Chapter 4

Ripening Index (RPI)

4.1 Abstract

Mangoes cv. Chok Anan, Nam Dok Mai and Khiew Sawoey were selected at fully mature stage and incubated at 28 ± 2 ˚C, 58 – 83 %RH until the desirable ripeness was reached. Fruits were daily withdrawn for the quality measurement.

The correlations of ripening behavior of the cultivar, fruit quality of the ripening were related to each other. They were fitted well with power law function for all, except pH value was used the linear function. However, each function parameter was dependent on cultivar and batches.

The measurements of firmness, total soluble solid and titratable acidity were evaluated. A function of dimensionless was determined by the following formula: RPI = ln (100 · F / (TSS / TA)). The ripening index (RPI) degree was oscillated, depending on crop year, cultivar and location. The experiment can be summarized that when PBZ application has a direct effect to fruit quality parameters (data from the previous chapter), it will then associate with RPI.

4.2 Introduction

The mango maturity indices are commonly used the peel colour, the softer flesh, an odour, and the brown colour of lenticels or others. The difference in variation of fruit species and analytical method, using single parameter such as total soluble solid (TSS), titratable acidity (TA), color values or firmness (F) is limited for the maturity index of fruit. (Crisosto, 1994; Mahayothee, 2004). During ripening process of mango fruit, the TSS increases with maturity and has been recognized as a good quality index for a long time (Mahayothee, 2004). However, there is an evidence of TA lost during maturation or ripening of the stone fruits which also depending on the varieties, growing areas and season (Crisosto, 1994) which both of them indicate the taste of fruit. The decline in TA and titratable levels was accompanied by a corresponding increase in pH during ripening (Zainon Mohd *et al*, 1993). In addition, the sugar-acid ratio content has been found to be more closely related to quality or sense (taste) than acid content or TSS value alone (Mahayothee, 2004 and Vásquez-Caicedo *et al*., 2005). Moreover, flesh firmness decreases during the postharvest ripening process, while the dependence is also on the cultivar, and seasonal (Vásquez-Caicedo *et al*., 2002). The firmness of mango pulp during the process of ripening was correlated positively with an increase in polygalacturonase activity, with solubilization of cell wall pectin (Zainon Mohd *et al*., 1993) or it is essentially due to depolymerization of the cell wall polysaccharides by a varieties of the hydrolytic enzymes (Yashoda *et al*., 2007) and also hemicellulosic polysaccharides with significant loss of galactose, arabinose, and mannose residues at the ripening stage (Yashoda *et al*., 2005).

According to the success of the ‘Streif Index’ in the European apple industry particularly in Germany, it was used nationwide to predict apple ripeness by using multiple parameters for ripening index (RPI). The Streif Index is named after its developer, Joset Streif, an apple postharvest physiologist working in southern Germany (University of Hohenheim). It is calculated as: ***Firmness (kg/cm2) / (soluble solid (˚Brix) x starch index (1-10)***. The appeal of this index is partly based on its simplicity. All three measurements are acceptably known as the importantly individual measurements. Theses measurements are rapid, inexpensive and easily done by any orchard manager. The application of the Streif index has been studied on various popular European cultivars grown in different regions of Europe (Prange *et al*., 1998).

The special three parameters are interesting in order to predict mango fruit ripeness they are definite as total soluble solid (TSS), titratable acidity (TA) and texture or firmness of flesh mango fruit (F) as describe by Mahayothee (2004). Fruit firmness is probably the most reliable indicator of maturity and related with total soluble solid and titratable acidity of mango flesh. Mahayothee (2004) found that the ripening index (RPI) was primarily deduced for monitoring the postharvest ripening of mango fruits. It was a function of dimensionless fruit firmness (F) and sugar-acid ratio presented as $RPI = \ln (100 \cdot F / (TSS / TA))$. Low RPI levels indicated an increase in fruit ripeness. Moreover, RPI has been derived from the kinetics of the individual properties and is not exclusively based on a regression analysis. Linear changes of the parameters in the course of the ripening process, being a characteristic of RPI, were previously found to be a prerequisite for satisfactory correlation with the NIR spectral data in maturity prediction since NIR spectra reflect the overall changes of the fruits during ripening rather than specific alterations (Mahayothee, *et al*, 2004 and Mahayothee, 2004).

The objective of this study was focused on using the data in the chapter 3 that was only for studying the inner correlation between quality parameter and calculating the ripening index (RPI) which was created by Mahayothee, (2004). In addition, the impact of PBZ on the ripening index was also observed such as: the impact of PBZ concentration and cultivars.

4.3 Materials and Methods

Three cultivar of mango fruits were harvested from Mea Jo University plot B and D, cv. Chok Anan, and San Sai orchard, cv. Nam Dok Mai and Khiew Sawoey, Chiang Mai, Thailand as described in previous chapter. Fruits were directly harvested from the trees which treated with PBZ and untreated. The fruits were stored at laboratory at Faculty of Agriculture, Chiang Mai University for ripening process and were sampled daily for quality determinations. The firmness, total soluble solid, pH-value titratable acidity, peel colour and flesh colour were investigated following the method described in chapter 3. Then, all data were calculated as following the formulation generated by Mahayothee, 2004 as for her preliminary study; and the data were compared. The effect of PBZ on the ripening index was evaluated.

4.3.1 Innercorrelation between quality parameters of mango fruit

The best parameter to predict maturity in mangoes was report as sugar-acid ratio (Mahayothee, 2005) which is decisive for the basic taste of the fruits. In this work, the correlation between this parameter and acidity (TA and pH), texture (Firmness, F) and appearance quality (colour of peel and flesh) was studied by using three simple equations: linear, power, exponential functions on Mircrosoft Excel® 2003.

4.3.2 Ripening Index

According to the correlation between sugar-acid ratio and firmness was found as a power function therefore Mahayothee *et. al.* (2004) proposed the ripening index (RPI) for mangos which was computed by the following function of dimensionless formula as:

$$RPI = \ln (100 \cdot F / (TSS / TA))$$

Regarding the firmness in this equation is dimensionless parameter, the experimental value have to multiply by 100 g and divided by 1 N. (Mahayothee, 2004). As described in chapter 3, the °$Brix_{corr}$ which eliminated the mass of soluble acid will be used instead of TSS from experiment.

