CHAPTER 4
INFLUENCE OF CROPPING SEASON ON PHYSICO-CHEMICAL, SENSORY ATTRIBUTES AND RIPENING OF PINEAPPLE FRUIT

4.1 Introduction

The physical and chemical changes during development, maturation and ripening of pineapple fruit (cv. Smooth Cayenne) has been extensively studied (Gortner, 1965; Gortner and Singleton, 1965; Singleton, 1965; Singleton and Gortner, 1965). The shell colors of pineapple are generally used to determine the various stages of maturity. Smooth Cayenne produces a light yellow or golden yellow flesh color when ripe. Pineapples with slightly yellowed to one-half yellowed surface have better shelf-life than those with more surface color, and fruit with no yellowing may not be mature enough for optimum eating quality (Pantastico, 1975). As the fruit ripeness, the 'eyes' change from pointed to flat, with a slight hollowness at the center, the fruit becomes enlarged, less firm and more aromatic.

The range of chemical constituents of ripe pineapple, depending upon stage of fruit ripeness and environmental factors, has been reported by Dull (1971) and Kermasha *et al*., (1987). Bartholomew and Malzieux (1994) reported that the rate of growth and development are positively correlated with temperature up to 29°C. In the cool season, the growth is delayed, leaves are narrow, rigid and short, the number of slips is high, fruit are small, with prominent eyes and the flesh is opaque, high in acidity and low in sugars. The same as the growth of fruit in Hawaii winter, temperatures rarely fall below 10°C, plants are small, leaves are short, fruitlets are more pointed, flesh color is pale yellow, flavor is poor and acid is high (Collins, 1968). While in Mexico, fruit produced for processing between June to August generally have low acid and total soluble solids. This lower quality is due to the combined effect of high temperature, excessive rain and an increased number of cloudy days (Nakasone and Paull, 1998).

The purpose of this chapter was studies to the influence of maturity and cropping season on physical attributes (shell and flesh color, L*, a*, b*, chroma, hue value and texture), chemical compositions (total soluble solids, titratable acidity, pH, soluble sugars, crude fiber and moisture content) and sensory attributes of pineapple fruits.

4.2.1 Experiment 1: Assessment of color qualities, color pigments and flesh translucency of pineapple fruit

4.2.1 Materials and Methods

(a) Samples

A total of 240 pineapple fruits cv. Smooth Cayenne after used in Experiment for morphological study in chapter 3 were used as samples in this experiment.

(*b) Analysis of color qualities, color pigments and translucency of pineapple fruits*

The harvested pineapples were evaluated for shell color score as percentage of yellow area on the whole fruit shells using following criteria: CS1 = green, CS2 = breaker, CS3 = 25% yellow, CS4 = 50% yellow, CS5 = 75% yellow and CS6 = 100%.

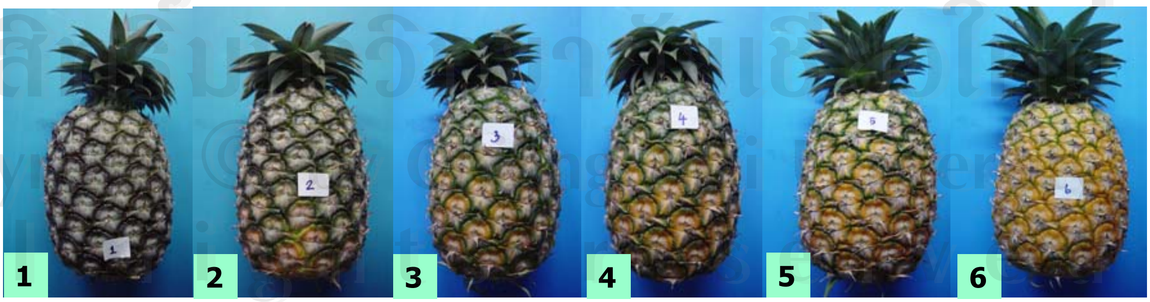


Figure 4.1 Shell color score of pineapple fruit.

After shell color were evaluated, the middle portion of the fruit was measured from center of horizontal circumstance up to the top 4.5 cm and down to the base 4.5 cm were cut and divided into 3 slices, each 3 cm in thickness as basal, medial and top pieces. Each slice was measured for its core diameter. Flesh color of each slice was measured at center of a pair of fruitlet from opposite side of the slices with a portable Minolta colorimeter model "CR-200" (Minolta, Osaka, Japan). The L*, a*, and b* values were calculated to hue angles as formula described by McGuire (1992). The instrument was calibrated against a standard white reflective plate, using CIE Illuminant D_{65} with a 2° Standard Observer. Other coordinates calculated from the CIELAB a* and b* values were chroma ($c^* = [a^{*2} + b^{*2}]^{1/2}$) or saturated index (intensity or purity) and the hue angle ($H_{ab} = tg^{-1}\ b^*/a^*$). Each value represents a mean of a duplicate determination of three different samples. Results were reported as average of individual values as L* (lightness), a* (+a = red, -a = green) and b* (+b = yellow, -b = blue).

Fruit harvested from each maturity from each crop season were cut and detected for translucency and calculated as percentage of translucent fruits. Extraction and determination of shell and flesh pigments from 3 parts slices, about 5 gram peel or flesh were cut finely by hand and added 20 ml alcohol 95%. The samples were kept in refrigerator overnight and then filtered with filter paper Whatman No.1. The solution was determined the optical density at 420, 447, 645, and 663 nm by Spectrophotometer UV-VIS Unicam 500 (Whitham *et al*., 1971).

