Chapter 5

Coating 'Queen' Pineapple Fruit by Antimicrobial Films at Low Temperature

5.1 Abstract

The incorporation between low temperature and antimicrobial coating for prolong postharvest storage life for 'Queen' pineapple cv. Ninhbinh was study. Three types of antimicrobial coating solutions were used in this study: chitosan/methylcellulose (C/MC) solution, C/MC solution incorporating vanillin (C/MC-vanillin) and C/MC solution incorporating carbendazim (C/MC-carbendazim). The pineapples uncoated and coated with different film solutions were stored at 12°C, 85%RH during 30 days and were determined on weight loss, total soluble solids (TSS), titratable acidity (TA), pH, flesh firmness, flesh color, ethanol content and microbial growth. Results show that the coating delayed the changes in total soluble solids, flesh firmness, flesh color and ethanol content. Especially, pineapple fruit coated with C/MC-carbendazim showed the lowest value on ethanol content and the highest value on TSS, firmness and L*, which were 16.73% Brix; 8.78 (N) and 71.18, respectively at the 30th day storage when compared with those in control. Significantly, both of three coating solutions provided microbial growth inhibitory effects on surface fruit. C/MC-carbendazim solution was more efficient than C/MC-vanillin and C/MC in reducing the amount of total aerobic counts (TAC) and the amount of TAC was less than ten times when compared with control throughout storage. However, unexpectedly, coating pineapple fruit by C/MC or C/MC-vanillin was not reduce the weight loss of fruit while no significant change in weight loss was found for pineapple uncoated and coated with C/MC-carbendazim. Storage condition at 12°C with 85%RH combined with C/MC-carbendazim coating are able to extend shelf life of pineapple fruit cv. Ninhbinh with consumers acceptable quality.

5.2 Introduction

In order to extend the postharvest life for fruit products, chitosan which is an antimicrobial film has been used. Recently, the antimicrobial activity of chitosan/methylcellulose (C/MC) film has been developed. Adding benzoate and sorbate into C/MC films to improve antimicrobial activity has also been reported (Chen *et al.*, 1996). Essential plant oils, including anise, basil, coriander, oregano, garlic oil, potassium sorbate and bacteriocin (nisin) into chitosan films and C/MC films as an supplemental antimicrobial activity agents (Pranoto *et al.*, 2005; Sangsuwan *et al.*, 2012; Zivanovic *et al.*, 2005). Carbendazim is a widely used broad-spectrum benzimidazole fungicide that plays a very important role in plant disease to control fungi and diseases of plants and fruits in postharvest food storage. In order to maintain fresh quality of fruits, postharvest treatment need to be applied, including coating. Several studies have been done and indicated that chitosan coating had the potential to improve the quality maintenance, prolong storage life and decrease the decay of strawberry (El-Ghaouth *et al.*, 1992a; Ribeiro *et al.*, 2007), cucumbers (El-Ghaouth *et al.*, 1991), longan (Jiang et al., 2002), litchi (Jiang et al., 2005), mango fruit (Abbasi *et al.*, 2009) and banana fruit (Malmiri *et al.*, 2011). Application of chitosan-based coating incorporated with citric acid and potassium sorbate to delay the decay of fresh longan fruit was reported (Apai, 2009b). Maintaining and extending the shelf-life of fresh-cut pineapple by wrapping with chitosan/methylcellulose and vanillin films was examined (Sangsuwan *et al.*, 2008b).

As far as we know, there is a little available scientific literature about the use of C/MC incorporated antimicrobial agent for maintaining and extending the shelf life of fresh pineapple fruit. Therefore, the aim of this study was to determine the effect of chitosan/methylcellulose film incorporated with carbendazim and vanillin coating on the weight loss of fruit, the change in the ethanol content, microbial growth and physical-chemical properties of 'Queen' pineapple fruit during storage at 12°C and 85% relative humidity.

5.3 Materials and Methods

5.3.1 Film-solutions preparation

Chitosan with a degree of deacetylation of 90% and purity >99.75% (Bannawach Bio-line Co. Ltd., Thailand) was prepared by dissolving 1.5 g of chitosan in 100 mL of 1% acetic acid solution. One gram of methylcellulose (viscosity 10-25 mP.s, Methocel # 64605) was dissolved in 100 mL of ethanol: water (1:3). Solutions of chitosan and methylcellulose were then mixed in a beaker with a stirrer. One gram of polyethylene glycol (PEG) 400 was used as a plasticizer. Vanillin, 0.9g (Sigma, St. Louis, USA) was incorporated after the temperature of the solution reached its melting point (83°C) (Sangsuwan *et al.*, 2008a). In another way, carbendazim (active ingredient, BaSF Co., Thailand), 1.6 g/100 g solids of C/MC, was blended into the C/MC film-solution. These solutions were then filtered, degassed and conditioned at 25±2^{o}C.

5.3.2 Raw materials

Pineapple fruits (*Ananas comosus* L.) cv. Queen which planted in a private farm at Tam Diep district, Ninhbinh province, Vietnam were used for the research. In the main season (April & May in 2010 and 2011), after 140 – 145 days from full bloom, pineapple fruit cv. Ninhbinh were selected for uniformity in sharp, size and similarly in maturity stage 2 (10-25% yellow color of fruit skin). The pineapple crown leaves were cut with the crown length about 1cm from the top of fruit. After that, the pineapples were washed by water and drained for 10 – 15 minutes.

Fruits were dipped in different film solutions (C/MC film, C/MC-vanillin film and C/MC-carbendazim film) for 5 minutes. Fruits were dipped in distilled water as control. Following treatment, pineapple fruits were dried for 2h at 25°C and then stored at 12°C and 85 ± 2% relative humidity for 30 days. For each treatment, three replicated were used. Weight loss, total soluble solids (TSS), titratable acidity (TA), firmness, color, ethanol content and microbial growth on 'Queen' pineapple fruits during 30 days storage were determined every 5 days.

5.3.3 Light microscopic changes on surface and cross-section of pineapple

The pineapples after coating with C/MC, C/MC incorporated with vanillin and carbendazim were dried at ambient temperature 1 day. The pineapples were then observed the fruit surface and cross-section at 25°C. Changes on the surface and cross-section structure of the peel pineapple uncoated and coated was observed with the light microscope (Olympus, Japan) at the range of magnifications from 100 to 400.

5.3.4 Analysis of physical properties of pineapple

Determination of flesh color and flesh firmness of the pineapple uncoated and coated had been written in chapter 3: 3.3.4.

5.3.5 Analysis of physical-chemical properties of pineapple

Determination of total soluble solids (TSS), titratable acidity (TA), and ethanol content of pineapple fruit had been written in chapter 3: 3.3.5.

5.3.6 Microbial analysis

Changes in the microbial population across the whole surface of each fruit during storage at different temperatures were determined in line with Parish *et al.* (2001) and Eni *et al.* (2010) had been written in chapter 3: 3.3.6.

5.3.7 Analysis of carbendazim residue

After 30 days storage at 12°C, 85% relative humidity, the pineapples coated with chitosan/methylcellulose incorporated with carbendazim (1.6 g/100 g solids of C/MC) were analyzed the carbendazim residue at the Southern Pesticide Control and Testing Center - Plant Protection Department – pasture Institute, Ho Chi Minh City, Vietnam.

