International Journal of Agricultural Technology 2018 Vol. 14(7): 1003-1016
Available online http://www.ijat-aatsea.com
ISSN: 2630-0613 (Print) 2630-0192 (Online)

Efficiency of salicylic acid immersion using fine-bubble technique on quality of *Musa* AAA fruit during ripening

Anuchai. J.[1*], Chumthongwattana, M.[1], Tepsorn, R.[2] and Supapavnich, S.[1]

[1]Department of Agricultural Education, Faculty of Industrial Education and Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand, 10520; [2]Department of Food Science and Technology, Faculty of Science and Technology, Thammasat University, Rangsit Center, Pathumthani Province, Thailand.

Anuchai. J., Chumthongwattana, M., Tepsorn, R. and Supapavnich, S. (2018). Efficiency of salicylic acid immersion using fine-bubble technique on quality of *Musa* AAA fruit during ripening. International Journal of Agricultural Technology 14(7): 1003-1016.

Abstract The physiological quality and bioactive compound in changes of banana (*Musa* AAA) fruit was determined by using 2 mM salicylic acid solution with 2 different methods. Dipping (SA) and immersion using fine-bubble technique (SAF) with 2 different period of time (15 and 30 minutes) were used. Peel color, fruit firmness, total acidity (TA), antioxidant, total phenol and total flavonoid were investigated. The result showed that banana treated with SAF for 15 minutes could maintain lightness (L*) and yellowness (b*) of peel color. In term of fruit firmness, there were not significantly different among the treatments. After 4 days of color break, banana treated with SAF for 15 minutes also resulted in high TA, antioxidant and total phenol. While SAF for 30 minutes resulted in high total flavonoid contents. It concluded that SAF technique can maintain and strengthen physiological quality and bioactive compound changes of banana (*Musa* AAA) fruit during ripening.

Keywords: Fine-bubble technique, *Masa* AAA, Postharvest quality, Salicylic acid

Introduction

Thailand's total land area is about 51.3 million ha which agricultural use area shares 20.97 million ha. Fruit crop area is 1.25 million ha with total production of 9.02 million tons, whereas banana area is about 76,815 ha. Banana is one of economic fruit crops which producing 117,427 tons of fruit annually. One of the most popular cultivars of banana in Thailand is "Hom Tong" (AAA group, Gros Michel). In 2012, Thailand produced banana "Hom Tong" 231,031 ton for domestic and 2,169 for export. The average farmgate price was 186 USD per metric tons for large grade. (OAE, 2012) Banana is a common fruit crop in Thailand. Thai people always use banana in many ways such as, fresh fruit, raw banana fruit is used as vegetable in Thai food, banana flowers, banana leaves, banana pastes and banana chips are also use in Thai cooking. The main varieties of banana in

[*]**Corresponding Author**: Anuchai, J.; **Email**: jatuporn.an@kmitl.ac.th

Thailand are 'Hom' banana, especially the “Hom Thong” variety (AAA group), “Kai” banana (AA group) and “Namwa” banana (AB group). The Hom Thong banana and the Kai banana are grown for export on the other hand the “Namwa” banana are grown for domestic consumption.

As we know, banana is one of the antioxidative food (Kanazawa and Sakakibara, 2000). The chemical composition of the banana has shown that it is rich in minerals and dietary fiber. It is one of the good source of vitamins C and E (von Loesecke, 1950). In term of the antioxidants gallocatechin, catechin, and epicatechin were previously identified in banana (Someya *et al.*, 2002). Antioxidant activities in banana were studied by using DPPH, ABTS and FRAP assays (Sulaiman *et al*., 2011 and Darsini *et al*., 2012).

Salicylic acid is a plant hormone which played role as an inhibitor of ethylene biosynthesis and delayed plant senescence (Ozeker, 2005). It has been shown to suppress ACC oxidase activity (Fan *et al*., 1996) then ACC was inhibited to convert to ethylene (Leslie and Romani, 1988). Salicylic acid is also related in the potential of plant pathogens resistance (Yalpani *et al.*, 1994; Kang *et al.*, 2003). Salicylic acid has been reported to correlate with postharvest diseases and can extend the shelf life. Salicylic acid and post-harvest guava fruit were reported using a 32 μmol /L to decrease fruit rot disease which associate with the activities of enzyme catalase (CAT) and ascorbate peroxidase (AsPOD). Aghdam *et al*. (2011) also reported the same effect as those reported. Zeng *et al.* (2006) studied the effect of salicylic acid and mango fruits on the mango fruit was found to be more resistant to the disease. Yu *et al*. (2007) found that salicylic acid was effective to control infection of *Penicillium expansum* and *B. cinerea* infection which caused fruit rot in Asian pear by stimulating activity of enzyme β-1,3-glucanase, Phenylalanine ammonia lyase (PAL), Polyphenol oxidases (PPO) and Peroxidase (POD). These enzymes are involved in the production of phenolics in plants, which inhibit the growth of pathogens that cause disease. Salicylic acid played role in physiological or biochemical processes which included ion uptake, membrane permeability, enzyme activity, heat production and growth development (Arberg, 1981). Salicylic acid was used to control the firmness of harvested in peaches and strawberry during storage (Li and Han, 1999; Wang *et al*., 2006; Shafiee *et al.*, 2010; Valero *et al.*, 2011). Junmatong *et al*. (2015) studied the effect of salicylic acid by dipping mature mango in 1 mM SA and distilled water for 10 min. To store the mango at 5±1℃ with 90±2% RH for 42 days. The result showed that salicylic acid treatment exhibited significantly higher antioxidant activities and increased levels of ascorbic acid, total glutathione, total phenolic compounds, and total antioxidant capacity compared to control.

