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Physiological responses and storage quality of fresh-cut red and white dragon fruit (*Hylocereus* spp.) treated with 1-methylcyclopropene (1-MCP)

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Abstract

The effects of 1-MCP post-cutting application on the storage quality of fresh-cut red and white dragon fruit were determined using headspace gases (ethylene and CO_2) concentration, antioxidant activity, visual evaluation (water soaking incidence and visual quality rating) and microbiological (yeast and mold count, aerobic plate count, and total coliform count) quality. Mature red and white dragon fruit were sanitized with ClO_2 prior to fresh-cut processing. Gaseous 1-MCP was injected to fresh-cut fruits packed in polyethylene terephthalate (PET) trays with polyvinyl chloride (PVC) stretch film overwrap. These packs were stored at 5-10°C and assessed in terms of the storage quality parameters mentioned above. Treatment with 1-MCP positively affected headspace CO_2 and ethylene in both species. Fresh-cut white dragon fruit showed better response to 1-MCP as compared to the fresh-cut red dragon fruit in terms of headspace CO_2 concentrations. No water soaking incidence was recorded all throughout storage for the 1-MCP treated fresh-cut red dragon fruit while for the fresh-cut white dragon fruit, water soaking was observed on the 12th day of storage. For both species, 1-MCP delayed visual quality deterioration and increased antioxidant activity. Lower yeast and molds count, aerobic plate count and coliform count were observed in both species with 1-MCP treatment. Post-cutting treatment with 5ppm 1-MCP may positively affect storage quality of fresh-cut red and white dragon fruit.

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Introduction

Presently there are various tools in prolonging shelf-life of postharvest commodities being used. An effective approach is by blocking ethylene binding to receptors through the use of an ethylene blocker, one of which is the ethylene antagonist 1-methylcyclopropene (1-MCP). Hampering ethylene binding to receptors prevents ethylene signal transduction, altering gene expression related to senescence and fruit ripening (Blankenship and Dole, 2003).

Literature on 1-MCP-related studies is extensive and includes application of 1-MCP on horticultural crops both at preharvest and postharvest stages. Aside from intact fruits, 1-MCP have also been used on fresh-cut or minimal processing systems where three different ways of applications have been used as follows: (1) treatment on freshly harvested produce just before storage, before processing; (2) treatment just before processing; and (3) treatment on fresh-cut product right after processing (Toivonen, 2008). These studies yielded information on the positive, negative and neutral effects of 1-MCP on fruits, vegetables, and other horticultural crops in relation to postharvest issues such as ripening and senescence, physiological and pathological disorders.

Climacteric fruits have been the predominant target in studying effects of 1-MCP on fresh-cut produce since the processing system requires wound induction which then increases ethylene production (Toivonen and De Ell, 2002 as cited in Hodges and Toivonen, 2007). Responses of these fruits prove that 1-MCP operates antagonistically to ethylene. On the other hand, studies on non-climacteric produce treatment with 1-MCP have also yielded positive results wherein ethylene dependent and independent ripening processes have been identified (Huber, 2008).

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Many fruits that are gaining popularity at present are non-climacteric in nature, one of which is dragonfruit. Dragon fruit (*Hylocereus* spp.) is a non-climacteric fruit widely cultivated in Southeast Asian countries such as Malaysia (Halimoon and Hasan, 2010) and the Philippines (Reynoso, 2012). It is considered as a high value crop not just because of its market value but also because of its nutritional components. It is low in calorie, and contains phytonutrients and antioxidants, vitamin C, fatty acids, several B vitamins, carotene and proteins.

Dragon fruit is ideal for fresh-cut processing due to its bulky and thick peel. It is highly marketable in fresh-cut form as minimal processing provides convenience and ease of consumption.

Although there are numerous 1-MCP-related studies on non-climacteric fruits, its effect on dragon fruit, especially at its fresh-cut state remains to be investigated. This study investigated on the possible use of 1-MCP as a tool in maintaining the quality of fresh-cut dragon fruit by evaluating various storage quality parameters. Influence of species on 1-MCP responses was also studied using the red and white dragon fruit species.

Materials and Methods

Raw material acquisition, fresh-cut processing, 1-MCP treatment and storage.

Mature red and white dragon fruit were obtained from Silan's Agrifarm and Queenstown Farm in Indang, Cavite, Philippines. Prior to processing, the fruits were washed, dipped in diluted liquid detergent mixture for 3 mins, rinsed thrice and sanitized using 3ppm chlorine dioxide for 1 mins followed by a potable water rinse. The fruits were peeled, cut into bite-size pieces and placed on polyethylene terephthalate (PET) trays (approx. 150 g per tray) and then wrapped around with polyvinyl chloride (PVC) stretch film. Fresh-cut processing was carried out in a clean and sanitized room. A 1 $\mu L \cdot L^{-1}$ 1-MCP concentration was prepared in an evacuated 1L volumetric flask by dissolving AnsiPTM (4.12% 1-MCP) powder in distilled water. The generated gas was obtained from the flask using a plastic syringe and injected into each fresh-cut pack. The packs (Figure 1) were stored at 5-10°C and monitored for various parameters during storage.

Headspace gas (CO_2, Ethylene) analysis.