5.3.8 Sensory evaluation

The pineapple fruits coated with different coating solutions and stored at 10°C were sensory evaluated at the 10th, 20th and 30th day storage. Fruit samples were removed from refrigerator before serving to allow them to equilibrate to room temperature. The fruits were hand peeled and transversely cut into three slices from each fruit and each slice was cut into 2 - 4 segments. Samples were labeled with three-digit random codes and placed in small white plastic cups. A 15-trained-members panel of both genders and of ages from 20 – 60 will be selected to evaluate the pineapple fruit quality**.** The acceptability of color, odor, flavor, taste, texture and overall quality were evaluated using a nine-point hedonic scale where 9=like extremely, 8=like very much, 7=like moderately, 6=like slightly, 5=neither like nor dislike, 4=dislike slightly, 3=dislike moderately, 2=dislike very much, 1=dislike extremely. The variability of acceptance was analyzed by ANOVA and Tukey'sb test ($p<0.05$).

5.3.9 Statistical analysis

Data were initially evaluated using analysis of variance (ANOVA) and Duncan's Multiple Range Test (SPSS 16.0 software program).

5.4 Results and Discussion

Pineapple fruit cv. Ninhbinh were used in this study had the fruit weight, total soluble solids, titratable acidity and pH in the range of 920-990g, 17.6-18.8°Brix, 0.79-0.82% and 4.0-4.2, respectively. The flesh fruit was crispy, high firmness and light yellow in color. The number of fruitlet was in the range of 110-130 fruitlet/fruit.

Regarding coating solutions, the chitosan/methylcellulose solution was colorless and transparent while C/MC solution incorporated with carbendazim was more opaque and light white, and C/MC with vanillin was transparent and bright yellow color. There was no flavor for the pineapples were coated with C/MC and C/MC with carbendazim while the fruit still kept a vanillin flavor until the end of the storage.

5.4.1 Light microscopic changes on the surface and cross-section of the peel pineapple

There was the change on the surface of the peel pineapple between uncoated and coated. After coating, fruit surfaces became shinier (Figure 5.1). The surface of the peel fruits without coating was non-smooth and contented many peel fiber while the coated fruit became more smooth and homogenous and also gain a uniform cover even at the fruit holes (Figure 5.1, 5.2). However, there was not significant difference in the fruit surface after coated with C/MC, C/MC-carbendazim or C/MC-vanillin (data not show). Light microscopic changes on cross-section of fruit were presented in Figure 5.3. Thickness of the peel fruit was in the range of 0.14 to 0.38 mm depended on the peel fruit areas. According to Figure 5.3, the peel color of the cross-section areas became lighter and the skin thickness was thicker after coating; but the change in skin thickness was a little.

Figure 5.1 Light microscopic changes on the surface of the peel pineapple uncoated and coated (200x)

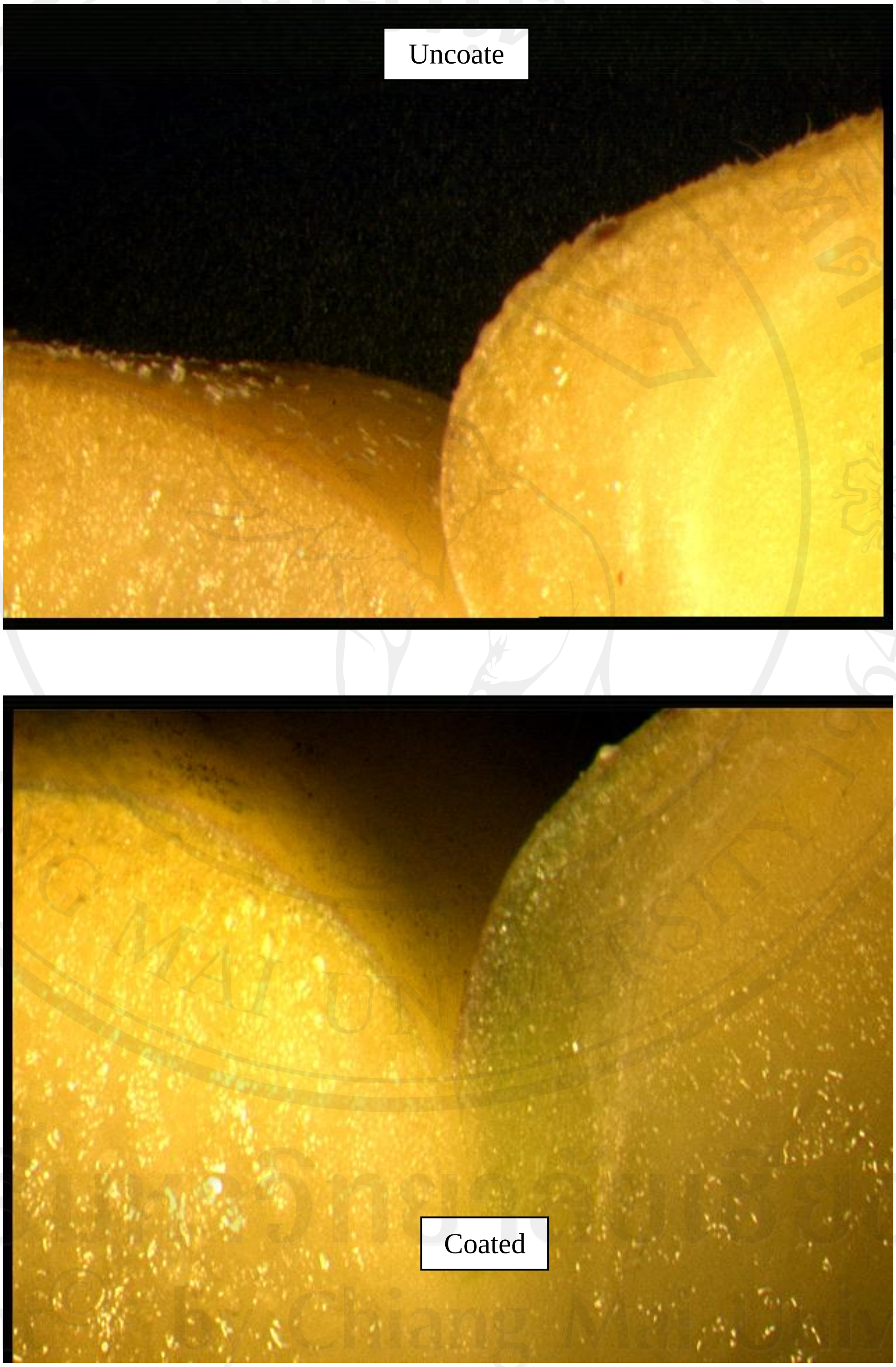


Figure 5.2 Light microscopic changes on the surface and cross-section of the peel pineapple uncoated and coated (200x)