Chlorophyll concentration was calculated for total chlorophyll, chlorophyll a and chlorophyll b components (mg/100g fresh weight) as follows:

$$\text{Total chlorophyll} = (20.2D_{645} - 8.02D_{663}) \times V/1000W$$
$$\text{Chlorophyll a} = (12.7D_{663} - 2.69D_{645}) \times V/1000W$$
$$\text{Chlorophyll b} = (22.9D_{645} - 4.68D_{663}) \times V/1000W$$

Where D = value of absorbance optical density at 645 and 663 nm
V = volume of pigment solution (ml)
W = fresh weight of sample (g)

Carotenoid concentration was calculated as β-carotene components (mg/100g fresh weight) as follows:

$$C = A\times 454 / 196\times L\times W$$

Where C = concentration carotene (mg/100g) in original sample
A = value of absorbance optical density at 420, 447, and 474 nm
L = cell length in cm
W = g product/ml final dilution
Convert by C×0.22

(c) Data analysis

Analysis of Variance (ANOVA) with Randomized Complete Block (RCB) using pineapple fruits as a block was performed by SPSS® program (SPSS, Illinois, U.S.A.). Tukey's Least Significant Difference (LSD) was used to test the significant difference at 95 % confidential of each variable.

4.2.2 Results and discussion

(a) Shell color

The shell color of pineapple fruit changes from green to yellow (color score 1 to color score 6) during maturation (Figure 4.2 (A), (B)). Fruit began to change color at 120 DAFB (days after full bloom) but the pattern of change of shell color depends on growing season. In early crop, at harvesting date of 120 DAFB, when the fruit is ready for consumption, 85% of fruits are still green (Figure 4.3 (B), 4.4 (B)). In contrast, 40% of fruit in the late crop had been changed to color score 3 (two lower row of eyes became yellow). At the optimum harvesting date 130 DAFB (Figure 4.3 (C), 4.4 (C)) more than 75% of the early crop was ripened with green shells (color score 1 and 2), whilst 85% of late crop fruits were yellow (color score 3-4) (Figure 4.3 (C), 4.4 (F)).

The results showed the pattern of delaying shell color change in the early crop. High night temperatures during summer season may delay shell color change. The night temperatures of the early crop in years 2002 and 2003 were as high as 31°C and 23°C, respectively. The late crop night temperatures in those years were on the average lower than 23°C and 15°C. The low night temperatures especially in year 2003 caused rapid color change of the fruit and most fruits were 75% yellow (color score 5) compared to the year 2002 which showed higher night temperatures and caused 70% of the fruits showed at the breaker stage (color score 2) at harvesting time (Figure 4.3 (B), (C)).

Murata (1997) reported that degreening of citrus fruit on the tree, due to the composition of chlorophyll in the rind, is induced by low night temperatures. Several cultivars in tropical producing areas can not usually attain the typical orange color, because of the high temperatures above 30°C. Smith (1984) reported that the degree of skin yellowness (skin color) present at optimum ripeness varies with season, rainfall, microclimate and field aspect. At various times of the year, the flesh of fruits with a dark green skin can be over-ripe, and at other times completely yellow fruits can be under-ripe.

Figure 4.3 and 4.4 shows the pattern of shell color change in the crop years 2002 and 2003. Comparing the rate of color changed of the late crop years 2002 and 2003. The late crop year 2003 changed color more rapidly than the previous year. Incidence of rain during harvesting period may be the cause of delay in color change of the late crop year 2002.

(b) Total chlorophyll and carotenoid of peel

The average total chlorophyll of shell pineapple fruits were evaluated from thirty fruits. The results showed decreasing of chlorophyll during maturation of all crop seasons. When comparing the total chlorophyll content of the same maturity stage of different crop seasons showed no significant differences, except fruit at 110 DAFB, total chlorophyll of early crop was higher than regular and late crops (Figure 4.5 A). The decreased of total chlorophyll agree with the results reported by Gortner (1965) and Py *et al*. (1987). The shell chlorophyll declined to the final 10-15 days before full shell yellowing. Shell carotenoid pigment remained reasonable constant during this phase and slightly decline before rising again as the fruit senescence. The carotenoids of the peel were increased during maturation of all crops. The carotenoid content of late crop was higher than early and regular crops at all stages of maturation (Figure 4.5 B). Shell carotenoids actually decrease during ripening and then increase in senescence (Dull, 1971). Goodwin (1980) reported that the development of carotenoids in ripening fruit is subject to a number of environmental and genetic factors. The most important environmental factors influencing carotenoids synthesis in fruit is temperature. Tomato is an example of fruit in which pigment development may be influenced by low or high temperature. The optimum temperature range for ripening in tomato is 16-20°C. Temperature above 30°C will inhibit development of lycopene but not carotene, and the fruit turn orange rather than red (Hobson and Grierson, 2000).

Table 4.1 Physico-chemical properties of pineapple fruits harvested at 130 DAFB from all crops for the years 2002 and 2003.