Gas samples were collected directly from the packs using 1mL syringes. The gas samples were injected into a gas chromatograph equipped with thermal conductivity detector (TCD) (Shimadzu GC-SA) and silica gel column for CO_2 measurements. Gas samples for ethylene determination were injected into a gas chromatograph with flame-ionization detector (FID) (Shimadzu GC-2014) and alumina column. The GC-TCD has the following settings: injection port temperature: 90°C, column temperature: 50°C, and gas pressure: 1.25 kg/cm^2. The GC-FID has the following settings: injection port temperature: 120°C, column temperature: 100°C, and gas flow rate: 35 mL/min. Three (3) samples each for ethylene and CO_2 were taken per pack per treatment. Gas concentrations were calculated as $\%CO_2$, and ppm C_2H_4 using the following formula:

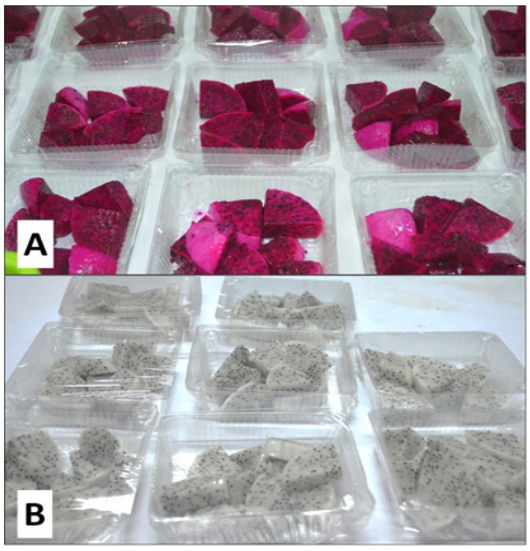

Figure 1. Packed fresh-cut red (A) and white (B) dragon fruit (*Hylocereus* spp.) with 5ppm 1-MCP post-cutting application and stored at 5-10°C.

$$\%CO_2 \text{ or ppm } C_2H_4 = \frac{\text{peak height of sample}}{\text{peak height of standard}} \text{ x std } CO_2 \text{ or } C_2H_4$$

Visual quality rating (VQR) and water-soaking (WS)

The visual quality of samples was evaluated using the VQR established and used at Postharvest Horticulture Research and Training Center [PHTRC], UPLB as follows: 9,8 – excellent, field fresh; 7,6 – good, with minor defects; 5,4 – fair, with moderate defects; 3 – poor, with serious defects, limit of saleability; 2 – limit of edibility; and 1 – non-edible under usual conditions. The WS was assessed using the WS index: 1 – no WS; 2 – <10% WS; 3 – 10-25% WS; 4 – 25-50% WS; and 5 – >50% WS.

Antioxidant activity determination

Samples were analyzed for percentage radical scavenging activity (%RSA) by 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical assay. Determination was performed according to the method described by Brand-Williams *et al*. (1995) as

cited in Garcia *et al.* (2012) with minor modifications. Extracts from total phenolic content determination was used. In 3 mL of 80% ethanol, 0.5 mL of sample extract and 0.3 mL of the stable DPPH radical solution (0.5 mM in 80% ethanol) was allowed to react in the dark for 100 mins. Absorbance was read at 517 nm using a UV-Vis Spectrophotometer (Secoman). A control solution was prepared by mixing 3.5 mL of 80% ethanol with 0.3 mL DPPH radical solution. According to Gandhiappan and Rengasamy (2012), %RSA can be computed using the equation below. Evaluation was carried out at day 0 and every other day thereafter until a VQR of 3 is reached.

$$\% \text{ DPPH}^{\cdot} \text{ Scavenging Activity} = \frac{(\text{Abs}_{control} - \text{Abs}_{sample})}{\text{Abs}_{control}} \times 100$$

Microbiological analyses (yeast and molds count, total plate count, coliform count).

Aerobic plate count, and yeasts and molds count were determined at 0, 2, 4, 7, 10, 14, and 16 days of storage. Coliform counts on the other hand were assessed at 0, 2, 4, 7, and 10 days of storage. Approximately 25 g of sample was blended with 225 mL of 0.1% sterile buffered peptone water for 30 s. Appropriate dilutions were pour plated in duplicate plates on Plate Count Agar (PCA) for aerobic plate count, Potato Dextrose Agar (PDA) for yeast and molds count, and Violet Red Bile Agar (VRBA) for total coliform count. PCA, PDA, and VRBA plates were incubated at 32°C for 48 hr, 25°C for 4 days and 35°C for 24 hr, respectively.

Statistical analysis

A completely randomized design (CRD) was followed for the experiments. Data for VQR and WS were analyzed non-parametrically using the Maximum Likelihood Rates Test. All other data were analyzed using ANOVA. Post hoc analysis was done using t Test (LSD) in comparing treatment means. All statistical analyses were carried out using Statistical Analysis System (SAS) Program at 5% significance level (α=0.05).

Results and Discussion

Figure 2A shows the mean headspace CO_2 concentration of treated and untreated fresh-cut red and white dragon fruit during cold storage. For the white dragon fruit, it can be noted that treatment with 5 ppm 1-MCP resulted to relatively lower headspace CO_2 concentration except at days 0, 6, 12 and 14. The results show how 1-MCP treatment affected CO_2 production by decreasing it. 1-MCP binding to receptor sites of ethylene inhibited ethylene action in inducing

