Chapter 5

Preharvest factors affecting mango fruit quality

5.1 Introduction

Preharvest factors such as growing locations with different soil properties and mineral nutrition and conditions at harvest with different maturities have been related to physiological disorders and fruit quality. Among them Ca has been reported to exert pronounced effects on fruit quality, particularly on fruit disorders such as water core (Perring, 1968) and bitter pit (Ferguson and Watkins, 1992; Shear, 1975) in apple, internal breakdown in mango (Raymond et al., 1998), softening in papaya (Qiu et al., 1995) and blossom end rot in tomato (Ho et al., 1993). It is agreed that Ca related disorders mainly result from the problem of Ca distribution within the plant. There have been very few investigations, however, on Thai mango concerning the relationship between soil composition, fruit mineral concentration, postharvest quality and elements distribution, in particular Ca distribution, within fruit. Because mineral analyses alone cannot provide the real localization and distribution of the mineral elements, in this chapter the structural and analytical features were also investigated on fruits by a scanning electron microscope equipped with an X-ray micro-probe to determine

whether differences in soil composition and maturity may be related to concentration, localization and distribution of the minerals, in particular Ca, in Thai mangoes.

5.2 Materials and Methods

Soil fertility trial

Soil samples were collected from different sites (hereinafter site 1; sandy clay loam soil, pH = 5.0 and very low CEC (<3 me/100g) and 2; sandy loam soil, pH = 4.5 and very low CEC (<3 me/100g) for convenience) from commercial orchards in Chiang Mai, Thailand for soil composition analysis.

Storage observation

At harvest the fruits were obtained from each site and treated with 500 ppm benomyl solution and the maturity was determined by specific gravity: in 1% NaCl solution, immature fruits floated while mature fruit sank. The fruit were stored at 25 °C until ripening when thirty fruits from each plot were assessed for fruit quality. Skin and pulp color were measured by a colorimeter (Hunter color meter, model CR-100, Minolta), flesh firmness by a firmness tester using a 7 mm ø plunger, total soluble solid (TSS) by a hand refractometer and titratable acid (TA) by titrating with 0.1 NaOH as expressed as percentage of citric acid. Decay was expressed by the appearance of

the damaged surface area of fruit and the rating as a score (1 = none, 2 = slight, 3 = moderate and 4 = severe) and storage life were determined as described in Chapter 4.

Fruit mineral analysis

For Ca, Mg and K concentrations, dried pulp tissue was digested using sulfuric acid: hydrogen peroxide (1:1) according to Mizuno and Minami (1980). The digested samples were made up to 100 ml with distilled water and analyzed by an atomic absorption spectrophotometer (Hitachi 170-10).

X-ray analysis

For electron microscopy, fruit samples were immediately frozen in liquid nitrogen and sections from the outer mesocarp (next to skin), middle mesocarp and inner mesocarp (next to seed) were freeze-dried and then sliced by a microtome (around 2 mm section thickness). Scanning electron microscope observation and x-ray microanalysis studies were done by the same method as described in Chapter 4.

5.3 Results

5.3.1 Relationship among post harvest fruit quality and soil and fruit mineral nutrition

Field assessment

Soil analysis revealed that the Ca concentration of soil at harvest from site 1 was higher than site 2 (Fig. 5-1). Differences in Ca/N and (Ca+Mg)/K ratios in soil were observed at both sites, Ca/N= 1.61 and 0.88, and (Ca+Mg)/K = 2.55 and 1.55 from site 1 and site 2, respectively (Table 5-1).

Fruit maturity and storage quality assessment

After storage, the immature fruits showed that they had longer storage life than mature ones (Table 5-1). When comparing the sites, fruits taken from site 1 showed a lower incidence of decay thought to be caused by internal physiological disorder, and higher firmness. Total soluble solids (TSS) and titratable acidity were not significantly different between the sites. Although the external appearance of the fruits from site 1 declined by the end of storage they still remained fairly good when compared with the fruits from site 2.

