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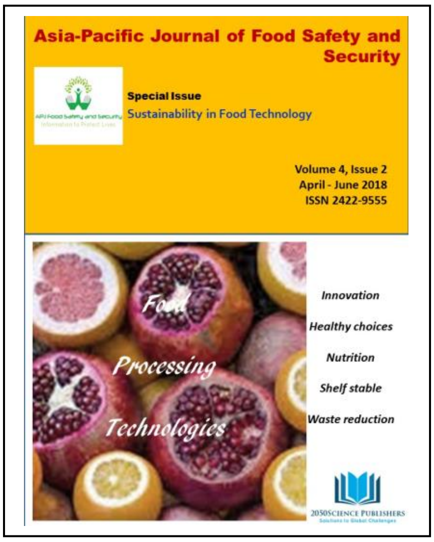

Physico-chemical quality of minimally processed potatoes (*Solanum tuberosum* L.) as affected by different anti-browning agents

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Highlights

- Extending shelf life of fresh-cut potatoes by reducing enzymatic browning
- Reducing postharvest losses to sustain product availability
- Nutrient retention of fresh-cut potatoes by heat treatment

About Authors

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Abstract

The shelf life of minimally potatoes is strongly limited by enzymatic browning that leads to a decrease in food quality. This study was conducted to determine the efficacy of enzymatic browning control agents in minimizing browning of minimally processed potatoes; determine the physico-chemical qualities of the different treatments; and determine the best enzymatic browning control agents. Product samples were collected from market of Ormoc City, Philippines. The experiment was arranged in simple Completely Randomized Design (CRD). Enzymatic browning control agents were used as 10% solution for ascorbic acid; pineapple and citrus juice, the processed potatoes were dipped in the solution for 1-2 mins, while for hot water treatments, minimally processed potatoes were dipped at 45^{o}C, 1-2 mins. After dipping, the treatments were stored at ambient (25^{o}C) and at refrigerated (2-5^{o}C) conditions. Dipping in anti-browning agents for 1-2 min totally reduced browning after treatment and during storage based on browning index. Tap water, ascorbic acid, pineapple and citrus juice reduced the intensity of browning but were less effective than hot water dip treatment. Objective lightness (L*) measurement produced the highest values for hot water dip treatments-treated minimally processed potatoes before, during and at the end of the 24 hours storage period coinciding with the browning scores. Objective a*value (green-red) and b* value (blue to yellow) had statistical significance among the different anti-browning agents after 30 minutes, 16 hours and 24 hours of treatment both stored under ambient and refrigerated conditions. Physico-chemical analysis (TSS, TA and pH) of minimally processed potatoes treated with anti-browning agents (tap water, hot water, ascorbic acid, pineapple juice and citrus juice) had no significant differences on total soluble solids and pH (ionic acidity) ranging from 3.63-3.86 and 5.96-6.30, respectively. The differences were more attributed to titratable acidity; heat-treated minimally processed potatoes and pineapple juice dip were significantly lower titratable acidity than the remaining treatments after 30 minutes of treatment. Hot water treatment at 45^{o}C, 2 minutes, and a non-chemical treatment and as anti-browning agent proved in minimally processed potatoes.

Keywords: anti-browning agents; hot water; minimally processed potato

1. Introduction

Potato (*Solanum tuberosum* L.) is a globally important crop plant producing high yields of nutritionally valuable food in the form of tubers. It has been the focus of substantial study because of its use both as a staple food crop and as a potentially significant source of compounds of interest. However, the shelf life of peeled and cut potatoes is strongly limited by enzymatic browning that leads to a decrease in food quality; since it implies spoilage. As a consequence of tissue damage, browning rapidly occurs. This is due to the release of polyphenol oxidase (PPO) from ruptured cellular compartment, particularly plastids, which then comes into contact with phenolic compounds released from ruptured vacuole, the main storage organelle of these compounds. O' Neill (1995) elaborated that browning reaction results from the oxidation of phenolic compounds catalyzed by PPO which is ubiquitous in plant tissues. Enzyme-catalyzed browning reactions involve the oxidation of phenolic compounds by the enzyme polyphenol oxidase (PPO) that can catalyze in two different reactions: the hydroxylation of monophenols to alpha di phenols and the oxidation of alpha diphenols to alpha quinones (Tomas-Barberan and Espin, 2001; Cantos et al., 2002). These reactions result in a deterioration of flavor, colour and nutritional quality (Friedman, 1997).

Enzymatic browning of fresh produce has great visual impact and decreases the commercial quality of the product. It is one of the main problems limiting shelf life of fresh produce (Artes et al., 1998). In addition, cuts or damages in the tissues promote intracellular release of nutrients and enzymes that favor enzymatic activities and the proliferation of microorganisms (Fantuzzi et al., 2004; Mattiuz et al., 2003). Hwang et.al (2001) reported that enzymatic browning occurred in many minimal processed produce. Since browning reduces qualities, several techniques and mechanisms have been developed to control PPO activity. A better understanding of the relationship among PPO activity, phenolic contents, and discoloration reaction in minimally processed products would facilitate development of control treatments.

Sodium metabisulfite (Na_2S_2O5) is usually used in the food industry as anti-browning agent (Sapers, 1993). However, sulfiting agents are now being eased out from the market since persons sensitive to sulphites could develop dermatological, pulmonary, gastrointestinal, and cardiovascular symptoms (Knodel, 1997). Sulphite use is banned in the US for fruits and vegetables as well as meat in which sulphites restore red color giving false freshness to raw meat (Cantwell, 2010). Thus, alternative safe treatment has to be developed.

The use of natural reducing agents, such as anti-browning agents, has become increasingly popular because of its positive effect on controlling browning and enhancing food safety and environmental preservation. Anti-browning agents include ascorbic acid (Vitamin C), citric acid and acetic acid have been shown to be very effective in reducing enzymatic browning; they are also safe, cheap and well accepted by consumers (Miranda, 2001). Anti-browning agents act by prohibiting PPO activity and reducing quinones back to phenols before forming dark pigments (Sapers and Miller, 1998; Chitarra, 2000; Golan-Goldhirsh et al., 1984). In general, the study aimed to evaluate the quality of minimally processed potato as influenced by different anti-browning agents and storage conditions. Specifically, it aimed to determine the efficacy of enzymatic browning control agents in minimizing browning of minimally processed potatoes; determine the physico-chemical qualities and determine the best enzymatic browning control agents.