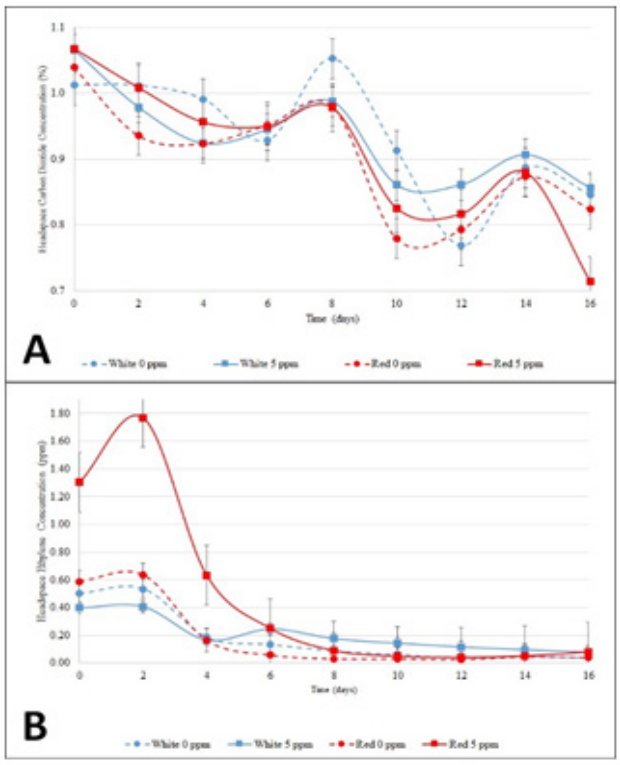

Figure 2. Headspace CO2 (A) and ethylene (B) concentrations during storage of fresh-cut red and white dragon fruit with 5ppm 1-MCP post-cutting application stored at 5-10°C.

heightened respiration rates. Low CO_2 production equates to low respiration rate since CO_2 is one of the products of respiration. Low respiration rate implies slow rate of metabolic processes in the tissues, thus resulting to slower deterioration and longer storage life. However for red dragon fruit, the mean values for headspace CO_2 concentration of 1-MCP treated samples were higher than those untreated. Based on previous studies, 1-MCP application may result to negative, positive or neutral effects in different fruits. Efficacy of 1-MCP is affected by various preharvest factors including species, cultivar, and maturity stage of the commodities among others (Ambuko *et al.*, 2013). 1-MCP did not consistently affect CO_2 production at the yellow stage of gac fruit (Win *et al.*, 2015). Additionally, 1-MCP treatment has no effect on nectarine, apricot and araza fruit (Dong *et al.*, 2001 and Carillo *et al.*, 2011 as cited in Win *et al.*, 2015). Depending on the species being treated, 1-MCP may have a variety of effects on respiration, ethylene production, volatiles production, chlorophyll degradation and other degradative changes, diseases, disorders, acidity and sugars (Blankenship and Dole, 2003).

Figure 2B shows the graph of headspace ethylene concentration of treated vs untreated fresh-cut red and white dragon fruit during cold storage. Significant

differences in headspace ethylene were observed in 1-MCP treated red dragon fruit until day 4 only. Thereafter, all samples did not vary significantly in headspace ethylene. For the white dragon fruit, from days 0 to 4, headspace ethylene concentration in 1-MCP treated samples were relatively lower than untreated samples. However, from day 4 onwards, headspace ethylene concentration became higher for treated samples compared to untreated samples. It can be inferred from this result that action of 1-MCP was only elicited in red dragon fruit. took place by day 4, where an increase in headspace ethylene was observed. It is known thatSince 1-MCP has 10x more affinity for ethylene receptor than ethylene (Altman and Hasegawa, 2012). , 1-MCP binds with the ethylene receptor, such that ethylene cannot bind and elicit action (Blankenship and Dole, 2003). The higher headspace ethylene exhibited by the 1-MCP treated red dragon fruit is due to the accumulation of ethylene in the headspace since 1-MCP was able to block the receptors, preventing the binding of ethylene. This action of 1-MCP was observed only until day 4. Possibly thereafter, dissociation of 1-MCP with the receptors have taken place, or degradation of receptors possibly occurred thus the ethylene-blocking effect diminished, resulting to insignificant variations in headspace ethylene among the treatments. Similar trend was observed in mango where the loss of ethylene-blocking effect of 1-MCP may be mainly due to the degradation of receptors and the dissociation of 1-MCP from the receptor (Castillo-Israel *et al*., 2014). As for the fresh-cut red dragon fruit, a decline in headspace ethylene concentration was also observed. However for the red species, the action of 1-MCP started immediately, as indicated by high headspace ethylene concentration starting at day 0 as compared to the control. A continuous decline in headspace ethylene concentration until day 16 was observed for both treated and untreated samples. This decline in headspace ethylene concentration is possibly due to the formation of new ethylene receptor sites. Ethylene present in the air binds to these new ethylene receptor sites, and the cells regain sensitivity to ethylene and its downstream signals (Blankenship, 2001).

1-MCP affects C_2H_4 by binding with the ethylene's receptor sites, thereby blocking ethylene action. Therefore, comparing 1-MCP treated and untreated samples, the former will theoretically have higher headspace C_2H_4 concentration values. High headspace C_2H_4 concentration values translate to longer shelf-life since ethylene action is blocked (ethylene does not bind to receptors but instead, just accumulates in the headspace) leading to delay

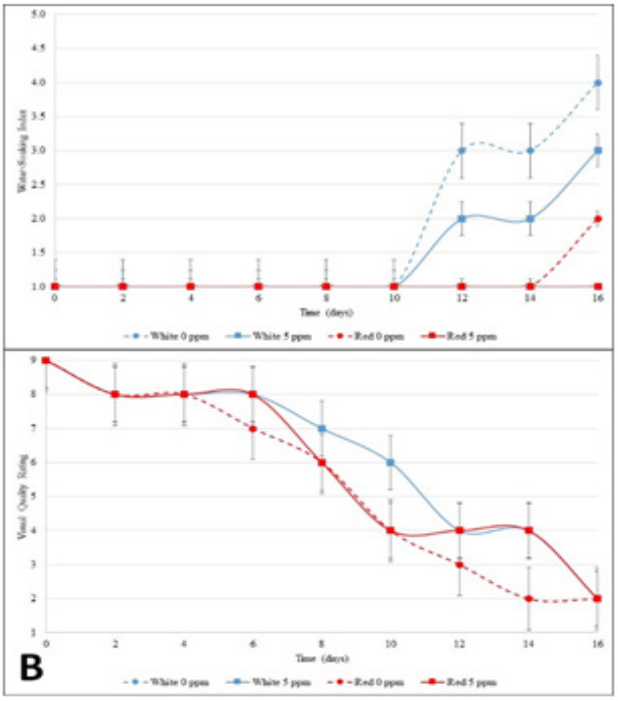

Figure 3. Water soaking (A) and visual quality rating (B) during storage of fresh-cut red and white dragon fruit with 5 ppm 1-MCP post-cutting application stored at 5-10°C.

