Application of AVG or 1-MCP-MBs on Postharvest Quality of Pummelo cv. "Tubtim Siam" (*Citrus maxima* Burm.)

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Abstract

Tubtim siam pummelo (*Citrus maxima* Burm.) is a geographical indentification (GI) product of Nakhon Si Thammarat province, Thailand and it has become more popular in the premium fruit market. Degradation of green peel and change in the red-ruby pulp color are two main deteriorative postharvest quality parameters caused by exogeneous ethylene. The aim of this study was to evaluate the effectiveness of AVG and 1-MCP-microbubbles (MBs) on maintaining postharvest quality of Tubtim siam pummelo through dipping in AVG and 1-MCP-MBs at 500 and 5 ppm, respectively. The control was fruit without any treatment. The fruits were stored at room temperature (25 ± 2 °C) for 21 days. Fruit treated with AVG resulted in a remarkably reduced respiration rate and ethylene production compared to other treatments. Moreover, delaying of peel yellowing was indicated by significantly higher total chlorophyll contents, hue angle values of peel and delayed degradation of red-ruby pulp color were also observed in 1-MCP-MBs treated fruit. On the other hand, application of AVG and 1-MCP-MBs retarded a reduction of weight loss compared to the control. Chemical composition in pulp including; total carotenoid, beta-carotenoid, lycopene, vitamin C, DPPH free radical scavenging activity and total phenolic content were maintained and were significantly different when compared with the control treatment. In conclusion, AVG and 1-MCP-MBs treatments could maintain both external and internal postharvest quality of Tubtim siam pummelo fruit.

Keywords: Tubtim siam pummelo, AVG, 1-MCP-MBs, Postharvest, Quality

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1. Introduction

Tubtim siam pummelo (*Citrus maxima* Burm) is a geographical indentification (GI) product of Nakhon Si Thammarat province, Thailand. Pummelo is an economically important tropical fruit in Thailand and is ranked as the sixth minor economic fruit crop in Thailand (FAO, 2012). Recently, the demand for this fruit has gradually increased in both domestic and international markets, especially in China, Taiwan, Malaysia, Singapore and Brunei. It has become more popular in fruit market because of the distinct characteristics such as red ruby pulp, fibreless, delicious taste, juicy flesh, and sweet aroma (Kaewtubtim and Issarakraisila, 2011); Additionally, the red ruby colored pulp is due to various dietary antioxidants and Phyto-compounds such as, ascorbic acid, α-tocopherol, phenolic, flavonoids (Kaewsuksaeng, 2015) and carotenoid. Carotenoid endow citrus fruit with nutritional function serve as precursors for vitamin A, which is essential to human and animal diets and as antioxidants, which play a role in reducing the risk of certain forms of cancer (Olson, 1989) and also play a key role in fruit color, the bright yellow, orange, and red colors provided by carotenoids accumulation in the chromoplasts of the peel and pulp of citrus fruit. The red color found in Red-flesh navel orange "Cara Cara", red ruby star, red blood orange and red grapefruit cultivars is comparable to what we found in Tubtim siam pummelo display an even bright color, which make them appealing for direct eating (Lee, 2001; Curl and Bailey 1957; Khan and MacKinney 1953; Rouseff *et al*. 1992). However, Degradation of green peel, red-ruby pulp color and biochemical compound are postharvest problem of Tubtim siam pummelo may cause by endogenous ethylene. Non-climacteric fruits are also reported to respond to the exogenous and endogenous of ethylene. Investigations on in planta levels of CO_2 and ethylene of fruits during storage supported the role and involvement of changes in the rate of respiration and ethylene production by presence of a characteristic rise in CO_2 levels and a burst in ethylene production in some non-climacteric fruits (Vijay Paul *et al*., 2012) such as strawberry (Trainotti *et al*., 2005; Cancel and Larsen, 2002; Iannetta *et al*., 2006) grapes (Chervin *et al*., 2004) and citrus (Stewart and Wheaton 1972; Purvis and Barmore 1981; Goldschmidt *et al*., 1993; Goldschmidt 1997; Katz *et al*., 2004). In citrus, the pigment changes in peel and pulp are the best visual markers of citrus fruit maturation. Pigment changes in peel of the most citrus cultivars consist of breakdown of chlorophyll and buildup of carotenoids, both of which are enhanced by ethylene and can delayed by plant bioregulators (Barmor, 1975; Shimokawa *et al*., 1978; Hirschfeld and Goldschmidt, 1983). Pigment changes in pulp of citrus cultivars is related to oxidative degradation of carotenoids has led to cis-trans isomerization and formation of carotenoid epoxides (Mordi *et al*., 1993 and Wacheä *et al*., 2003). Carotenoids act as antioxidants against lipid peroxidation by quenching singlet oxygen and trapping free peroxyl radicals (Palozza and