2. Materials and Methods

2.1 Preparation of Potatoes for Minimally Processing

Freshly procured medium size potatoes were obtained from the local market of Ormoc City, Philippines. The potatoes were carefully transported to the Food Science laboratory of the Department of Food Science, VSU. The potatoes peeled carefully using a sharp knife. Right after peeling, the potatoes were cut longitudinally into thin slices. About 100-150 g of each pack of sliced potatoes per treatment per replication was used in this experiment. A total of nine kilograms of potatoes was used.

2.2 Treatments and Experimental Design

The experiment composed of six (6) treatments arranged in Completely Randomized Design (CRD) was used. All treatments were replicated three times. Some sliced potatoes were set aside for measurement of parameters that required destructive samples. Enzymatic browning control agents were used as 10% solution for ascorbic acid; pineapple and citrus juice, while hot water treatments, 45ºC. The processed potatoes were dipped in the solution for 1-2 mins. After dipping, the treatments were stored at ambient (25ºC) and at refrigerated (2-5ºC) conditions.

Table 1. Experimental treatments used in determining the enzymatic browning control treatment on physico-chemical quality on minimally processed potato

Treatments	Independent parameters	Time
T_1	No treatment	1-2 mins
T_2	Tap water dip	1-2 mins
T_3	Hot water dip, 45ºC	1-2 mins
T_4	Ascorbic acid	1-2 mins
T_5	Pineapple juice dip	1-2 mins
T_6	Citrus juice dip	1-2 mins

2.3 Data Gathered

2.3.1. Browning Incidence

Degree of browning of each sample was assessed using the browning index used by Acedo, (1997): 1 for no browning; 2 for slightly brown (less than 25% of surface brown; 3 for moderately brown (26%-50% of surface brown) and 4 for severely brown (>50% of surface brown). Quantitative measurement of browning was done by taking the lightness (L*), a* and b* (color) values using a Minolta CR-13 colorimeter. This was done before storage of the representative samples of the whole lot and after 1 day of storage using replicate samples per treatment.

2.3.2. Weight Loss

The weight of each packed and unpacked sliced potatoes was daily monitored and determined. Weight loss was expressed as percent of the initial weight (Acedo, 1997).

*2.3.3. Visual Quality Rating (VQR***)**

The physical appearance of each sample was evaluated daily using the following VQR used by Acedo, (1997): 9 for excellent, no defect; 7 for good, minor defect; 5 for fair, moderate defects; 3 for poor, serious defects and 1 for inedible under usual condition (Acedo, 1997).

2.3.4. Physico-chemical Analysis

Total Soluble Solids (TSS), ionic acidity (pH) and titratable acidity (TA) of the treatments were evaluated.

2.3.5. Total Soluble Solids (TSS)

TSS as an approximate measure of sugar content was measured before and at the end of storage using a hand-held refractometer (Hanna instrument, HI 96801). Two or three drops of the juice extracted from the samples were placed into the refractometer prism and the reading was taken against the light.

2.3.6. pH

pH as a measure of the acidity/alkalinity, pH of the extracted juice was measured using pH meter (Hanna instrument, HI 98130).

2.3.7. Titratable Acidity (TA)

For titratable acidity (TA) analysis, 10 ml of juice extract (aliquot) was placed in the beaker with 2 drops of 1% phenolphthalein indicator and determined using digital autotitrator ; Hanna instrument, HI 84532.

2.4 Data Analysis

Statistical analysis of results was performed using the STAR program of the International Rice Research Institute (STAR, 2014).

3. Results and Discussion

3.1 Degree of Browning

Browning rapidly occurred after peeling and increased with storage at ambient and refrigerated condition (Table 1 and Table 2; Figure 2). Anti-browning agents significantly influenced the incidence of browning of minimally processed potatoes relative to the control. Among the anti-browning agents, tap water, hot water dip and ascorbic acid were the most effective, totally inhibiting browning, with scores of 1.0 (no browning symptom) after 30 minutes of dipping than the remaining treatments. After 16 hours of storage minimally processed potatoes treated with hot water and ascorbic acid had comparably lower degree of browning with scores of 2-2.5.The effect of hot water dip on the treated minimally processed potatoes was much more effective than that of ascorbic acid after 24 hours of storage both in ambient and refrigerated conditions. The other anti-browning agents, pineapple juice and citrus juice dip, the natural weak acid used as anti-browning agents as well as tap water were found less effective control against browning. This was evident after 24 hours of storage (Table 1).

Table 1. Degree of browning of minimally processed potato in response to different enzymatic anti-browning agents stored at ambient condition

Treatment	Degree of browning		
	(30 mins)	(16 hours)	(24 hours)
Control	3.0^{a}	4.0^{a}	4.0^{a}
Tap water	1.0^{d}	3.5^{b}	4.0^{a}
Hot water dip	1.0^{d}	2.5^{d}	2.5^{c}
Ascorbic acid	1.0^{d}	2.5^{d}	3.0^{b}
Pineapple juice	2.0^{b}	3.0^{c}	4.0^{a}
Citrus juice	1.5^{c}	3.0^{c}	4.0^{a}
5% LSD	0.00	0.00	0.00
CV (%)	0.00	0.00	0.00

Browning index 1 for no browning; 2 for slightly brown (less than 25% of surface brown; 3 for moderately brown (26%-50% of surface brown) and 4 for severely brown (>50% of surface brown).

Table 2. Degree of browning of minimally processed potato in response to different enzymatic anti-browning agents stored at refrigerated condition

Treatment	Degree of browning		
	(30 mins)	**(16 hours)**	**(24 hours)**
Control	3.0^{a}	4.0^{a}	4.0^{a}
Tap water	1.0^{d}	2.5^{b}	4.0^{a}
Hot water dip	1.0^{d}	2.0^{b}	3.0^{b}
Ascorbic acid	1.0^{d}	2.0^{b}	3.8^{a}
Pineapple juice	2.0^{b}	3.5^{a}	3.7^{a}
Citrus juice	1.5^{c}	2.5^{b}	3.8^{a}
5% LSD	0.00	0.64	0.54
CV (%)	0.00	12.86	8.0

Browning index 1 for no browning; 2 for slightly brown (less than 25% of surface brown; 3 for moderately brown (26%-50% of surface brown) and 4 for severely brown (>50% of surface brown).