Fruit mineral concentration

Table 5-1 also shows the differences in fruit mineral concentration and it reflects the differences in sites and maturity; immature fruit in site 1 had the highest amount of Ca and mineral ratio of (Ca+Mg)/K. Table 5-2 shows the correlation between

several parameters with storage life, firmness and decay. The highly positive correlation between Ca concentration in fruit and storage life was found in immature fruit with r = 0.63 and 0.66 in site 1 and 2, respectively (Fig. 5-2 a) but lower in mature fruit with r = 0.38 and 0.34 in site 1 and site 2, respectively ($p \leqq 0.001$, n = 30) (Fig. 5-2b). Similar to Ca alone, the correlation between (Ca+Mg)/K and storage life was also found to be significant with r =0.62 ($p \leqq 0.001$, n = 60) in site 1 (Fig. 5-3a) and 0.51 ($p \leqq 0.05$, n = 60) in site 2 (Fig. 5-3b). A high positive correlation between Ca, (Ca+Mg)/K ratio and firmness was also found. Moreover, a positive correlation between K and decay was found with r = 0.43 ($p \leqq 0.01$). The influence of sites on fruit quality with good marketability acceptance could be mainly attributable to the differences in soil mineral condition.

5.3.2 Distribution of mineral elements within the fruits as revealed by microanalysis

To elucidate the feature of mineral distribution in mangoes, the elements in the cells were analyzed by X-ray microanalysis. Fig. 5-4a shows whole cells of immature fruit with cut surfaces while Fig 5-4b shows cell separation and cell wall degradation of mature fruit. X-ray mapping showed the different localization of Ca in parenchyma cells. Figs. 5-5 and 5-6 show that the amount of Ca in

mesocarp was the highest in the outer part (Fig. 5-5a; 5-6a) while the lowest was in the inner mesocarp (Fig. 5-5c and Fig.5-6c) where yellow coloration and softening around the seed occurred. When compared for maturity, the immature (Fig.5-5) fruits showed the higher amount of Ca elements which attached inside the cells than that in mature fruits (Fig. 5-6).

In addition, X-ray spectra demonstrated that the localization of Ca was highest in the outer mesocarp decreasing towards the inner mesocarp, in contrast with K distribution which was highest in inner mesocarp (Fig. 5-7). The results from the different sites confirmed that Ca was located at a considerably higher level in fruits from site 1 than from those in site 2.

5.4 Discussion

It has been observed in mango that the increase in fruit maturity reduces storage life (Table1), confirming the previous reports of reduced mango shelf life with increasing fruit maturity (Hofman et al., 1995), which may have been indirectly related to the retention of more green skin than mature fruit. The skin of unripe green mango contains a high level of antifungal compounds which decompose to non-toxic substances during ripening (Cojocaru et al., 1986). When comparing the sites, fruits from site 1 showed higher firmness and lower decay thought to be caused by internal

physiological disorder. Although the results in total soluble solid and titratable acidity showed no difference between the sites, the external appearance of fruits from site 1 still remained acceptable after storage. As for the relations between Ca concentration and storage life, there were positive relationships between storage life and Ca. Tagliavini et al. (1995) reported that the lower concentrations of Ca and Mg in kiwifruit resulted in earlier softening in the fruits. In addition it is reported that Ca improved fruit quality by increasing the structural integrity of cell wall (Ferguson and Drobax, 1988). Also, high Ca concentration could reduce the rate of softening (Bower and Cutting, 1988), and decrease fruit respiration and production of ACC and ethylene (Marcelle, 1991). Ca contents were higher in immature fruits than in mature ones possibly due to the difference in transpiration of plant organs. The decrease in Ca concentration with fruit development may be a dilution effect caused by the inability of fruit to uptake Ca during fruit growth (Witney et al., 1990). The influence of sites on storage life and fruit quality could be mainly attributable to the difference in soil mineral condition as Ca/N and (Ca+Mg)/K were positively correlated with storage life. Koen et al. (1990) found in avocado that the relationship between soil Ca, Mg and K, and the development of pulp spot was significant. The results indicate that the ratio of (Ca+Mg)/K could be used as a better indicator than each element alone to predict storage life.

The mineral elements distribution within the fruit by microanalysis also confirmed that there was a difference in the Ca concentration in the tissue of fruit, that is, the outer mesocarp had a higher amount of Ca than the inner mesocarp, where there was yellow coloration and a pronounced softening around the stone as jelly seed (Raymond et al., 1998). These findings are similar to those of Burdon et al. (1991) in that the inner flesh of the distal region where the soft nose disorder developed had the lowest Ca concentration. Prasad and Spiers (1991) also found that a low concentration of Ca in whole kiwifruit was related with premature softening. As for maturity, the mature fruit showed lower Ca concentration, which is consistent with the previous report by Witney et al. (1990). This also implies that as Ca moves in the tree by transpiration mass flow in the xylem during fruit growth, organs which transpire slowly, such as fruit, accumulated less Ca than leaves (Boyer, 1985; Himelrick and McDuffie, 1983). In fruit, Ca may move from the inner mesocarp to the outer mesocarp according to the direction of Ca transport. After harvesting, there is no Ca influx to fruits, and Ca slowly moves from inner to outer mesocarp. Therefore Ca contents decreases in the inner mesocarp, which in turn results in the breakdown and softening of the inner tissue region.

