Chapter 5

Discussion

At an early stage of storage at ambient temperature and 13ºC, the 'Keaw Morakot' mango fruit at Maturity 3 had the lower firmness than Maturity 1 and 2, because the younger mature fruit (Maturity 1 and 2) had higher content of protopectin, an insoluble pectin, in cell wall while is an overmature fruit, pectic substances changed from an insoluble to soluble form. Softening of mango fruit is characterized by an increase in the solubility of cell wall pectins (Mitra and Baldwin, 1997) and pectin content (Lazan and Ali, 1993). However, the mango fruit at Maturity 2 showed the highest firmness, compared with the fruits at Maturity 1 and 3 at the later storage of ambient temperature and during storage at 13˚C for 12 days and then storage for ripening at 25˚C for 0 and 7 days, because the fruit at Maturity 2 might be of proper maturity for this cultivar. The suitable mature fruit had lower metabolic changes during ripening and might retain chemical composition such as starch which was related to the fruit texture than the unsuitable mature fruit (Abbott, 1999, Mattheis and Fellman, 1999) found in this study. The immature fruit also had some disordor such as jelly seed (van Lelyveld and Smith, 1979) during ripening which might cause extreme softening of ripened fruit (Lazan and Ali, 1993). The firmness of the mango fruit rapidly decreased after 2 days of storage at ambient temperature, during 3-5 days at 25˚C, but slowly decreased during storage at 13˚C. Because of the condition with high temperature, the produce rapidly ripened (Boonyakiat and Rattanapanone, 2006). De Morias and de Assis (2004) reported that temperature is one of the most important factors that delay the natural processes of maturation and ripening, such as color changes, softening, carbohydrate metabolism and decrease of tritable acid. Moreover, Roe and Bruemmer (1981) found that the peak of ripeness is associated with a fairly narrow range of firmness. Limited information is available on mango cell walls and the softening process during ripening (Ali *et al*., 1995), and there are considerable differences among cultivars (Selvaraj and Kumar, 1989). Moreover, in this study, the mango fruit were stored at ambient temperatre, so they were rapidly ripening. Nakasone and Paull (1998) reported that at ambient temperatures, shelf life of the

climacteric fruit (such as mango) is short. Ripening of the mango fruit is characterized by softening of the flesh (Roe and Bruemmer, 1981). During ripening, mango fruit was accompanied by softening of fruits and is brought about by alterations in the cell wall metabolism and is due frequently to the partial solubilisation of pectin or cellulose (Parikh *et al*., 1990). This observation indicated that the high firmness of the fruit at Maturity 2 was related to the WSP content and PG activity which were the lowest. Since the WSP content of the mango fruit increased during storage and the mango fruit at Maturity 2 tended to increase less than Maturity 1 and 3, this led to a less decrease of the firmness. Similar to the reports by Tandon and Kalra (1984), Lazan *et al*. (1986) and Brinson *et al*. (1988) who found that water-soluble polysaccharides of the mango fruit increased during ripening. Moreover, Roe and Bruemmer (1981) reported that water-soluble and alkali-soluble pectin of 'Keitt' mango fruit increased as the fruit lost its firmness and became soft. Brinson *et al*. (1988) found that the uronic acid content of the water-soluble polysaccharides from the cell wall preparations increased from only 7% in the unripe to 90% in the ripe mango fruit. The galactose and arabinose each constitutes about 30% of the water-soluble polysaccharides of the cell walls of the unripe fruit. A higher uronic acid content of the water-soluble polysaccharides was observed in the ripe compared to the unripe mesocarp. These observations were interpreted to indicate that during ripening: the mango cell walls are degraded, releasing the combined monosaccharides of the pectin complex, and the water-soluble pectic materials in the cell walls lose arabinose and galactose, accounting for the galacturonan-rich polysaccharides in the mesocarp. In mango fruit, pectin depolymerization appeared to begin earlier in the inner mesocarp than in the outer mesocarp tissue (Lazan and Ali, 1993), which related in softening of the fruit, such found in 'Carabao' mango (Cua and Lizada, 1990). In this study, it was found that the PG activitiy of the fruit at Maturity 2 tended to be lower than Maturity 1 and 3, thoughout storage period at ambient temperature, 13 and 25˚C because the suitable maturity might result in low physico-chemical and enzyme activity changes (Lazan *et al*., 1993). The PG activity of the mango fruit rapidly increased during 0-5 days of storage at ambient temperature and during 6-9 days at 13˚C and increased a little thereafter, similar to 'Zebda' mangoes (Labib *et al*., 1995). Furthermore, during storage at 25˚C, it was found that the PG activities of the fruits at Maturity 1 and 3 rapidly increased at day 3 while Maturity 2, at day 4, but tended to slowly increase thereafter. Generally, the PG activity of mango fruit is present during ripening (Abu-Sarra and