in ripening and other deteriorative processes. Mean values of treated vs untreated samples for the fresh-cut white dragon fruit showed no statistical difference all throughout storage. However, for the red-fleshed fresh-cut dragon fruit, statistical differences exist for mean values of treated vs untreated samples from days 2 to 8. Ethylene suppression is the main mode by which 1-MCP retards deteriorative changes in most fruits. Studies have shown that application of 1-MCP resulted to a decline in ethylene production rate. Such include studies on, but not limited to, fresh-cut pineapple (Rocculi *et al*., 2009), fresh-cut apples (Mao *et al*., 2007), fresh-cut 'Sinta' papaya (Relox *et al*., 2014), and fresh-cut 'Hami' melon (Guo *et al.*, 2011).

The assay for free radical scavenging activity used is based on the reduction of 2,2-Diphenyl-1-Picrylhydrazyl Radical (DPPH). As the electron of a radical pairs off with hydrogen donation from the free radical scavenging antioxidant, the absorption strength will be decreased (Halimoon and Hasan, 2010). Figure 3 shows the plot of antioxidant activity during storage of treated vs untreated fresh-cut red and white dragon fruit. In fresh-cut white dragon fruit, throughout storage, antioxidant activity is higher in 1-MCP treated samples than in control samples. It can also be noted that values for antioxidant activity remained constant from day 0 until day 16. For fresh-cut red dragon fruit, the same with the white species, 1-MCP treated samples have higher antioxidant

activity than its 1-MCP treated counterpart. A decline in antioxidant activity is noted from days 0 to 16 regardless of treatment. However, values for antioxidant activity remained constant from day 2 until 12. Statistical difference between mean values of untreated and treated fresh-cut white dragon fruit exist except at days 0 and 4. On the other hand, mean values of treated and untreated red dragon fruit are not statistically different from one another except at day 4.

Comparing between species, it can be noted that fresh-cut white dragon fruit have relatively higher antioxidant activity than in fresh-cut red dragon fruit. This observation is contrary to that reported by Charles (2006) that red dragon fruit varieties have higher antioxidant activity than the white dragon fruit varieties (Halimoon and Hasan, 2010). This difference may probably be due to differences in sample preparation and extraction, environmental growth variation and/or differences in maturity (Choo and Yong, 2011). In both species, it can be seen that those treated with 5 ppm 1-MCP showed higher reducing power than the control samples. A study by Li *et al.* (2008) showed similar results where 1-MCP remarkably increased free radical scavenging activity of the peel of 'Starking' apple. Application of 1-MCP on mature 'Fuji' apples also resulted to increased antioxidant activity (Lu *et al.*, 2012). However, application of 1-MCP on 'Cripps Pink' apples decreased total antioxidant activity in the peel and did not increase norneither increase nor decrease total antioxidant activity of the flesh (Hoang, 2011). 1-MCP may have possibly regulated antioxidant activity of fresh-cut red and white dragon fruit.

Incidence of water-soaking in fresh-cut white dragon fruit was noted on the 12th day of storage where median score for water soaking index (WSI) in untreated samples was 3 (10-25% of the surface is water-soaked) while those treated with 5 ppm 1-MCP have a median score of 2 (not more than 10% of the surface is water-soaked). By day 16, untreated samples have a median score of 4 (25-50% of surface is water-soaked), while treated samples have a median score of 3 (Figure 4). This goes to show that there are higher incidences of water-soaking in untreated samples than in 1-MCP treated samples. For the fresh-cut red dragon fruit, it can be seen that incidence of water-soaking was noted only at the last day of storage (day 16). Water-soaking was observed only in the untreated samples where a median score of 2 was given. The difference in the incidences of water-soaking in both species of fresh-cut dragon fruit can be attributed to the difficulty in visualizing

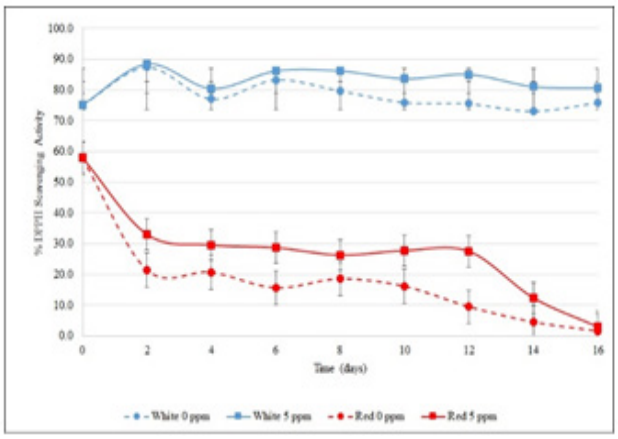

Figure 4. Antioxidant activity during storage of fresh-cut red and white dragon fruit with 5ppm 1-MCP post-cutting application stored at 5-10°C.

water-soaking in fresh-cut red dragon fruit because of its dark purple color.