Fine-bubbles refer to all bubbles with a diameter below 100 μm (ISO20480). Recent attention has been given to industrial application of fine

bubbles for example, in agriculture, aquaculture, medical treatment, industries or household appliances. Fine bubble technology is expected to be successfully applied in agriculture from the following viewpoints 1) To improve agricultural productivity by enhancing growth rate of vegetables, 2) To improve biological or physiological conditions for soil in production sites in terms of suppression of a failure caused by continuous cropping, suppression of eutrophication in field soil caused by nitrogen chemicals, to increase a number of aerobic bacteria and microorganism, to encourage aerobic microorganism in decomposing organic matters 3) Agricultural water treatment by fine bubbles, oxygen dissolution with high efficiency, higher performance of water permeability through soil particles 4) Fine bubble water is a beneficial tool, as already used, for culture solution in hydroponics for the purpose of purification and sterilization (ozone bubbles) (Akimi, 2017). A study of fine-bubble and nano-bubble of 1-MCP treatment to delay the ripening of banana by dipping and spraying. It was found that dipping method can delay the ripening, decrease respiratory rate, ethylene production and maintain the firmness of banana during storage (Pongprasert and Srilaong, 2014). A study on the use of dynamic systems and fine-bubble technology on decontamination of *E. coli* O157: H7 on chili pepper demonstrated that using fine-bubble technology resulted in the highest possible to decontamination of *E. coli* O157: H7 in 40 minutes after treatment (Todsapong and Pokpong, 2016).

In this study, we investigated postharvest quality including physical quality, chemical quality and bioactive compounds in banana (*Musa* AAA) fruit during storage which had different application technique (dipping, fine-bubble) to involve postharvest quality during storage.

Materials and Methods

Raw Material

"Hom Thong" banana (*Musa* AAA) fruits at the full mature stage were ordered from Chumphon province. The fruit bunches were de-handed and selected for uniformity of shape, size, skin color, physical damage and disease., cleaned the fruits with tap-water and dried at room temperature.

Treatments and Application of salicylic acid

Fine-bubble technique was used to compare with the conventional method on the application of salicylic adcid. "Hom Thong" banana (*Musa* AAA) fruits were subjected to the following treatments:-Treatment 1 was control, Treatment 2 was 2 mM salicylic acid by dipping for 15 minutes (SA15), Treatment 3 was 2 mM salicylic acid by dipping for 30 minutes (SA30), Treatment 4 was 2 mM salicylic acid by using fine-bubble

technique for 15 minutes (SAF15) and Treatment 5 was 2 mM salicylic acid by using fine-bubble technique for 30 minutes (SAF30). The tested fruits were dried after immersion.

Color measurement

Peel color of banana fruits were measured using HunterLab MiniScan photometer (MiniScan@ XE Plus; Hunter Associates Laboratory Inc.; Reston, VA, USA). The lightness (L^*), greenness ($-a^*$), redness ($+a^*$) and yellowness (b^*) values were recorded (Bolin and Huxsoll, 1991).

Firmness measurement

Five fingers from each hand of banana were used for firmness measurement. Peeled banana was used a Texture Analyzer (TA Plus; Lloyd Limited; Fareham, UK) with a 6 mm cylindrical probe at the middle part of fruit. The result was showed in newton unit at the maximum force.

Total acidity measurements

Five fingers from each hand of banana were selected. 10 g of banana pulp was homogenized with 20 ml. of distilled water and filtered through a cloth. Then used 5 ml aliquot and titrated with 0.1 N NaOH using 1% (w/v) phenolphthalein as the indicator. The result was expressed as % malic acid (Association of official analytical chemists, 1990).

Total antioxidant capacity measurements

Two methods were used to assay the antioxidant activity of the banana pulp; DPPH (2,2-diphenyl-1-picrylhydrazyl) and FRAP (ferric reducing antioxidant potential). The antioxidant activity of the extracts was determined using the method desc ribed by Brand-Willians *et al.* (1995); this methodology is based on the scavenging capacity of the DPPH free radicals. The absorbance was determined by a spectrophotometer at 517 nm. The percentage of antioxidant activity was calculated as the percentage of the DPPH radicals, using Equation: $AA\% = [(A0 – A10)/A0] \times 100$, where A0 is the absorbance of the sample at 0 min and A10 is the absorbance of the sample at 10 min. To determine the FRAP of the banana pulp, the method described by Benzie and Strain (1996) was used. The absorbance of the colored complex formed with acetate buffer pH 3, 20 mM ferric chloride hexahtdrate and TPTZ (2,4,6-Tri(2-pyridyl)-s-triazine) in ratio 10:1:1 (v/v/v) was measured at 630 nm using a spectrophotometer after incubated at room temperature for 30 min. The results were expressed in micromoles of Trolox equivalents per gram fresh weight (μmol TE/gFW).