Abu-Goukh, 1992, Lazan *et al*., 1993). Besides, Mitcham and McDonald (1992) studied the cell wall modification of the mangoes during ripening and found that PG activities of both 'Keitt' and 'Tommy Atkins' mango fruits increased with ripening. The PME activities of the fruits slowly increased during 0-9 days of storage and slowly declined thereafter. They observed that cell wall neutral sugars, particularly arabinosyl, rhamnosyl and galactosyl residues, decreased with ripening in both cultivars. 'Keitt' had more loosely-associated, chelator-soluble pectin, accumulated more soluble polyuronides and retained more total pectin at the ripe stage than did 'Tommy Atkins'. Both cultivars had similar PG activity which increased with ripening. The molecular mass of cell wall hemicellulose decreased with ripening. They indicated that enzymatic and/or non-enzymatic processes, in addition to PG activity, were involved in the extensive softening of fruit. Even though, the PME which catalases the deesterification of methyl groups from acidic pectins, is also detectable in ripening mangoes (Abu-Sarra and Abu-Goukh, 1992, Ali *et al*., 1995), however, in this study, it was found that the PME activity of the mango fruit at different maturities was not significantly different during storage. The PME activity of the mango fruit tended to slowly increase during 0-3 days of storage at ambient temperature and 25˚C, and then decreased rapidly. For storage at 25˚C, the PME activity slowly increased during 0-9 days, and slowly declined thereafter. These changes had similarly pattern which was observed in 'Keitt' (Roe and Bruemmer, 1981) and 'Carabao' mangoes (Selvaraj and Kumar, 1989). In 'Carabao' mango, considerable PME activity could be measured during ripening, increasing as the fruit approaches the half-life (50% yellow peel color) stage and declining thereafter (Selvaraj and Kumar, 1989), same as the study of van Lelyveld and Smith (1979) who found that physiological maturity in tree-ripened mango fruit dropped in PME activity.

For the L* value of the mango pulp, the fruit at Maturity 3 showed the lowest L* value, differed with Maturity 1 and 2 during storage at ambient temperature. Because of the fruit at Maturity 3 were more ripened, while storage at 13˚C, the L* value of the mango pulp at Maturity 2 had the highest, and significantly different with the fruits at Maturity 1 and 3. Furthermore, storage at 25˚C, the fruit at Maturity 2 tended to have higher L* value than the others. The L* value is the visual lightness, 0 is black and 100 is white, so the fruits which have lower value are more ripen (Askar and Treptow, 1993) such found in 'Kensington' mango (Zora and Janes, 2001). The color changes of mango pulp during storage can be measured to ripen stage, because

the pulp color of fruit changes on ripening from white or light yellow to yellow or orange-yellow, depending on the cultivar (Lizada, 1993). In this study, it was found that the L* value of the mango pulp was related to the β-carotene during storage, such as, storage at 25˚C, the L* value decreased during 2-3 days while the β-carotene rapidly increased after 2 days of storage. This result is similar to 'Choke Anan', 'Nam Dokmai # 4', 'Rad', 'Mon Duen Gao', 'Keaw Sawoei', 'Okrong Thong', 'Kaew' and ' Maha Chanok' mangoes (Vasquez-Caicedo *et al*., 2002). During ripening of the fruit, some pigments are synthesized, such as carotenoids (Medlicott *et al*., 1986). The principal carotenoids reported in ripe 'Alphonso' mango were β–carotene, xanthophylls esters and xanthophylls, while β-carotene and auroxanthin were found in 'Tommy Atkins' (Medlicott, 1985). For the fractions of carotenoids, it was found that more than 50% of total carotenoids consist of β-carotene (Mitra and Baldwin, 1997). In this study, it was found that the β-carotene of the mango fruit at Maturity 3 tended to be higher than Maturity 1 and 2. During long-term storage, the β-carotene of the fruit increased. Lizada (1993) reported that pulp carotenoids continues to increase in the detached fruit as ripening proceeds, such found in 'Badami', 'Alphonso', 'Tommy Atkins' (Medlicott, 1985), 'Chok Anan', 'Nam Dok Mai #4', 'Rad', 'Okrong Thong', 'Kaew' and 'Maha Chanok' mangoes (Vasquez-Caicedo *et al*., 2004). The L* value of the mango fruit decreased during storage, as the fruit at Maturity 3 tended to decrease more than the others because Maturity 3 were more mature, so more ripened. In this study, it was also found that the fruit at Maturity 2 had lower L* value than Maturity 1 and 3 because it was slowly ripening. This was related to the ºH and the chroma values of the mango pulp at Maturity 2 which showed higher than Maturity 1 and 3. The ºH and the chroma of the fruit decreased during storage, as the fruit at Maturity 2 decreased less than the others. Because this stage was proper for harvesting of this variety, so low physiological changes occurred during storage then led to slowly ripening (Lizada, 1993, Kader, 2003). The L*, ºH and chroma values of mango pulp decreased more during storage at ambient temperature and 25˚C than storage at 13˚C. By, de Morias and de Assis (2004) reported that temperature is one of the most important factors that delay the natural processes of maturation and ripening, such as color changes, softening, carbohydrate metabolism and decrease of tritable acid. However, during storage, the L*, the ºH and the chroma values of the mango peel at different maturity were not significantly different, and these values had a little change because although the fruit riped, the mango peel still