Assay	Season 2002			Season 2003		
	Early	Regular	Late	Early	Regular	Late
Shell color	Green	Yellow -green	Yellow	Green	Yellow -green	Yellow
Flesh color	Light yellow	Yellow	Pale Yellow	Light yellow	Yellow	Pale Yellow
Color						
L*	64.51^{b}	70.01^{c}	61.37^{a}	61.85^{a}	67.67^{bc}	62.78^{a}
a*	-1.63^{a}	-0.39^{b}	-0.14^{b}	-0.95^{b}	0.00^{bc}	0.32^{c}
b*	22.19^{a}	33.20^{c}	32.07^{c}	27.00^{b}	34.27^{c}	25.87^{a}
Chroma	22.26^{a}	33.22^{c}	31.57^{c}	27.04^{b}	34.28^{c}	25.87^{a}
Hue angle	94.34^{c}	90.75^{bc}	90.33^{ab}	92.09^{c}	90.03^{ab}	88.05^{a}
Texture (N)	11.18^{b}	11.18^{b}	10.63^{b}	8.54^{a}	8.95^{a}	10.13^{a}
Total soluble solids (%)	12.53^{a}	12.60^{a}	14.56^{b}	12.44^{a}	14.53^{b}	15.35^{c}
Titratable acidity (g citric acid/100g f.w.)	0.48^{a}	0.49^{a}	0.67^{c}	0.59^{b}	0.51^{ab}	0.65^{c}
TSS: TA ratio	31.09^{c}	29.74^{bc}	22.50^{a}	21.15^{a}	30.47^{c}	24.50^{b}
pH	4.28^{c}	3.54^{b}	3.19^{a}	4.03^{c}	3.78^{b}	3.79^{b}
Taste	Sweet	Sweet-slightly sour	Sweet-sour	Sweet	Sweet-slightly sour	Sweet-sour

f.w. = fresh weight.

Sample harvested at 130 days after full bloom.

Different letters in the same row indicate significant differences, $P \leq 0.05$

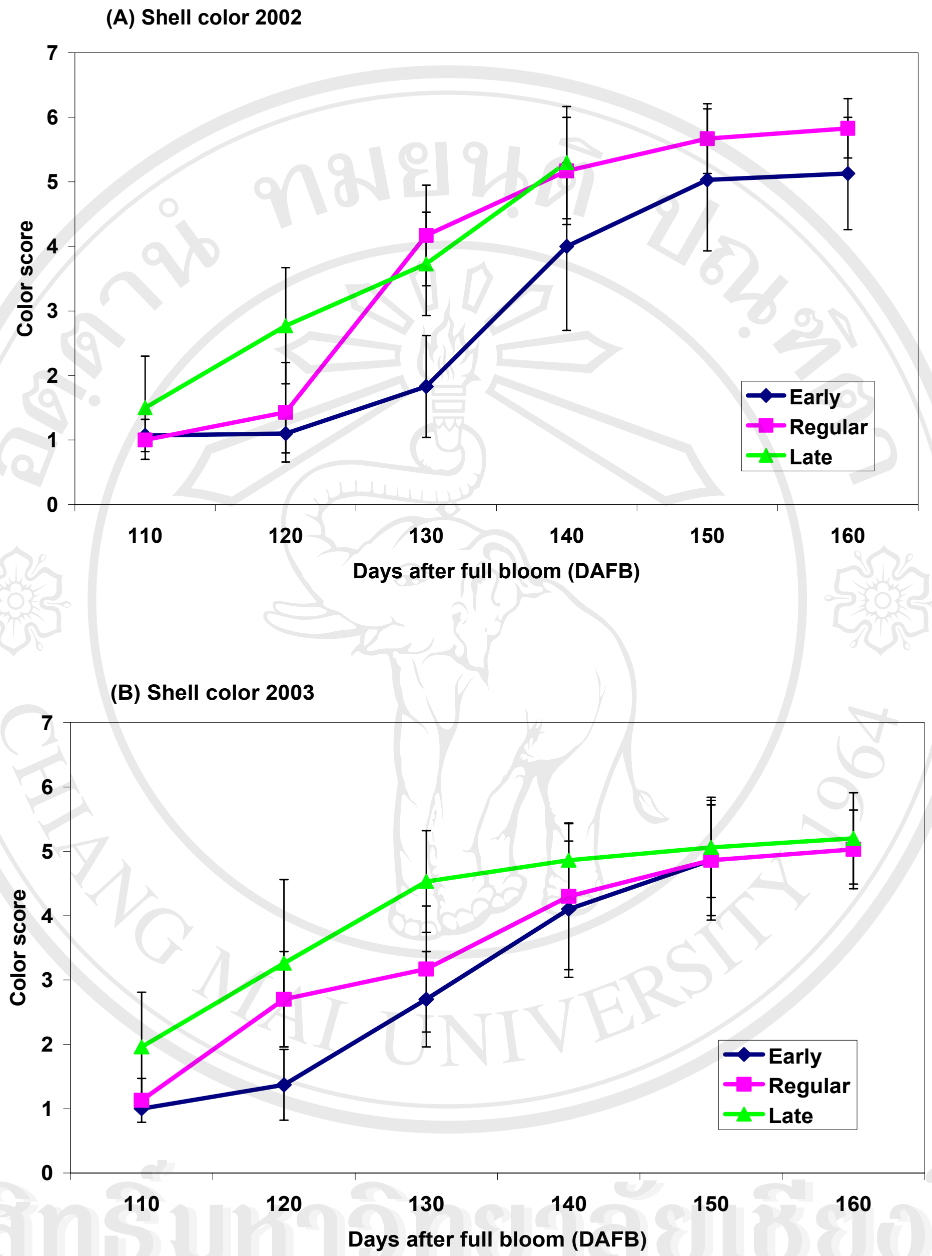


Figure 4.2 Average of shell color score changes during harvesting period in the early, regular and late crops for the years 2002 (A) and 2003 (B). Color shell score (CS): CS1 = green, CS2 = breaker, CS3 = 25% yellow, CS4 = 50% yellow, CS5 = 75% yellow and CS6 = 100% yellow.