Determination of total phenolic content

Total phenolic content of banana pulp extract was measured according to the method reported by Alothman *et al.* (2009) using Folin-Ciocalteu reagent with some modification. 1 ml of supernatant was mixed with 1ml of 50% (v/v) Folin-Ciocalteu's phenol reagent and 2ml of saturated Na_2CO_3 solution. The mixture was kept at room temperature for 30 min. Absorbance was measured at 750 nm using a spectrophotometer. The total phenolic contents were expressed as micrograms of gallic acid per gram fresh weight (μg GA/g FW).

Determination of total flavonoids content

Total flavonoids contents of the extracts were determined according to the procedure of Zhishen *et al.* (1999). 0.25 ml of the supernatant was added into a mixture of 1.25 ml of distilled water and 0.5% $NaNO_2$ 75 μl. After 6 min at room temperature, 150 μl of (10% w/v) $AlCl_3$ was added. After another 5 min, o.5 ml of 1M solution of NaOH was added. The mixture was shaken vigorously and the absorbance of mixture was recorded at 510 nm using spectrophotometer. The results were expressed as μg of catechin per gram fresh weight (μg catechin/g FW).

Statistical analysis

All data analyses were carried out in ten replications ± SD. The results were submitted to analysis of variance (ANOVA) with a significance level of 95% ($p < 0.05$) using SPSS software program (SPSS Inc.; Chicago, IL, USA).

Results

Fruit color

Lightness (L^*) and yellowness (b^*) of the banana (*Musa AAA*) peel are shown in Figure 1. After color break, the L^* value remained constant (Figure 1A). After color break for 4 days, the L^* value decreased significantly in all treatments ($P \leq 0.05$). The control had the lowest L^* value compared to the others treatments. This showed that 2mM salicylic treatment delayed the loss of L^* value in banana peel during storage especially when using fine-bubble technique for 15 minute (SAF15). The yellowness (b^*) of banana peel were increased continuously until color break ($P \leq 0.05$). In the treatment using fine-bubble technique for 15 minute (SAF15), the increased of b^* values seemed constant until 4 days after color break (Figure 1B). From the visual appearance of banana (Figure 2), it was

found that on the first day of color break, the banana peel was changed from green to yellow color. The yellow color increased in the following day on day 2. After the color break, the color changed to yellow in all treatments. After 4 days of color break, the results showed that banana peel in treatment using fine-bubble technique for 15 minute (SAF15) had better appearance than other treatments. The brownish appearance on the peel occurred less than other treatments. The control treatment showed the highest percentage of browning on the banana peel surface compared to other treatments. In figure 2 showed that salicylic treatment using fine-bubble technique for 15 minute (SAF15) maintained lightness (L*) and yellowness (b*) of peel color with less senescent spots until the fourth day after color break.

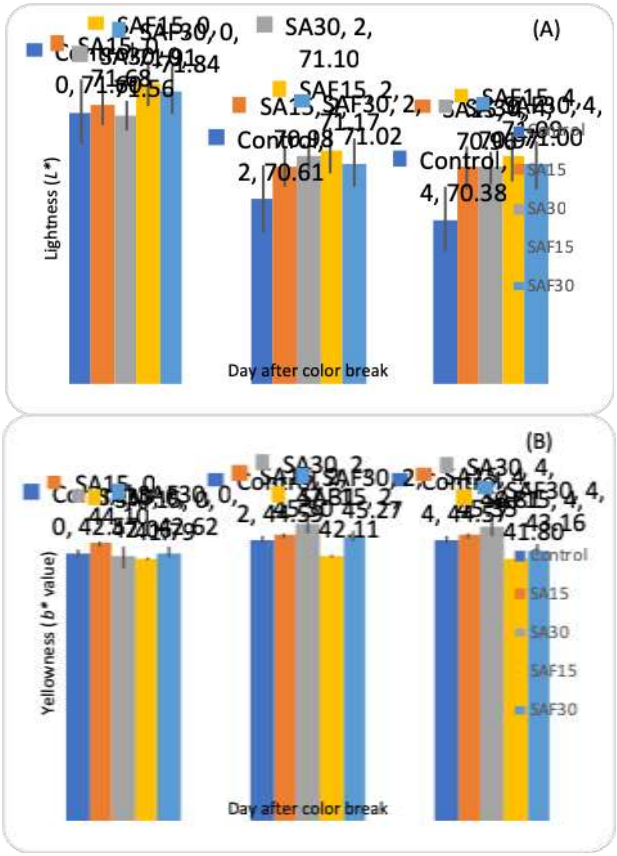

Figure 1. Peel color of banana (*Musa* AAA) after color break with different treatment; control, dipping with 2mM salicylic acid for 15 minute (SA15), Dipping with 2mM salicylic acid for 30 minute (SA30), immersion using fine-bubble technique for 15 minute (SAF15) and immersion using fine-bubble technique for 15 minute (SAF15). Each bar represents the mean ± standard deviation of the results from 5 replicates.