4.4 Results

4.4.1 Relationship between TA, Firmness, pH, colour and sugar-acid ratio

In order to detect the specific ripening behavior of each cultivar, alterations of their quality parameters were related to sugar acid ratio, thus eliminating extrinsic effects. Sugar-acid ratio has been reported to be the best parameter to predict maturity in mangoes (Mahayothee, 2004) and is decisive for the basic taste and palatability of the fruits. During the postharvest ripening, TA is related to ascendant sugar-acid ratio, a uniform power law function relation valid for all cultivars resulted $R^2 = 0.84 – 0.99$ (Figure 4.1). Moreover, the increasing of sugar-acid ratio was associated with linear increase of pH which was resulted $R^2 = 0.46 – 0.98$ (Figure 4.2). However, the batches of the crop year were affected with the trend line. pH values were especially occurred during ripening of Khiew Sawoey, which may be associated to low TA after harvesting at mature green. Firmness rapidly decreased at the initial low levels of sugar-acid ratio and remained almost constant until fruits reached their fully ripe stage, thus following a power law behavior specific for each cultivar (Figure 4.3). The hue of peel and flesh decreased with increasing of sugar-acid ratio according to power law relations (Figure 4.4, 4.5). The changes of both hue angle and firmness were cultivars and batches dependent. Nam Dok Mai was softened and evolved yellow coloration faster than other cultivars. Chok Anan was developed coloration faster than softened. The power law describing the relationship between TA, fruit firmness, colour and sugar-acid ratio statistically obtained for each mango batch was confirmed by R^2 of them.

The majority data of the interrelation between peel colour and flesh colour was assembled. There was no clear correlation between hue of peel and hue of flesh for three cultivars as illustrated in Figure 4.6. The degreening of peel colour and the yellow development of flesh colour were obtained dependent. It could not used to predict the flesh colour.

In this study, PBZ was observed no clear effect on the interrelation between physical and chemical quality parameters such as firmness, peel and flesh colour.

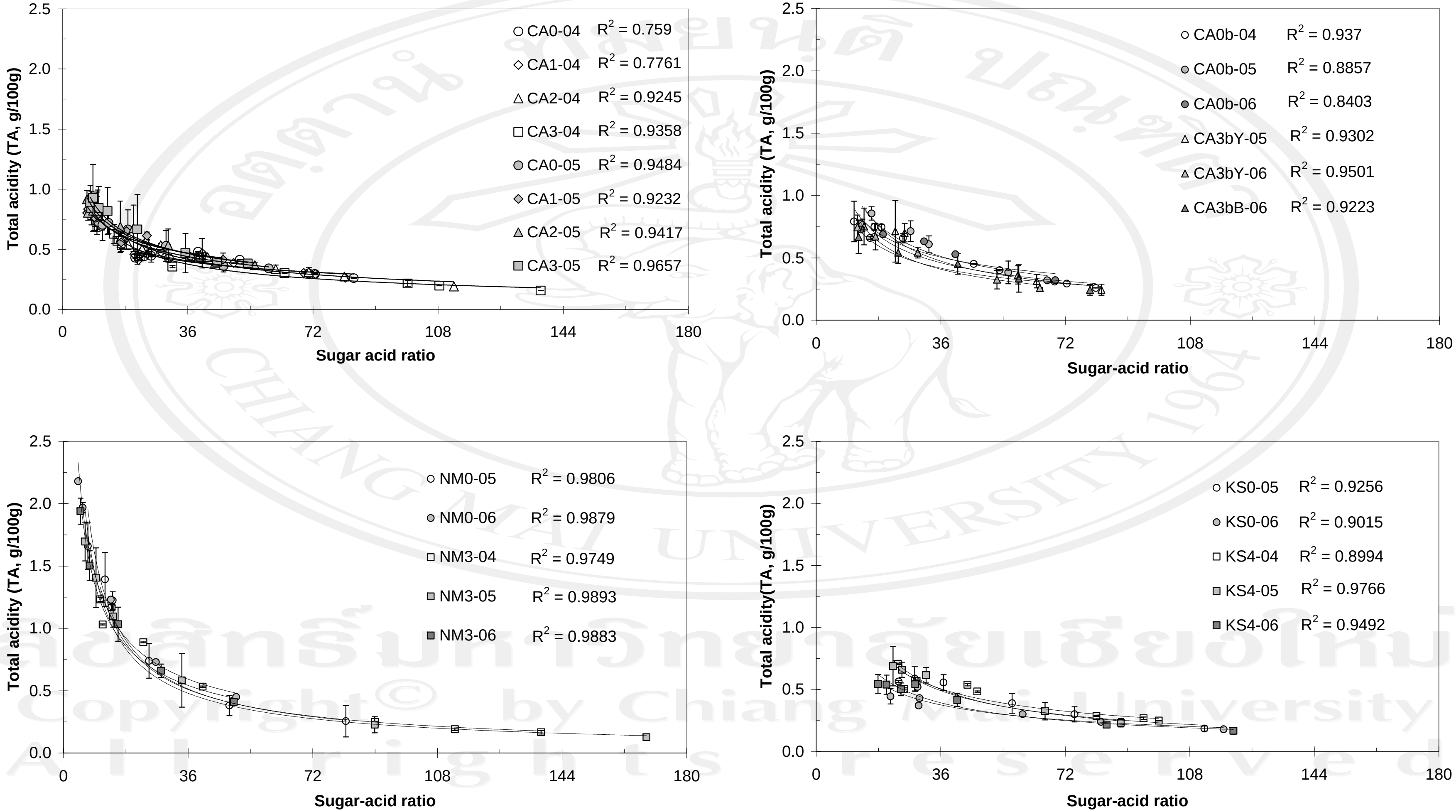

Figure 4.1 General changes in TA at increasing sugar-acid ratio in ripening mangoes cvs. CA, NM and KS.