X-ray mapping showed that the K element in the mesocarp of immature fruit was predominantly localized in the vacuole of

parenchyma cells (data not shown). Fig. 5-5 shows that the Ca element of immature fruit adjacent to cell wall was greater than that of mature fruit (Fig.5-6). Besides, Ca was located at a considerably higher level in fruit taken from site 1 (Fig. 5-7a) than that from site 2 (Fig. 5-7b). This coincides with the results of the relationship between soil and fruit mineral nutrition, and postharvest fruit quality. In contrast, the concentration of K in the fruits from both sites was highest in the inner mesocarp, as demonstrated by x-ray spectra (Fig.5-7).

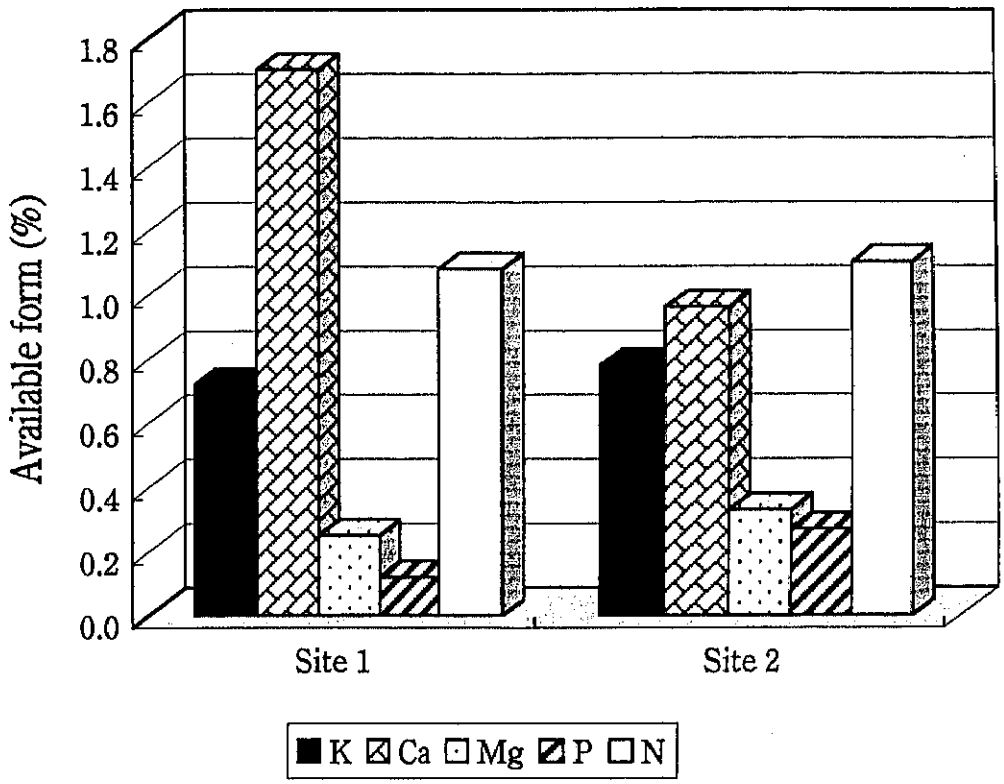

Fig. 5-1. Soil minerals composition from different sites.

Table 5-1. Effect of soil condition on fruit mineral concentration, fruit firmness, decay and fruit quality when ripened at 25℃ until table ripe stage. Values are means of 30 fruits per treatment.

Site	Soil condition[x]			Fruit mineral concentration[y]			Fruit quality				
	Ca/N	(Ca+Mg)/K		Ca	Mg (mg/gDW)	K	Firmness (Kg)	TSS (Brix)	TA (%)	Decay[z] (%)	Storage life (days)
1	1.61	2.55	Immature	0.53 ±0.03	0.36 ±0.03	10.5 ±0.24	0.97 ±0.03	14.14 ±0.59	0.05 ±0.008	20.41 ±2.9	11.8±0.29
			Mature	0.43 ±0.02	0.5 ±0.03	19.08 ±0.75	0.75 ±0.02	15.57 ±0.68	0.06 ±0.005	20.41 ±4.2	8.5±0.86
2	0.88	1.55	Immature	0.48 ±0.03	0.45 ±0.04	26.76 ±0.34	0.56 ±0.03	12.43 ±0.29	0.06 ±0.005	40.81 ±3.7	10.8±0.67
			Mature	0.39 ±0.02	0.44 ±0.02	30.3 ±0.55	0.56 ±0.03	14.57 ±0.68	0.06 ±0.005	38.77 ±4.1	8.43±0.48

Mean±SE

[x] The data were shown as available form of mineral nutrition.