Objective lightness (L*) measurement produced the highest values for hot water dip treatments-treated minimally processed potatoes before, during and at the end of the 24 hours storage period coinciding with the browning scores (Figure 1). However, L* values for the other treatments differed both in ambient and refrigerated conditions. After treatment, hot water, ascorbic acid, pineapple juice dip and citrus juice resulted in significantly higher L* than the control but at the end of storage, only hot water treatment maintained significantly higher L* than the control both in ambient and refrigerated conditions.

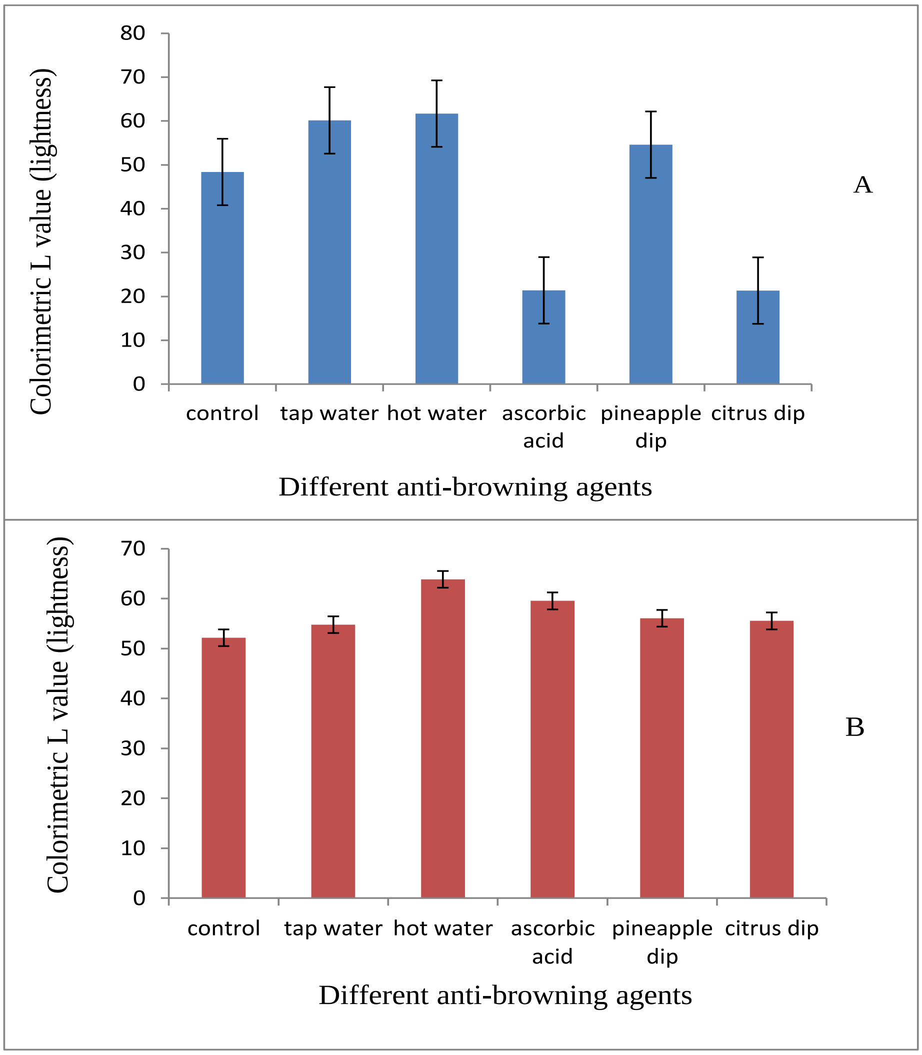


Figure 1. Colorimetric L* (lightness) value of minimally processed potato in response to different enzymatic anti-browning agents after 30 minutes of storage, A – ambient condition; B – Refrigerated condition.

Objective a*value (green-red) and b* value (blue to yellow) had statistical significance among the different anti-browning agents after 30 minutes, 16 hours and 24 hours of treatment both stored under ambient and refrigerated conditions. (Table 3-6; Figure 3-4). The effects of hot water treatments on (a*), and b*were significantly higher values than the remaining anti-browning agents as well as untreated minimally processed potatoes both stored at ambient (25°C) and refrigerated (2-5°C)conditions, coinciding with the L* value results and the degree of browning which corresponded in delaying browning incidence.

Table 3. Colorimetric a* value of minimally processed potato in response to different enzymatic anti-browning agents stored at ambient condition

Treatment	a* value (30 mins)	a* value (16 hours)	a* value (24 hours)
Control	-1.8022[a]	0.2767[a]	0.6033[ab]
Tap water	-4.1867[b]	-1.7683[abc]	0.1033[ab]
Hot water dip	-4.7633[b]	-2.98[c]	-1.4433[c]
Ascorbic acid	-1.1367[a]	-1.26[abc]	-0.2867[bc]
Pineapple juice	-3.6433[b]	-2.3333[bc]	-0.1833[abc]
Citrus juice	-1.0967[a]	-0.42[ab]	1.27[a]
5% LSD	1.28	2.20	1.47
CV (%)	-25.35	-25.52	55.59

Table 4. Colorimetric a* value of minimally processed potato in response to different enzymatic anti-browning agents stored at refrigerated condition