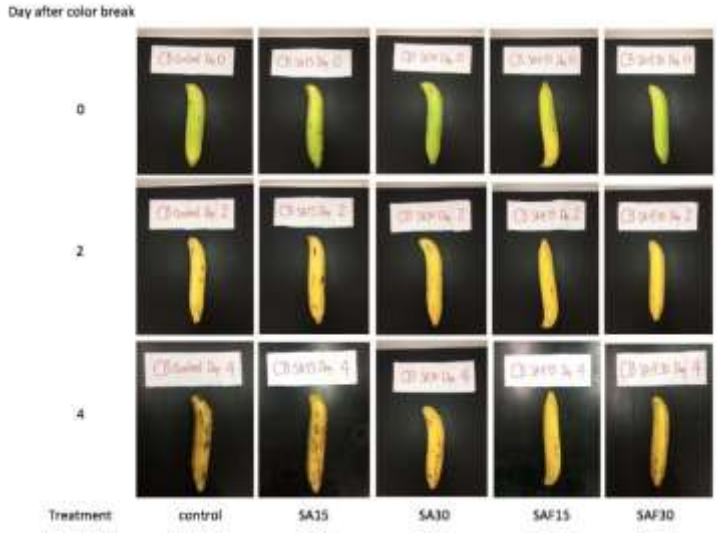

Figure 2. Appearance of banana (*Musa* AAA) fruit after color break with different treatment; control, dipping with 2mM salicylic acid for 15 minute (SA15), Dipping with 2mM salicylic acid for 30 minute (SA30), immersion using fine-bubble technique for 15 minute (SAF15) and immersion using fine-bubble technique for 30 minute (SAF30).

Firmness

Figure 3 showed the changes in pulp firmness after color break. The fruit pulp firmness decreased continuously throughout storage but there were not significantly different among the treatments. But there was higher amount of firmness in immersion using fine-bubble technique for 30 minute (SAF30) treatment compare with control.

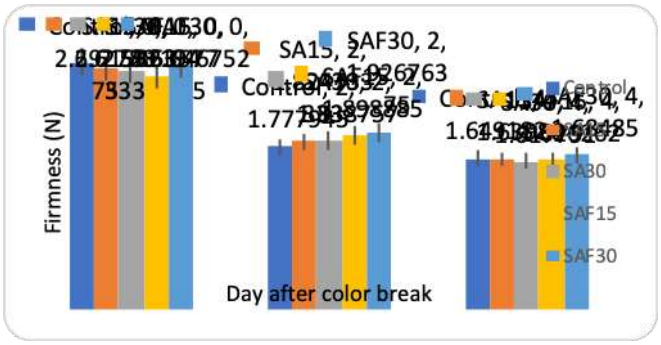

Figure 3. Firmness of banana (*Musa* AAA) pulp after color break with different treatment; control, Dipping with 2mM salicylic acid for 15 minute (SA15), Dipping with 2mM salicylic acid for 30 minute (SA30), immersion using fine-bubble technique for 15 minute (SAF15) and immersion using fine-bubble technique for 30 minute (SAF30). Each bar represents the mean ± standard deviation of the results from 5 replicates.

Total acidity

The result was found that the total acidity content highest after 2 day of color break and then slowly decrease after 4 after 4 days of color break. After 2 and 4 days of color break, the treatment immersion using fine-bubble technique for 15 minute (SAF15) showed highest amount (0.25 and 0.24 % malic acid, respectively) of total acidity compare to others treatment (Figure 4).

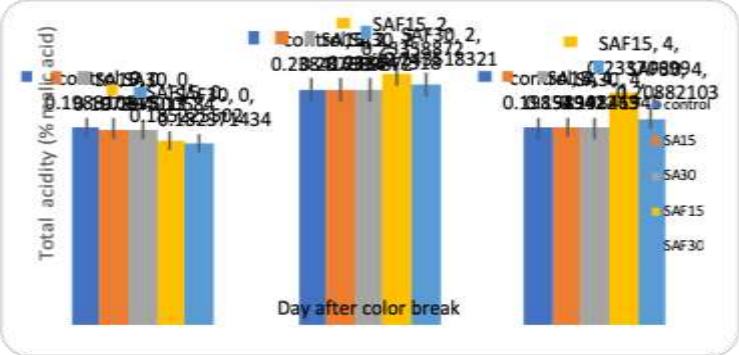

Figure 4. Total acidity (TA) of banana (*Musa* AAA) with different treatment; control, Dipping with 2mM salicylic acid for 15 minute (SA15), Dipping with 2mM salicylic acid for 30 minute (SA30), immersion using fine-bubble technique for 15 minute (SAF15) and immersion using fine-bubble technique for 30 minute (SAF30). Each bar represents the mean ± standard deviation of the results from 5 replicates.