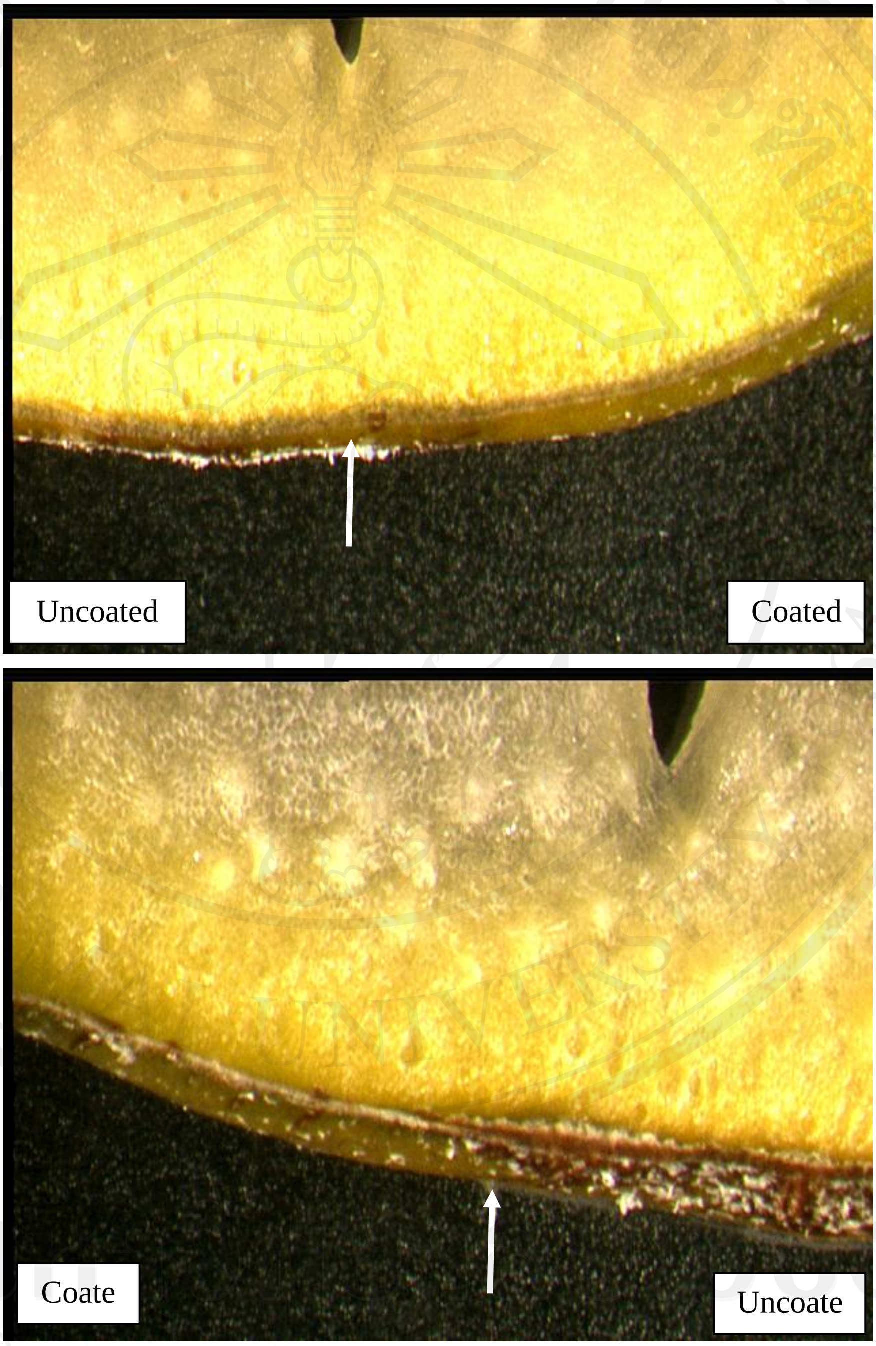


Figure 5.3 Light microscopic changes on the cross-section of the peel pineapple uncoated and coated (400x)

5.4.2 Physical properties of pineapple fruits

5.4.2.1 Weight loss

The change of percentage weight loss and TSS value of pineapple fruits coated with different antimicrobial films were showed in Fig.5.4. Coating processing was expected to decrease the weight loss of pineapple fruits during storage. However, at low temperature (12°C) and high relative humidity (85% RH) condition, C/MC, C/MC-carbendazim, C/MC-vanillin coating materials did not significantly alter the weight loss of the fruits. Results showed that the weight loss of pineapple fruit increased with storage time in all treatments and the smallest loss of weight was obtained with uncoated fruit and C/MC-carbendazim coating (Figure 5.4).

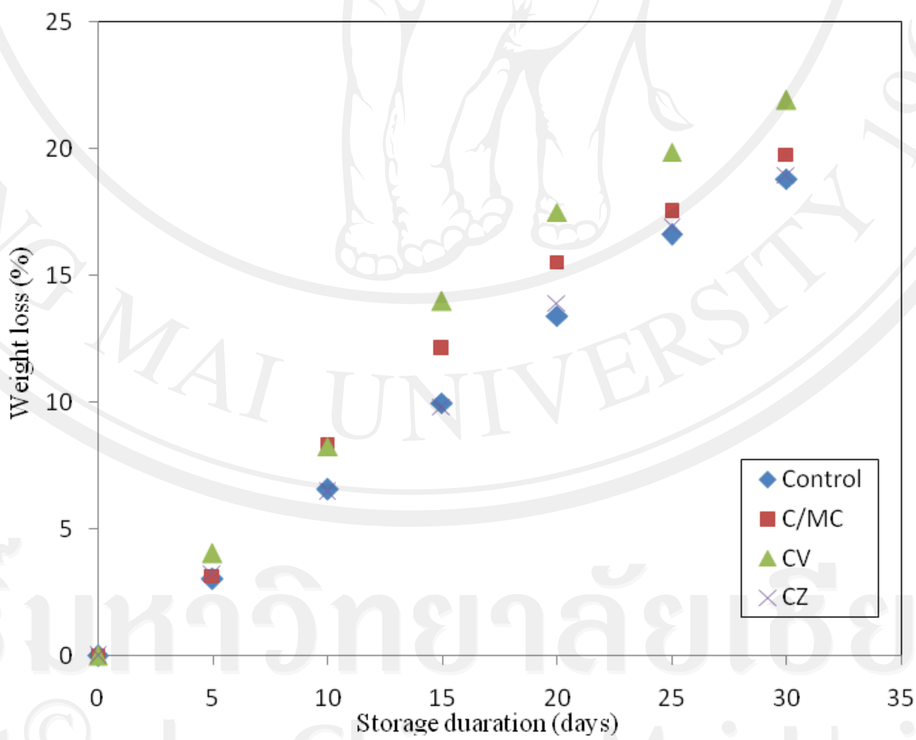


Figure 5.4. Change in weight loss of Queen pineapple coated with different antimicrobial coating solutions: C/MC, C/MC-vanillin (CV) and C/MC-carbendazim (CZ) at 12 ± 1°C and 85 ± 2% RH.

There was no significant difference on weight loss between pineapple fruit uncoated and coated with C/MC-carbendazim solution, which was 18.8 and 18.98% on 30th day storage, respectively. Coating the fruit by C/MC film solution showed a little higher on weight loss during storage. In another way, presence of vanillin in C/MC solution increased the weight loss of fruit. The highest value of weight loss was occurred in fruit coated with C/MC-vanillin solution, which was 21.91% on 30th day storage, followed by C/MC and C/MC-carbendazim as compared with non-coated fruit. It was found that as the storage time was prolonged, the weight loss percentage was also increased and the maximum weight loss was recorded at the end of storage.

Our results also are in accordance with the reported data and the trend on weight loss of apricot fruit stored at 0°C, 80%RH and longan fruit stored at 5°C, 85%RH (Apai *et al.*, 2008; Ghasemnezhad *et al.*, 2010). However, accoding to Nimitkeatkai *et al*. (2006) and Hu *et al*. (2011), pineapple fruit treated with Sta-fresh 7055 wax and then stored at 7°C and 10°C, 90-95% RH was significantly delayed the change in weight loss compared to the control fruit.