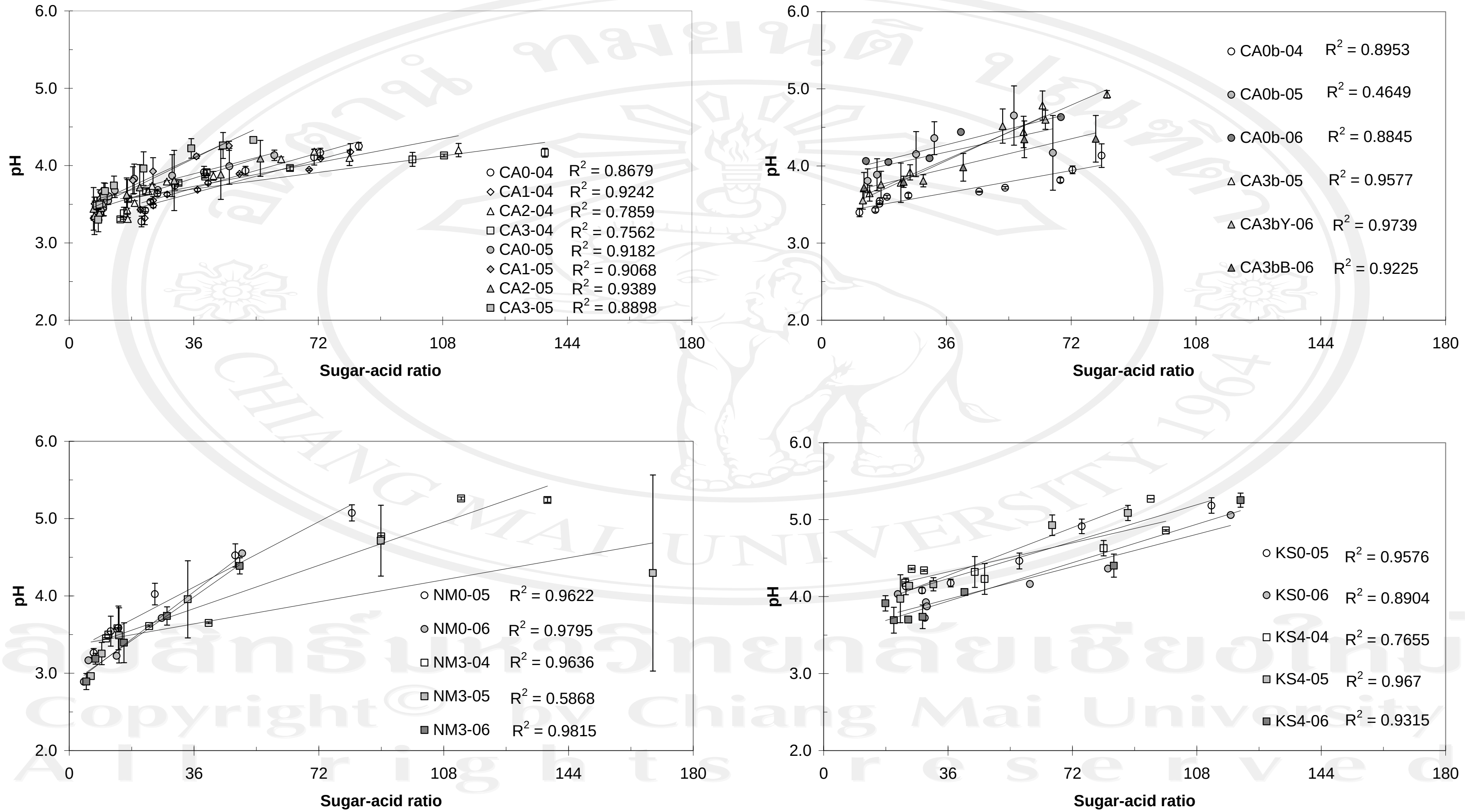

Figure 4.2 pH changed with increasing sugar-acid ratio in mango cvs. CA, NM and KS during ripening.

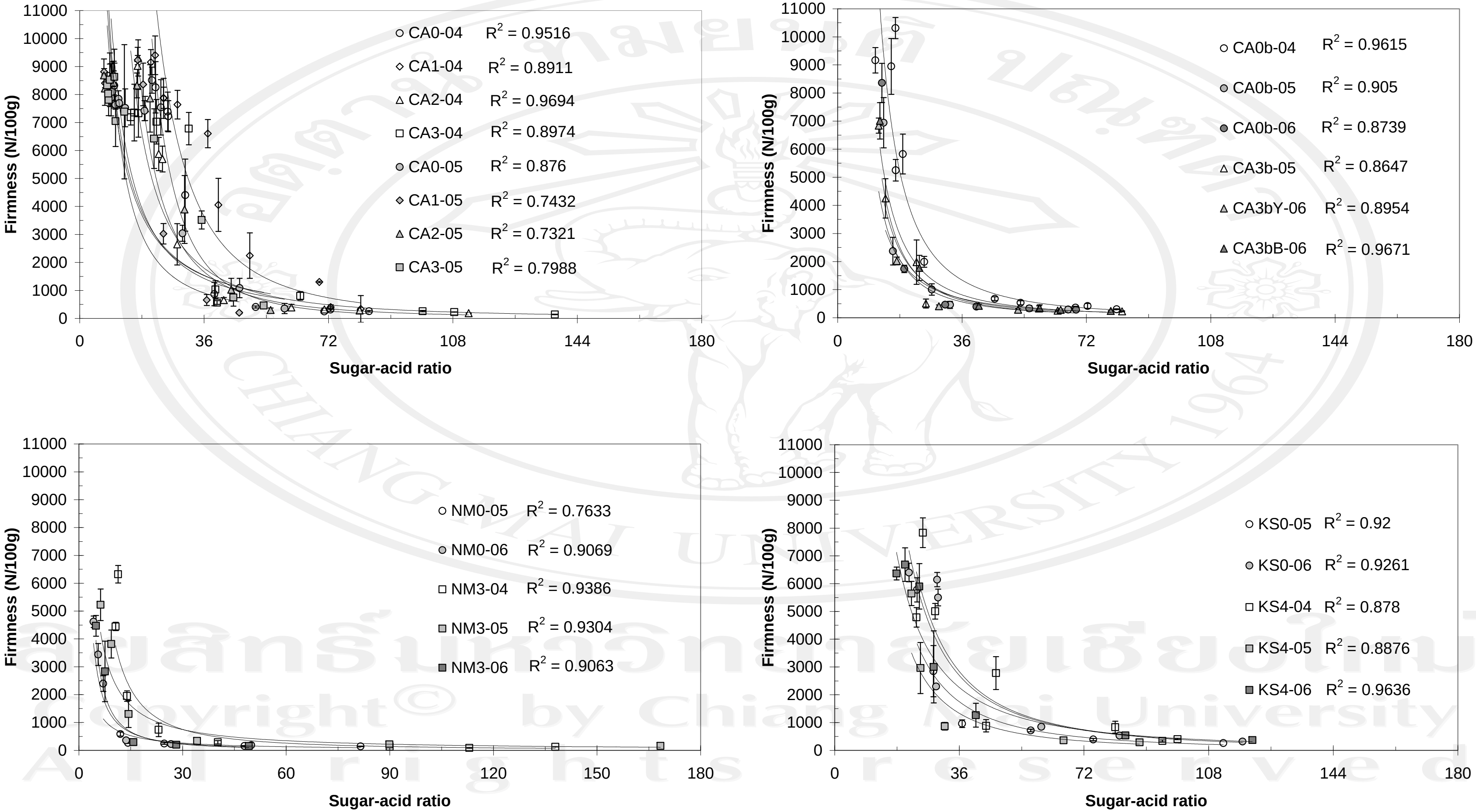

Figure 4.3 General changes in flesh firmness with rising sugar-acid ration during ripening of mangoes cvs. CA, NM and KS.