Bioactive compound

The changes in antioxidant capacity, total phenols and total flavonoids contents of banana (*Musa AAA*) fruit are shown in Figure 5. On the initial day after color break, the antioxidant capacity measured by FRAP assay was remained very low (Figure 5A). After 4 days of color break, the antioxidant capacity was higher in all treatment. The antioxidant capacity of the treatment using fine-bubble technique for 15 minute (SAF15) was significant higher (1.07 μmole TE g/FW) than others treatments. The result of DPPH radical scavenging activity of banana (*Musa AAA*) fruit are shown in Figure 5B. The amount of the DPPH radical scavenging activity was significant higher in the treatment using fine-bubble technique for 15 minute (SAF15) compares to others treatment. The results are shown that the DPPH radical scavenging activity in the treatment using fine-bubble technique for 15 minute (SAF15) after 0, 2 and 4 days after color break were 19.01, 67.60 and 70.27 %, respectively. Total phenols of the treatment using fine-bubble technique for 15 minute (SAF15) was significantly highest than others treatment. After 0, 2, 4 days after color break total

phenol content were 2.00, 2.35 and 244 mg GA/g FW, respectively (Figure 5C). Total flavonoids of all the treatments decreased significantly after 2 days of color break then small increased after 4 days of color break (Figure 5D). After 4 days of color break, total flavonoids of the treatment using fine-bubble technique for 15 minute (SAF15) was 21.92 µg catechin g/FW which showed the highest amount of total flavonoid content.

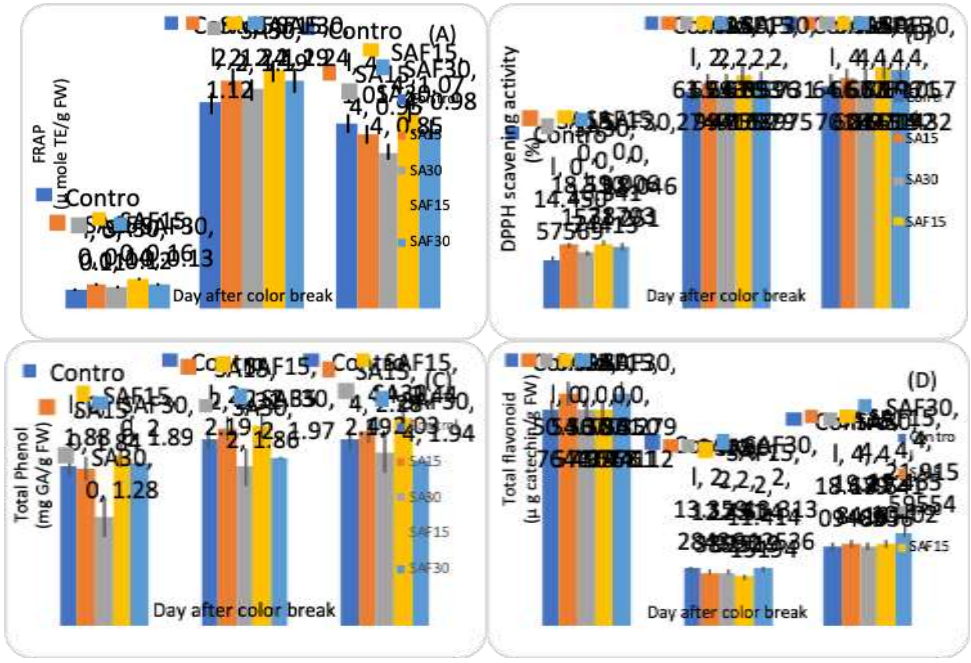

Figure 5. Antioxidant capacity by FRAP assay (A), DPPH radical scavenging activity (B), total phenolic compounds (C) and total flavonoids (D) content of banana (*Musa* AAA) control, Dipping with 2mM salicylic acid for 15 minute (SA15), Dipping with 2mM salicylic acid for 30 minute (SA30), immersion using fine-bubble technique for 15 minute (SAF15) and immersion using fine-bubble technique for 30 minute (SAF30). Each bar represents the mean ± standard deviation of the results from 5 replicates.

