3. Effect of combined treatments on the browning index of potato slices 2h after cutting.

Antibrowning Agent	pH	Browning Index var. Bintje 1mo.	5mo.	8mo.	var. Van Gogh 1mo.	5mo.	8mo.	var. Nicola 1mo.	5mo.	8mo.
0.3% AA + 0.5% citric acid	2.4	0	1	1	0	6	2	4	3	3
0.5% AA + 0.5% citric acid	2.4	0	2	0	1	3	2	6	1	2
0.3%AA + 0.3% citric acid + 0.1% $CaCl_2$	2.4	0	2	2	6	5	2	4	2	4
0.3% AA + 0.3% citric acid + 0.2% K sorbate	3.2	0	3	3	4	4	4	9	3	3
0.5% AA + 0.5% citric acid + 0.2% K sorbate	2.8	0	2	1	1	2	2	6	2	2
0.1% AA + 0.1% citric acid + 0.1% Na benzoate	3.5	0	4	2	2	7	3	4	8	6
0.5% citric acid + 0.005% 4-hexylresorcinol	2.6	0	1	2	0	3	2	5	3	3
Water	5.7	1	4	6	10	22	9	67	39	13

Dipping solution was applied at 5°C for 1 min in a ratio of 2 L of solution/kg of potato slices; slices were drained for 1 min and then kept for 2h at 23°C prior to browning evaluation.
(Adapted from Mattila *et al.*, 1993)

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