Translucency is easier detected in fresh-cut white dragon fruit because of its white color. The development of translucency or water-soaking can be related to textural changes such as tissue softening. In fresh-cuts processing, peeling, and cutting and other mechanical factors may promote an increase in ethylene production that can initiate physiological responses like tissue softening (Vilas-Boas and Kader, 2006). Tissue softening results to water soaking due to leakage of cell contents into intercellular spaces outside of the cell. This is a consequence of membrane lipid degradation where phospholipase D (stimulated by ethylene) acts on free fatty acids forming free radicals. This then results to altered membrane protein function, increased membrane permeability and ion leakage (Brecht, 2012).

1-MCP treatment of both species of fresh-cut dragon fruit showed increased resistance to water-soaking. Watermelon and cucumber also responded positively to ethylene suppression by 1-MCP, which provided complete protection from the effects of continuous ethylene for up to 8 and 16 days respectively (Huber, 2008). Responses to 1-MCP in terms of textural changes differ not only between different types of fruits but also within fruit types by difference in cultivars, postharvest handling, storage periods and ripening rates (Watkins, n.d.). An example is with the different cultivars of apple - 'Empire', 'Cortland', Macintosh' and 'Idared' - where tissue softening is significantly delayed by 1-MCP (Watkins, 2008). No significant delay in tissue softening was reported for the 'Northern Spy' apple cultivar.

Figure 4 shows the median visual quality of treated and untreated fresh-cut red and white dragon fruit during storage. For the white dragon fruit it can

be seen that although visual quality declined during storage for both treatments, samples treated with 5 ppm 1-MCP exhibited a slower rate of deterioration. Separation of median scores for both treatments happened at day 6 where control samples declined to a visual quality rating (VQR) of 7 while samples treated with 5 ppm 1-MCP remained at a VQR of 8. A steady decline is noticed from day 6 until day 16 where those treated with 5 ppm 1-MCP showed relatively higher median scores than the control. It can also be observed that those treated with 5 ppm 1-MCP were given a median score of 4 until day 14. A VQR of 4 means that the commodity is of fair quality with moderate defects. As for untreated samples, a median score of 3 was already given at day 12. VQR of 3 means that the commodity is of poor quality with serious defects. This rating also means that the commodity is not good enough to be sold. Similar to that in white dragon fruit, separation of median scores was evident on day 6 for the red species where treated samples were given a VQR of 8 while those untreated have a median score of 7. By day 12, median scores for treated samples isare 4 until day 14. Untreated samples already have a median score of 3 by day 12, eventually leading to a median score of 2 from days 14 to 16. Although median scores were not as separated as with fresh-cut white dragon fruit, it can still be observed that treated fruits have a slower rate of deterioration compared to the untreated samples. Browning or discoloration at the surface of the fruit pulp is the main contributor to the decline in visual quality of fresh cut white dragon fruit. As for the red dragon fruit, causes of decline in visual quality are softening or mushiness of the tips and obvious drying of the pulp surface.

Major contributor to spoilage of fresh-cut produce is microbiological spoilage. Microbial decay of fresh-cut fruits may occur more rapidly than in vegetable products because of high levels of sugars found in most fruits which acts as food or substrate for microbial growth and proliferation. On a general note, low yeasts and molds count, total coliform count and aerobic plate count correlate with increased shelf-life (Beaulieu and Gorny, 2014). In the Philippines, there is no established limit or specification for acceptable microbial load of fresh-cut fruits. In some European countries, specifications have been established to assess quality of fresh-cut produce. For example, the Spanish limit for microbial populations on minimally processed fruit for safe consumption are 7, 5, and 3 $\log_{10}$ CFU/g for aerobic bacteria, yeasts, and molds count, respectively (Barth *et al*., 2009). The European Union (EC/2073.2075) set a limit of 3 $\log_{10}$ CFU/g for E. coli in pre-cut fruits and vegetables (Graffham, 2006).

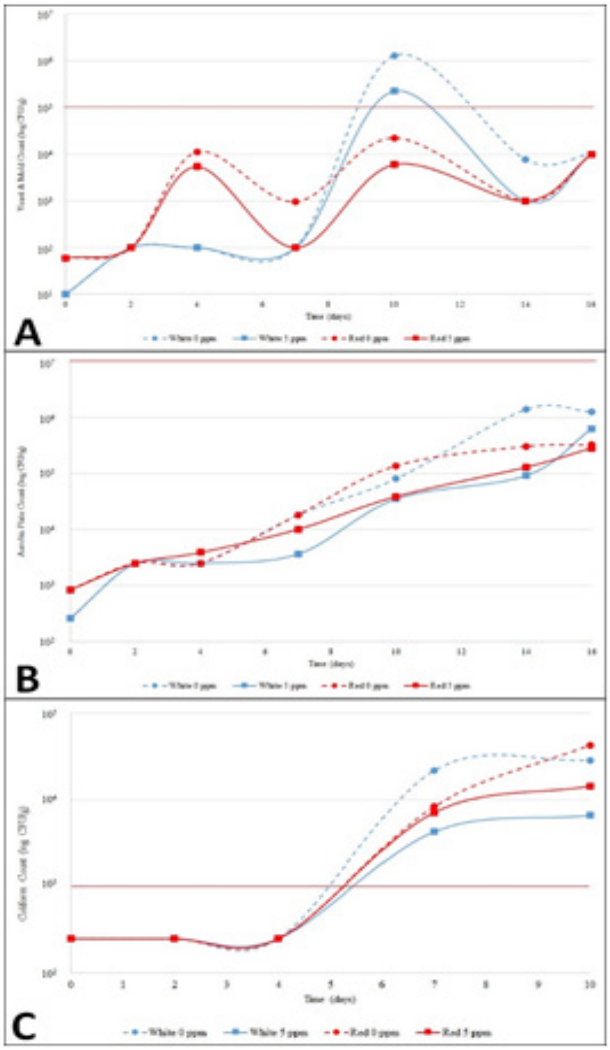

Figure 5. Yeast and mold count (A), Aerobic plate count (B), and Total coliform count (C) during storage of fresh-cut red and white with 5ppm 1-MCP post-cutting application stored at 5-10°C.