remained green, as same as ‘Harumanis’ and ‘Katchamita’ mangoes (Lizada, 1993). These results are related to the chlorophylls content of the fruit which had a little reduction, and did not differ during storage. This result showed the contrast with many other studied (Parikh *et al*., 1990, Lizada, 1993, Vasquez-Caicedo *et al*., 2004). In general, the peel color of fruit changes on ripening from dark green to olive-green, sometimes reddish, orange-yellow or yellowish hues appear from the base color, depending on the cultivar (Lizada, 1993, Kader and Mitcham, 2003) because of chloroplasts in the peel are transformed into chromoplasts containing red and yellow pigments (Lizada, 1993). Such found in the study of Vasquez-Caicedo *et al*. (2002) who showed that fruit maturity did not correlate with peel color in all cultivars. Color saturation (chroma) and yellowness (b*) showed the highest correlation coefficients between color of peel and flesh, repectively. Only the peel of ‘Maha Chanok’ ‘Kaew’ ‘Rad’ and ‘Chok Anan’showed visible color changes that could indicate full ripeness as well. Peel of ‘Maha Chanok’ mango showed red spots over a green-yellowish background at its harvest time, and devolped up to a bright yellow peel color with red chicks. Peel color of ‘Kaew’ mango completely turned to yellow-orange at full maturity. Also peel ‘Chok Anan’ and ‘Rad’ mangoes turned to a dark yellow color, but still showed some grrenish parts that did not vanish during ripening. However, in this study, it was found that the chlorophylls content of peel tended to decrease during 0-5 days of storage at ambient temperature, and had a little change thereafter. For storage at 13˚C, the total chlorophyll and chlorophyll a tended to decrease during 0-15 days of storage, and had a little change thereafter, while the chlorophyll b decreased a little during 6-15 days of storage. Abbott (1999) suggested that the fruit and vegetable lose chlorophyll as they ripen. However, the substantial loss in peel chlorophyll content of mango occurs after the fruit begins to soften, such found in ‘Keitt’ mango (Medlicott and Thompson, 1985). Furthermore, in this study, it was also found that the reduction of total chlorophyll content was related to the chlorophyll a content. Medlicott *et al*. (1986) reported that a rapid destruction of chlorophyll in ‘Tommy Atkins’ mango, chlorophyll a was preferentially degraded relative to chlorophyll b. A more rapid loss in chlorophyll a is typically observed in senescence. Furthermore, this study found that the chlorophylls contents tended to decline more when stored at 13˚C than storage at ambient temperature and 25˚C. Lizada (1993) suggested that the chlorophyll degradation occurred by chlorophyllase activity which had low effectiveness in action when temperature as above 20ºC.

In this study, it was found that the starch content of the older mature mango fruit (Maturity 3 and 2) was higher than the younger one (Maturity1) , the same as 'Alphonso' (Subramanyam *et al*., 1976), 'Dashehari' (Kapur *et al*., 1985), 'Haden' (Fuchs *et al*., 1980), 'Kensington Pride' (Baker, 1984), 'Carabao' (Cua and Lizada, 1990) and 'Kaew' (Pimpimol and Khamsee, 2001) mangoes because of the immature fruit had lower accumulated starch than the mature fruit (Lizada, 1993). When storage at 13ºC for 12 days, the fruit at Maturity 2 had the highest starch and differed with Maturity 1. Besides, during storage at 25˚C, the fruit at Maturity 2 tended to have higher starch content than Maturity 1 because the mango fruit at Maturity 2 ripened slowly. The higher starch content is related to the dry matter of mango fruit which Maturity 3 and 2 was higher than Maturity 1. Tandon and Kalra (1984) reported that the longer the period of growth, the more starch accumulation. The starch content of the mango fruit decreased during storage, rapidly during 0-2 days, which related to reduction of the fruit firmness when storage at ambient temperature. Furthermore, during storage at 25˚C, it was found that the starch content of the fruit at Maturity 1 rapidly decreased at day 3, while Maturity 2 and 3, at day 5. Generally, the starch that has accumulated in the maturing fruit is rapidly lost during ripening (Kader, 2003, Kader and Mitcham, 2003), and this loss is evident in the chloroplast where the starch granules become progressively smaller as ripening proceeds (Parikh *et al*., 1990). During ripening, the accumulated starch hydrolyses, with formation of sugars. The hydrolysis of starch granules in the chloroplast continues until ripening (Kumar *et al*., 1994). The hydrolysis of starch and formation of sugars have been associated with amylase activity (Fuchs *et al*., 1980). Therefore, in this study, it was found that the TSS content of the mango fruit at Maturity 2 and 3 was higher than Maturity 1. At the beginning of storage at ambient temperature, the fruit at Maturity 3 had the highest TSS and glucose contents, and differed with Maturity 1. Because the fruit had longer growth period, may result in high amylase activity, as reported in 'Dashehari' (Tandon and Kalra, 1984) and 'Haden' mangoes (Fuchs *et al*., 1980). However, at the late storage, the fruit at Maturity 2 had higher TSS, fructose and sucrose contents than Maturity 1 and 3 because Maturity 2 might have lower metabolism than the others. Thus, the fruit at Maturity 2 had more remaining sugars content than Maturity 1 and 3. Furthermore, in this study, it was found that the fructose content which was the predominant reducing sugar (Lizada, 1993) had rapid increase after 3 days, while the glucose increased during 0-5 days of storage at ambient