Discussion

According to the result, it showed that the positive effect of salicylic acid on visual appearance and color measurement. The treatment using fine-bubble technique for 15 minute (SAF15) maintained lightness (L*) and yellowness (b*) of peel color with less senescent spots better than others treatments. The result from Seymour *et al.* (1987) showed the reduction of total carotenoid content in banana peel due to carotenoid biosynthesis during the early stage of ripening that caused the peel color change from green to yellow. It was found that dipping method can delay the ripening and decrease respiratory rate during storage. Wei *et al.* (2011) reported the

use of salicylic acid can delay the chlorophyll degradation in asparagus at concentration 0.1 mmol/L. In this study, the result showed that the firmness of banana fruit not significant different in each treatment. However, the treatment using fine-bubble technique was showed higher amount of firmness compare to control. Sayyari *et al.* (2011) studied the effect of salicylic acid solution on pomegranate after harvest. The salicylic acid treatment of pomegranate showed a firmness of 16-17 newton while control showed a firmness of only 9 newton. As in the bananas, the study of Srivastava and Dwivedi (2000), salicylic acid has been shown to maintain the firmness of the banana fruit. As a result of salicylic acid, the rate of ethylene production decreased. It also helps in inhibiting the activity of enzymes involved in the decay of cell walls and cell membranes. The enzymes involved, such as polygalacturonase (PG), lipoxygenase (LOX), cellulose and pectinmethylesterase (PME). The result from the treatment immersion using fine-bubble technique for 15 minute (SAF15) showed a high amount of total acidity, antioxidant capacity and total phenols. Moreover, the treatment immersion using fine-bubble technique for 30 minute (SAF30) showed a high amount of total phenol. In some previous study showed that salicylic acid treatment enhanced the activity of antioxidant system and increased the activity of antioxidant in plants which helped to prevent fruit chilling injury during storage (Hayat *et al.*, 2005). Salicylic acid solution was found to promote antioxidant activity in plants. The results showed that salicylic acid solution was able to stimulate antioxidant content in mango (Suwanna *et al*., 2007). Same as Hooper and Cassidy (2006) that studied the effect of salicylic acid on external exposure in asparagus, it was found that salicylic acid increased the total phenolic content of asparagus (Wei *et al.*, 2011). As in the pomegranate, salicylic acid, affected to increase the total phenolic content during storage (Sayyari *et al*., 2011). Wang *et al*. (2006) suggested that salicylic acid can prevent chilling injury of peach fruit caused the induction of antioxidant activity. According to Knorzer *et al.* (1999) reported that salicylic acid solution promoted antioxidant activity in plants. Supapvanich *et al.* (2015) reported the use of pre-harvest salicylic acid in vegetables promoted antioxidant activity and prevent the antioxidant activity of lemon basil during storage. Sulaiman *et al*. (2011) which studied regarding antioxidant activities from 8 cultivars of banana grown in Malaysia demonstrated that antioxidant activity of n-hexane, chloroform and methanol peel extracts of Nangka banana were 1.00, 2.01, 0.65 mg TE/g fresh weight and 2.26, 3.99, 3.36 mg TE/g dried weight, respectively by DPPH method and 2.5, 7.40, 3.54 mg TE/g fresh weight and 3.69, 7.50, 10.32 mg TE/g dried weight, respectively by FRAP method. Xavier *et al.* (2016) also showed the result that banana (*Musa acuminata* L. AAA group cv. Grand Naine) which treated with methyl jasmonate and salicylic acid could faster induce the production of phenolic compound. The result also showed that 2.5 mM salicylic acid

treatment had double accumulation of phenolic compounds from 31.20 to 68.75 mg/g of dry leaf within 24h. Phenolic compounds have been reported to stimulate some biological effects, included antibacterial and antioxidant activity (Mokbel and Hashinaga, 2005; Fawole *et al*., 2012) such as banana, guava, papaya, tea and coffee (Castillo *et al.,* 2002; Thaipong *et al.,* 2006; Chan *et al.*, 2007). To compare the application of salicylic acid, dipping method and fine-bubble technique were used. The fine-bubble technique showed the greatest result compare to dipping method. Both physiological quality and bioactive compound also showed the greatest result in the treatment using fine-bubble technique. Fine bubble technique has been used in many application ways such as ozone fine-bubble treatment. It showed the effective result in remove the residual of fenitrothion and this can apply for continuous bubbling ozone fine-bubble technique that more effective than the previous one (Akimi, 2017). The previous study was conducted by Pongprasert and Srilaong (2014) used 1-MCP micro and nano-sized bubbles to delay banana ripening by dipping and spraying. Our study has been used fine-bubble technique with salicylic acid application. Salicylic acid is adsorbed at the interface with hydrophobic group towards the gas side. On still surface, organic substrate distributes uniformly over the surface at equilibrium condition. However, on moving surface, it distributes non-uniformly, which leads to non uniform surface condition. Accumulation of surfactant starts from the rear side of the bubble and smaller surface tension force with surfactant accumulated (Akimi, 2017). That's the reason why salicylic acid can easily to absorb at fine-bubble surface.

In conclusion, the research indicated that the salicylic treatment with fine-bubble technique for 15 minutes is the most effective treatment in physical quality, certain chemical quality and bioactive compounds in banana (*Musa* AAA).

Acknowledgement

We would like to thank the faculty of Industrial Education and Technology King Mongkut's Institute of Technology for financial support.