Krinsky 1991). Investigations have shown that singlet oxygen quenching ability of the carotenoids depends on their structural differences, such as number of conjugated double bonds, end groups (acyclic or cyclic), and substituent functional groups in the rings (Stahl and Sies 1996; Hirayama and others 1994). As lycopene with a lesser extent of beta-carotene are the major pigments in red grapefruit cultivars (Curl and Bailey 1957; Khan and MacKinney 1953; Rouseff *et al*. 1992) Di Mascio and others (1989) reported that the singlet oxygen quenching capacity of the carotenes was as follows: lycopene > alfa-carotene > beta-carotene. Esterification of carotenoids with fatty acids occur during fruit ripening and post-harvesting of the fruit may induce ripening process by endogenous ethylene, which play affect the color intensity (Minguez and Mendez, 1994). The physiological and chemical changes associated with fruit ripening can be halted or delayed by inhibiting ethylene perception, even when the fruit has reached advanced stages of ripening (Hoeberichts *et al*., 2002). Ethylene accelerates the above-mentioned changes, but plant bioregulators such as 1-methylcyclopropene (1-MCP) and aminoethoxyvinyl glycine (AVG) are commonly used in postharvest pre-storage treatments for mandarins (Asrey, 2012) and 'Kinnow' mandarin (Tavallali and Moghadam, 2015). 1-MCP is an ethylene action inhibitor, prevents the ripening effects of ethylene in many climacteric and non-climacteric fruits (Blankenship and Dole, 2003), but its effects differ by species. 1-MCP significantly reduces ethylene production, delays degreening, weight loss and softening in citrus (Fan *et al*, 1999; Cin, 2006; Laamim, 2005 and Asrey, 2012). As with originally formulated and prior applications, 1-MCP is usually delivered as a gas in sealed environments to prevent the 1-MCP gas from being released. However, using 1-MCP as fumigation technique may not be practical on a commercial scale because of high investment costs for airtight systems, take for a long time to fumigate. In the case of climacteric fruits for example banana, the periods of fumigation are between 6 and 24 hours at concentrations ranging from 5 to 1000 nLL^{-1} and higher (Blankenship and Dole, 2003). And other facilities. 1-MCP is easily released as a gas when the powder is dissolved in water. Recently, preparation of 1-MCP designed for use as aqueous has been formulated, facilitating broader agricultural applications of this ethylene-action inhibitor (Elfving *et al*., 2007). Microbuble (MB) technology has been used in many fields, including foam fractionation, food processing and purification processing of polluted water. One of the most significant characteristics of MBs are a highly efficient way of delivering dis solved gas into a solution. A crucial characteristic of MBs is that they are negatively changed on their surface (Takahashi, 2005) and have a high potential to be used for a variety of practical purpose (Pongprasert, and Srilalong, 2014). 1MCP-MBb application were used for delay ethylene production cause by maintain the postharvest quality change in non-climacteric fruit such as Hom thong bananas (Pongprasert *et al*., 2012) and Khai bananas