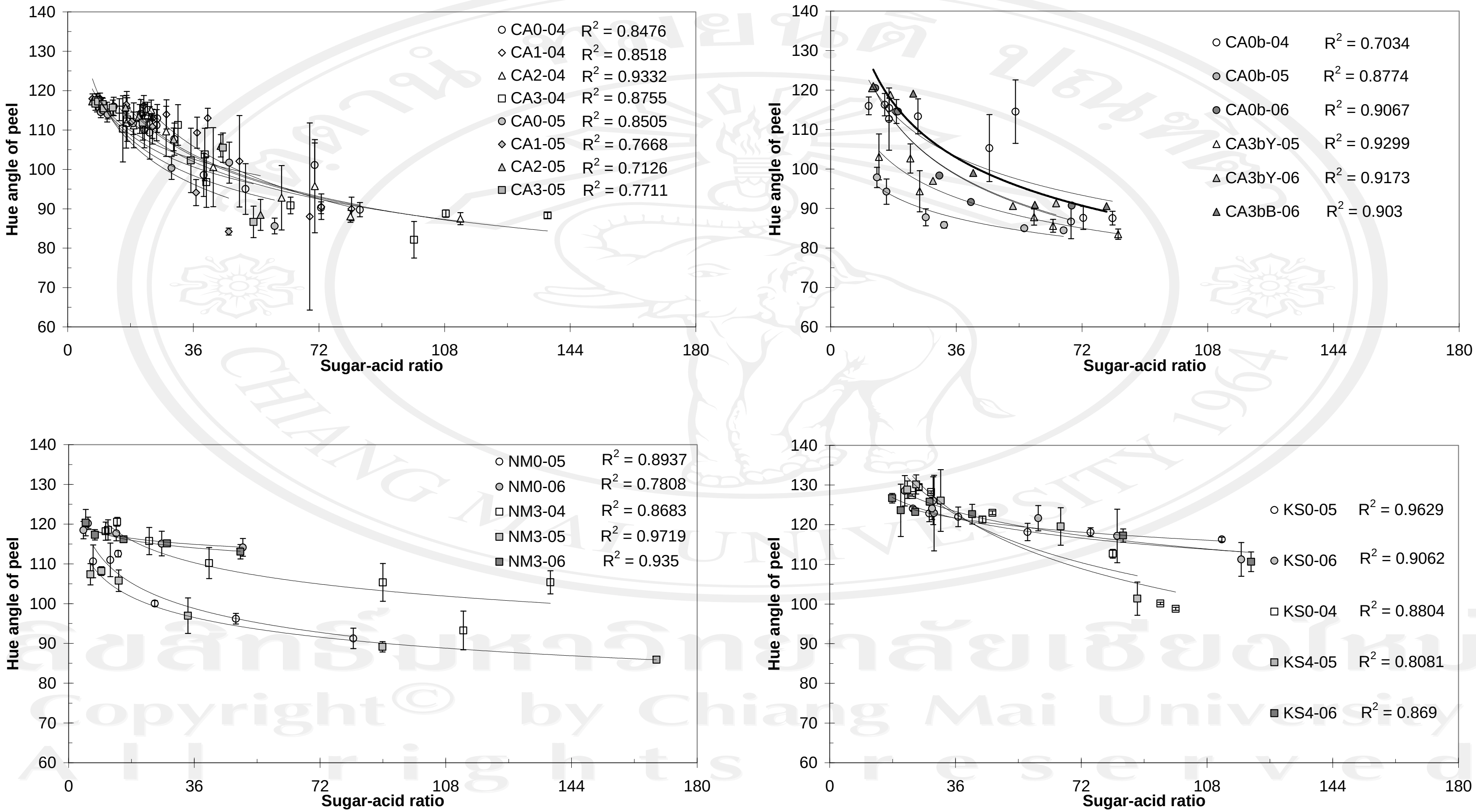

Figure 4.4 Changes in hue of peel with increasing sugar-acid ratio during ripening of mangoes cvs. CA, NM and KS.