5.4.2.2 Flesh color

Flesh color is one of the major properties of pineapple fruit during storage at low temperature. The change of flesh color (L* and hue angle) of pineapple fruit cv. Queen with and without coating maintained at 12°C, 85%RH during 30 days was illustrated in Fig 5.5. The L* parameter was used to describe the darkness to whiteness color with the ranged from 0 to 100. Hue angle parameter showed the actual color that altered from red-yellow to yellow and yellowish-green color when hue angle increase from 49° to 90° and 135°, respectively. The present of carbendazim in C/MC coating solution affected significantly on the L* value profile of flesh pineapple while there was no significantly different in L* value of fruit uncoated and coated with C/MC and C/MC-vanillin (Figure 5.5a). The L* value increased slightly on the first 5 days and then decreased at the later stage in all treatments. At 30th storage, the fruit coated with C/MC-carbendazim still kept light-yellow flesh color, which was 71.18 in L* value, while fruits uncoated and coated with C/MC and C/MC-vanillin became less lighter, which were 64.8, 64.1 and 65.1, respectively. In addition, the flesh color of pineapple fruit was also evaluated with hue angle value.

Figure 5.5b described the change in hue angle value or actual color of the pineapple fruit with and without coating that was kept at 12°C, 85%RH. With all treatments, flesh color of the fruit was yellow (hue angle value = 45-90°), but there was a difference in the level of yellow color. At the end storage period, the flesh color of pineapple uncoated and coated with C/MC and C/MC-carbendazim still kept in slight yellow color, which was in the range of 81.65-82.70° in hue angle, while flesh color of pineapple coated with C/MC-vanillin tended to orange-yellow color, which was 78.84°. This result agrees with Sangsuwan *et al*. (2008b) who reported that vanillin film was more effective in flesh color of fresh-cut pineapple during storage at 10°C. The decreased dramatically in hue angle value of pineapple fruit coated C/MC-vanillin solution may be concern on vanillin migration from the solution to fruit surface during storage (Sangsuwan *et al.*, 2008b). Moreover, there was no significant difference on the peel color of Queen pineapple uncoated and coated with different antimicrobial coating (Figure 5.6) while the flesh color turned to more yellow for fruits uncoated and coated by C/MC and C/MC incorporated with vanillin solutions (Figure 5.7).

5.4.2.3 Fruit firmness

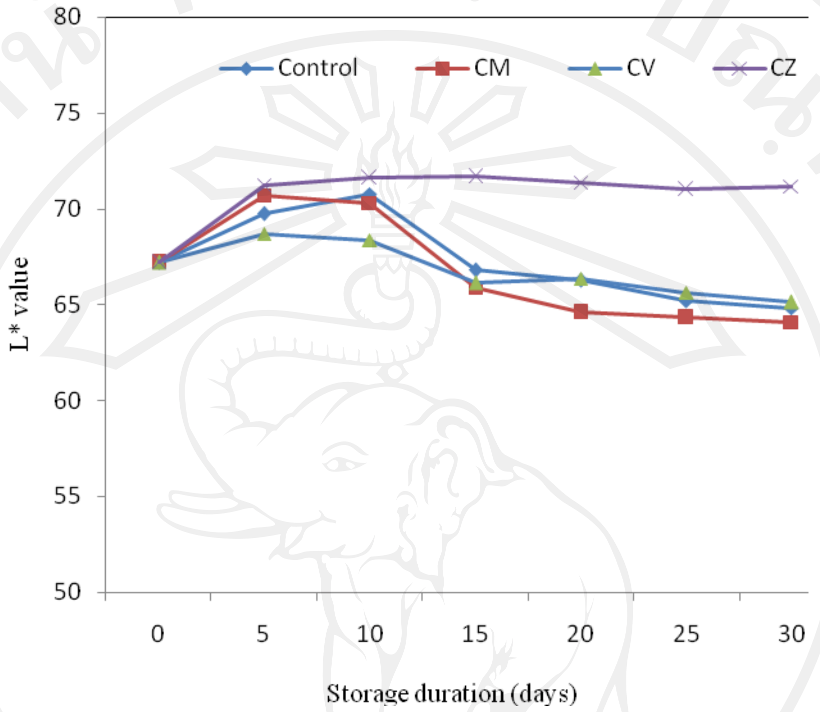
Loss of firmness is one of the main factors limiting quality and the postharvest shelf-life of fruits and vegetable. Figure 5.3 illustrated the changes in flesh firmness of Queen pineapple fruit being stored at 12 ± 1°C, 85 ± 2% RH and coated with different antimicrobial coating solutions as C/MC, C/MC-carbendazim (CZ) and C/MC-vanillin (CV). The firmness decresed with increased storage time in all treatments. The initial firmness value of 15.95 (N) on the first day was dropped to the range of 6.95-8.78 (N) on the 30th day of storage. The decrease in firmness of pineapple flesh might relate to the direct result of cell waff modification during fruit ripening that in turned decreased cells rigidity and eventually generated softness (Beaulier and Gorny, 2001).

Accoding to Figure 5.8, there was no significantly different in firmness value of fruit uncoated and coated with C/MC and C/MC-vanillin. However, expectedly, the present of carbendazim in C/MC solution delayed the decline of firmness. After 30 days storage, the pineapple fruit coated with C/MC-carbendazim achieved the highest value of firmness, which was 8.78 (N) as compared with non-coated fruit and coated by other antimicrobial coating solutions. Our results also are similar with the reported data and the trend on firmness of Smooth Cayenne (Comte de Paris) fruit treated by wax (Sta-Fresh 2952 and Sta-Fresh 7055) and stored at 7°C, 90% RH (Hu *et al.*, 2011). These authors found that pineapple fruit coated by the wax solutions delayed the change in firmness when compared with that in control.

5.4.3 Physical-chemical properties of pineapple fruits

5.4.3.1 Total soluble solids, titratable acidity and pH

Total soluble solids (TSS) content in all treatments increased slightly during the first 15 days and then decreased in the last 10 days (Figure 5.9). Higher TSS values were recorded for fruits coated and the highest TSS value was occurred in fruit coated with C/MC-carbendazim, which was 16.73 (%). The TSS values were 15.3 and 13.9 (%) for control and waxing pineapple fruit published by (Hu *et al.*, 2011). Thus, coating fruit by C/MC incorporated with carbendazim might be a useful technique to remain the sweet taste during cold storage. Increasing the TSS values at the first stage might be concern on metabolism processes, ripening stage and water loss of fruit during storage. By contrast, fruit fermentation by microorganism is a main cause that relates to the decrease the TSS at the last stage. On another hand, coating pineapple fruit by the antimicrobial solutions did not significantly affect on TA and pH values. After 30 days storage, the TA and pH values were in the range of 0.69-0.74 and 3.4-3.7, respectively (data not show).