(Promkaew *et al*., 2015) in addition, also effect in non-climacteric fruit such as dragon fruit (Vera *et al*., 2017) and lime fruit (Tadmala, 2014). AVG (a water-soluble powder) is commercially sold under the name of ReTain®. It is a human and environmentally friendly organic product registered use for apples, pears, peaches, plums, mandarins and nectarines in several countries (Greene and Schupp, 2004; Rath and Prentice, 2004). AVG inhibits the synthesis of ethylene at the level of the aminocyclopropane carboxylic acid synthase enzyme (ACS), responsible for the conversion of S-adenosylmetionine to 1-aminocyclopropane 1-carboxylic acid (ACC), the latter an immediate precursor of ethylene (Adams and Yang, 1979). ACC synthase is considered a key enzyme in the biosynthesis of ethylene (Kende, 1993). Autio and Bramgage (1982) observed that AVG treatments delayed ripening and harvest, increased fruit firmness and prolonged storage life of fruit. Pre-harvest treatment of fruits with AVG decreases ethylene production, delays fruit maturity, and allows fruit to ripen more slowly (Bregoli, 2002; Torrigiani, 2004; Cline, 2006). However, the effect is timing or cultivar dependent (Byers, 1997; Belding and Lokaj, 2002). Furthermore, it is difficult to directly evaluate the shelf-life of AVG-treated fruit, because AVG affects fruit maturity, which in turn influences shelf-life. Postharvest application of AVG significantly suppresses ethylene production and reduces fruit ripening and therefore postharvest rotting (Byers, 1997; Garner, 2001). Therefore, the aim of this study was to evaluate the effectiveness of AVG and 1MCP-MBb on maintaining postharvest quality of Tubtim siam pummelo through dipping in AVG and 1-MCP-MBs.

2. Materials and Methods

2.1 Plant materials

Tubtim siam pummelo at commercial harvesting time (about 210 days after fruit setting), were harvest and transported to the Postharvest Technology laboratory, School of Bioresources and Technology, King Mongkut's University of Technology Thonburi, Bangkhunthien Campus, Bangkok. Fruit samples were selected for uniformity of color, size and free from disease. Afterwards, fruit were cleaned with tap water and dried at room temperature.

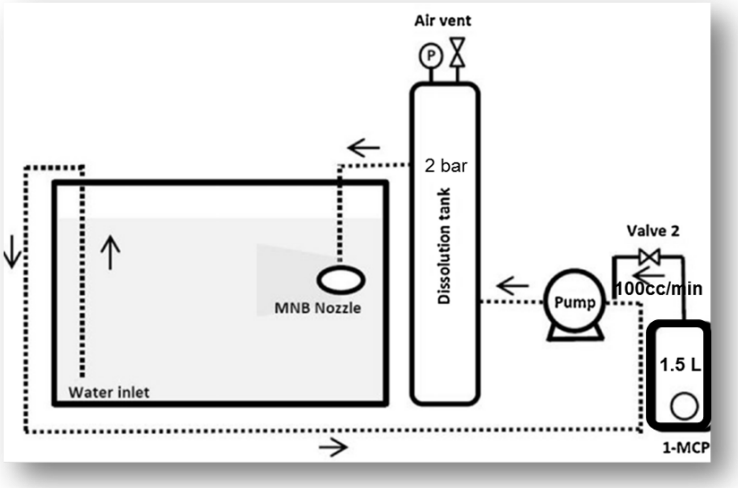

Figure 1 Schematic diagram of 1-MCP micro bubble generation system.

2.2 Treatment

A 1-MCP microbubble (1-MCP-MBs) generator system was constructed by the Department of Technology Thonburi (Bangkok, Thailand) according to the design (show in Figure1). Before starting the processes, 1-MCP (0.19% 1-MCP tablet, BioLene Co., Ltd., China) at doses corresponding to 5 ppm was fumigated in a 1.5L closed chamber for 5 min. The pummelo fruit were put into 40 L of water, then water with 1-MCP-MBs were generated by a swiveling microbubble generator (56 mm diameter × 86 mm long; 5 and 13 mm diameter outlet and inlet, respectively; Model.BT-50; Thai Isekyu Co., Ltd., Bangkok, Thailand) (Pongprasert and Srilalong, 2014). Figure 1 show a schematic diagram of the experimental set up used in this study. For AVG treatment, fruit was applied by dipped with ReTain® (Valent Biosciences Corp., USA), a commercial product containing 15% (w/w) AVG, at doses corresponding to 500ppm for 5 min at room temperature (Palou and Crisosto, 2003). The control was fruit without treatment. The fruit were stored at room temperature (25 ± 2 °C) and 85 ± 5% RH for 21 days. The fruit were analyzed on every 7 days to determine changes in fruit quality parameters. For each analysis period, 5 fruits were randomly selected and used for the fruit physiological and chemical characteristics.