temperature, and tended to decrease a little thereafter. For storage at 13 ºC, the glucose increased during 0-6 days and almost became consistent thereafter while the fructose tended to increase after 9 days, before that it was almost consistent. Because the enzymes which affect each sugar have varying effect on mango fruit-ripen stages, Kumar and Selvarai (1990) reported that the activity of glucose-6-phosphatase increased up to the three-quarter-ripe stage, whereas fructose-1, 6-diphosphatse activity increased as the mango fruit ripened from the three-quarter-ripe to full-ripe stage. The glycolytic enzyme hexokinase activity was detected only at the ripe stage. The phosphofructokinase showed maximum activity at the ripe stage while pyruvate kinase activity was found to increase until the three-quarter-ripe stage and declined at ripening (Selvaraj and Kumar, 1994). The pattern of change in hexokinase, phosphofructokinase and pyruvate kinase activities suggests the activation of glycolysis in ripening mango fruit (Lizada, 1993). The sucrose content of the fruit rapidly increased during 5 days of storage at ambient temperature. For storage at 13˚C, the sucrose tended to increase, varying and depending on maturity, as Maturity 3 increased during 0-6 days, Maturity 1, 0-12 days and Maturity 2, 0-15 day of storage and tended to be consistent thereafter while it rapidly increased after 2 days of storage at 25˚C. Selvaraj *et al*. (1989) reported that non-reducing sugars, principally sucrose, increased in later stages of ripening. This is consistent with the high activity of the gluconeogenic enzyme fructose-1, 6-diphosphatase in the ripe fruit of several mango cultivars (Kumar and Selvaraj, 1990). For the study of sugar changes in mango fruit, although, several reports (Lizada, 1993) suggest simultaneous increase of glucose, fructose and sucrose during ripening but Vazquez-Salinas and Lakshminarayana (1985) observed a gradual reduction in both glucose and fructose and a continuous increase of sucrose during ripening in Florida mango cultivars such as Haden, Irwin, Kent and Keitt. Glucose, fructose and sucrose have been reported to be in similar concentrations in ripe mangoes (Selvaraj *et al*., 1989), with sucrose being the predominate sugar (Kumar *et al*., 1994). Sucrose contributed 57% of total sugar in ripe 'Keitt' mangoes, with fructose and glucose making up 28 and 15%, respectively (Medlicott and Thompson, 1985).

During storage at ambient temperature and 13ºC, the TA content of the mango fruit at Maturity 1 was higher than Maturity 2 and 3, as Maturity 3 showed the lowest content. In most fresh produce, the older mature had lower organic acids than the younger one (Lizada, 1993). There were several researches on TA content of fruit, such as Del Mundo *et al*. (1984) who found

that TA correlated very well with days after flower induction in the ‘Carabao” mango, decreased in the fully-mature fruit, while in ‘Alphonso’ mango, TA increased from the sixth to the tenth week after fruit set and steadily declined thereafter as the fruit matured (Lizada, 1993). Moreover, Kumar *et al*. (1993) found that citric acid and malic acid of ‘Fazli’ and ‘Zardalu’ mangoes at two-thirds mature, three-quarters mature and fully-mature stage became lower gradually. However, after storage for 7 days at ambient temperature, late storage at 13˚C and during storage at 25˚C, the fruit at Maturity 2 had the highest of these acids, and differed with Maturity 1 and 3. Because the fruit at Maturity 2 might have lower metabolism changes than Maturity 3, therefore, it had high remaining of organic acids such found in ‘Zardalu’ mango (Kumar *et al*., 1993), ‘Anna’ apple (Pre-Aymard *et al*., 2005) and ‘Pedro Sato’ guava (Bassetto *et al*., 2005). As a result, the plant could use the acids for respiratory process (Mitra and Baldwin, 1997) as it was observed in this study that the TA and citric acid contents of the mango rapidly decreased after 5 days of storage at ambient temperature, at 13ºC, after 6 days and at 25ºC, after 3 days. Furthermore, the fruit at Maturity 2 also had ripened less than Matirity 1 and 3, as in general, TA declined as the mango ripens, such as ‘Badami’ (Lizada, 1993), ‘Kaew’ (Pimpimol and Khamsee, 2001, Vasquez-Caicedo *et al*., 2004, Homdork *et al*., 2006), ‘Chok Anan’ (Vasquez-Caicedo *et al*., 2002, Homdork *et al*., 2006), ‘Nam Dok Mai #4’, ‘Rad’, ‘Mon Duen Gao’, ‘Keaw Sawoei’, ‘Okrong Thong’ and ‘Maha Chanok’ mangoes (Vasquez-Caicedo *et al*., 2002) and several varieties (Morga *et al*., 1979). Overmore, in this study, it was found that the pH value had relation with the TA, citric acid and malic acid contents because during of storage, the mango fruit which had the highest pH value (less acidity) while it showed the highest TA, citric acid and malic acid contents. In this study, it was also found that the content of citric acid was higher than malic acid. Lizada (1993) reported that the predominant acid of mango fruit is citric acid, followed by varying amounts of glycolic, malic, tartaric and oxalic acids. The predominant organic acids in ‘Keitt’ mangoes were citric acid and malic acid but tartaric, oxalic, ascorbic and œ–ketoglutaric acids were also identified (Medlicott and Thompson, 1985). Furthermore, in ‘Badami’ mangoes, citric acid was identified as the major organic acids though malic acid and succinic acid were also present (Mitra and Baldwin, 1997). However, Lizada (1993) reported that in general, levels of citrate and succinate gradually decrease during ripening, while malate shows different changes with different cultivars. In ‘Alphonso’ mangoes, the levels of malic dehydrogenase and succinic

dehydrogenase increased with the onset of ripening, whereas the level of citrate synthase increased several folds on maturation but decreased markedly at ripening. Besides, the activity of malic enzymes increased during ripening, reaching its maximum a little ahead of the climacteric peak and then declining (Dubery *et al*., 1984). On the other hand, in 'Fazli' mangoes, five organic acids (oxalic, citric, malic, pyruvic and succinic acids) were detected, tartaric acid was also present in 'Zardalu', where all these acids were in higher concentration (Kumar *et al*., 1993).