80
75
70
65
60
55
50
Control
CM
CV
CZ
L* value
0
5
10
15
20
25
30
Storage duration (days)

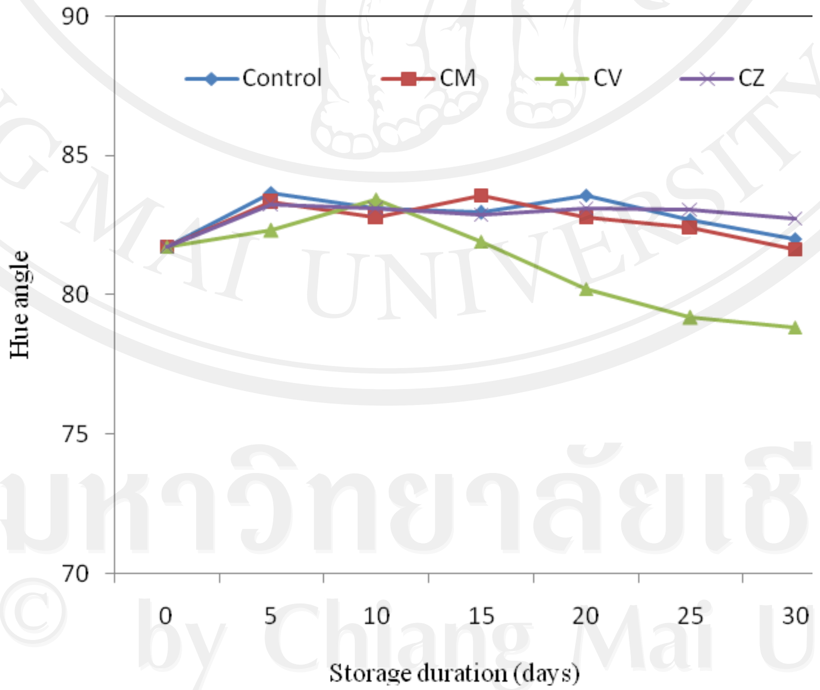

90
85
80
75
70
Control
CM
CV
CZ
Hue angle
0
5
10
15
20
25
30
Storage duration (days)

Figure 5.5. Change in flesh color of Queen pineapple coated with different antimicrobial coating solutions: C/MC, C/MC-vanillin (CV) and C/MC-carbendazim (CZ) at 12 ± 1°C and 85 ± 2% RH.

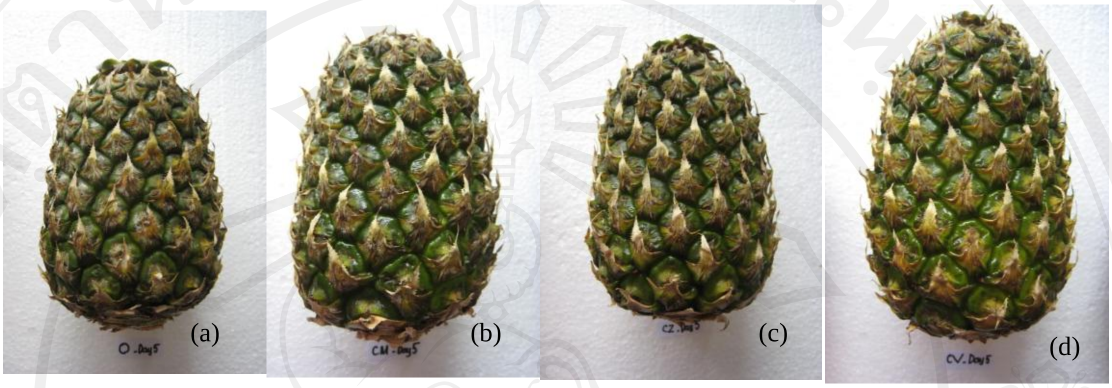


Figure 5.6 Peel color of Queen pineapple coated with different antimicrobial coating solutions: (a) Control, (b) C/MC, (c) C/MC-carbendazim and (d) C/MC-vanillin at 12 ± 1°C and 85 ± 2% RH at the 5th day storage.

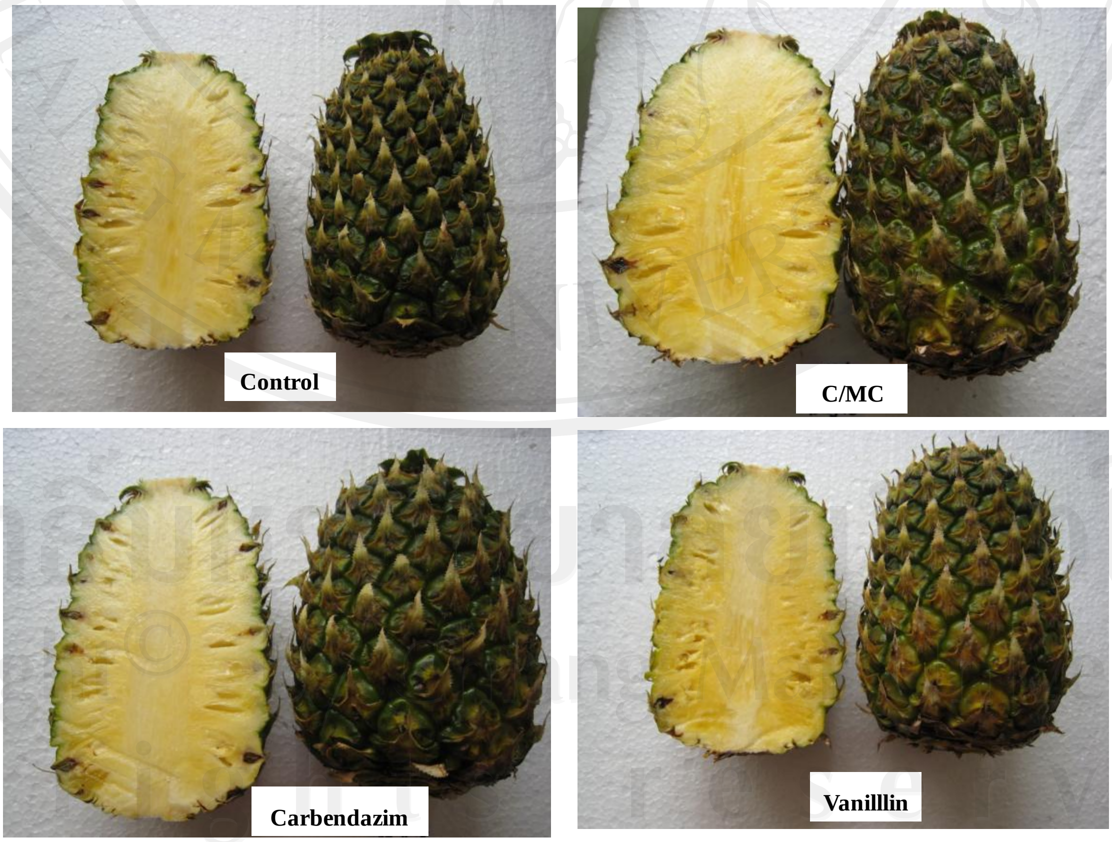


Figure 5.7 Peel and flesh color of Queen pineapple coated with different antimicrobial coating solutions: Control, C/MC, C/MC-carbendazim and C/MC-vanillin at 12 ± 1°C and 85% RH at the 15th day storage.