[y] The data were shown as total form of Ca, Mg and K.

[z] Decay thought to be caused by jelly seed mostly.

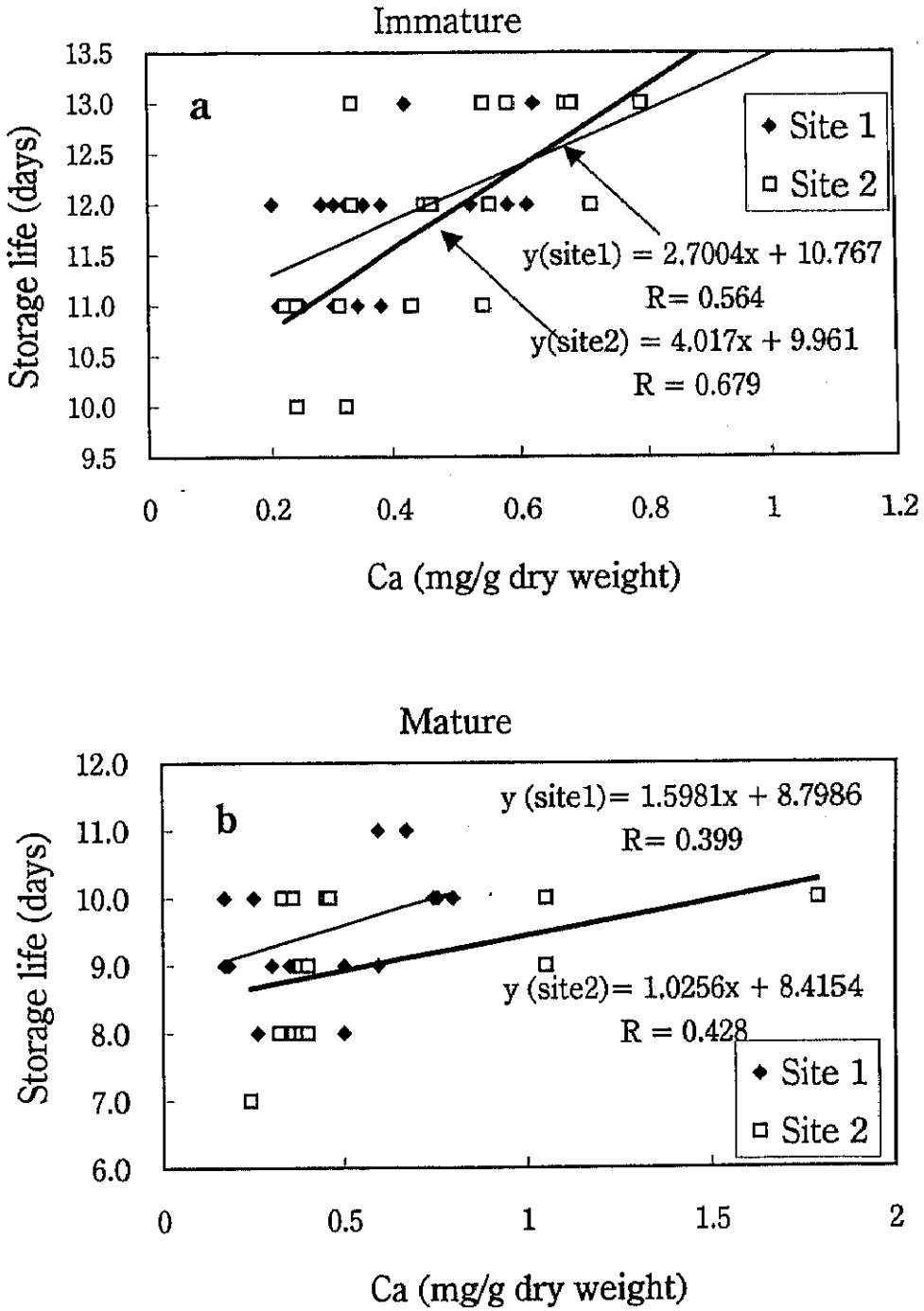

Fig. 5-2. Regression relationship between fruit Ca concentration and storage life of mango fruit harvested from different sites and maturities.