2.3 Physiological analysis

Physiological changes, like change in respiration rate and ethylene production, weight loss and peel and pulp colors (hue angle value) were evaluated in every 7 day for 21 day. For respiration rate and ethylene production were measured by placing each lot and replication of pummelo fruit in a 3.5 L air tight plastic chamber for 3 h at (25 ± 2 °C). Gas sample (1 mL) was withdrawn with one milliliter plastic syringe and injected in the gas chromatography (GC–

2014 B (Shimadzu, Japan)), installed with a flame ionization detector (FID) equipped with a 60/80 mesh Porapack-Q column. Nitrogen was used as a carrier gas with a flow rate of 35 mL min^{-1} and temperature of the injector and column maintained at 120 and 95 °C respectively.

For weight loss each sample was weighed to calculate the percentage of weight loss as follows: Weight loss (%) = ((Initial weight – Final weight) × 100)/Initial weight. For peel and pulp surface color, hue angle was measured with a colorimeter (Chromameter Model RC-400, Minolta Corp,).

2.4 Chemical Analysis

Chemical change, which include the change in total chlorophyll content, total carotenoid content, total beta-carotene content, total lycopene content, total phenolic content, total ascorbic content and DPPH free radical scavenging activity were evaluated in 7day intervals. For total chlorophyll content of peel was determined using N, N-Dimethylformamide (Moran, 1982). Carotenoid content was measured using hexane, ethanol and acetone containing 0.05% butylated hydroxytoluene and determined at different absorbances at 445 nm for total carotenoid, 450 for beta carotene and 503 nm for lycopene (Fish *et al*., 2002). Total phenolic content was measured using the Folin–Ciocalteu method (Singleton, 1999). Total ascorbic content was measured according to the DNPH method (Kapur *et al*., 2012) and total antioxidant activity was measured by the DPPH method (Krings and Berger, 2001).

2.5 Statistical analysis

Experiment at design was completely randomized design. jData were analyzed by means of ANOVA. The data are presented as means ±SE. All data analysis was performed with SAS statistical software (SAS Institute Inc, 2006). The statistical analysis program procedure was used and mean separation was analysis by least significant difference (Duncan, $p \leq 0.05$).

3. Results and Discussion

3.1 Effects of AVG and 1-MCP-MBs on respiration rate, ethylene production and weight loss.

Respiration rate in all treatments markedly increased in 7 days after the treatment application but not significant difference was observed among treatments. After 7 storage days, the control treatment showed the highest respiration metabolism when compared to AVG and 1-MCP-MBs treatments, however AVG, treatment registered a significantly the low respiration rate until the end of the storage period (Figure 2A). Ethylene production in all fruit increase slightly during the first week there after a peak of ethylene production was observed at 14 days. Control treatment exhibited the highest increment of ethylene production at 14 days, followed by the AVG and 1-MCP-MBs treatments which significantly suppressed ethylene production with AVG treated observing the lowest treatment After the peak (14 days), ethylene production decreased as the storage proceeded in all treatments, however was not significant in AVG and 1-MCP-MBs treatments on the last day of storage (Figure 2B). Ethylene accelerates ripening and senescence effects, but plant bioregulators such as 1-MCP and AVG have been developed to mitigate its effect. These results differ from other studies into the application of AVG and 1-MCP-MBs as an inhibitor to the biosynthesis of ethylene. The inhibitory effect on ethylene biosynthesis by AVG was reported in mandarins (Asrey, 2012), 'Kinnow' mandarin (Tavallali and Moghadam, 2015). AVG is an analog of rhizobiotoxine. This phytotoxin competitively inhibits the conversion of S-adenosylmethionine (SAM) to 1aminocyclopropane-1-carboxylic acid (ACC) in the synthesis of ethylene (Byers, 1997). 1-MCP is an ethylene action inhibitor by blocking access to the ethylene binding receptor, lowers action of maturation associated genes and enzymes (Sisler and Serek, 1997; Khan and Singh, 2007; Martinez, 2002) were affected on non-climacteric fruits, such as the strawberry (Tian *et al*., 2000) and the tangor cv. Murcote (Tavares *et al*., 2003), where a reduction in respiration rate was seen with the application of 1-MCP. Numerous research studies demonstrated that weight loss was associated with respiration processes and evaporation of water from the fruit (Amarante, 2001). In our study, after treatment of pummelo fruit, AVG showed a lowest of weight loss percentages from the first week to the last week of storage period (1.56% and 2% respectively) compere to other two treatments. However, 1-MCP-MBs also delayed weight loss in the last week of storage (2.5%) compare to control treatment (2.86%) (Figure 2C). AVG seemed to be more effective than 1-MCP-MBs in controlling weight loss. Similar result with Tavallali and Moghadam (2015) work in 'Kinnow' mandarin found that AVG treatment showed positive effect to delayed weight loss than in 1-MCP treated.