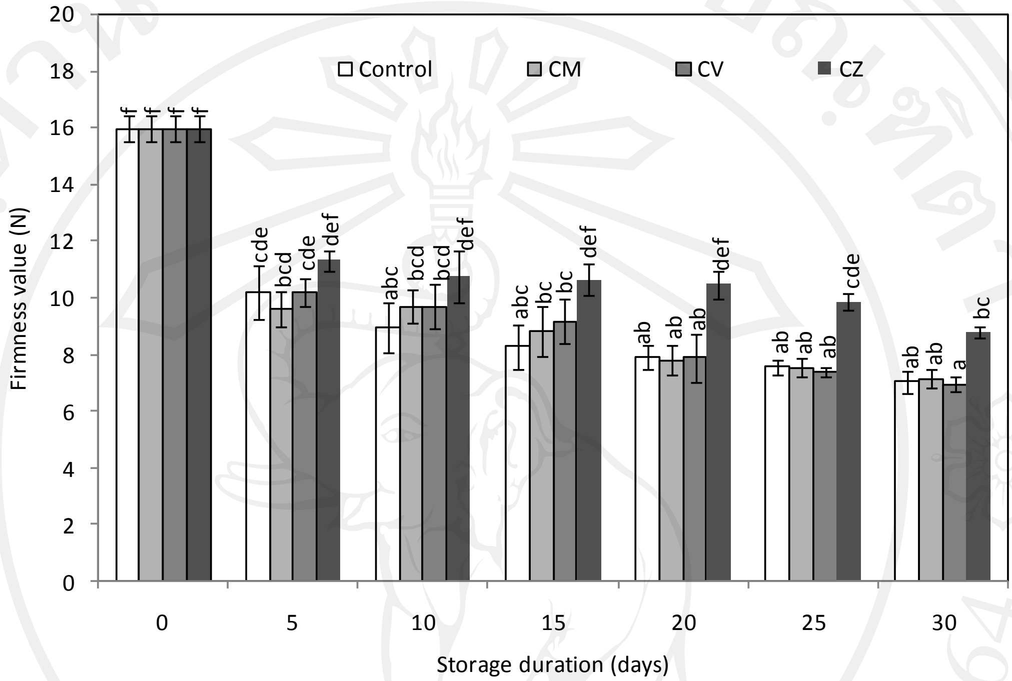


Figure 5.8 Change in flesh firmness of Queen pineapple coated with different antimicrobial coating solutions: C/MC, C/MC-vanillin (CV) and C/MC-carbendazim (CZ) at 12 ± 1°C and 85 ± 2% RH.

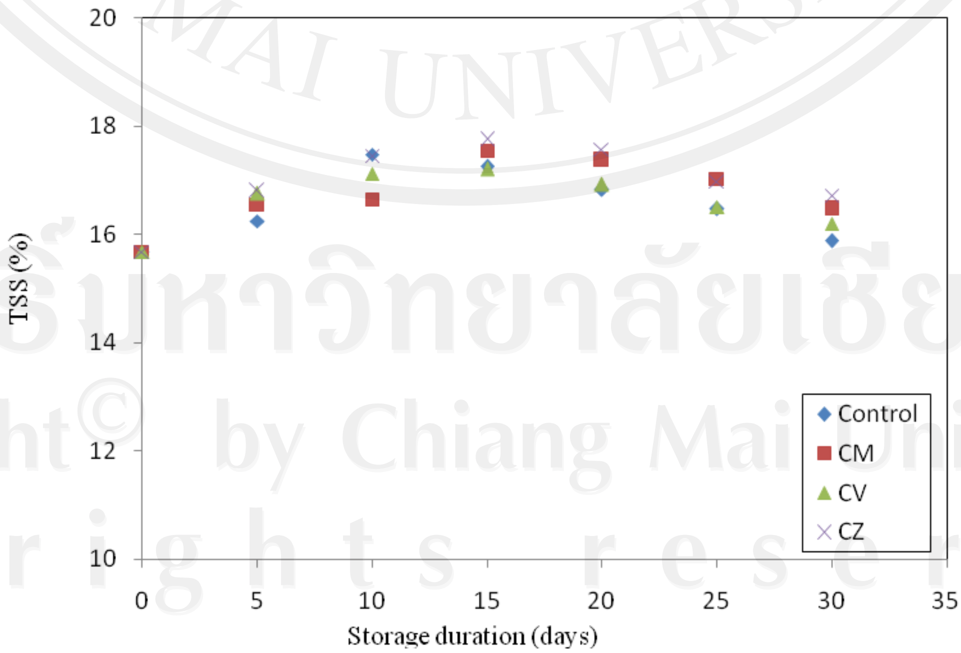


Figure 5.9 Change in TSS of Queen pineapple coated with different antimicrobial coating solutions.

5.4.3.2 Ethanol content

In general, fermentation from the fruit sugar and formation of ethanol are popular processing of pineapple fruit in ripening state. The statistical analysis showed that there was significant difference among the mean of ethanol contents in pineapple fruit in all treatments. During the storage time, the ethanol content of uncoated and coated fruits increased but the rate of increasing in the ethanol content was different with various treatments (Figure 5.10). During the first 15 days storage, as storage time increased, the ethanol level in pineapple fruits increased and the lowest value of the ethanol was recorded for uncoated pineapple. The fruit coated with C/MC-vanillin contained the highest value of the ethanol, which was 1.96 (µL/g) at the 15th day, following by fruit coated with C/MC-carbendazim and C/MC solution. Increasing in the ethanol content in fruit during storage might relate to the decrease of total soluble solid content in fruit and fermentation metabolism from microbial activities. Total soluble solid amount in Queen pineapple is very high (16.25-17.53°Brix) and it becomes an available nutrient sources for microbial growth and then increase the fermentation and ethanol producing.

However, in the last 15 days, the coating delayed the increasing of the ethanol content in fruit. It was found that the ethanol content in coated pineapple fruit was lower than that in uncoated fruit. Especially, the fruit coated with C/MC-carbendazim (CZ) remained the lowest amount of ethanol until the end of the storage, which was 1.12 (µL/g) as compared with non-coated fruit and other treatments. Higher ethanol content in control fruit and fruit coated by C/MC and vanillin solutions might be due to higher microbial count. Similar results on ethanol content of fresh-cut pineapple cv. Smooth Cayenne was reported by Sangsuwan *et al.,* (2008b), which were in the range of 0.35-0.6 (µL/g) on the 12th day storage at 10°C.

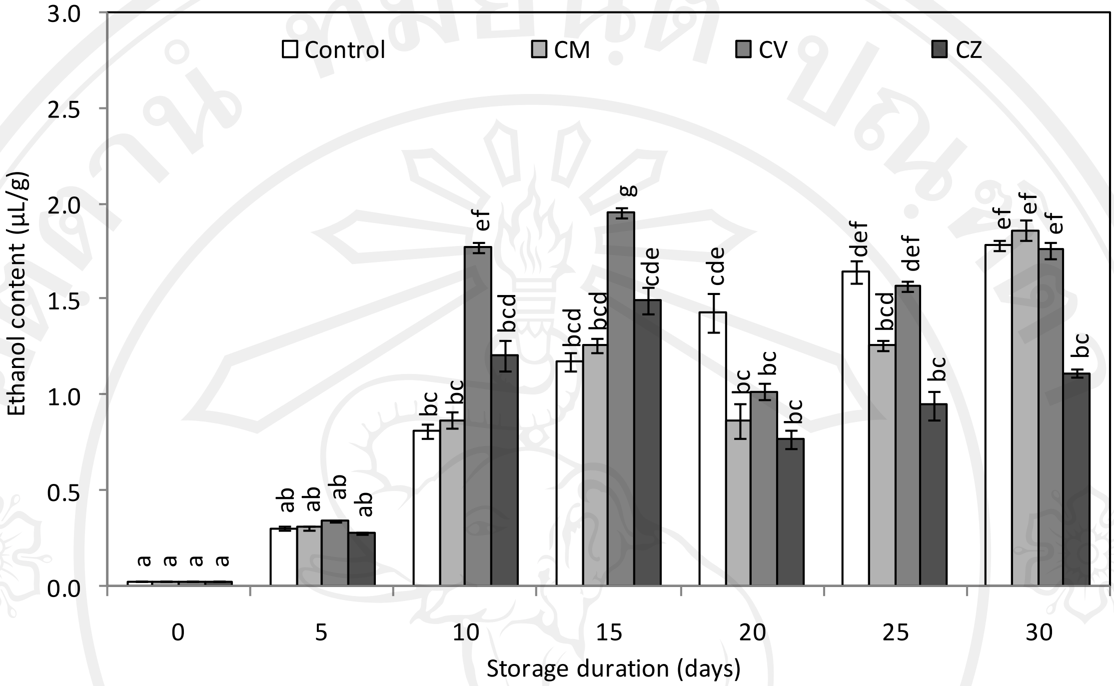


Figure 5.10 Change in ethanol content of Queen pineapple coated with different antimicrobial coating solutions at 12 ± 1°C and 85 ± 2% RH.