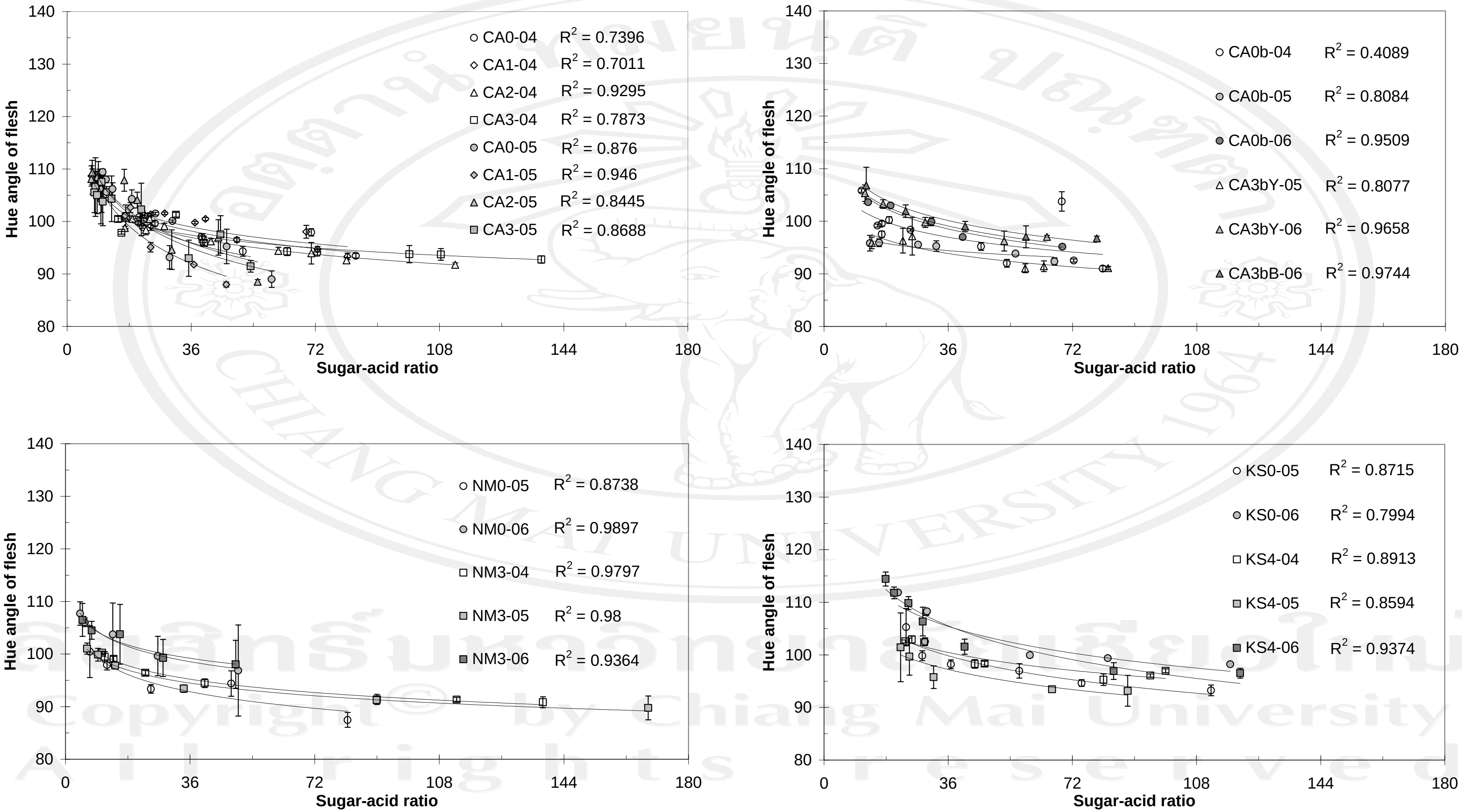

Figure 4.5 Changes in hue of flesh with rising sugar-acid ratio in ripening mangoes cvs. CA, NM and KS.

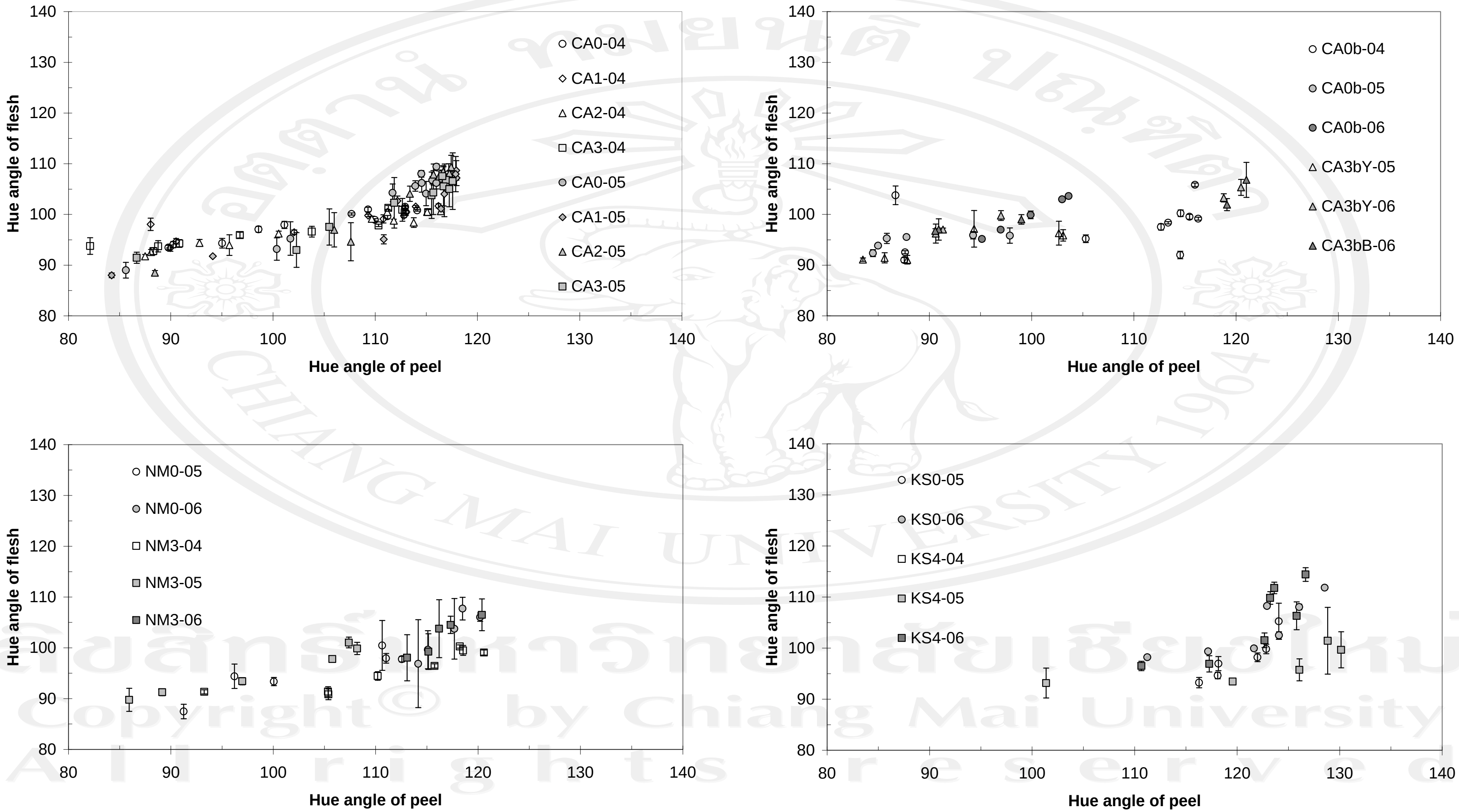

Figure 4.6 Interrelation between hues of flesh with hue of peel development during ripening for three cultivars CA, NM, KS.

4.4.2 The impact of the different PBZ concentrations on RPI

The results of the ripening index (RPI) for Chok Anan cultivar which treated with PBZ in different concentration (0, 0.5 and 1.0 g *a.i.* per square meter) and Prohexadione-Calcium 0.5 g *a.i.* per square meter for crop year 2004 evaluated that the ripening index was rather constant at the beginning until day 4 of the ripening process. Then, it was decreased to low RPI as illustrated in Figure 4.7A. The coefficient of determination (R^2) were highly obtained in all treatments in range of 0.84 – 0.93. According to Mahayothee, 2004 indicated that Chok Anan was ripened in day 3 or day 4. The data at the initial 3 days of the ripening process was excluded and it was found that the coefficient of determination (R^2) were changed not much, especially in PBZ treatment (CA2-04, CA3-04) and control, but only in Prohexadione-Calcium (CA1-04) was much differed from the old data (Figure 4.7B). On the other hand, the ripening index degree at full ripeness stage was highly occurred in Prohexadione-Calcium (CA1-04) as 9.64. However, the control trees (CA0-04) and PBZ treatment (CA2-04, CA3-04) were exhibited as 7.71, 7.36, and 7.26, respectively.