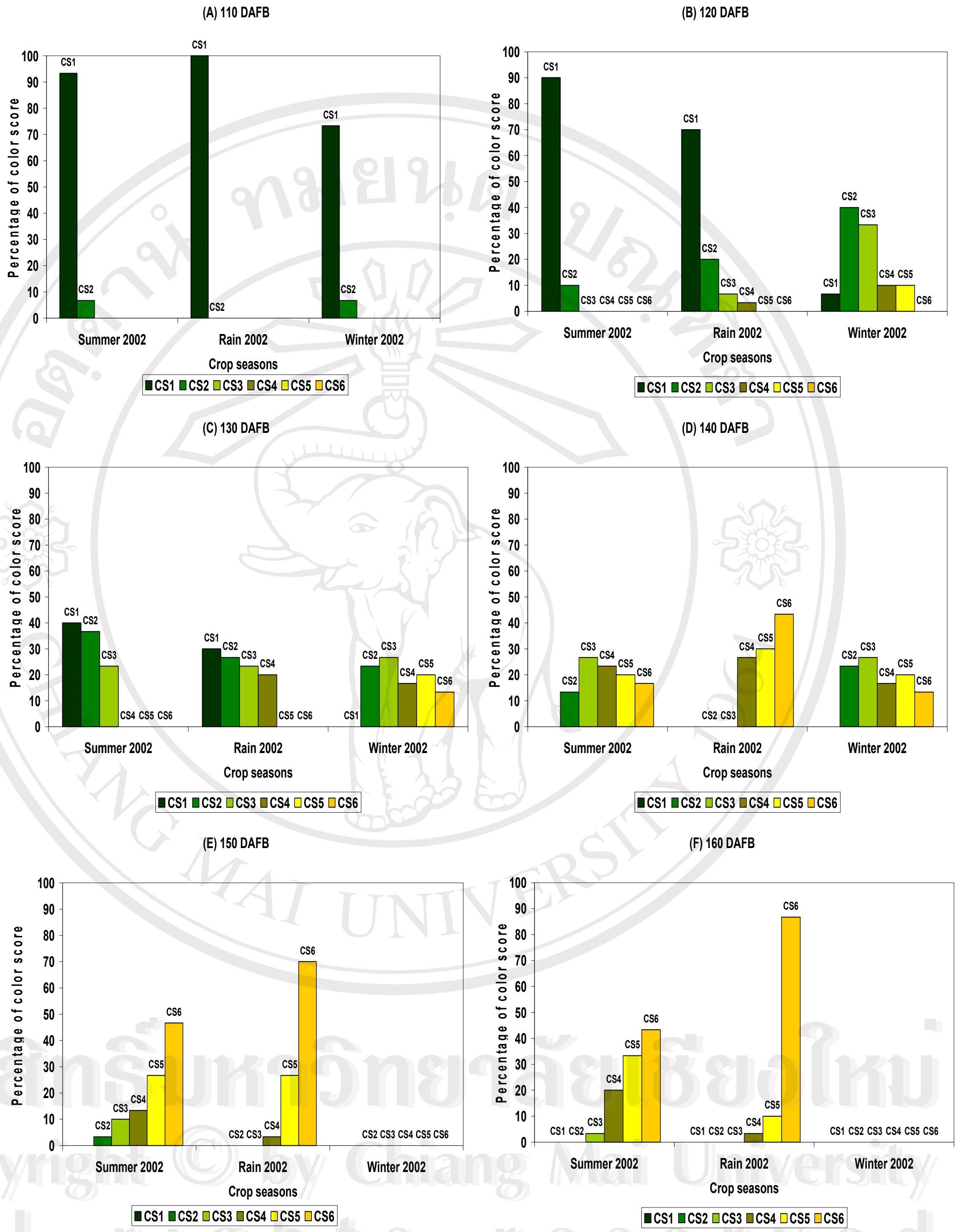


Figure 4.3 Percentage of fruit with different shell color scores of all crops at harvesting dates 110-160 DAFB (A-F) for the year 2002. Color score (CS): CS1 = green, CS2 = breaker, CS3 = 25% yellow, CS4 = 50% yellow, CS5 = 75% yellow and CS6 = 100% yellow.