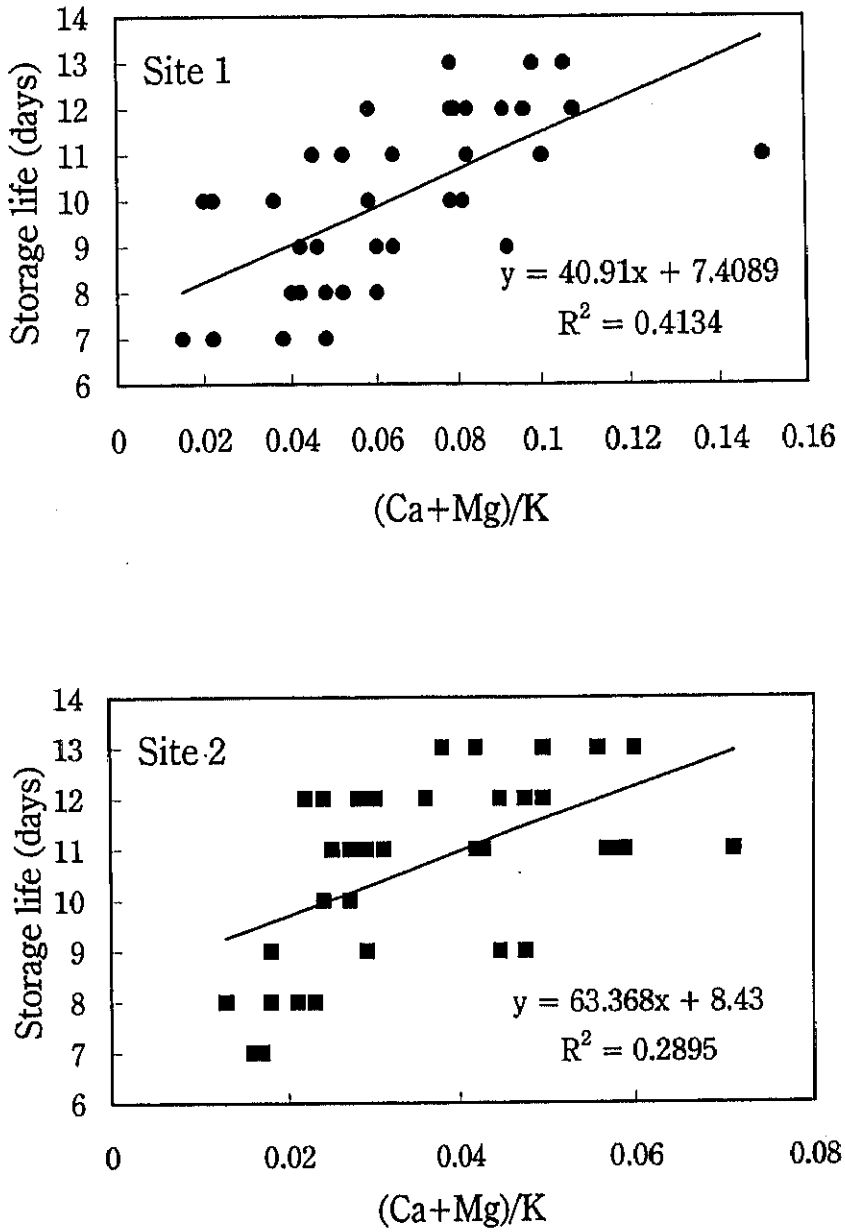

Fig. 5-3. Regression relationship between fruit (Ca+Mg)/K ratio and storage life of mango fruit harvested from different sites.

Table 5-2. Correlation coefficients of storage life, firmness and decay with Ca, Mg and K concentration (mg/gDW) and K/Ca and Ca/Mg and (Ca+Mg)/K ratios in fruits.

	R value	
	Site 1	Site2
Ca v Storage life	0.64***	0.68***
Mg v Storage life	0.06	0.46
K v Storage life	0.30	0.48
Ca/Mg v Storage life	0.23	0.35
K/Ca v Storage life	0.12	0.04
(Ca+Mg)/K v Storage life	0.64***	0.53**
Ca v firmness	0.52*	0.45
K v firmness	-0.33*	-0.07
K v decay	0.48*	0.57***

*, **, *** Correlations significant at $p<0.05$, 0.01 and <0.001, respectively.