This result probably could be due to a protective role of AVG on fruit peel integrity which reduced water evaporation, gas exchange and decreased nutrient loss (Sigal-Escalada, 2006).

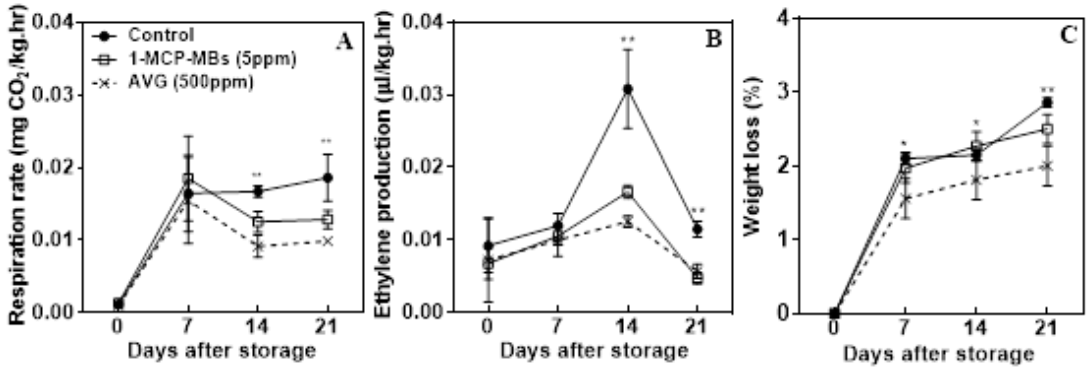

Figure 2 showed changes in respiration rate (A), ethylene production rate (B) and weight loss (C) of Tubtim siam pummelo fruit. Fruit were treated with 1-MCP-MBs and AVG at 5ppm and 500ppm concentration respectively. The control was fruit without treatment. The fruit were stored at room temperature (25 ± 2 °C) for 21 day. Each point represents the means ±SE *Significant difference between means at each storage time (Duncan, $p \leq 0.05$)

3.2 Effects of endogenous ethylene production on senescence occurrence in Tabtim Siam pummelo fruit treated with AVG and 1-MCP-MBs.

In most fruit, chlorophyll degradation occurs during development or in postharvest storage (Shemer *et al*., 2008), such as citrus (Jacob-Wilket al., 1999), tomato (Guyer *et al*., 2014), and banana (Pongprasert *et al*., 2012). 1-MCP treatment prevented or delayed chlorophyll degradation in a wide range of fruit specie. In orange cv. Pera, the degradation of chlorophyll and green peel change to yellow/orange was delayed by the application of 1-MCP (Golding *et al*., 1998). 1-MCP-MBs has also been reported to delay change in total chlorophyll content and hue angle value in Hom thong bananas (Pongprasert *et al*., 2012), Khai bananas (Promkaew *et al*., 2015), dragon fruit (Loor *et al*., 2017) and mature green lime fruit (Tadmala, N., 2014). However, to our knowledge AVG has no report in delaying chlorophyll degradation or change in green peel color in citrus fruit but has been report to effect in delaying postharvest change in respiration and ethylene production and softening in ‘Kinnow' mandarin (Tavallali and Moghadam, 2015). Interesting in this study, we found that AVG and 1-MCP-MBs treatment delayed peel yellowing as indicated by significantly higher total chlorophyll contents and hue angle value of peel. The decrease was relatively slow from 0 day to 14 days of storage period and became rapid after 14 days in the following 7 days to the end of storage (Figure 3). In contrast, the peel chlorophyll content of the control treatment observed a rapid