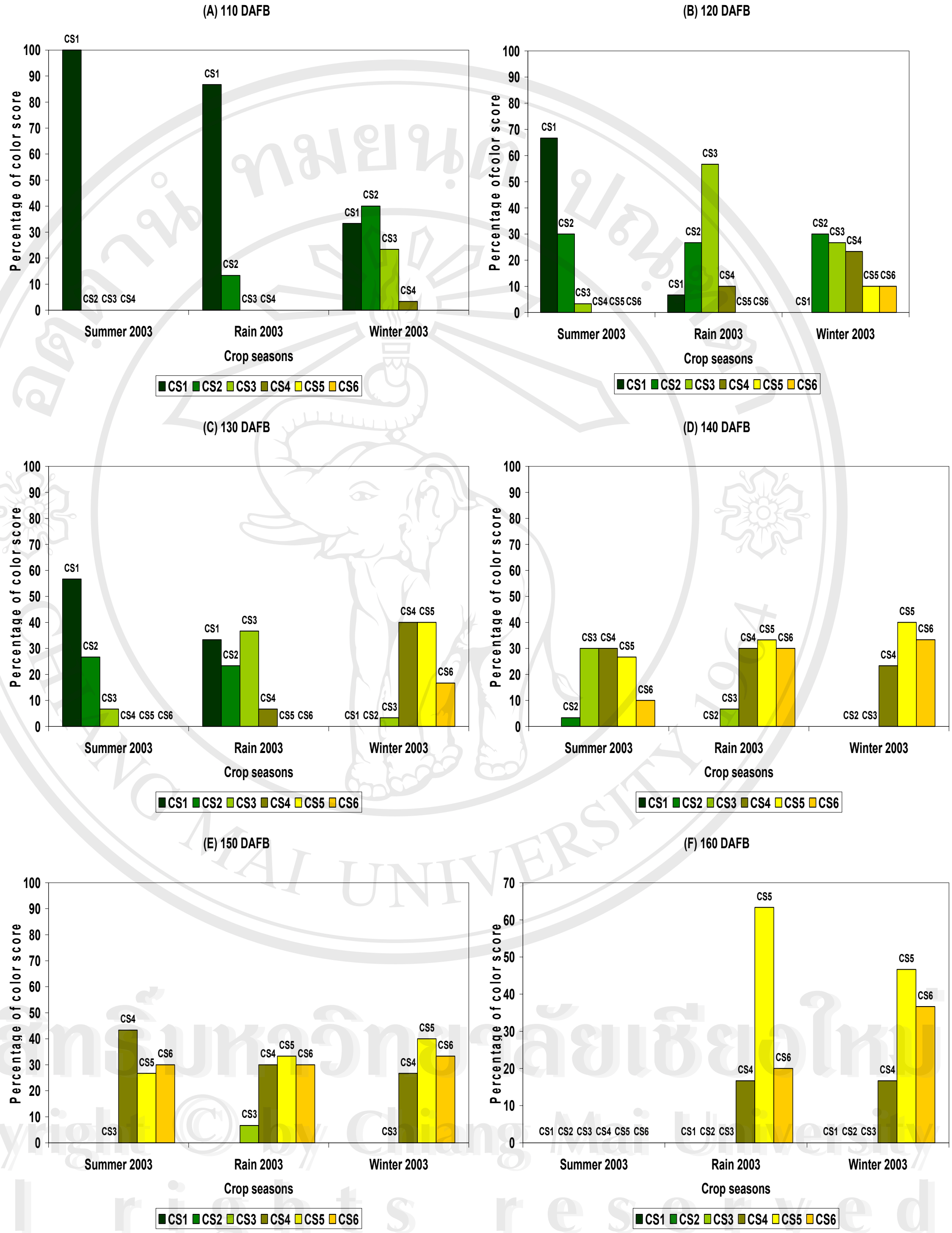


Figure 4.4 Percentage of fruit with different shell color scores of all crops at harvesting dates 110-160 DAFB (A-F) for the year 2003. Color score (CS): CS1 = green, CS2 = breaker, CS3 = 25% yellow, CS4 = 50% yellow, CS5 = 75% yellow and CS6 = 100% yellow.