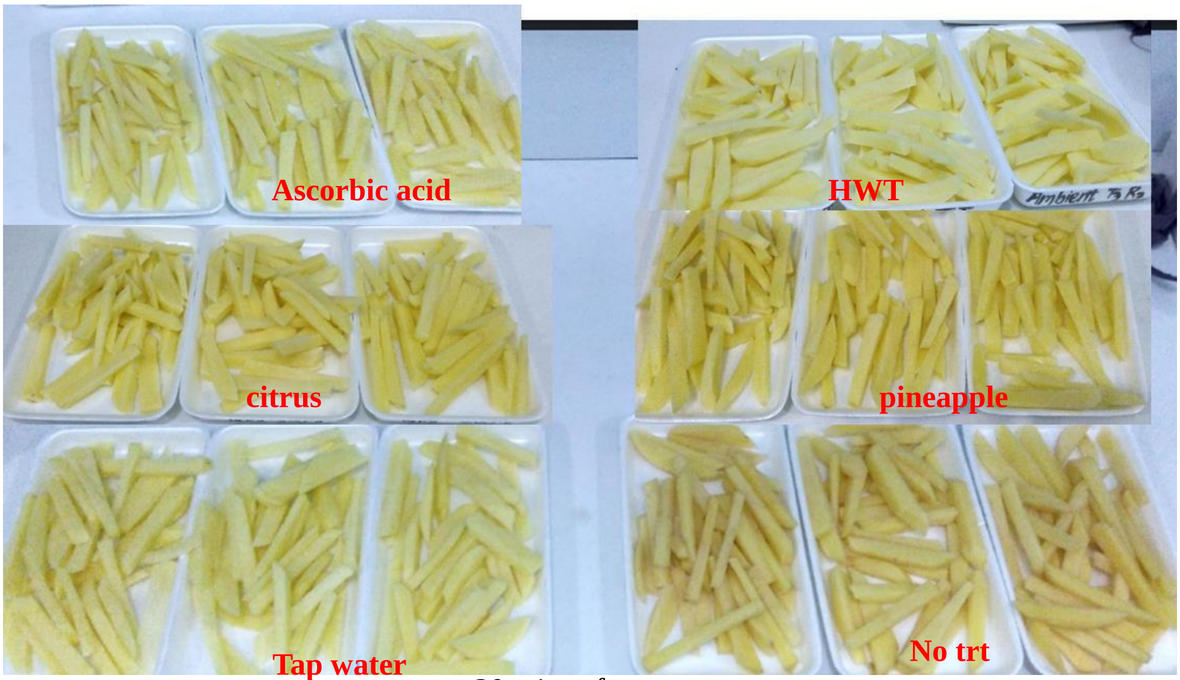
Treatment	a* value (30 mins)	a* value (16 hours)	a* value (24 hours)
Control	-1.2289[a]	-1.2149[a]	0.5022[ab]
Tap water	-3.14[ab]	-2.2611[b]	0.1[ab]
Hot water dip	-4.96[b]	-2.8411[bc]	-1.3433[c]
Ascorbic acid	-5.15[b]	-3.3722[c]	-0.3864[bc]
Pineapple juice	-4.1267[b]	-2.537[bc]	-0.1923[abc]
Citrus juice	-4.6433[b]	-4.32[d]	1.33[a]
5% LSD	2.01	0.88	1.47
CV (%)	-28.56	-17.51	55.59

Table 5. Colorimetric b* value of minimally processed potato in response to different enzymatic anti-browning agents stored at ambient condition

Treatment	b* value (30 mins)	b* value (16 hours)	b* value (24 hours)
Control	13.23[bc]	14.91[ab]	13.53[c]
Tap water	16.89[ab]	14.29[b]	14.67[bc]
Hot water dip	17.35[a]	18.39[a]	17.57[a]
Ascorbic acid	11.19[c]	18.04[ab]	17.10[ab]
Pineapple juice	12.53[c]	17.74[ab]	15.28[abc]
Citrus juice	11.21[c]	16.39[ab]	15.06[abc]
5% LSD	3.92	3.91	2.60
CV (%)	20.73	12.92	9.19

Table 6. Colorimetric b* value of minimally processed potato in response to different enzymatic anti-browning agents stored at refrigerated condition

Treatment	b* value (30 mins)	b* value (16 hours)	b* value (24 hours)
Control	15.87^{ab}	11.11^{b}	13.53^{c}
Tap water	14.02^{b}	13.12^{ab}	14.67^{c}
Hot water dip	17.87^{a}	14.53^{a}	17.57^{a}
Ascorbic acid	17.10^{ab}	14.80^{a}	17.10^{ab}
Pineapple juice	15.13^{ab}	13.83^{ab}	15.28^{abc}
Citrus juice	15.48^{ab}	14.67^{a}	15.06^{abc}
5% LSD	3.67	2.80	2.60
CV (%)	12.68	11.26	9.19



30 mins after treatment

Figure 2. Visual appearance of minimally processed potatoes in response to different enzymatic anti-browning agents after 30 minutes of storage at ambient condition