For the vitamin C or ascorbic acid, although, at harvest and storage at 13ºC for 12 days, the mango fruit at Maturity 3 had the highest vitamin C content, and differed with Maturity 1. However, after storage at ambient temperature for 7 days, late storage at 13ºC and during storage at 25ºC, the fruit at Maturity 2 had the highest vitamin C content, differed with Maturity 1. Because the fruit at Maturity 2 had proper maturity, might have low physio-chemical changes and senescence (Mitra and Baldwin, 1997). Therefore, the fruit at Maturity 2 had less vitamin C loss than Maturity 1 and 3. During long-term storage, the vitamin C content of the fruit declined and rapidly during storage at ambient temperature and storage at 25ºC because the produce had more physio-chemical changes at high temperature condition (Kader, 2003).

During storage at ambient temperature, respiration rate and ethylene production of the mango fruit at Maturity 3 was higher than Maturity 1 and 2 because the fruit at Maturity 3 were more mature, so rapidly ripened. However, after storage at 13ºC for 12 days and at 25ºC for 7 days, the respiration rate of the fruit at different maturities did not differ, but ethylene production of the fruit at Maturity 3 was highest and differed with Maturity 1 and 2. Lizada (1993) reported that the patterns of respiration and ripening behavior vary among the maturities. Although, in general, the respiration of mango fruit decreases as the fruit matures, but, the respiration then commences and rise with ripening. Ethylene production also decreases as the fruit matures, is then undetectable for a time and reappears upon ripening (Lizada, 1993). Moreover, mango is a climacteric fruit and such undergoes increased ethylene production (Mitra and Baldwin, 1997), enhanced respiration and softening (Salunkhe and Desai, 1984). Together with the ethylene evolution and respiratory climacteric in mango fruit, the catalase and peroxidase activities were found to increase considerably, due to the disappearance of the heat-labile and non-dialysable inhibitor of these enzymes (Mitra and Baldwin, 1997). Lizada (1993) reported that as the ethylene production is associated with maturation and postharvest ethylene production is accompanied by

increase in both ACC synthase and ACC oxidase. In this study, the respiration rate of the mango fruit rapidly increased to the peak at day 5 of storage at ambient temperature and at day 18 of storage at 13ºC, similar to the study by Phimphimol and Khamsee (2001) who found that the respiration peak of 'Kaew' mango fruit was reached at day 5 and day 8 when storage at ambient temperature and 15ºC, respectively. However, after storage at 13ºC for 21 days and then stored at 25ºC, the respiration peak of the fruit varied among maturity groups, as Maturity 1 and 3 was day 3, while Maturity 2 was day 4. Therefore, the fruit at Maturity 2 had slow respiration peak. Since, Krishnamurthy and Subramanyam (1973) reported that the patterns of respiration and ripening behavior vary among the varieties, the climacteric conditions and the locations where the fruit is grown. The respiration rate of 'Manila' mango increased to the peak at day 6 (Dinora *et al*., 1996). In 'Alphonso' mango, the respiratory peak was observed at five days after harvest and fruits ripen within seven or eight days, while in 'Kent' and 'Haden' varieties, the peak was observed at ninth and eleventh days, respectively, and in 'Pairi' mangoes on the ninth day after harvest (Mitra and Baldwin, 1997).

For the ethylene production, it was found that the fruit at Maturity 1 increased to the peak at day 4, while Maturity 2 and 3, at day 5 of storage at ambient temperature. And, storage at 13ºC, the fruit at Maturity 1 and 3 increased to the peak at day 15, while Maturity 2, at day 18. Moreover, this study also found that the ethylene production peak of fruit at Maturity 1 and 3 were reached by day 2, while, Maturity 2, day 3 of storage at 25ºC. This result indicated that the fruit at Maturity 2 had late ripeness, so might be of slow senescence. Although, some researcher stated that ethylene rises when or before carbon dioxide production rises in ripening mangoes, but other researcher included mangoes among the fruit in which ethylene rises after carbon dioxide production rises (Mitra and Baldwin, 1997). Lizada (1993) reported that ethylene production by mango fruit tissue, as in many other climacteric fruit, is maximal at the onset of the climacteric phase of fruit ripening. The ethylene production starts before full ripeness is reached (Cua and Lizada, 1990).