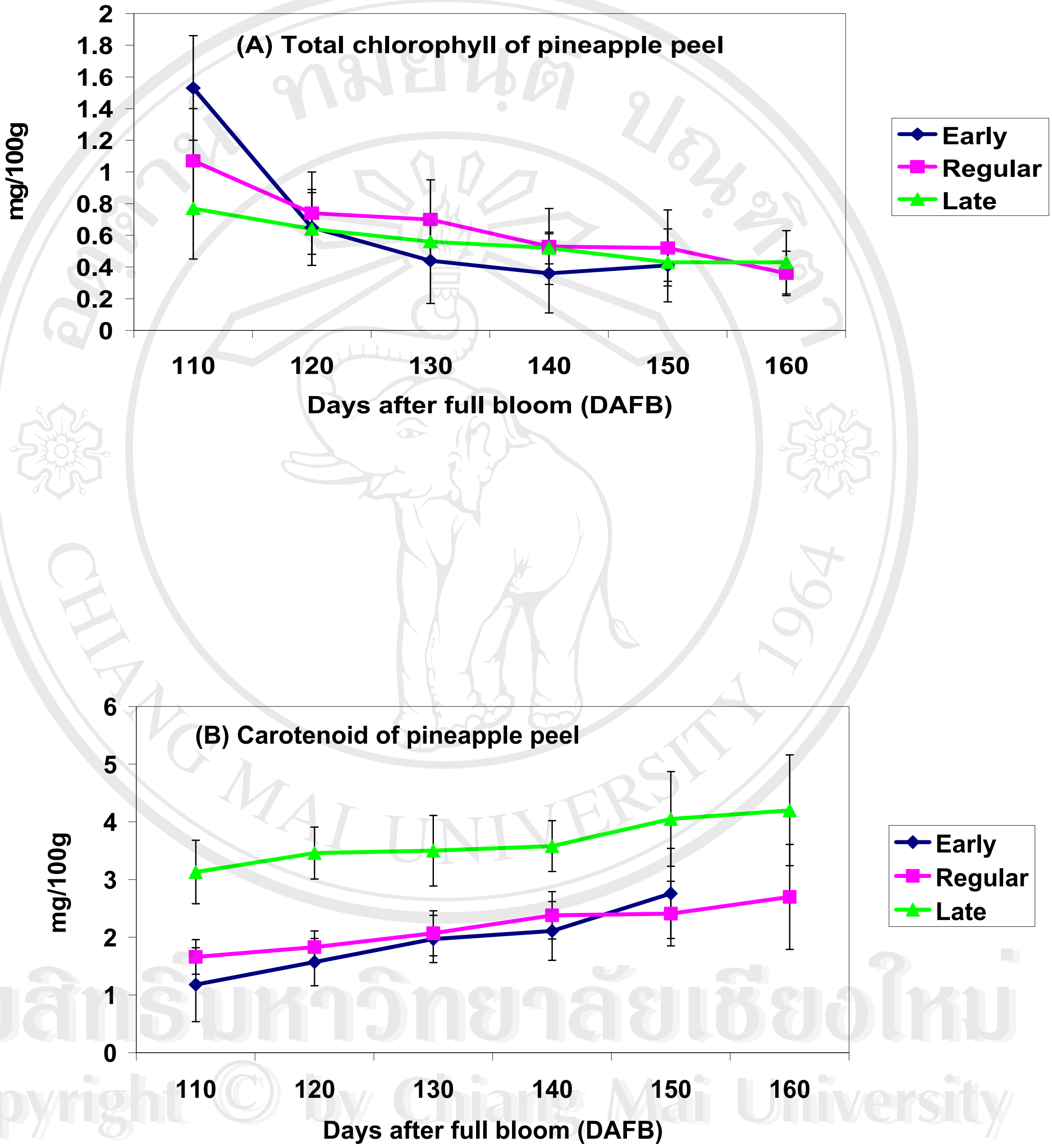


Figure 4.5 Comparative changes of total chlorophyll (A) and carotenoids (B) of pineapple peel for the year 2003.

(c) Flesh color and carotenoid

Carotenoid content of pineapple flesh increased at harvest time (120 DAFB) but it was not significant differences 3 weeks later harvesting period until overripe in all cropping seasons (Figure 4.6). The flesh carotenoids increased during these final ten days before the fully ripe stage (Gortner, 1965; Dull *et al.*, 1967; Dull, 1971; Lodh *et al.*, 1972; Teisson and Pineau, 1982; Py *et al.*, 1987 and Chen and Paull, 1995). The carotenoids pass through a minimum concentration about 40 days before ripeness and then undergo an extremely rapid increase during the last three weeks of ripening. Pineapple fruit carotenoids undergo rapid isomerization in tissue homogenates due to the high acidity (Dull, 1971). In this experiment, carotenoid content of the late crop was higher than other crop. The average carotenoid content of all crops was about 1 to 1.5 mg/100g fresh weight. Akamine (1976) reported that flesh pineapple carotene was 1.3-2.9 mg/100g fresh weight.

The flesh color changed from white to bright yellow in the later harvested fruits, indicated by the decreasing of its hue angle, L* and increasing a*, b* and chroma values. The L* value of all cropping seasons decreased during harvesting period (Figure 4.7) indicated that flesh was yellow in color. The b* and chroma values of the regular crop were higher than the late and early crops in both years (Figure 4.9 and 4.11). The yellow color of pineapple flesh in the regular crop was more intense than in the early and late crops although no significant statistical differences were detected in flesh carotenoid content. The a* value in the late and regular crops were higher than the early crop during harvesting time 110-140 DAFB in both years (Figure 4.8). The a* value of pineapple flesh from all cropping seasons were increased during ripening to senescence.