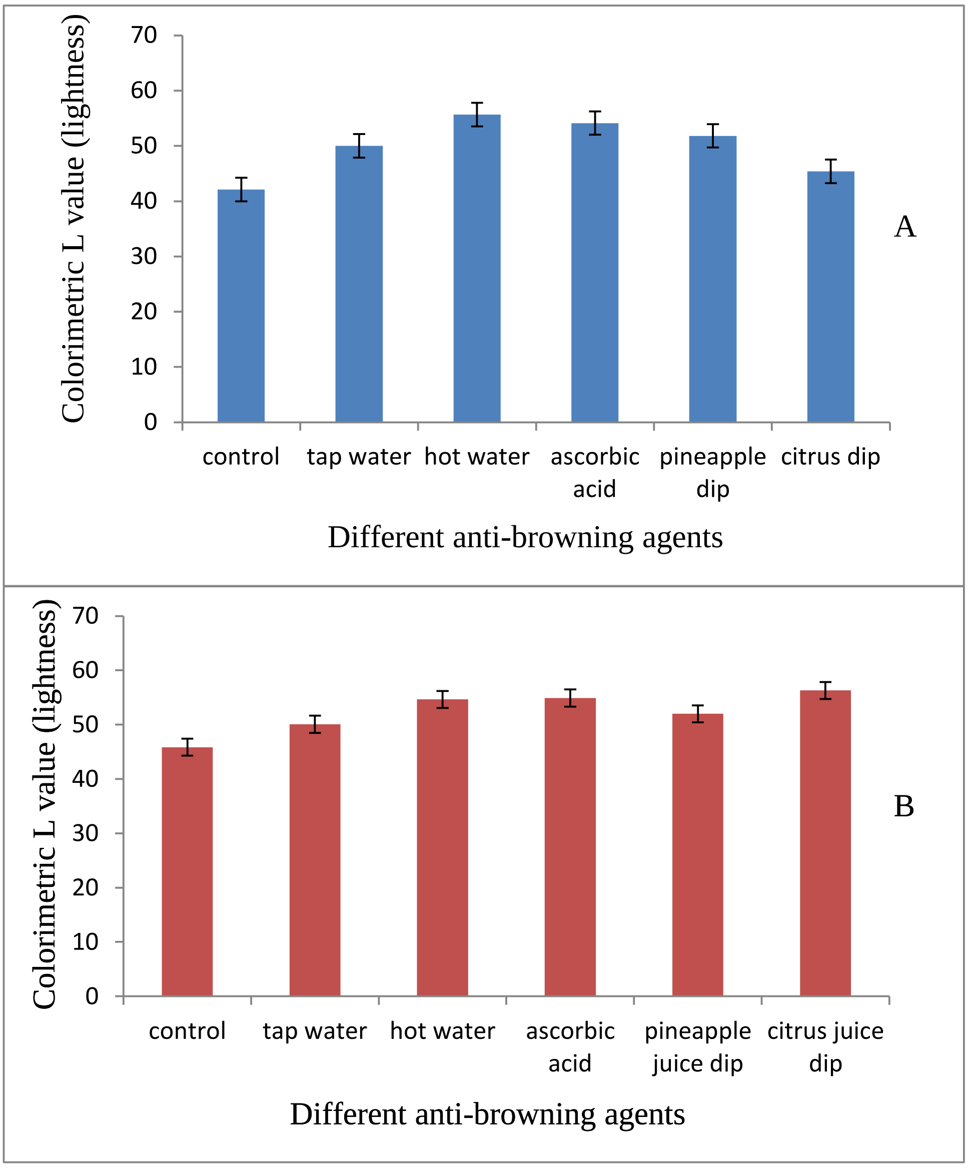


Figure 3. Colometric L* (lightness) value of minimally processed potato in response to different enzymatic anti-browning agents after 16 hours of storage, A – ambient condition; B – Refrigerated condition.

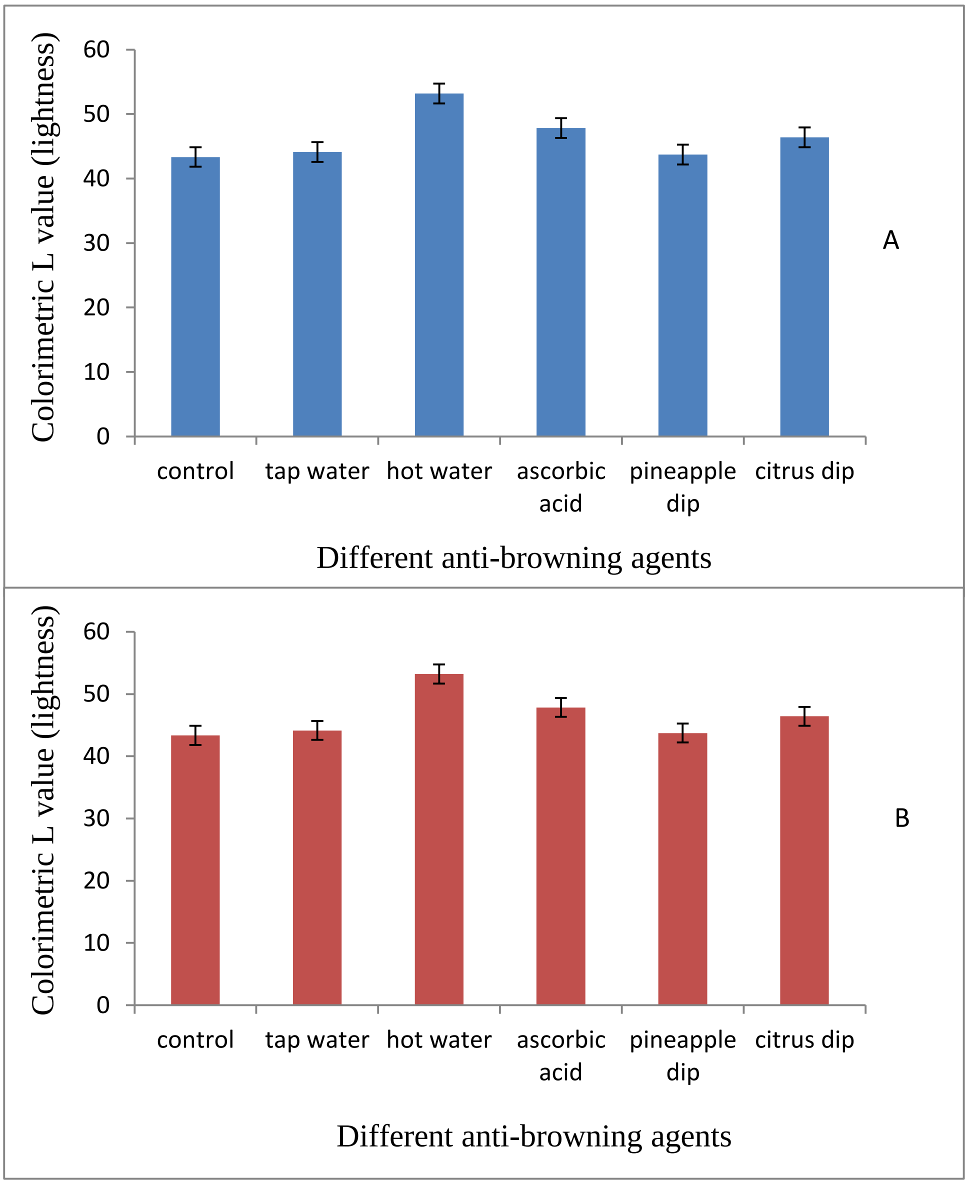


Figure 4. Colometric L* (lightness) value of minimally processed potato in response to different enzymatic anti-browning agents after 24 hours of storage, A – ambient condition; B – Refrigerated condition.

Enzymatic browning of fresh produce has great visual impact and decreases the commercial quality, sensory acceptance and nutritional value of the product. As a consequence of tissue damage, browning rapidly occurs. This is due to the release of polyphenol oxidase (PPO) from ruptured cellular compartment, particularly plastids, which then comes into contact with phenolic compounds released from ruptured vacuole, the main storage organelle of these compounds. O' Neill (1995) elaborated that browning reaction results from the oxidation of phenolic compounds catalyzed by PPO which is ubiquitous in plant tissues. Enzyme-catalyzed browning reactions involve the oxidation of phenolic compounds by the enzyme polyphenol oxidase (PPO) that can catalyze in two different reactions: the hydroxylation of monophenols to alpha di phenols and the oxidation of alpha diphenols to alpha quinones (Tomas-Barberan and Espin, 2001; Cantos et al., 2002). These reactions result in a deterioration of flavor, colour and nutritional quality (Friedman, 1997).