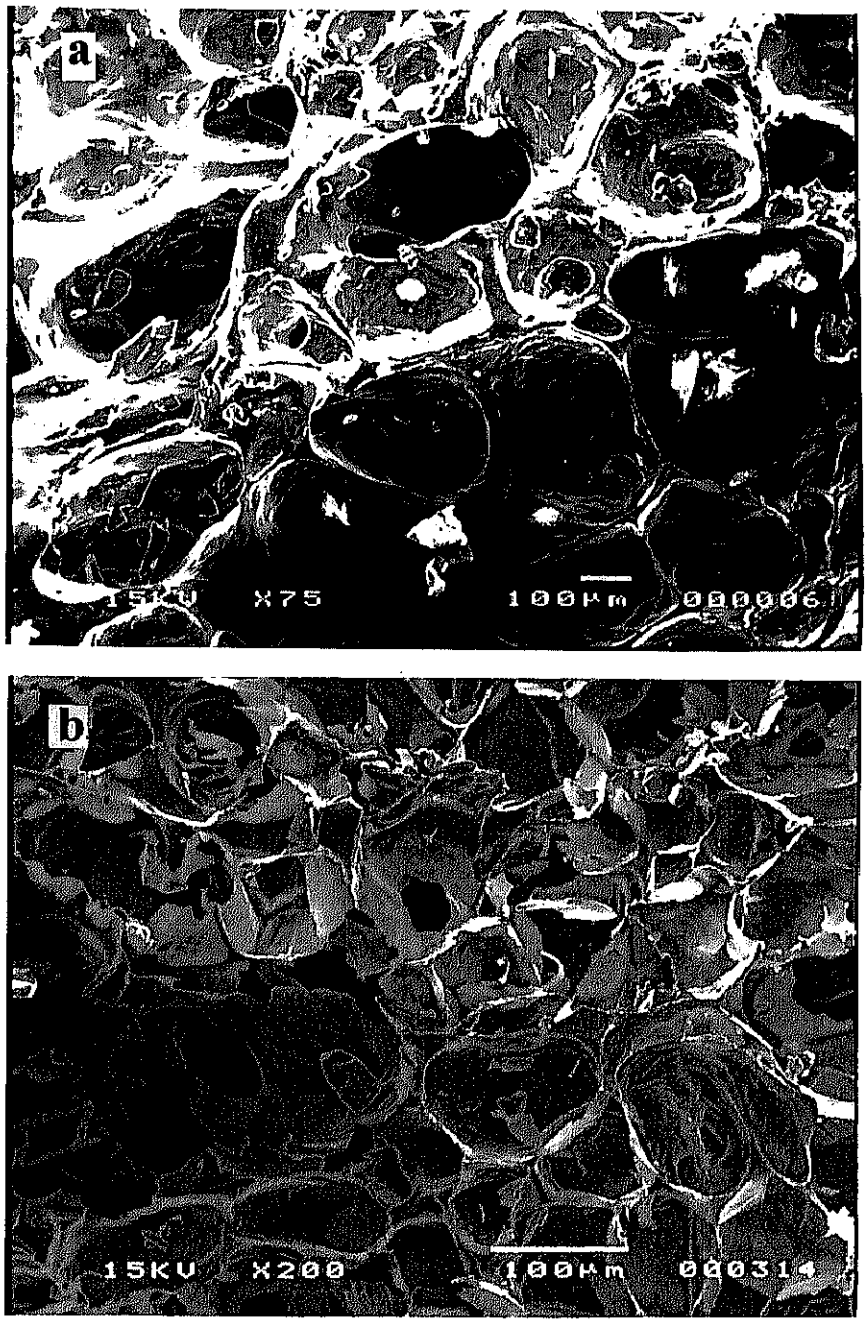

Fig. 5-4. Mesocarp of mango fruit observed by scanning electron microscope(SEM).
(a) Immature fruit after ripening showed whole cells and cut surfaces without distortion.
(b) Mature fruit showed cell separation and cell wall degradation.