The ripening index (RPI) of Chok Anan in crop year 2005 was found rather constant at the beginning until day 4 of the ripening process. After that the degree was reduced to low. The coefficient of determination (R^2) were rather lower in range of 0.66 – 0.77, especially in the control trees (CA0-05), as shown in Figure 4.8A. Mahayothee, 2004 indicated that Chok Anan was ripened in day 3 or day 4. The data about 4 days at the beginning of the ripening process was removed. The coefficient of determination (R^2) were highly observed in range of 0.91 – 0.95 in all treatments (Figure 4.8B). Moreover, the ripening index (RPI) degrees at the fully ripe stage were highly found in control (CA0-05) and the treated trees with high dose of PBZ (CA3-05) as 10.62 and 10.41, respectively. Prohexadione-Calcium (CA1-05) and the treated trees (CA2-05) were 9.43 and 9.51.

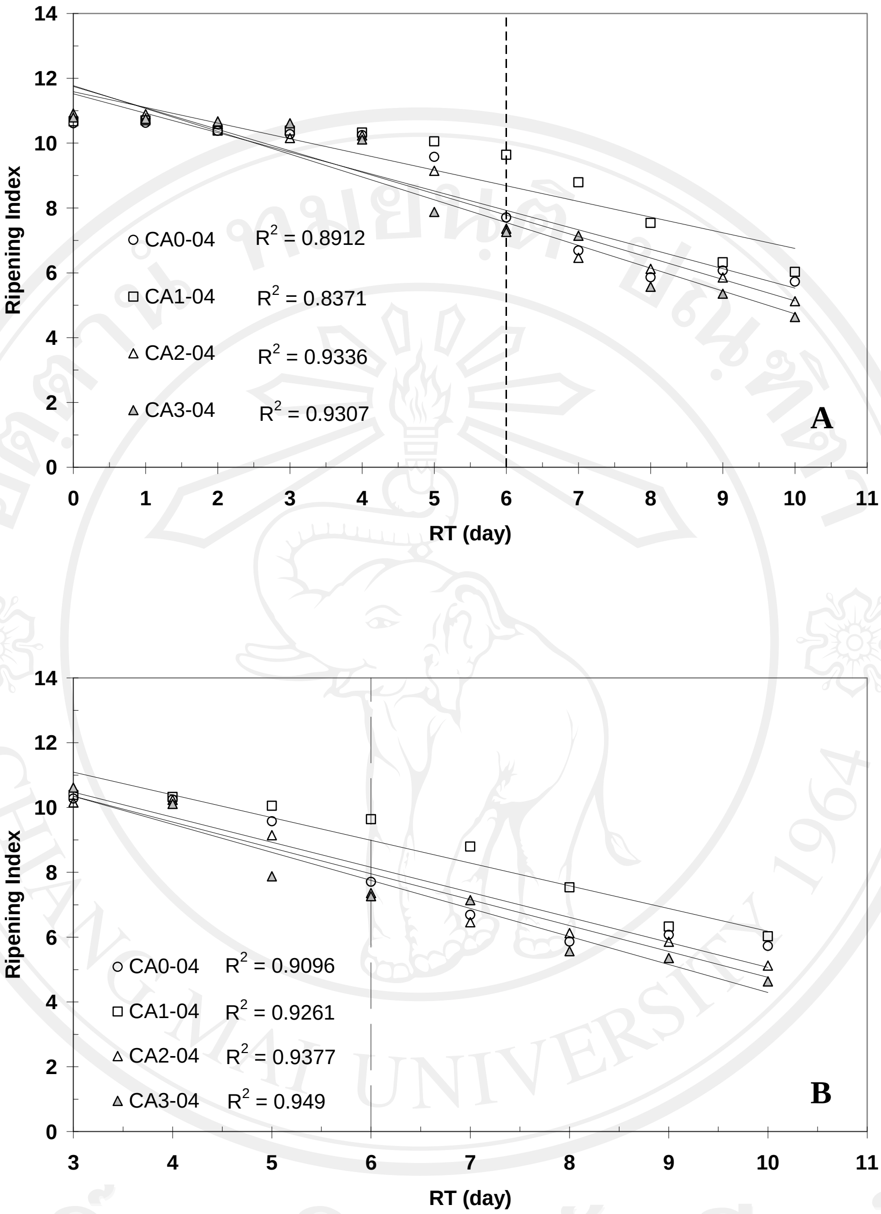

Figure 4.7 Exponential development of the ripening index (RPI) during postharvest ripening of cultivar mango Chok Anan in D plot crop year 2004.