The most dominant microorganism associated with spoilage of fresh-cut fruits are yeasts and molds where the acidity in fruits usually suppress bacterial growth (Fan and Song, 2008; Beaulieu and Gorny, 2014; Fan and Song, 2008). Molds cause spoilage and some are of public health concern due to their production of mycotoxins (Fan and Song, 2008). The mycotoxins most commonly found in fruits and their processed products are aflatoxins, orchatoxin A, patulin, and the Alternaria toxins – alternariol, alternariol methyl ester, and altenuene (Fernandez-Cruz *et al.*, 2010). Yeasts have a higher growth rate than molds (Raybaudi-Massilia *et al.*, 2009), ferment sugars to alcohols and are responsible for off-flavors and off-odors (Barth *et al*., 2009). Figure 5A shows the growth of yeast and molds in 1-MCP treated and untreated fresh-cut red and white dragon fruit. For both species, higher yeasts and molds count were

noted in untreated samples as compared to those 1-MCP treated samples. Similar to the result of this study, yeast and mold count in fresh-cut pineapple is lower in 1-MCP treated fruits (Bernardino *et al*., 2016). Lower yeasts and molds count were also reported in fresh-cut papaya (Ergun *et al*., 2006). Likewise 1-MCP treatment combined with modified atmosphere packaging resulted to lower yeasts and molds count for loquat fruit (Oz and Ulukanli, 2011). Looking into the limits mentioned above, yeasts and molds count for fresh-cut white dragon fruit became unacceptable by day 10 for both treated and untreated samples with values greater than 105 CFU/g. However, for fresh-cut red dragon fruit both treated and untreated samples did not exceed count limit. Highest count for both treatments were noted in day 10 at about 10^4 CFU/ g. Low counts (not exceeding limits) in the red species may be attributed to its pH. Yeasts can grow in a pH range of 4 to 4.5 and molds can grow from pH 2 to 8.5, but favor an acid pH (Mountney and Gould, 1988 as cited in Battcock and Azam-Ali, 1998). As mentioned earlier, the pH of the red dragon fruit is higher compared to its white counterpart at a range of 4.7 to 5.1 during storage. The high pH in the red dragon fruit may have inhibited the proliferation of yeast and molds in the fresh-cut fruits.

Mesophilic microorganisms can persist at refrigeration temperature and may begin to grow during temperature abuse (Fan and Song, 2008). Mesophilic microorganisms found on surfaces of plants that contribute to fresh-cut contamination are *Listeria monocytogenes, Salmonella, Enterobacter* spp., and *Pseudomonas* spp. among others (Barth *et al*., 2009). Aerobic plate count (APC) is an indicator used to cover both the level of aerobic and mesophilic bacteria in a product. The aerobic plate count for both species of fresh-cut dragon fruit during storage are shown in Figure 5B. It can be noticed that on both species, lower counts were observed for those with 1-MCP treatment. Similar results were obtained for fresh-cut fruits such as pineapple (Bernardino *et al*., 2016), and papaya (Ergun *et al*., 2006). Furthermore, the combination of 1-MCP treatment and modified atmosphere packaging lowered aerobic plate count in loquat fruit (Oz and Ulukanli, 2011). Although it can be observed that there is a continuous increase in counts on both species regardless of treatment, counts did not exceed acceptable limits until day 16. Increase in aerobic plate count may be associated to eventual decay of the commodities during prolonged storage (Carlin *et al.*, 1989 as cited in Varoquaux and Mazollier, 2002). Also, optimum pH for most microorganisms is near neutral point (pH 7.0) (Battcock and Azam-Ali, 1998). The maximum pH recorded during storage is at pH 5.1 (red dragon fruit), which may not have satisfied growth requirement of bacteria thereby impeding its proliferation.

Indicator microorganisms such as coliforms are utilized in order to assess the health risk associated with microbiological spoilage of produce. Coliform bacteria are a group of Gram negative, spore-forming, aerobic or facultative anaerobic rods that ferment lactose forming acid and gas within 48hr at 35°C (Fan and Song, 2008). Coliforms are used because: (1) they have similar growth and survival characteristics as pathogens, (2) they are present in higher numbers than true pathogens, and (3) their presence in high numbers is often assumed as an indication of the co-presence of intestinal pathogens which are usually more difficult to detect (Fan and Song, 2008). Figure 5C shows the total coliform count during storage of 1-MCP treated and untreated fresh-cut red and white dragon fruit. It is observed that 1-MCP treated samples have lower coliform count than control samples, evident at days 7 and 10 on both species. The results obtained are similar to that reported by Relox *et al.* (2015) on fresh-cut papaya packed in clamshell, and in fresh-cut pineapple (Bernardino *et al*., 2016). Comparing results with the limits given above, fresh-cut red and white dragon fruit regardless of treatment exceeded maximum acceptable count at day 7 with values at 10^4 CFU/g. Counts increased dramatically from day 4. Many factors may have contributed to the microbial contamination of the fresh-cut produce including not only the initial microbial load of the commodities processed. Factors during minimal processing that may have contributed to the increase in coliform load of the packed fresh-cuts may include contamination of process water, poor worker hygiene and poor equipment and utensil sanitation (Johnston *et al*., 2005). Also, according to Chung *et al*. (2011), the use of chlorine dioxide by flowing washing treatment is more effective than dipping treatment, which was the one employed in the fresh-cut preparation for this study. Another possible reason for the onset of increased coliform count can be associated to the storage conditions of the fresh cut red and white dragon fruit packs. Highest temperature (11.6°C) and relative humidity (98%) were recorded at day 6, a day before packs with high coliform counts were sampled. Also, humidity was high since day 2 (RH = 98%) which may have caused condensation and possible contamination of fresh-cut packs.