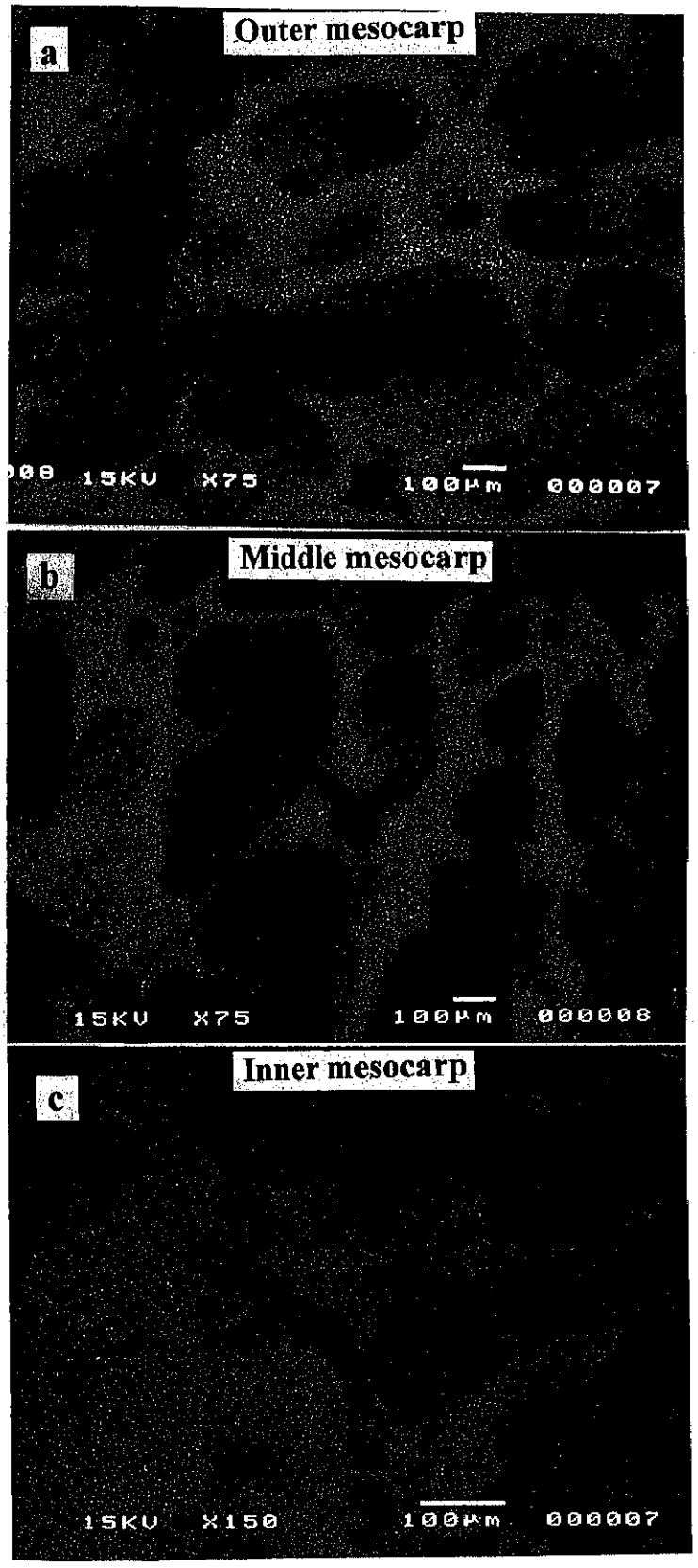

Fig. 5-5. Digital mapping showing the distribution of Ca from outer mesocarp (a) middle mesocarp (b) and inner mesocarp (c) of immature fruit.