In general, consumers expect fresh produce to be without defects, of optimum maturity and in fresh condition. Condition covers general appearance, sensory quality (such as texture and taste) and nutrient quality. Maturity is an important quality attribute of fresh produce because immature fruit lack good sensory quality and over-mature fruit has limited shelf life (Abbott,

1999, Shewfelt, 1999, Watada and Qi, 1999). In this study, it was found that the fruit at Maturity 2 had the highest texture score, as related to the highest firmness of fruit during storage at ambient temperature and at 25ºC for 7 days, similar to apple, cherry, citrus, carrot and tomato (Abbott, 1999, Auerswald *et al*., 1999). Moreover, the fruit at Maturity 2 had the highest feeling (related to astringent) and taste scores after storage for 7 days at ambient temperature. Although, after storage at 25˚C for 7 days, they did not differ, Maturity 2 tended to have higher scores than Maturity 1 and 3 because it had the highest sugar contents and tended to have higher acids and vitamin C contents which related to taste quality (Vasquez-Caicedo, 2002), as found in honey dew melon (Watada and Qi, 1999)

For the study on the effects of 1-MCP, it was found that the fruit treated with 1000 nl/l 1-MCP had the highest firmness, significantly different with untreated (0 nl/l 1-MCP). The result indicated that 1-MCP could maintain the firmness of mango fruit, same as 'Anna', 'Delicious' 'Granny Smith', 'Fuji', 'Ginger Gold', 'Gala', 'Idared', 'Jonagold' and 'McIntosh' apples (Rupasinghe *et al*., 2000, Watkins *et al*., 2000, Mir *et al*., 2001, Pre-Aymard, 2005), strawberry (Ku *et al*, 1999), broccoli (Ku and Wills, 1999), apricot (Fan *et al*., 2000a), nectarine (Dong *et al.*, 2001), peach (Kluge and Jacomino, 2002), plum (Dong *et al*., 2002), pear (Trinchero *et al*., 2004), guava (Bassetto *et al*., 2005) and kiwifruit (Mao *et al*. 2005). Because 1-MCP had inhibitory effects on ethylene action, so, it has potential for the control of ripening and senescence of fruits (Serek *et al*., 1995, Sisler *et al*., 1996, Bassetto *et al*., 2005). Therefore, it delayed softening in mango fruit, as found in avocado (Feng *et al*., 2000, Hofman *et al.*, 2001, Jeong *et al*., 2002), custard apple, mango, papaya (Hofman *et al.*, 2001), persimmon (Nakano *et al*., 2002), plum (Menniti *et al*., 2004) and strawberry (Jiang *et al*., 2001). Furthermore, Serek *et al*. (1995), Sisler *et al*. (1996), Abdi *et al*. (1998) and Golding *et al*. (1998) reported that 1-MCP inhibited ripening of tomato, banana and plum fruit. During 6-21 days of storage, the 1000 nl/l 1-MCP was more effective in delaying the softening of the mango fruit than 500 and 0 nl/l 1-MCP, respectively, same as the 12 hours of exposure was better in delaying of softening of mangoes than 6 hours. Blankenship and Dole (2003) reported that the effective concentrations of 1-MCP vary widely and with commodity, similarly, they vary with respect to time, temperature and method of application, such as 0.09 µl/l 1-MCP for 24 hours was not enough to elicit a response in avocado softening, while 0.45 µl/l for 24 hours affected softening and associated enzyme

activity (Jeong *et al*., 2002). Furthermore, there were researches which a time/concentration relationship of such higher concentrations of 1-MCP were required for shorter treatment times, were noted with broccoli (Ku and Wills, 1999), banana (Jiang *et al*., 1999, Sisler *et al.*, 2001, Pelayo *et al*., 2003), apples (Sisler *et al*., 1996, Fan *et al*., 1999a, Rupashinghe *et al*., 2000, Jiang and Joyce, 2002, Lurie *et al*., 2002), green tomatoes (Wills and Ku, 2002), bananas (Sisler *et al*., 1996, Harris *et al*., 2000), avocado (Feng *et al*., 2000, Hershkovitz *et al*., 2005). Besides, Feng *et al*., (2000) suggested that low concentrations of 1-MCP may be as effective as higher concentrations if the low concentrations are applied over longer duration. Such that, 250-300 nl/l 1-MCP for 5 minutes was as effective on carnation as 0.5 nl/l 1-MCP for 24 hours (Sisler *et al*., 1996). In this study, it was also found that using 1000 nl/l 1-MCP and 12 hours of exposure time had the lowest PG and PME activites and WSP content and differed with 0 nl/l 1-MCP and 6 hours, respectively. Thus, the 1000 1-MCP and 12 hours of exposure time had effectiveness in delaying increasing of PG and PME activities and WSP content, such as in avocado which was found that fruit softening showed that PG and cellulose activities were lowered by 1-MCP (Feng *et al*., 2000, Jeong *et al*., 2002, Ali *et al*., 2004), and PME activity was delayed in 1-MCP-treated fruit compared with the control, as uronic acid content in avocado decreased in the control but the 1-MCP-treated fruit showed little change (Jeong *et al*., 2002). Moreover, Dong *et al*. (2001) found that exo-PG and endo-glucanse were lower in 1-MCP-treated fruit when compard to the untreated fruit, while PME and endo-PG were similar. In this study, it was observed that the PG activity increased during 0-15 days of storage, and it tended to be consistent thereafter, same as 'Keitt', 'Tommy Atkins' (Mitcham and McDonald, 1992) and 'Zebda' mangoes (Labib *et al*., 1995) because the PG of mango fruit had been present during ripening (Abu-Sarra and Abu-Goukh, 1992, Lazan *et al*., 1993). The PME activity had a little increase during the 0-6 days, and rapidly increased during 6-9 days, but, rapidly decreased during 9-15 days, and a little decrease during 15-21 days of storage, similar pattern was observed in 'Keitt' (Roe and Bruemmer, 1981) and 'Carabao' mangoes (Selvaraj and Kumar, 1989) because the PME was also detectable in ripening mango (Abu-Sarra and Abu-Goukh, 1992, Ali *et al*., 1995) and may be declining in activity in over-ripe mango fruit (van Lelyveld and Smith (1979). For the WSP content, there was a littlte increase during 0-15 days, but rapidly increased during 15-18 days and consistent thereafter. Water-soluble polysaccharides of the mango fruit increased during ripening (Lazan *et*