Conclusion

This study highlighted the responses of fresh-cut

red and white dragon fruit to 1-MCP post cutting-treatment. 1-MCP affected both dragon fruit species in that headspace CO_2 concentration was decreased in fresh cut white dragon fruit and increased in the fresh cut red dragon fruit. High headspace ethylene concentration was observed in both species which is indicative of the action of 1-MCP towards blocking ethylene from binding with its receptor sites. Water-soaking and decline in visual quality was delayed and antioxidant activity was positively increased by 1-MCP treatment in both species. For microbiological quality, post-cutting application of 5 ppm 1-MCP resulted to lower yeast and mold count (YMC), aerobic plate count (APC), and coliform count of both fresh-cut red and white dragon fruit. YMC of fresh-cut red dragon fruit did not exceed maximum acceptable limit of 10^5 CFU/g during storage. YMC of fresh-cut white dragon fruit exceeded this limit by day 10. As for APC, both fresh-cut red and white dragon fruit did not exceed maximum limit of 10^7 CFU/g during storage. For coliform count, both exceeded maximum limit of 10^3 CFU/g at day 7. From the results of this study, fresh-cut red and white dragon fruit is safe for consumption up to 5 days when stored at 5-10°C. It can also be concluded that 1-MCP may be an effective postharvest treatment in improving the storage quality of fresh-cut red and white dragon fruit.

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References

Altman, A. and Hasegawa, P. M. 2012. Plant Biotechnology and Agriculture: Prospects for the 21st Century, p. 586. United States: Academic Press.

Ambuko, J., Githiga, R. W., Hutchinson, M. J., Gemma, H. and Owino, W. O. 2013. Effect of maturity stage and cultivar on the efficacy of 1-MCP treatments on mango. Acta Horticulturae 1007: 39-47 [Abstract]. doi:10.17660/ActaHortic.2013.1007.1

Battcock, M. and Azam-Ali, S. 1998. Fermented Fruits and Vegetables: A Global Perspective. FAO Agricultural Services Bulletin No. 134. Rome: Food and Agriculture Organization of the United Nations.

Barth, M., Hankinson, T. R., Zhuang, H. and Breidt, F. 2009. Microbiological spoilage of fruits and vegetables. In Sperber, W. H. and Doyle, M. P. (Eds.) Compendium of the Microbiological Spoilage of Foods and Beverages, p. 135-184. United States: Springer.

Beaulieu, J. C. and Gorny, J. R. 2014. Fresh-cut fruits. In Gross, K.C., Wang, C.Y. and Saltveit, M. (Eds.), The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. Agricultural Handbook Number 66, p. 130. Beltsville Area: United States Department of Agriculture Agricultural Research Services [USDA-ARS].

Bernardino, M. A., Castillo-Israel, K. A. T., Serrano, E. P., Gandia, J. B.L. and Absulio, W. L. 2016. Efficacy of 1-methylcyclopropene (1-MCP) post-cutting treatment on the storage quality of fresh-cut 'Queen' pineapple (*Ananas comosus* (L) Merr. cv. 'Queen'). International Food Research Journal 23(2): 667-674.

Blankenship, S. 2001. Ethylene effects and the benefits of 1-MCP. Perishables Handling Quarterly 108: 2-4.

Blankenship, S. M. and Dole, J. M. 2003. 1-Methylcyclopropene: a review. Postharvest Biology and Technology 28(1): 1-25.

Brand-Williams W., Cuvelier M.E. and Berset C. 1995. Use of a free radical method to evaluate antioxidant activity. Lebensmittel-Wissenschaft and Technologie 28: 25-30.

Brecht, J. 2012. Fresh-cuts and cell integrity, translucency, and juice leakage [Presentation]. Retrieved April 21, 2016 from *http://ucanr.edu/datastoreFiles/608-353.pdf*

Carlin, F. Nguyen-The, C., Cudenned, P. and Reich, M. 1989. Microbial spoilage of fresh ready-to-use grated carrots. Sciences Des Aliments 9:371-386.

Charles, M.D. 2006. Total antioxidant activity and fiber content of selected Florida grown tropical fruits. Journal of Agriculture and Food Chemistry 54: 7355-7363. DOI: abs/10.1021/jf801983r

Choo, W. S. and Yong, W. K. 2011. Antioxidant properties of two species of *Hylocereus* fruits. Advances in Applied Sciences Research 2(3): 418-425.

Chung, C. C., Huang, T. C., Yu, C. H., Shen, F. Y. and Chen, H. H. 2011. Bactericidal effects of fresh-cut vegetables and fruits after subsequent washing with chlorine dioxide. In Proceedings of the International Conference on Food Engineering and Biotechnology 9:107-112.

Dong, L., Zhou-hong, W., Sonego, L., Lers, A. and Lurie, S. 2001. Ripening of 'Red Rosa' plums: effect of ethylene and 1-methylcyclopropene. Australian Journal of Plant Physiology 28: 1039-1045.

Ergun, M., Huber, D. J., Jeong, J. and Bartz, J. A. 2006. Extended shelf life and quality of fresh-cut papaya derived from ripe fruit treated with the ethylene antagonist 1-methylcyclopropene. Journal of the American Society of Horticultural Science 131(1): 97-103.

Fan, L. and Song, J. 2008. Microbial quality assessment methods for fresh-cut fruits and vegetables. Stewart Postharvest Review 4(3): 1-9. doi:10.2212/spr.2008.3.10

Fernandez-Cruz, M. L., Mansilla, M. L. and Tadeo, J. L. 2010. Mycotoxins in fruits and their processed products: analysis, occurrence and health implications.