References

Aghdam, M. S., Motallebiazar, A., Mostofi, Y., Moghaddam, Y. J. F. and Ghasemnezhad, M. (2011). Methyl salicylate affects the quality of Hayward kiwifruit during storage at low temperature. Agricultural science. 3:149-156.

Akimi, S. (2017). Fundamentals and Applications of Micro/Nano Bubbles. 1st International Symposium on Application of High voltage, Plasmas & Micro/Nano Bubbles to Agriculture and Aquaculture, pp.43.

Alothman, M., Bhat, R. and Karim, A. A. (2009). Antioxidant capacity and phenolic content of selected tropical fruits from Malaysia, extracted with different solvents. Food Chemistry. 115:785-788.

Arberg, B. (1981). Plant growth regulators: monosubstituted benzoic acid. Swedish Journal of Agricultural Research. 11:93-105.
Association of Office Analytical Chemists (1990). Official Methods of Analysis, 15th ed. George Banta, Washington, DC.
Benzie, I. F. F. and Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of "Antioxidant Power": FRAP Assay. Analytical Biochemistry. 239:76-76.
Bolin, H. R. and Huxsoll, C. C. (1991). Control of minimally processed carrot (*Daucus carota*) surface discoloration caused by abrasion peeling. Journal of Food Science. 56:416-418.
Brand-Williams, W., Cuvelier, M. E. and Berset, C. (1995). Use of free radical method to evaluate antioxidant activity. Lebensmittel Wissenschaft and Technologie. 28:25-30.
Castillo, M. D. D., Ames, J. M. and Gordon, M. H. (2002). Effect of roasting on the antioxidant activity of coffee brews. Journal of Agricultural and Food Chemistry. 50:3698-3703.
Chan, E. W. C., Lim, Y. Y. and Chew, Y. L. (2007). Antioxidant activity of Camellia sinensis leaves and tea from a lowland plantation in Malaysia. Food Chemistry. 102:1214-1222.
Darsini, D. T. P., Maheshu, V., Vishnupriya, M. and Sasikumar, J. M. (2012). In vitro antioxidant activity of banana (*Musa* spp. ABB cv. Pisang Awak). Indian Journal of Biochemical and Biophysics. 49:124-129.
Fan, X., Mattheis, J. P. and Fellman J. K. (1996). Inhibition of apple fruit 1-aminocyclopropane-1-carboxylic acid oxidase activity and respiration by acetylsalicylic acid. Journal of Plant Physiology. 149:469-471.
Fawole, O. A., Makunga, N. P. and Opara, U. L. (2012). Antibacterial, antioxidant and tyrosinase-inhibition activities of pomegranate fruit peel methanolic extract. BMC Complementary and Alternative Medicine. 12:200-218.
Hayat, S., Fariduddin, Q., Ali, B. and Ahmad, A. (2005). Effect of salicylic acid on growth and enzyme activities of wheat seedlings. Acta Agronomica Hungarica. 53:433-437.
Hooper, L. and Cassidy, A. (2006). A review of the health care potential of bioactive compounds. Journal of the Science of Food and Agriculture 86:1805-1813.
Junmatong, C., Faiyueb, B., Rotarayanonta, S., Uthaibutra, J., Boonyakiat, D. and Saengnil, K. (2015). Cold storage in salicylic acid increases enzymatic and non-enzymatic antioxidants of Nam Dok Mai No. 4 mango fruit. ScienceAsia 41:12-21.
Kanazawa, K. and Sakakibara, H. (2000). High content of dopamine, a strong antioxidant, in Cavendish banana. Journal of Agricultural and Food Chemistry. 48:844-848.
Kang, G. Z., Wang, G. C. and Sun, G. C. (2003). Participation of H202 in enhancement of cold chilling by salicylic acid in banana seedlings. Acta Botanica Sinica. 45:567-573.
Knorzer, O. C., Lederer, B., Durner, J. and Boger, P. (1999). Antioxidative defense activation in soybean cells. Physiol. Planta 107:294-302.
Leslie, C. A. and Romani, R. J. (1988) Inhibition of ethylene biosynthesis by Salicylic acid. Plant Physiology 88:833-837.
Li, L. P. and Han, T. (1999). The effects of salicylic acid in the storage of peach. Food Science. 7:61-63.
Office of Agricultural Ecoomics (OAE) Thailand (2012). Agricultural Statistics of Thailand 2012. Ministry for Agricultural and Cooperatives. Bangkok. 176 p.
Ozeker, E. (2005). Salicylic acid and its effects on plants. E.U. Faculty of Agriculture Journal. 42:213-223.

Mokbel, M. S. and Hashinaga, F. (2005). Antibacterial and antioxidant activities of banana (*Musa*, AAA cv. Cavendish) fruits peel. American Journal of Biochemistry and Biotechnology. 1:125-131.

Pongprasert, N. and Srilaong, V. (2014). A Novel Technique Using 1-MCP Microbubbles for Delaying Postharvest Ripening of Banana Fruit. Postharvest Biology and Technology. 95:42-45.