Previous studies further reported that heat treatment could inhibit the enzyme activation, resulting to the inhibition of browning (Howard et al., 1993; Ketsa et al., 1999). Furthermore, the results show that browning scores coincide with quantitative L* values. L* values indicate the intensity of discoloration. The present study is in agreement with the previous findings on celery. Heat treatments have been shown to prevent the wound-induced synthesis of phenols by inhibiting PAL activity and, thus, reducing browning development in fresh-cut vegetables such as celery (Viña and Chaves, 2008) and lettuce (Loaiza-Velarde and Saltveit, 2001).

The results indicate that hot water dip (HWD) at lower temperature of 45ºC, 2 mins dip has anti-browning potential in minimally processed potatoes. It could be used as a possible safe alternative to ascorbic acid anti-browning agent considering that both treatments had comparable inhibitory effect on browning after treatment (30 minutes) and its great potential as a safe alternative anti-browning agent. Heat treatments had been used to control browning of fresh cut products but lower water temperatures of 46-50ºC and longer dipping times of 30-110 min were applied (Barrancos et al., 2003; Dea et al., 2008; Djious et al., 2009). In addition, the heat treatment was applied to the whole produce prior to minimal processing. The anti-browning effect of heat treatment has been attributed to the inactivation of enzymes involved in the browning reactions. On the other hand, citrus juice as anti-browning agent was less effective probably because the concentrations used (10%) was not sufficient to elicit the same effect with that of hot water treatments and 10% ascorbic acid. Pineapple juice as anti-browning agent has not been tried before and the present study shows that it has no potential in controlling browning.

Ascorbic acid (AA) can inhibit enzymatic browning, primarily due to the reduction of quinones before they undergo condensation to form coloured pigments (Martinez and Whitaker, 1995). Ascorbic acid (AA) may also chelate the copper at the active site of PPO. However, once AA has been completely oxidized to dehydroascorbic acid, quinones accumulate and undergo polymerization reactions leading to browning (Friedman, 1997). Citric acid, another widely used anti-browning agent, has a dual inhibitory effect by lowering the pH and chelating the copper at the active site of PPO (Martinez and Whitaker, 1995). AA is often applied in combination with for improved efficacy (Laurila et al., 1998b; Limbo and Piergiovanni, 2006, 2007; Rocculi et al., 2007).

3.2. Cumulative Weight Loss

With anti-browning agents, weight loss markedly decreased except with the tap water and ascorbic acid (Figure 5-6). However hot water, pineapple juice and citrus juice were not significantly differ with that of untreated minimally processed potatoes. It was kept below 8-14% after 24 hours of treatment both stored under ambient and refrigerated conditions whereas that of minimally processed potatoes without anti-browning agents increased to more than 22-23% after 24 hours of treatment particularly at ambient condition. However minimally processed potatoes stored at refrigerated condition decrease percent weight loss when treated with tap water, pineapple and citrus juice dip with an average of 5-5.5% relative to hot water, ascorbic acid as well as untreated samples with an average of 8%. The results indicate that water loss did play a role in the development of browning considering that anti-browning agents had significant effect on browning despite marked reduction of weight loss. This is unlike the central role of water loss in browning of other commodities (Landrigan et al., 1996; Jiang and Fu, 1999). These findings suggest that browning in minimally processed potatoes was enzymatic in nature rather than a physical process (water loss) mediated response. Weight loss reduction induced by the anti-browning agents (ascorbic acid, pineapple juice and citrus juice) and tap water treatment was not anticipated. Whether this is due to their inhibitory effects on oxidative reactions, other deteriorative changes associated with senescence, and/or microbial infections need to be elucidated in future studies.

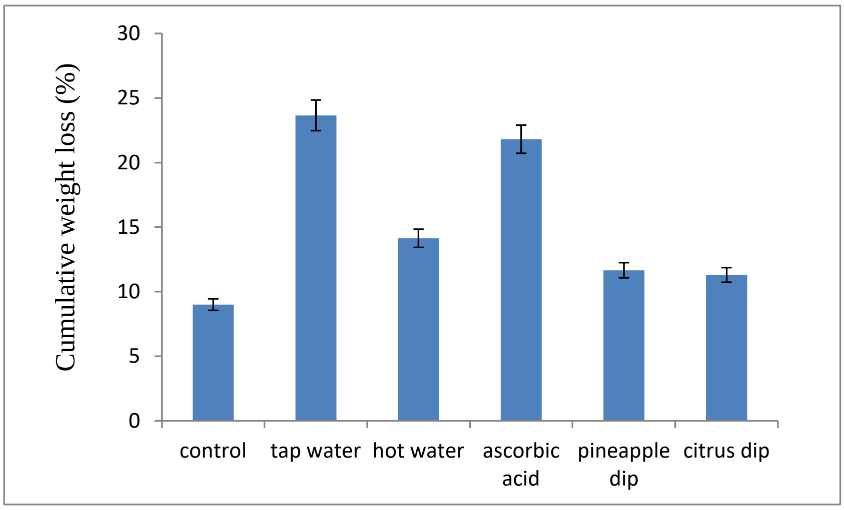


Figure 5. Cumulative weight loss (%) of minimally processed potato in response to different enzymatic anti-browning agents after 1 day of storage at ambient condition