decline from the initial time of storage to the end. Furthermore, the hue angle value of the same treatment was significantly lower in the last two weeks od storage. Generally, both AVG and 1-MCP-MBs maintained a significantly high of the peel chlorophyll content and hue angle value on 14 and 21 days after storage (Figure 3A and 3B). The effectiveness of AVG and 1-MCP-MBs in inhibiting chlorophyll degradation confirmed by the reduction of total chlorophyll contents and hue angle value of pummelo fruit peel especially after one week of storage time. Exogenous or endogenous ethylene released from fruit flesh and core may accelerate chlorophyll degradation in fruit peel (Garcia-luis, Fornes,Guardiola, 1986; Jacob-Wilk, Holland, Goldschmidt, Riov ans Eyal, 1999; Porat *et al*., 199; Purvis and Barmore, 1981; Trebitsh *et al*., 1993). In this work, we observed that the ethylene production pattern in pummelo fruit was exactly matched the pattern of peel yellowing or decrease in total chlorophyll content and hue angle value. On the other hand, ethylene production was related to chlorophyll degradation in the second week of the storage period in which the peak of ethylene production appeared (Figure 2B). Therefore, the AVG and 1-MCP massive reduction of endogenous ethylene could act as a signal to delayed enzyme and gene expression in chlorophyll catabolism such as PAO, CHL1 and RCCR in fruit peel (harpaz-Saad *et al*., 2007 and Jacob-Wilk *et al*., 1999)

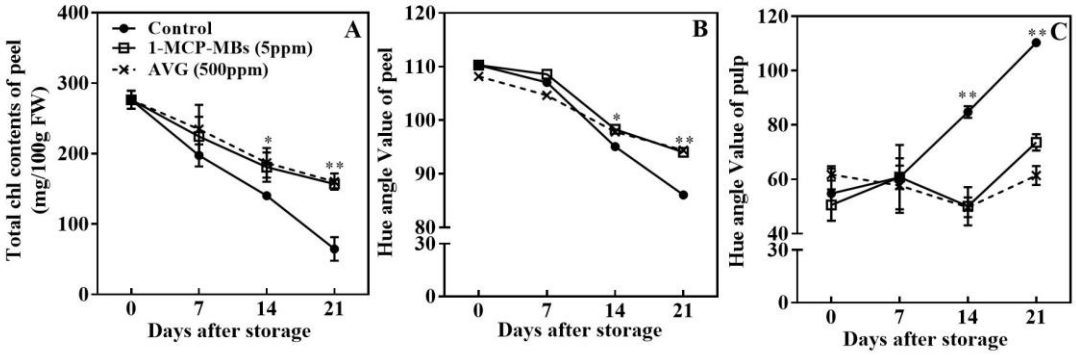

Figure 3 showed changes in total chlorophyll content of peel (A), hue angle value of peel (B) and hue angle value of pulp (C) of Tubtim siam pummelo fruit. (Hue angle $h^{o}=\tan^{-1}(b^*/a^*)$ represents different color, 0^{o} = red-purple, 45^{o} = orange, 90^{o} = yellow, 180^{o} =bluish green and 270^{o} =blue.) Fruit were treated with 1-MCP-MBs and AVG at 5ppm and 500ppm concentration respectively. The control was fruit without treatment. The fruit were stored at room temperature (25 ± 2 °C) for 21day. Each point represents the means ±SE *Significant difference between means at each storage time (Duncan, $p \leq 0.05$)