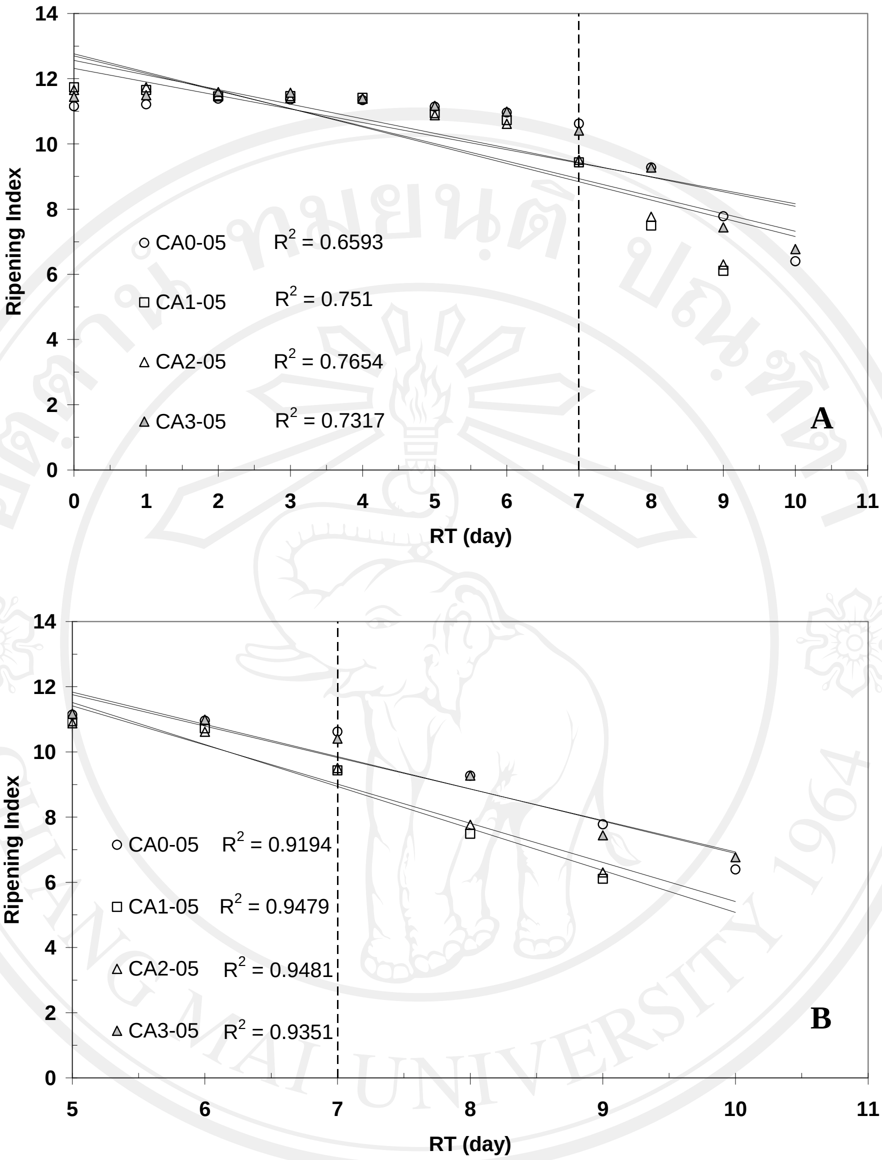

Figure 4.8 Exponential development of the ripening index (RPI) during postharvest ripening of cultivar mango Chok Anan in D plot crop year 2005.

4.4.3 The impact of the cultivars on RPI

Chok Anan at B plot was applied with PBZ concentration 0 and 1.0 g *a.i.* per square meter. It was shown that the ripening index had high coefficient of determination (R^2) at above 0.93 in all treatments (Figure 4.9). Furthermore, the ripening index degrees at full ripeness were in the range of 6.98 – 8.98. The lower degree was found in the treated trees with high dose of PBZ (CA3bB-06) as 6.98. Moreover, the remaining of treated trees with PBZ (CA3bY-05, CA3bY-06) were 7.61 and 7.42. As for the control trees (CA0b-04, CA0b-05, and CA0b-06) were 8.98, 8.24, and 7.30, respectively. When the RPI in control (CA0b-04) about 3 days at the beginning of the ripening process was cut out, the coefficient of determination (R^2) was altered, but it was still high as 0.90 (data not shown). Unless the control trees in 2004 (CA0b-04) had only the long ripening time. In addition to this, they had the short ripening time that was indicated that the mango fruit precedent started ripe since it hung on the tree.

The results of the ripening index for Nam Dok Mai cultivar which was applied by PBZ concentration 0 and 1.0 g *a.i.* per square meter found that the high coefficient of determination (R^2) was happened in all treatments as above 0.92 (Figure 4.10). Therefore, the different of the ripening time was occurred. The ripening index degree at the full ripeness was indicated in the range of 7.55 – 9.12. The high degree of RPI was found in the treated trees with PBZ (NM3-05) as 9.12. By the way, the lower of RPI was observed in the treated trees with PBZ (NM3-06) with the next treated year as 7.55. In control trees (NM0-05 and NM0-06) were 8.52, and 7.87, respectively. Furthermore, the treated trees with PBZ (NM3-04) in year 2004 w 8.07. The difference of the picking date was also affected to the RPI such as Nam Dok Mai as treated trees (NM3-05) which harvested 7 days earlier than control trees (NM0-05).

In addition of the RPI in Khiew Sawoey cultivar was drenched by PBZ concentration 0 and 1.5 g *a.i.* per square meter resulted that the high coefficient of determination (R^2) was obtained in all treatments as above 0.92 (Figure 4.11). The RPI degree was slightly fluctuated in the range of 7.26 – 8.05. Moreover, the RPI of the untreated trees (KS0-05 and KS0-06) were 7.87 and 7.26. The treated trees (KS4-04, KS4-05, and KS4-06) were 7.61, 7.92, and 8.05, respectively.

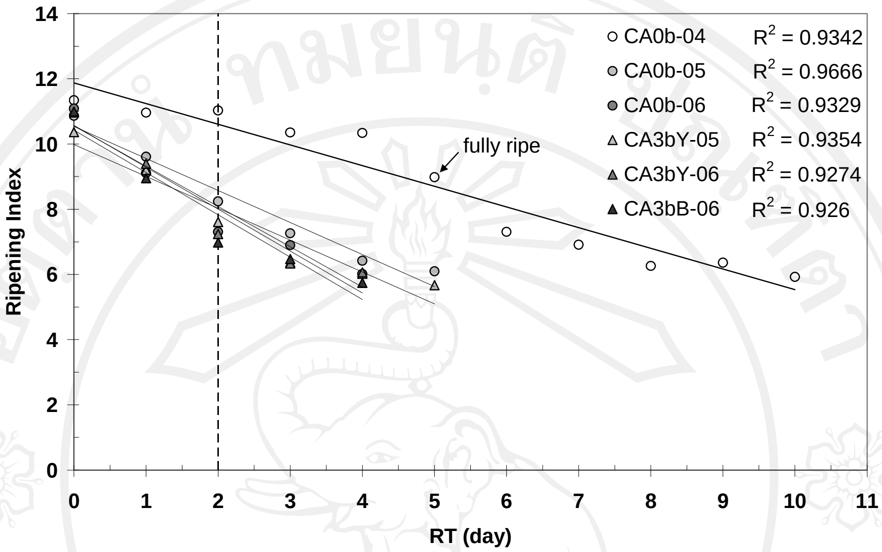

Figure 4.9 Exponential development of the ripening index (RPI) during postharvest ripening of cultivar mango Chok Anan in B plot crop year 2004-2006.

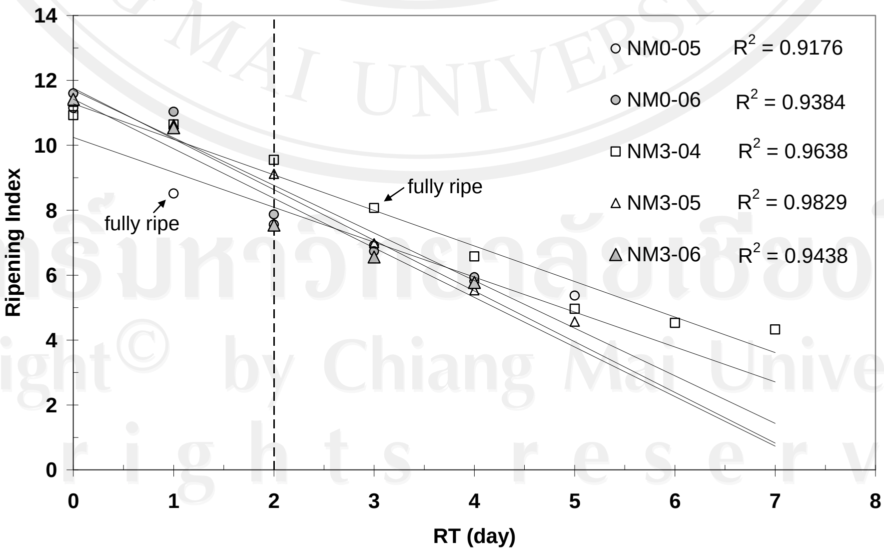

Figure 4.10 Exponential development of the ripening index (RPI) during postharvest ripening of cultivar mango Nam Dok Mai in SS plot crop year 2004-2006.