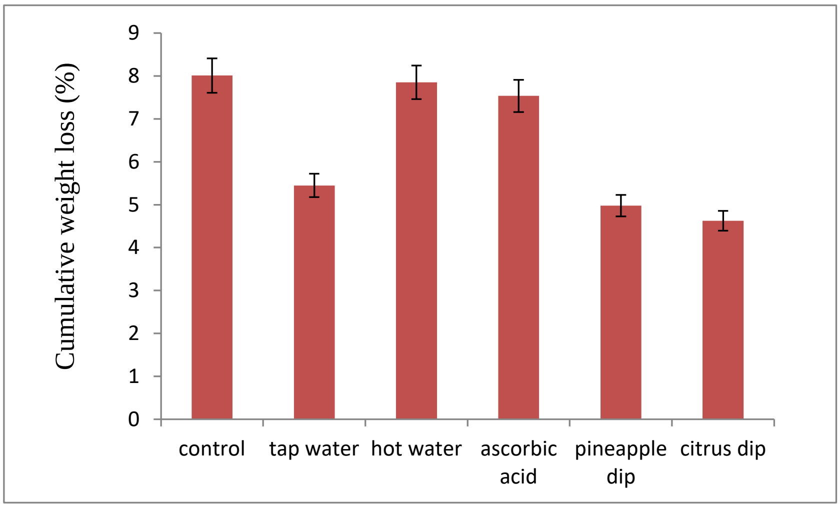


Figure 6. Cumulative weight loss (%) of minimally processed potato in response to different enzymatic anti-browning agents after 1 day of storage refrigerated condition

3.3. Visual Quality Rating

Deterioration of quality due to browning and rotting resulted in the reduction of quality scores of minimally processed potatoes.. Visual quality of minimally processed potato samples were significantly affected by different anti-browning agents (tap water, hot water, ascorbic acid, pineapple juice and citrus juice) from 30 minutes-24 hours of storage (Table 7-9). Heat-treated samples with tap water, hot water and ascorbic acid were significantly higher visual quality rating after 30 minutes to 24 hours of storage relative to the remaining treatments. Thereafter insignificant results were obtained. The present study are in agreement with the previous findings of Wang, 1998 on heated kale at 45ºC which was effectively maintained better postharvest quality during subsequent storage at 15ºC. Bautista, 1990 also mentioned that produce stored in refrigerated or cold storage with higher relative humidity are generally required to reduce the rate of deteriorative process such as respiration and transpiration which improves the visual quality appearance thereby prolonging the shelf-life of the produce. Moreover, Fallik et al., 1999, reported that HWD significantly lower the respiration and ethylene production rates fresh produce, thus maintained better visual quality of perishable commodities.

Table 7. Visual quality rating (VQR) of minimally processed potato in response to different enzymatic anti-browning agents stored at ambient and refrigerated conditions

Treatment	VQR (30 mins)		VQR (16 hours)		VQR (24 hours)	
	Ambient	REF	Ambient	REF	Ambient	REF
Control	7.0^{d}	7.0^{d}	3.0^{c}	3.0^{c}	3.0^{c}	3.0^{b}
Tap water	9.0^{a}	9.0^{a}	3.0^{c}	5.7^{b}	3.0^{c}	3.0^{b}
Hot water dip	9.0^{a}	9.0^{a}	7.0a	7.0^{a}	7.0^{a}	5.0^{a}
Ascorbic acid	9.0^{a}	9.0^{a}	7.0^{a}	7.0^{a}	5.0^{b}	3.0^{b}
Pineapple juice	8.0^{c}	8.0^{c}	5.0^{b}	3.0^{c}	3.0^{c}	3.7^{b}
Citrus juice	8.5^{b}	8.5^{b}	5.0^{b}	7.0^{a}	3.0^{c}	3.0^{b}
5% LSD	0.00	0.00	0.00	0.88	0.00	0.88
CV (%)	0.00	0.00	0.00	8.69	0.00	13.69

VQR: 9 for excellent, no defect; 7 for good, defect minor; 5 for fair, defects moderate; 3 for poor, defects serious and 1 for inedible under usual condition

Table 8. Visual quality rating (VQR) of minimally processed potato in response to different enzymatic anti-browning agents stored at ambient condition

Treatment	Visual quality rating (VQR)		
	(30 mins)	(16 hours)	(24 hours)
Control	7.0^{d}	3.0^{c}	3.0^{c}
Tap water	9.0^{a}	3.0^{c}	3.0^{c}
Hot water dip	9.0^{a}	7.0^{a}	7.0^{a}
Ascorbic acid	9.0^{a}	7.0^{a}	5.0^{b}
Pineapple juice	8.0c	5.0^{b}	3.0^{c}
Citrus juice	8.5^{b}	5.0^{b}	3.0^{c}
5% LSD	0.00	0.00	0.00
CV (%)	0.00	0.00	0.00

VQR: 9 for excellent, no defect; 7 for good, defect minor; 5 for fair, defects moderate; 3 for poor, defects serious and 1 for inedible under usual condition

Table 9. Visual quality rating (VQR) of minimally processed potato in response to different enzymatic anti-browning agents stored at refrigerated condition

Treatment	Visual quality rating (VQR)		
	(30 mins)	(16 hours)	(24 hours)
Control	7.0^{d}	3.0^{c}	3.0^{b}
Tap water	9.0^{a}	5.7^{b}	3.0^{b}
Hot water dip	9.0^{a}	7.0^{a}	5.0^{a}
Ascorbic acid	9.0^{a}	7.0^{a}	3.0^{b}
Pineapple juice	8.0c	3.0^{b}	3.7^{b}
Citrus juice	8.5^{b}	7.0^{b}	3.0^{b}
5% LSD	0.00	0.88	0.88
CV (%)	0.00	8.69	13.69

VQR: 9 for excellent, no defect; 7 for good, defect minor; 5 for fair, defects moderate; 3 for poor, defects serious and 1 for inedible under usual condition

3.4. Total soluble solids (TSS), TA and pH

Physicochemical analysis (TSS, TA and pH)of minimally processed potatoes treated with anti-browning agents (tap water, hot water, ascorbic acid, pineapple juice and citrus juice) are presented in Table 10-12).

Initially, results measured right after treatment with anti-browning agents (tap water, hot water, ascorbic acid, pineapple juice and citrus juice) had no significant differences on total soluble solids and pH (ionic acidity) ranging from 3.63-3.86 and 5.96-6.30, respectively. The differences were more attributed to titratable acidity; heat-treated minimally processed potatoes and pineapple juice dip were significantly lower titratable acidity than the remaining treatments after 30 minutes. On the other hand, after 24 hours, TSS, TA and pH were significantly affected with the anti-browning agents. At ambient, untreated minimally processed potatoes has significantly higher TSS, comparably noted with that of hot water and ascorbic acid treatments. Percent TA was significantly lower and with higher pH of minimally processed potatoes particularly those treated with hot water dip than the remaining treatments even when stored at ambient or refrigerated conditions. This means no strong effects on storage conditions. Results implicated that TSS was enhanced when stored after 1 day of storage both in ambient and refrigerated conditions. This was possibly triggered the metabolic activity within the fruit samples leading to an increase in soluble solid content. As Amin, 2012 revealed that TSS was gradually increased in total soluble solid content during storage.