al., 1986), as a higher uronic acid content of the water-soluble polysaccharides was observed in the ripe compared to the unripe mesocarp (Brinson *et al*., 1988, Lazan and Ali, 1993).

Although the L* value of mango pulp at all concentrations and exposure times of 1-MCP did not differ when storage for 12 days, however, the L* value of mango pulp which was treated with 1000 nl/l 1-MCP tended to be higher than 500 and 0 nl/l 1-MCP, while the fruit with 12 hours of exposure had higher L* value than 6 hours of exposure. The treaments (500 and 1000 nl/l 1-MCP) and 12 hours of exposure were better in delaying of decreasing of the ºH and chroma values than untreated treatment (0 nl/l 1-MCP) and 6 hours of exposure, respectively, after 6 days of storage. Becuase 1-MCP has potential for the control of fruit ripening, such found in tomato, banana, plum (Serek *et al*., 1995, Sisler *et al*., 1996, Macnich *et al*., 1997, Abdi *et al*., 1998, Golding *et al*., 1998), avocado (Feng *et al*., 2000, Jeong *et al*., 2002), pear (Ekman *et al*., 2004, Trinchero *et al*., 2004), persimmon (Nakano *et al*., 2002), strawberry (Jiang *et al*., 2001) and mango (de Melo Silva *et al*., 2004). These results were relative to the β-carotene content of mango fruit which was found that the 1000 nl/l 1-MCP treated fruit had the lowest β-carotene, same as apricot (Fan *et al*., 2000) and peach (Kluge and Jacomino, 2002) which 1-MCP-treated fruit exhibited color change less than untreated controls. Furthermore, Jiang *et al*. (2001) also found that 1-MCP maintained fruit color in strawberry, as it inhibited phenylalanine ammonia lyase activity and lowered anthocyanin production. Thus, during storage, the 1000 nl/l 1-MCP and 12 hours of exposure were better in delaying increasing of β-carotene than 0 and 500 nl/l 1-MCP and 6 hours, respectively. However, in this study, it was found that the concentrations and exposure times of 1-MCP did not affect the L*, ºH and chroma values of mango peel. The L* value of mango peel tended to have a little decrease during long-term storage, as 500 and 1000 nl/l 1-MCP and 12 hours exposure time tended to slightly decrease than 0 nl/l and 6 hours, respectively. After that, the chlorophyll contents of mango fruit did not differ, same as 'Oroblanco', a pummelo-grapefruit hybrid (Porat *et al*., 2001), sweet cherry (Gong *et al*., 2002) and apricot and plum (Dong *et al*., 2002). On the other hand, Blankenship and Dole (2003) reported that 1-MCP prevented or delayed chlorophyll degradation and various types of color changes in a wide range of crop species such as coriander (Jiang *et al*., 2002), strawberry (Tain *et al*., 2000) and avocado (Feng *et al*., 2000, Jeong *et al*., 2002).

As 1-MCP has inhibititory effects on ethylene action and has potential for the control of ripening and senescence of fruits and vegetables (Serek *et al*., 1995, Sisler *et al*., 1996) such as tomato, banana and plum (Serek *et al*., 1995, Sisler *et al*., 1996, Abdi *et al*., 1998, Golding *et al*., 1998), thus, in this study, it was found that the 1-MCP treated fruit still had higher starch content than untreated fruit. The fruit which were treated with 1000 nl/l 1-MCP and 12 hours of exposure had higher starch content than 500 and 0 nl/l 1-MCP and 6 hours, respectively. Similar to dry matter content of the fruit, it was found that the 1000 nl/l 1-MCP and 12 hours of exposure time tended to have more dry matter than 500 and 0 nl/l 1-MCP and 6 hours, respectively. Kumar *et al*. (1994) and Kader and Mitcham (2003) reported that during ripening of mango fruit, the accumulated starch hydrolyses, with formation of sugars. However, in this study, it was found that the fruit which were treated with 1000 nl/l 1-MCP and 12 hours of exposure had the lowest TSS, fructose and sucrose and differed with 0 nl/l 1-MCP and 6 hours, respectively. Thus, either this concentration or exposure time might be suitable to control ripening of the mango fruit, same as strawberry (Tian *et al*., 2000) and kiwifruit (Mao *et al*., 2005). But, there were some contrasts in pineapple (Selvarajah *et al*., 2001), papaya (Hofman *et al*., 2001) and apples (Fan *et al*., 1999a). After that, in this study, it was shown that the glucose content of the fruit which were treated with different concentrations and exposure times of 1-MCP did not differ. During long-term storage, the fructose and sucrose contents increasd after 9 days of storage, as the glucose tended to increase a little after 6 days. Lizada (1993) reported that in most of the mango varieties examined, fructose was the predominant reducing sugar. Moreover, Selvaraj *et al*. (1989) reported that non-reducing sugars, principally sucrose, increased in later stages of ripening. For the study of sugar changes in mango fruit, although several reports (Lizada, 1993) suggest simultaneous increase of glucose, fructose and sucrose during ripening, but, some reports observed a gradual reduction in glucose during ripening (Vazquez-Salinas and Lakshminarayana, 1985).