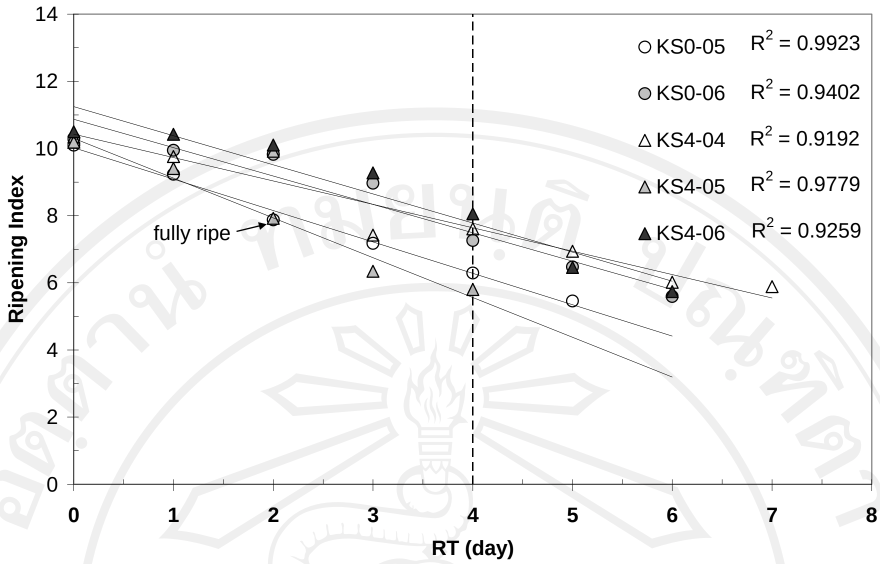

Figure 4.11 Exponential development of the ripening index (RPI) during postharvest ripening of cultivar mango Khiew Sawoey in SS plot crop year 2004-2006.

4.5 Discussion

The interrelation of quality parameters could be fitted well with power law function, except pH was a linear line function. Similarly, Vásquez-Caicedo *et al.* (2002, 2004) found that the postharvest ripening behavior of nine Thai mango cultivars. For individual characterization of the ripening behavior of the cultivars, quality parameters of the ripening fruit were related to each other, thus eliminating extrinsic effects on ripening kinetics. Acidity decreased with rising TSS/TA ratio following a power law relationship independent of cultivar. Decreasing mesocarp firmness and hue angle of flesh may be correlated with increasing TSS/TA ratio by analogy, but power law parameters were dependent on cultivar. Moreover, the correlation of peel and flesh colour were not showed the relationship of them. It concurs with Mahayothee (2004).

The multiple indices was better than used the single index (TSS, TA, colour) for predict the ripening or maturity of fruit because the variation of physical and chemical changes during the postharvest ripening process. In addition of the influence of ripening time on the quality related to TSS, TA, firmness, weight loss and TSS/TA which are normally used for maturity identification by exporters or wholesalers and also by the fruit industry to select the suitable raw material (Mahayothee, 2004). Nevertheless, the variations of crop year, picking date and location were clearly affected to the ripening index which shown in Chok Anan cultivar at D plot and others. The maturity stage (hard mature green, sprung mature green, half-ripe and ripe) at harvest may be affected to fruit quality. By analogy, Prange *et al*. (1998) found that the Streif Index in apple was appeared to be insensitive to year and location variation, giving it good potential for regional utilization. Furthermore, Ullah *et al*. (2004) studies the effect of optimum harvesting dates on the quality of apple suggested that the fruit firmness varied from season to season and it known to be influenced by mineral composition and crop load. In addition, the different dates of picking and the position of the detecting fruit firmness (penetration test) were affected. However, in this study the measurement of fruit firmness was evaluated by the Kramer shear measurement which could be then generated RPI when compared to Mahayothee (2004). For her study, the RPI was applied by the plunger, and the most critical feature of this testing is the speed as insert the plunger into the fruit or the distance of penetration. The RPI degrees for Chok Anan and Nam Dok Mai were compared with Mahayothee (2004). It was found that it was negligible differed in some treatments. It may due to the different of the method for measurable fruit firmness or environment (season, picking date, location). According to sugar-acid ratio levels enhance human perception of specific flavour notes in mango, including aromatics (Malund *et al*., 2001) and test (Vásquez-Caicedo *et al*., 2005). However, the change of sugar-acid ratio was important with RPI, which depended on the different development of TSS and TA during the ripening process, and specified to cultivar, crop year and others.

When PBZ affects to fruit firmness, total soluble solid and titratable acidity, it will also, as a result, reflect to RPI. This was described in chapter 3. However, the prediction of the proper maturity degree and postharvest ripening behaviour has become more important for growers, traders and industries in order to assure the supply of consistently high quality fruits for various applications (Mahayothee, 2004).

Thus, traditional destructive fruit measurements could become non-destructive measurements. If this new technology becomes available, it will induce major changes in the stone fruit industry regarding determination of maturity and quality attributes (Crisosto, 1994). Therefore, Saranwong *et al*. (2004) found that the NIR could be shown the relative between dry matter and starch in flesh mango. If the fruit contained sufficient amounts of dry matter and starch at harvest date and the SSC of ripe mango fruit could be precisely predicted from the dry matter and starch measured non-destructively with NIR at harvest. NIR would used to predict the maturity and ripening of mango. However, those experiments need the long time for improving, developing and confirmative. It could be successfully developed in a way that it would have most useful purpose for common good. In addition, the RPI is expected to deliver a more reliable method to determine fruit maturity and optimize ripening procedures, to improve the quality of the raw materials for both fresh consumption and drying. This would contribute to upgrade the marketing of mango fruits (Mahayothee, 2004).

4.6 Conclusion

It was concluded that the ripening index (RPI) was followed by formula: $RPI = ln (100 \cdot F / (TSS / TA))$, which its degree was negligible vacillated when compared with another. However, that was depended on several factors such as season of production, location, cultivar and picking date, etc. In addition, it was the basic data for developing in the future.