Natural anti-browning agents such as pineapple and citrus juice, though insignificant results were obtained, numerically lowered pH value was found relative to the remaining treatments.

Table 10. Total soluble solids, titratable acidity (%TA) and potential hydrogen (pH) of minimally processed potato in response to different enzymatic anti-browning agents before storage at ambient and refrigerated conditions

Treatment	TSS (ºB)	TA (% malic acid)	pH
Control	3.7000^{a}	0.2546^{ab}	6.3033^{a}
Tap water	3.6667^{a}	0.2903^{ab}	6.0267^{a}
Hot water dip	3.6667^{a}	0.1697^{b}	6.0567^{a}
Ascorbic acid	3.6333^{a}	0.3529^{ab}	5.9900^{a}
Pineapple juice	3.8667^{a}	0.0759^{b}	5.9600^{a}
Citrus juice	3.7667^{a}	0.5271^{a}	6.0400^{a}
5% LSD	0.41	0.33	0.40
CV (%)	6.04	64.65	3.66

Table 11. Total soluble solids, titratable acidity (%TA) and potential hydrogen (pH) of minimally processed potato in response to different enzymatic anti-browning agents after 1 day of storage at ambient condition

Treatment	TSS (ºB)	TA (% malic acid)	pH
Control	6.23^{a}	0.92^{a}	6.07^{a}
Tap water	4.70^{bc}	0.31^{b}	6.04^{ab}
Hot water dip	5.43^{ab}	0.27^{b}	6.08^{a}
Ascorbic acid	5.27^{abc}	0.22^{bc}	6.00^{bc}
Pineapple juice	4.33^{c}	0.072^{c}	5.97^{c}
Citrus juice	4.50^{bc}	0.31^{b}	5.98^{bc}
5% LSD	1.05	0.20	0.06
CV (%)	11.38	30.79	0.55

Table 12. Total soluble solids, titratable acidity (%TA) and potential hydrogen (pH) of minimally processed potato in response to different enzymatic anti-browning agents after 1 day of storage at refrigerated condition

Treatment	TSS (°B)	TA (% malic acid)	pH
Control	5.87[a]	0.50[ab]	5.48[c]
Tap water	5.87[a]	0.40[b]	5.62[bc]
Hot water dip	5.47[a]	0.30[b]	5.79[a]
Ascorbic acid	5.93[a]	0.43[b]	5.77[ab]
Pineapple juice	5.43[a]	0.45[b]	5.47[c]
Citrus juice	5.83[a]	0.91[a]	5.64[abc]
5% LSD	0.69	0.20	0.17
CV (%)	6.57	30.79	1.64

4. Conclusion

Tap water, ascorbic acid, pineapple and citrus juice reduced the intensity of browning but were less effective than hot water dip treatment. Hot water treatment remarkably inhibited browning of minimally processed potatoes. This can be tested in larger scale in order to determine its commercial viability and establish solid recommendation for the industry.

References

Acedo, A. A., (1997). Postharvest physiology of perishable crops. *A course syllabus in Horti culture* 111; 1997 edition. p. 63.

Artes, F., M. Castaner and M.I. Gil (1998). Enzymatic browning in minimally processed fruits and vegetables. *Food Sci. Technol. Int.*,

Cantos, E., Tudela, J. A., Gil, M. I., Espin, J. C. (2002). Phenolic compounds and reduced en zymes are not rate-limiting in browning development of fresh-cut potatoes. *J. Agri. Food Chem.*, 50:3015-3023.

Cantwell, M. (2010). Treatments to maintain product quality. In: *4th European Short-Course on Quality & Safety of Fresh- cut Produce,* 27-29 Sept 2010, Mesagne, Italy

Chitarra, M.I.F., (2000). Minimal processing of fruits and vegetables. Larvas UFLA/FAEPE

Fantuzzi, E., R. Puschmann and M.C.D. Vanetti, (2004). Microbial contaminants in fresh-cut cab bage. *Cienc Tecnol. Pwr.*

Friedman, M. (1997). Chemistry, biochemistry and dietary role of polyphenol: A review. J. *Agric. Food Chem.*, 45:1523-1540.

Hwang T. (2001). The relationship among fresh browning, polyphenoloxidase activity, and total phenolic contents in minimally processed potato (*Solanum tuberosum* var. Romano). Department of Food Science and Technology. Cornell Univ. W. North St. NYSAES, Geneva, NY.

Knodel, L.C. (1997). Current issues in drug toxicity: Potential health hazards of sulfites. *Toxic Substance Mechanisms,*16:309-311.

Loaiza-Velarde, J.G. and Saltveit, M.E. (2001). Heat shocks applied either before or after wounding reduce browning of lettuce leaf tissue. *J. Amer. Soc. Hort. Sci.,*126:227–234.

Miranda, R. B. (2001). Assessment of quality of papaya (*Carica papaya* L.) minimally pro cessed. M. Sci. Thesis, Federal University of Lavras.

O'Neill, G. (1995). Beating the browning reaction. *Food Australia,* 47(10):454.

Sapers, G. M. (1993). Browning of foods: Control by sulfites, antioxidants and other means. *Food Technol*., 47:75-84.

Sapers, G.M. and R. Miller (1998). Browning inhibition in fresh-cut pears. *J. Food Sci.,*63:342-346.

STAR, version 2.0.1 (2014). Biometrics and breeding informatics, PBGB Division, International Rice Research Institute, Los Baños, Laguna.

Tomas-Barberan, F. A. and J. C. Espin (2001). Phenolic compounds and reduced enzymes as de terminants of quality in fruits and vegetables. *J. Food. Sci. Agric.,* 81:853-857.

Viña, S.Z. and Chaves, A.R (2008). Effect of heat treatment and refrigerated storage on antioxidant properties of pre-cut celery (*Apium graveolens* L.) *Int. J. Food Sci. Technol.,* 43:44–5