The TA**,** citric acid and ascorbic acid (vitamin C) contents of the fruit which were treated with 1000 nl/l 1-MCP and 12 hours of exposure time showed the highest values and differed with 0 nl/l 1-MCP and 6 hours of exposure. Therefore, the 1000 1-MCP and 12 hours of exposure time were effective in delaying reduction of them comparing with 0 nl/l 1-MCP and 6 hours of exposure. These contents related to the lowest pH value of mango fruit. However, storage for 12

days, the malic acid of the fruit was not significantly different which decreased after 6 days of storage. Blankenship and Dole (2003) reported that the effect of 1-MCP on TA content is irregular, with some crops being affected and others not. Furthermore, 1-MCP delayed the decline in ascorbic acid in pineapple (Selvarajah *et al*., 2001), prevented ethylene-induced acidity loss in apricot (Fan *et al*., 2000), completely inhibited TA loss in tomato (Wills and Ku, 2002), delayed TA loss in plum (Dong *et al*., 2002) and maintained TA in 'Red Delicious', Granny Smith', Fuji', 'Jonagold' Ginger Gold' and 'Galra' apples (Fan *et al*., 1999a,b). Watkins *et al*. (2000) found that TA of 'Law Rome', 'Delicious', 'Empire' and 'McIntosh' apples were always higher in 1-MCP-treated fruit during air storage, but effects were inconsistent in controlled-atmosphere storage. On the other hand, 1-MCP did not affect TA in apricot (Dong *et al*., 2002) or 'Red Chief' apple during storage at several temperatures (Mir *et al*., 2001) and 'Shamouti' orange (Porat *et al*., 1999).

The 1000 nl/l 1-MCP treated fruit had the lowest respiration rate and differed with 0 nl/l 1-MCP. Similarly, the fruit which 1-MCP fumigation for 12 hours had the lowest respiration rate and differed with 6 hours after storage for12 days. Blankenship and Dole (2003) reported that, in general, 1-MCP reduced respiration rates or delayed increase in respiration, such as the respiration rate of apricots (Fan *et al*., 2000), pear (Trinchero *et al*., 2004), guava (Bassetto *et al*., 20005) and kiwifruit (Mao *et al*., 2005) was reduced, while, the respiration rate of 'Fuji' (Fan and Mattheis, 1999b), 'Granny Smith' and 'Red Delicious' apples was inhibited (Fan *et al*., 1999a,b) after being treated with 1-MCP. During storage, the respiration rate of the fruit increased to peak, varying and depending on 1-MCP used. The fruit treated with 0 and 500 nl/l 1-MCP and 6 hours of exposure increased to peak at day 15 while 1000 nl/l 1-MCP and 12 hours of exposure, at day 18. It was also found that, respiratory increase in avocado was delayed by about 6 days and reduced in magnitude by about 40% with 1-MCP treatment and the respiratory climacteric in plum (Abdi *et al*., 1998, Dong *et al*., 2002) and tomato (Wills and Ku, 2002) was delayed by 1-MCP. On the other hand, 1-MCP treatment did not affect nectarine (Dong *et al*., 2001) and apricot (Dong *et al*., 2002), as the differing results in apricot might be due to fruit maturity, cultivar or some other unknown factors. In this study, it was found that the ethylene production of 1000 nl/l 1-MCP treated fruit was lowest and differed with 0 nl/l 1-MCP, while, 12 hours exposure 1-MCP was lowest and differed with 6 hours. During storage, the 1000 nl/l 1-MCP and

12 hours of exposure were better in delaying increasing of ethylene production comparing with 0 and 500 nl/l 1-MCP and 6 hours. Similarly, in avocado (Jeong *et al*., 2002), plum (Abdi *et al*., 1998), apricot (Fan *et al*., 2000) and pear (Trinchero *et al*., 2004), it was found that the 1-MCP treated fruit delayed the ethylene climacteric and reduced in magnitude. Furthermore, many researches found that 1- MCP lowered ethylene production in strawberry (Jiang *et al*., 2001) and apple (Jiang and Joyce, 2002), slowed ethylene production in pineapple (Selvarajah *et al*., 2001), apricot and plum (Dong *et al*., 2002) and inhibited ethylene production in 'Fuji' (Fan and Mattheis, 1999a,b), 'Granny Smith', 'Red Delicious' (Fan *et al*., 1999a,b) and 'Anna' apples (Lurie *et al*., 2002).