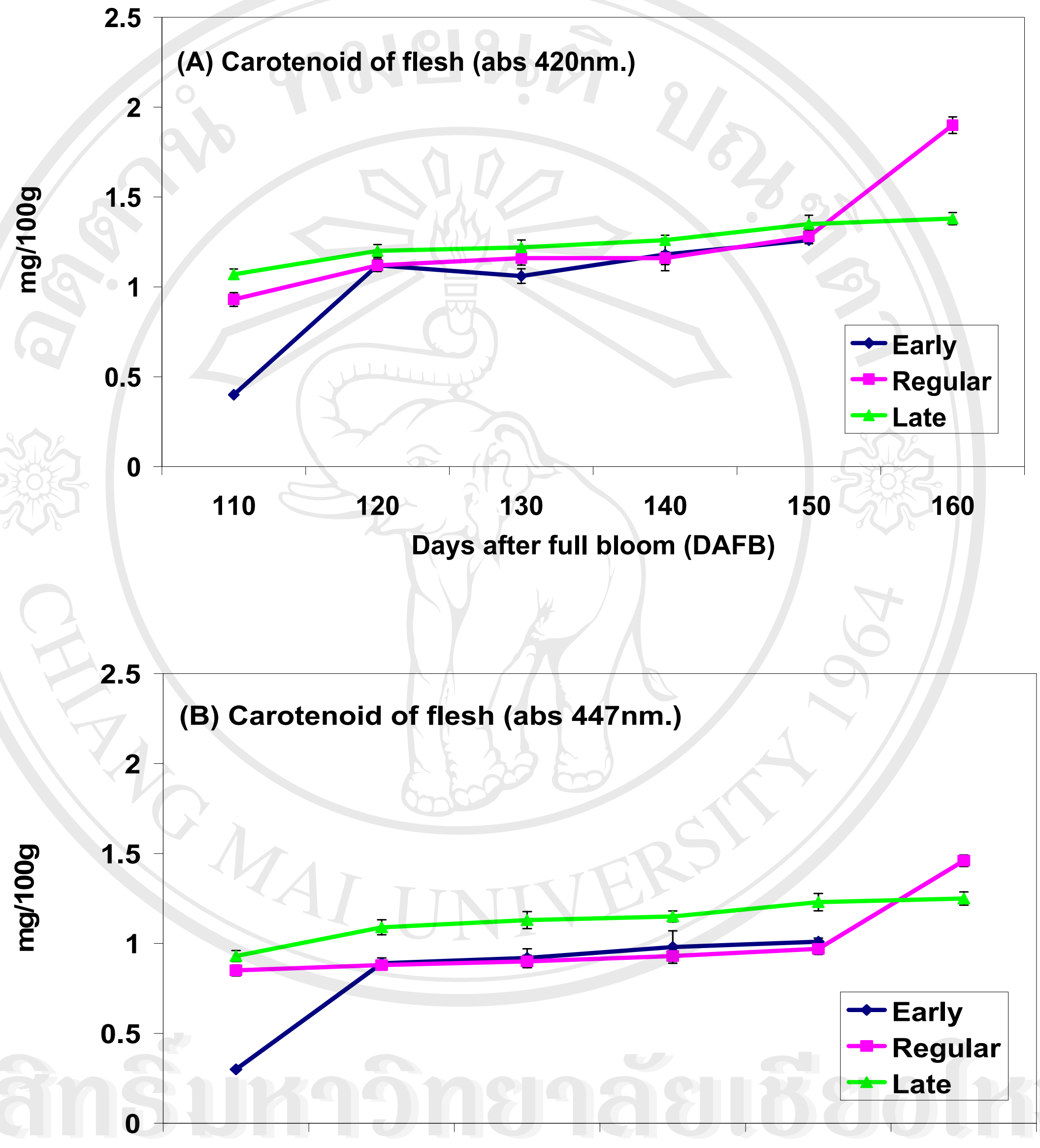


Figure 4.6 Carotenoids of pineapple flesh from all crops at harvesting time for the year 2003 at absorption 420 nm and 447 nm (A and B).