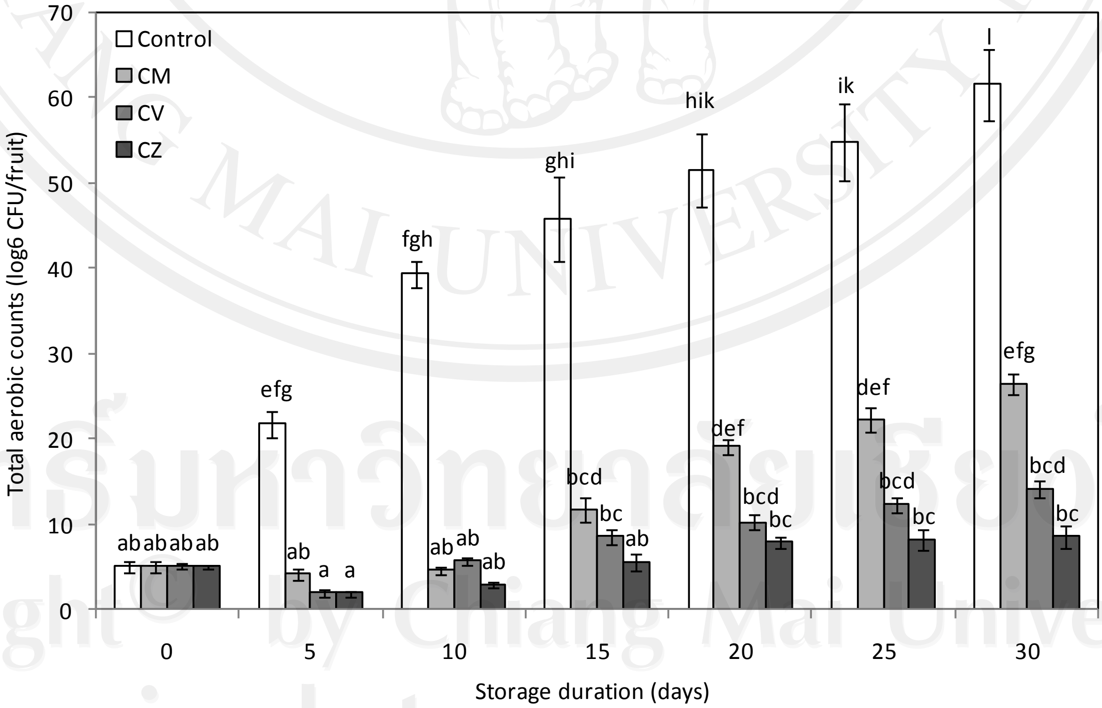


Figure 5.11 Change in total aerobic count on the surface- pineapple coated with different antimicrobial coating solutions: C/MC, C/MC-vanillin (CV) and C/MC-carbendazim (CZ) at 12 ± 1°C and 85 ± 2% RH.

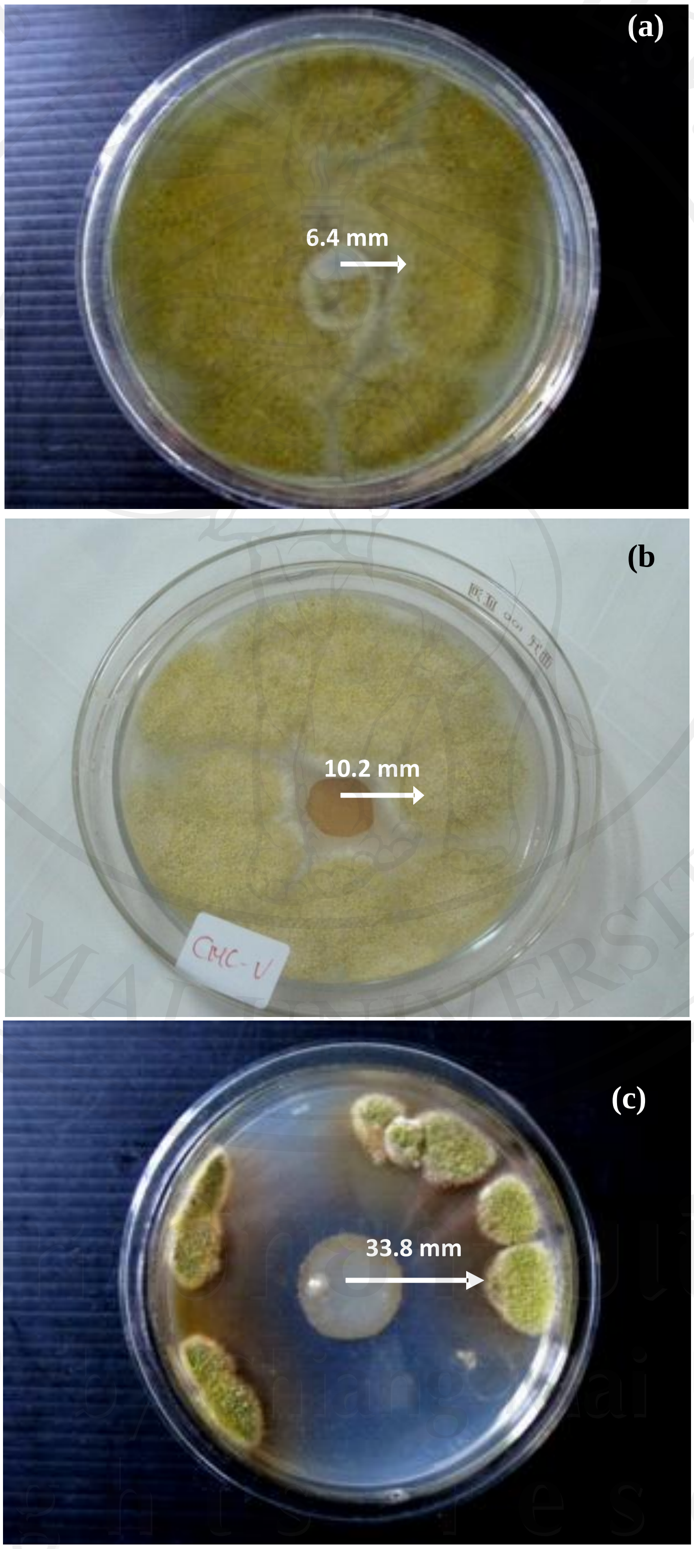


Figure 5.12 Inhibition effect of film solutions against *Aspergillus oryzae* on the surface- pineapple coated by C/MC, C/MC-vanillin (CV) and C/MC-carbendazim (CZ) at 12 ± 1°C and 85 ± 2% RH.