3.3 Effects of AVG and 1-MCP-MBs on quality of biochemical composition of fruit.

Pulp quality determined by color is important when considering a postharvest application of AVG and 1-MCP-MBs. Equable red color was observed by H^o angle value. Found that 1-MCP-MBs and AVG significantly delayed increased of H^o angle value from 14 days to the last day of storage period (Figure 3C). The trends observed for pulp color were like those for total carotenoids content, total lycopene content and total beta-carotene content. 1-MCP-MBs and AVG treatment were delayed the reduction of total carotenoids, total lycopene and total beta-carotene contents from 0 day to the last day and significant effect was observed in 14 and 21 days when compare to the control treatment. On the last day, the contents of total carotenoids, total lycopene and total beta-carotene in 1-MCP-Mbs treatment showed 12.77, 15.26 and 9.91 mg/100g, AVG treatment were 11.61,16.87 and 12.32 mg/100g and control treatment were 5.28, 6.79 and 5.94 mg/100g of each respectively. Changes in carotenoid levels during storage depend on the ripening process factor, the length of storage time light, temperature and high relative humidity. In this study fruit were storage at room temperature (25 ± 2 °C), 85 ± 5% relative humidity, ethylene is the main factor to inhibit increasing respiration processes and evaporation of water from the fruit (Amarante, 2001). Increased of relative humidity may cause to reduction of carotenoid and carotenoid intensity. Furthermore, Minguez and Mendez, 1993 report that maybe O_2 could be resulting to degradation of the structure, allowing carotenoids to oxidise by oxidation of the unsaturated fatty acids that form part of the lipid components of the membranes. This reaction is catalyzed by lipoxygenase during ripening and post-harvesting of the fruit (Minguez-Mosquera, M.I., 1990). Oxidative degradation of carotenoids also leads to cis-trans isomerization and formation of carotenoid epoxides (Mordi *et al*., 1993 and Wacheä *et al*., 2003). This is support by Henry *et al*. (2000) report that lycopene and beta-carotene degradation during hydroperoxide by Oxygen. 1-MCP-MBs and AVG are plant bioregulators reported the inhibitory effect on ethylene (Greene and Schupp, 2004; Rath and Prentice, 2004 and Blankenship and Dole, 2003). Byers (1997) reported biosynthesis and consequent suppression of ethylene production by various plant tissues. In agreement with the above, this present study found that AVG and 1-MCP-MBs delayed the reduction in contents of total carotenoids total lycopene and total beta-carotene including delayed increased hue angle value of pulp. 1-MCP-MBs and AVG treatment significantly maintained total phenolic content with slight reduction observed in the last day of storage. Compare to the control treatment that showed remarkable decline throughout the storage period (Figure 5A), similarly the content of total ascorbic acids registered significantly higher content in both AVG and 1-MCP-MBs treatment after the first week of storage compare to the control (Figure 5B). The antioxidant activity delineated by DPPH scavenging activity observed significantly higher percentage in both AVG

and 1-MCP-MBs treatment in most days during storage. Meanwhile, the control on the other hand showed lower DPPH scavenging activity. Natural substances with known antioxidant potential are phenolic compounds such as flavonoids vitamins A, C, E and carotenoids (Ara and Nur 2009, Arnao *et al*. 2001). Ethylene has a correlation with production of reactive oxygen species in fruits and vegetable during storage (Larrigudiere *et al*., 2004). This suggest that the ethylene inhibitory action of 1-MCP and AVG is involved in suppression of the generation of free radicals of plant tissues through the inhibition of ethylene. Thus, in agreement with what this study found.