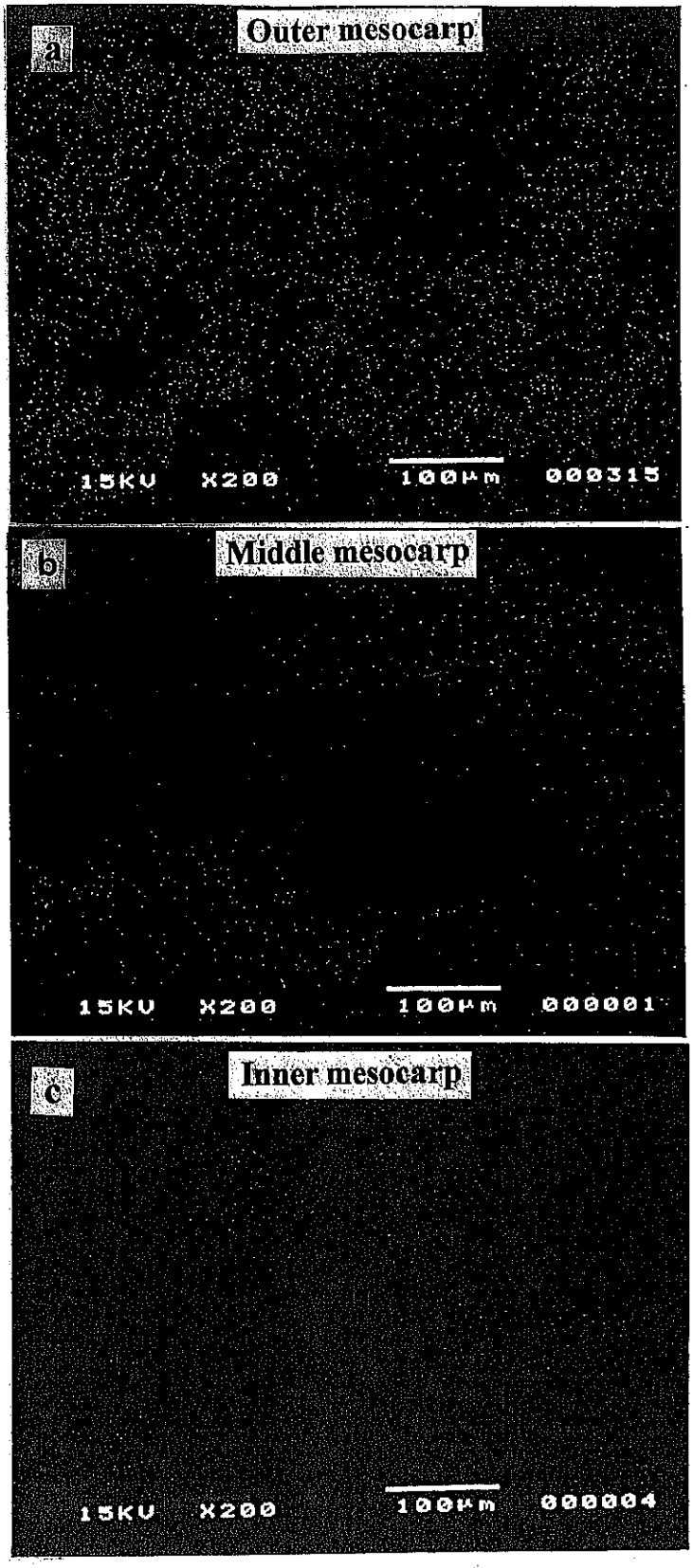

Fig. 5-6. Digital mapping showing the distribution of Ca from outer mesocarp (a) middle mesocarp (b) and inner mesocarp (c) of mature fruit.

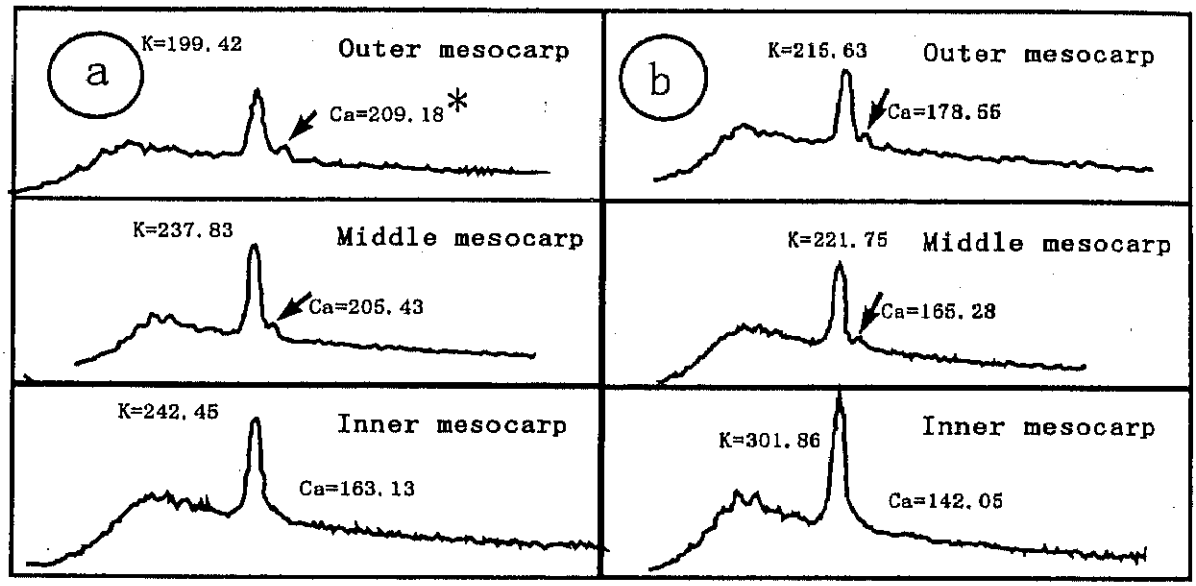

Fig. 5-7. X-ray spectra showing the distribution of Ca and K from inner to outer mesocarp of immature fruit cv. 'Nam Dok Mai' with different sites; site 1 (a) and site 2 (b).
* values are averages of three replicate tissues