Journal of Advance Research 1(2): 113-122. doi:10.1016/j.jare.2010.03.002

Gandhiappan, J. and Rengasamy, R. 2012. Comparative study on antioxidant activity of different species of Solanaceae family. Advances in Applied Research 3(3):1538-1544.

Graffham, A. 2006. EU legal requirements for imports of fruits and vegetables (a suppliers guide). Fresh Insights. No. 1, DFID/IIED/NRI.

Guo, Q., Cheng, L., Wang, J., Che F., Zhang, P. and Wu, B. 2011. Quality characteristics of fresh-cut 'Hami' melon treated with 1-methylcyclopropene. African Journal of Biotechnology 10(79):18200-18209. doi:10.5897/AJB11.2439

Halimoon, N. and Hasan, M. 2010. Determination and evaluation of antioxidative activity in red dragon fruit *(Hylocereus undatus)* and green kiwi fruit *(Actinidia deliciosa)*. American Journal of Applied Sciences 7(11): 1432-1438.

Hoang, N. T. T., Golding, J. B. and Wilkes, M. A. 2011. The effect of postharvest 1-MCP treatment and storage atmosphere on 'Cripps Pink' apple phenolics and antioxidant activity. Food Chemistry 127:1249-1256. doi:10.1016/j.foodchem.2011.01.052

Hodges, D.M. and Toivonen, P. M. A. 2007. Quality of fresh-cut fruits and vegetables as affected by exposure to abiotic stress. Postharvest Biology and Technology 48: 155-162.

Huber, D. J. 2008. Suppression of ethylene responses through application of 1-Methylcyclopropene: a powerful tool for elucidating ripening and senescence mechanisms in climacteric and nonclimacteric fruits and vegetables. HortScience 43(1): 106-111.

Johnston, L. M.,Jaykus, L., Moll, D., Martinez, M. C., Anciso, J., Mora, B. and Moe, C. L. 2005. A field study of the microbiological quality of fresh produce. Journal of Food Protection 68(9): 1840-1847.

Li, L., Zhang, Y., Chen, X.,Zhang, L. and Li, Y. 2008. Effects of 1-MCP on phenolic compounds and antioxidant activity of 'Starking' apples. Acta Horticulturae 774: 217-220. doi:10.17660/ActaHortic.2008.774.27

Lu, X. G., Ma, Y. P. and Liu, X. H. 2012. Effects of maturity and 1-MCP treatment on postharvest quality and antioxidant properties of 'Fuji' apples during long-term cold storage. Horticulture, Environment and Biotechnology 53(5): 378-386.

Oz, A. T. and Ulukanli, Z. 2011. Effects of 1-methylcyclopropene (1-MCP) and modified atmosphere packaging (MAP) on postharvest browning and microbial growth of loquat fruit. Journal of Applied Botany and Food Quality 84: 125-133.

RaybaudiI-Massilia, R.M., Mosqueda-Melgar, J., Soliva-Fortuny, R. and Martin-Bellosso, O. 2009. Control of pathogenic and spoilage microorganisms in fresh-cut fruits and fruit juices by traditional and alternative natural antimicrobials. Comprehensive Reviews in Food Science and Food Safety 8(3): 157-180.

Relox, P. E. Jr., Castillo-Israel, K. A. T., Serrano, E. P., Absulio, W. L. and Gandia, J. B. L. 2015. Efficacy of 1-methylcyclopropene post-cutting treatment on fresh-cut papaya (*Carica papaya* L. cv. 'Sinta') storage quality using two packaging forms. International Food Research Journal 22(3): 910-917.

Reynoso, Z. B. 2012. Enter the dragon fruit [Report]. Department of Agriculture - Bureau of Agricultural Research (DA-BAR). Quezon City, Philippines: BAR Digest. Retrieved May 10, 2015 from *www.bar.gov.ph*

Rocculi, P., Cocci, E., Romani, S., Sacchetti, G. and Rosa, M. D. 2009. Effect of 1-MCP treatment and N2O MAP on physiological and quality changes of fresh-cut pineapple. Postharvest Biology and Technology 51: 371-377.

Toivonen, P. M. A. 2008. Application of 1-Methylcyclopropene in fresh-cut/ minimal processing systems. HortScience 43(1): 102-105.

Toivonen, P. M. A. and De-Ell, J. R. 2002. Physiology of fresh-cut fruits and vegetables. In Lamikanra O. (Ed.), Fresh-cut fruits and vegetables. Science, Technology and Market. Boca Raton, FL: CRC Press.

Varoquaux, P. and Mazollier, J. 2002. Overview of European fresh-cut produce industry. In Lamikanra O. (Ed.). Fresh-Cut Fruits and Vegetables: Science, Technology, and Market, p. 21-44. Boca Raton, FL: CRC Press.

Vilas-Boas, E. V. and Kader, A. A. 2006. Effect of atmospheric modification, 1-MCP and chemicals on quality of fresh-cut banana. Postharvest Biology and Technology 29: 155-162.

Watkins, C. B. 2008. Overview of 1-Methylcyclopropene trials and uses in edible horticultural crops. HortScience 43(1): 86-94.

Watkins, C. B. n.d. 1-Methylcyclopropene (1-MCP). Washington, DC: US Department of Agriculture, Agricultural Research Services. Retrieved May 15, 2015, from *http://www.ba.ars.usda.gov/hb66/1-MCP.pdf*

Win, S., Buanong, M., Kanlayaranat, S. and Wongs-Aree, C. 2015. Response of gac fruit (*Momordica cochinchinensis* Spreng) to postharvest treatments with storage temperature and 1-MCP. International Food Research Journal 22(1): 178-189.