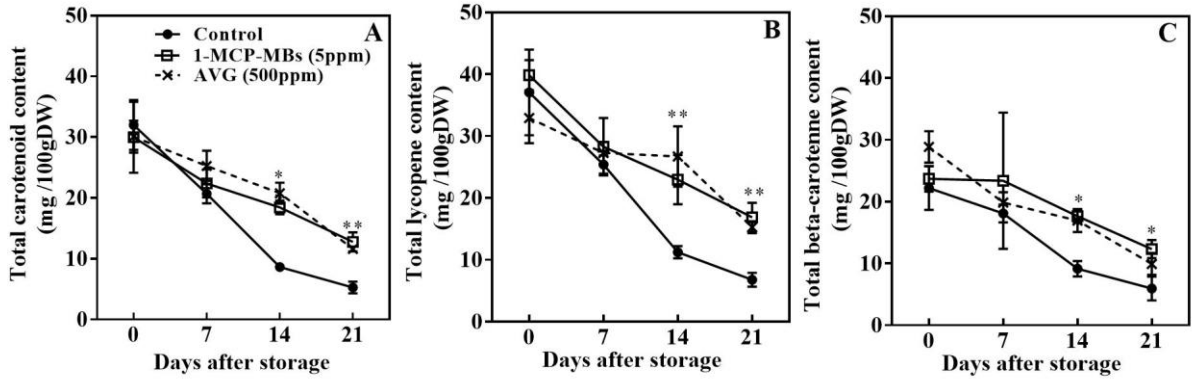

Figure 4 showed changes in total carotenoid content (A), total lycopene content (B) and total beta-carotene content (C) of Tubtim siam pummelo fruit. Fruit were treated with 1-MCP-MBs and AVG at 5 and 500 ppm concentration respectively. The control was fruit without treatment. The fruit were stored at room temperature (25 ± 2 °C) for 21 day. Each point represents the means ±SE *Significant difference between means at each storage time (Duncan, $p \leq 0.05$)

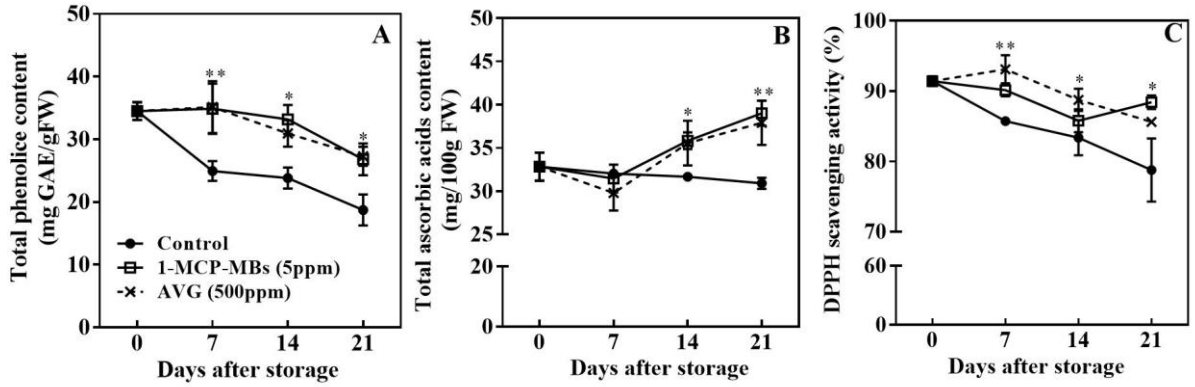

Figure 5 showed changes in total phenolic content (A), total ascorbic content (B) and DPPH scavenging activity (C) of Tubtim siam pummelo fruit. Fruit were treat withed 1-MCP-MBs and AVG at 5 and 500 ppm concentration respectively. The control was fruit without treatment. The fruit were stored at room temperature (25 ± 2 °C) for 21 day. Each point represents the means ±SE *Significant difference between means at each storage time (Duncan, $p \leq 0.05$)

4. Conclusion

This study clearly indicates that fruit treated with AVG resulted in a remarkably reduced respiration rate and ethylene production compared to other treatments. Consequently, delayed peel yellowing as indicated by significantly higher total chlorophyll contents, hue angle value of peel and delayed degradation of red-ruby pulp color was also observed in 1-MCP-MBs treated fruit. On the other hand, application of AVG and 1-MCP-MBs retarded a reduction of weight loss compared to the control. Chemical composition in pulp including; total carotenoid, beta-carotenoid, lycopene, vitamin C, DPPH free radical scavenging activity and total phenolic content were maintained and were significantly different when compared with the control treatment. In conclusion, AVG and 1-MCP-MBs treatments maintained both external and internal postharvest quality of Tubtim siam pummelo.

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