Sayyari, M., Babalar, M., Kalantari, S., Martínez-Romero, D., Guillén, F., Serrano, M. and Valero, D. (2011). Vapour treatments with methyl salicylate or methyl jasmonate alleviated chilling injury and enhanced antioxidant potential during postharvest storage of pomegranates. Food Chemistry. 124:964-970.

Seymour, G. B., Thompson, A. K. and John, P. (1987). Inhibition of degreening in the peel of banana ripened at tropical temperatures. Annals of Applied Biology. 110:145-151.

Shafiee, M., Taghavi, T. S. and Babalar, M. (2010). Addition of salicylic acid to nutrient solution combined with postharvest treatments (hot water, salicylic acid, and calcium dipping) improved postharvest fruit quality of strawberry. Scientia Horticulturae. 124:40-45.

Someya, S., Yoshiki, Y. and Okubo, K. (2002). Antioxidant compounds from banana (*Musa* Cavendish). Food Chemistry. 79:351-354.

Srivastava, M. K. and Dwivedi, U. N. (2000). Delayed ripening of banana fruit by salicylic acid. Plant Science. 158:87-96.

Sulaiman, S. F., Yusoff, N. A. M., Eldeen, I. M., Seow, E. M., Sajak, A. A. B., Supriatno and Ooi, K. L. (2011). Correlation between total phenolic and mineral contents with antioxidant activity of eight Malaysian bananas (*Musa* sp.). Journal of Food Composition and Analysis. 24:1-10.

Supapvanich, P., Phonpakdee, R. and Wongsuwan, P. (2015). Chilling injury alleviation and quality maintenance of lemon basil by preharvest salicylic acid treatment. Journal of Food and Agriculture. 27:801-807.

Suwanna B., Varich. S., Hathaitip N. and Sirichai, K. (2007). Effect of salicylic acid on postharvest quality of mango 'Namdokmai'. Agriculture Science Journal. 38:78-81.

Thaipong, K., Boonprakob, U., Crosby, K., Zevallos, L. C. and Byrne, D. H. (2006). Comparison of ABTS, DPPH, FRAP, and ORAC assays for estimating antioxidant activity from guava fruit extracts. Journal of Food Composition and Analysis. 19:669-675.

Todsapong, P. and Pookpong, L. (2016). Application of advanced oxidation process combined with a fine-bubble technology to reduce *Escherichia coli* O157: H7 contaminated on chili. (Master Thesis). Thammasat University, Thailand.

Valero, D., Diaz-Mula, H. M., Zapata, P. J., Castillo, S., Guillen, F., Martinez-Romero, D. and Serrano, M. (2011). Postharvest treatments with salicylic acid, acetylsalicylic acid or oxalic acid delayed ripening and enhanced bioactive compounds and antioxidant capacity in sweet cherry. Journal of Agriculture and Food Chemistry. 59:5483-5489.

von Loesecke, H. W. (1950). Bananas: Chemistry. *In*: Bananas Chemistry, Physiology, Technology. Interscience Publishers, New York, USA, pp.189.

Wang, L., Chena, S., Kong, W., Li, S. and Archbold, D. (2006): Salicylic acid pretreatment alleviates chilling injury and affects the antioxidant system and heat shock proteins of peaches during cold storage. Postharvest Biology and Technology. 41:244-251.

Wei, Y., Liu, Z., Su, Y., Liu, D. and Ye, X. (2011). Effect of salicylic acid treatment on postharvest quality, antioxidant activities and free polyamines of asparagus. Journal of the Science of Food and Agriculture. 76:126-132.

Xavier, E. N., Doumbia, M. L., Traore, S., Konan, Y. K. F., Kone, M. and Kouakou, T. H. (2016). Estimation of total phenolic compounds in treated leaves with methyl jasmonate and salicylic acid of banana (*Musa acuminata* L. AAA group cv. Grand Naine) susceptible to the Black Leaf Streak Disease. Agricultural Science Research Journal. 6:175-181.

Yalpani, N., Enyedi, A. J., Leon, J. and Raskin, I. (1994). Ultraviolet light and ozone stimulate accumulation of salicylic acid pathogenesis related proteins and virus resistance in tobacco. Planta. 19:372-376.

Yu, T., Jishuang, C., Rongle, C., Bin, H., Donghong, L. and Xiaodong, Z. (2007). Biocontrol of blue and gray mold diseases of pear fruit by integration of antagonistic yeast with salicylic acid. International Journal of Food Microbiology. 116:339-345.

Zeng, K. F., Cao, J. K. and Jiang, W. B. (2006). Enhancing disease resistance in harvest mango (*Mangifera indica* L. cv. Matisu) fruit by salicylic acid. Journal of the Science of Food and Agriculture. 86:694-698.

Zhishen, J., Mengcheng, T. and Jianming, W. (1999). The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radical. Food Chemistry. 64:555-559.

(Received: 2 September 2018, accepted: 30 October 2018)