5.4.4 Microbial growth on pineapple fruit

Microorganism is an important factor that affect on the fruit quality after harvest. Fermentation, blackheart and spoilage are popular symptoms of pineapple fruit during storage. Thus, the amount of total aerobic counts (TAC) on the surface of pineapple fruits was determined for all treatments throughout storage. The effect of coating materials on total aerobic counts (TAC) on the fruit during 30 days storage was described in Figure 5.11. As expected, coating controlled significantly the microbial growth on pineapple surfaces. The antimicrobial effect of various coating solutions on fruit was different. It was found that the inhibitory effect on microbial growth of chitosan/methylcellulose incorporated with carbendazim solution was highest, following by C/MC-vanillin and C/MC. At the first day, the initial amount of TAC on all fruits was 5.04 x 10^6 (CFU/fruit). After 5 days storage, the TAC was increased dramatically to 21.8 x 10^6 (CFU/fruit) for uncoated fruit while the TAC decreased slightly in the range of 1.9-4.09 for coated fruit.

As can be observed in Figure 5.8, amount of TAC increased with storage time in all treatments and the highest amount of TAC obtained for fruit without coating at the end of storage time, which was 14.15 x 10^6 (CFU/fruit). These results might concern on the composition and nutrients in the pineapple fruit. High total soluble solid in the initial stage in the range of 16.25-17.58% for fruit (Figure 5.9) is a comfortable condition to develop microorganism, fermentation and ethanol producing. This result can explain the increasing of ethanol content in pineapple fruit during storage, especially for uncoated pineapple.

Significantly, it is well know that both of vanillin and carbendazim in chitosan/methylcellulose solution showed the antimicrobial effect on microbial development. However, the present of carbendazim in the film solution showed the higher on the antimicrobial activity (Figure 5.11) comparing with control and other treatment. Throughout storage, the lowest amount of TAC was recorded for pineapple fruit coated with C/MC-carbendazim (CZ), which was less than about 10 times when compared with control fruit. Moreover, the antimicrobial activity of C/MC, C/MC incorporated with carbendazim and vanillin on *Aspergillus oryzae* was studied (Figure 5.12). The maximum inhibition zone was occurred for the C/MC-carbendazim films and followed by C/MC–vanillin and C/MC film. Thus, the incorporation of low temperature storage and C/MC-carbendazim coating solution can create the best condition to delay significantly the microbial growth on pineapple fruit. According to Brody *et al*. (2001), the antimicrobial effect of chitosan occurs when organisms are in direct contact with active sites of chitosan. When antimicrobial agents are incorporated into film solution, they diffuse out of the film, thus improving its antimicrobial efficacy. Moreover, the incorporation of antimicrobial agents into chitosan films, create an environment inside the package that may delay or prevent the growth of microorganisms on the product's surface and lead to an extension of its shelf-life (Cha and Chinnan, 2004).

5.4.5 Carbendazim residue in the coated pineapples

Carbendazim is used for the control of a wide range of fungal diseases and the application rates of carbendazim for products is presented (FAO, 2005; APVMA, 2007). However, the active constituents must reconsider because of public health and occupational health and safety concerns. According to Europe Commission Regulation (2011), maximum residue levels (MRLs) of carbendazim in or on fruit and peel of pineapple were set in the range of 0.1-0.7 mg/kg and 0.1 mg/kg, respectively.

The level of carbendazim residue in the pineapple coated by chitosan/methylcellulose incorporated with carbendazim (1.6 g/100 g solids of C/MC) after 30 days storage was evaluated. The pesticide residue level is based on two doses, which are 0.01 mg/kg for limit of detection (LOD) and 0.05 mg/kg for limit of quantitaion (LOQ) (Appendix 1). The result shows that carbendazim residue in the coated pineapples less than 0.01 mg/kg. It means that the pineapple after coating by the C/MC-carbendazim film solution and stored at low temperature during 30 days is still safe for people health. The carbendazim residue in the pineapple was presented in the range of the acceptation daily intake (ADI), which is 0-0.03 mg/ kg bw (FAO, 2005), and in the range of MRLs of carbendazim in fruit.

5.4.6 Sensory evaluate

Pineapple coated with chitosan/methylcellulose incorporated with carbendazim was not significantly different from the control (uncoated) in most of attributes after storage at 12°C, 85% RH for 10, 20 and 30 days storage (Table 5.1).

Table 5.1 Sensory scores of pineapple uncoated and coated with different coating solutions, and stored at 12°C, 85% RH for 10, 20 and 30 days.

	Day	Uncoated	C/MC	C/MC-carbendazim	C/MC-vanillin
Acceptance	10	6.60^{d}	6.33^{cd}	6.60^{d}	5.53^{bc}
	20	5.87^{c}	6.07^{cd}	6.27^{cd}	4.80^{b}
	30	3.53^{ab}	3.67^{ab}	3.93^{ab}	3.07^{a}
Color	10	6.53^{bc}	6.67^{bc}	6.73^{bc}	6.07^{bc}
	20	6.87^{c}	6.87^{c}	6.93^{c}	5.53^{bc}
	30	5.13^{ab}	5.07^{ab}	5.40^{ab}	4.33^{a}
Flavor	10	6.07^{bc}	5.87^{bc}	5.80^{bc}	4.93^{b}
	20	6.33^{c}	5.93^{bc}	5.87^{bc}	4.93^{b}
	30	4.13^{a}	4.27^{a}	4.20^{a}	3.93^{a}
Taste	10	6.47^{d}	6.40^{d}	6.40^{d}	6.13^{c}
	20	5.87^{bc}	5.93^{bc}	6.20^{c}	4.87^{b}
	30	3.67^{ab}	3.53^{ab}	3.80^{ab}	2.93^{a}
Firmness	10	6.80^{cd}	6.87^{cd}	7.27^{d}	6.67^{c}
	20	5.93^{b}	6.20^{b}	6.67^{c}	6.07^{b}
	30	3.67^{a}	3.73^{a}	3.93^{a}	3.67^{a}

Comparing with the control and other treatments, pineapple coated with C/MC-carbendazim showed the higher acceptability for color and firmness. At the

30th day storage, there was a drop in acceptance, color, taste, flavor and firmness scores for all treatments, which was lower than 5. Overall attributes, color, flavor and taste had low acceptability for pineapple coated with C/MC incorporated with vanillin. Our results agreed with the change of sensory evaluate for fruit wrapped or treated with vanillin (Sangsuwan *et al.,* 2008b; Ferrante *et al*., 2007; Moon *et al,* 2006). The fresh-cut pineapple declined its taste and flavor and had low acceptability after 6 days storage at 10°C (Sangsuwan *et al.*, 2008b). Ferrante *et al.* (2007) found that the flavor of orange juice with 2,000 ppm vanillin was not acceptable.

5.5 Conclusions

The influence of coating and low storage temperature on quality of 'Queen' pineapple planted cv. Ninhbinh was studied. After coating, fruit surfaces became shinier, more smooth and homogenous and also gain a uniform cover even at the fruit holes. Addition vanillin or carbendazim into chitosan/methylcellulose solution reduced the changes in total soluble solids, flesh firmness, flesh color and microorganisms levels, thus delayed the ethanol producing. C/MC incorporated with carbendazim (1.6 g/100 g solid of C/MC) was more effective at inhibiting microorganisms. Lower ethanol content, higher in total soluble solids, flesh firmness and lighter in flesh color were also found in pineapple fruit coated with C/MC incorporated with carbendazim. Quality attributes of fresh pineapple were generally acceptable and carbendazim residue level in fruit was lower than LOD (Limit of detection). Therefore, these results suggested that combining the coating the pineapple fruit by C/MC-carbendazim and maintaining the fruit at 12°C, 85%RH might be a useful technique to extend the shelf life for fruit with the good quality.