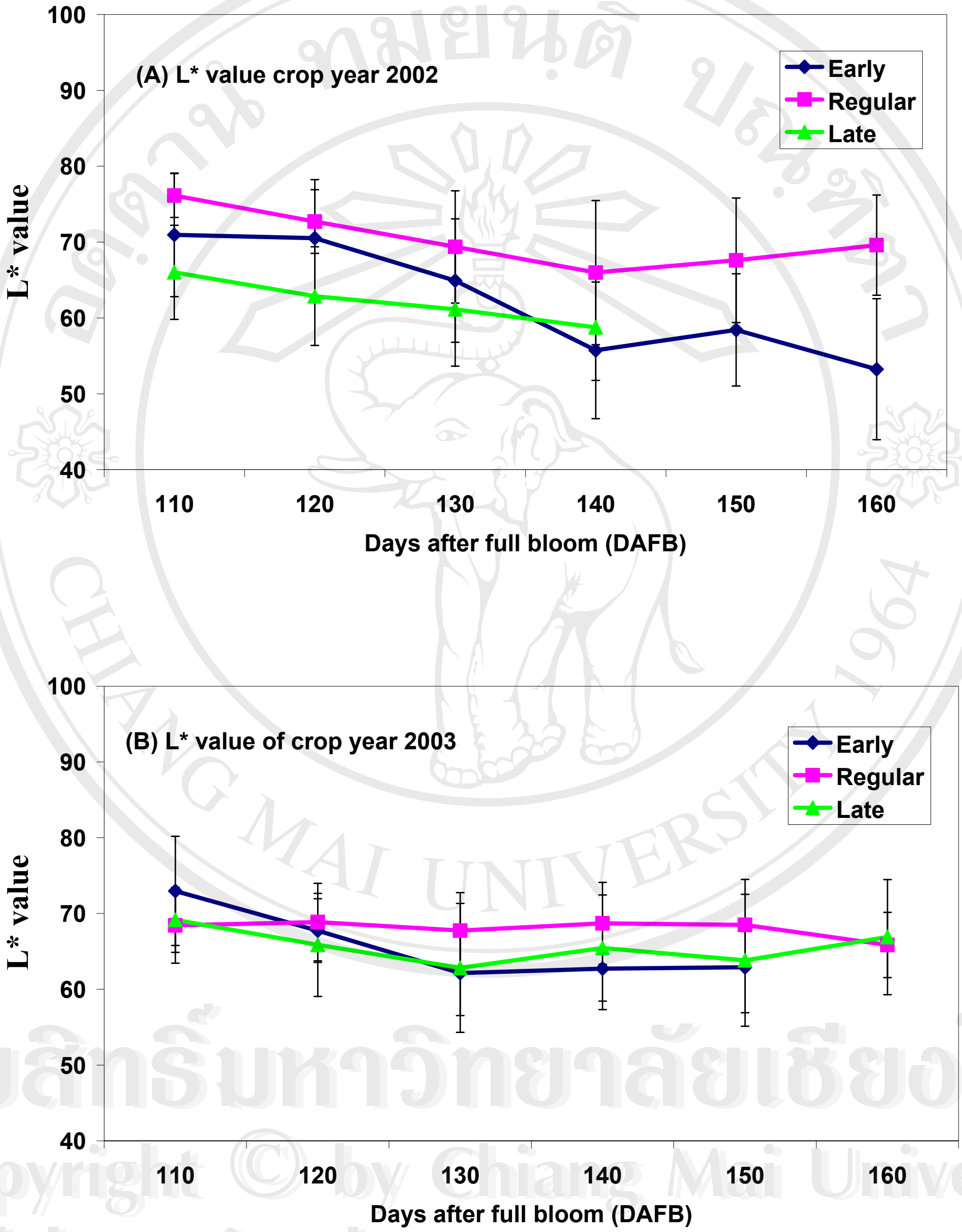


Figure 4.7 L* value of pineapple flesh from all crops at harvesting time for the years 2002 and 2003 (A and B).

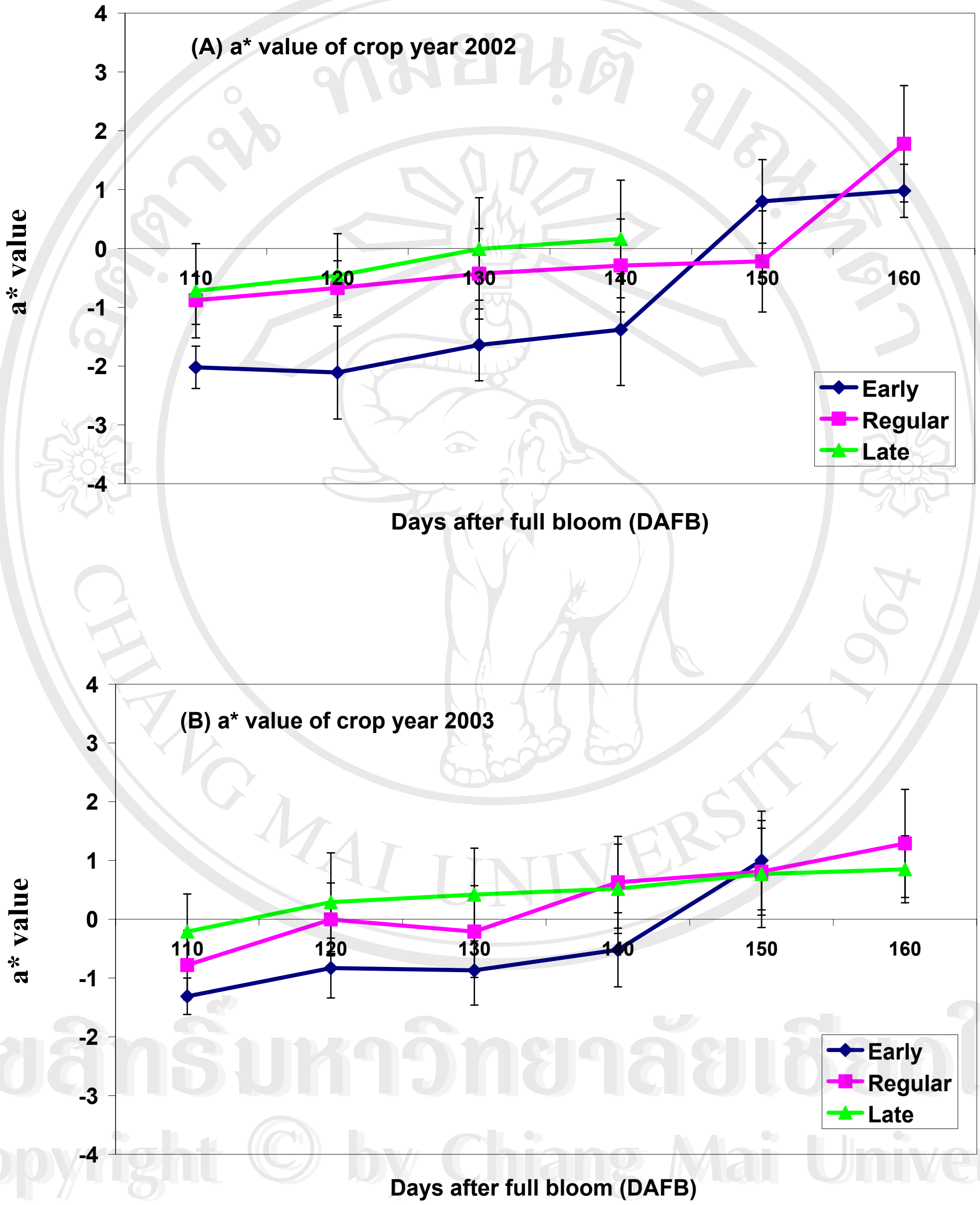


Figure 4.8 a* value of pineapple flesh from all crops at harvesting time for the years 2002 and 2003 (A and B).

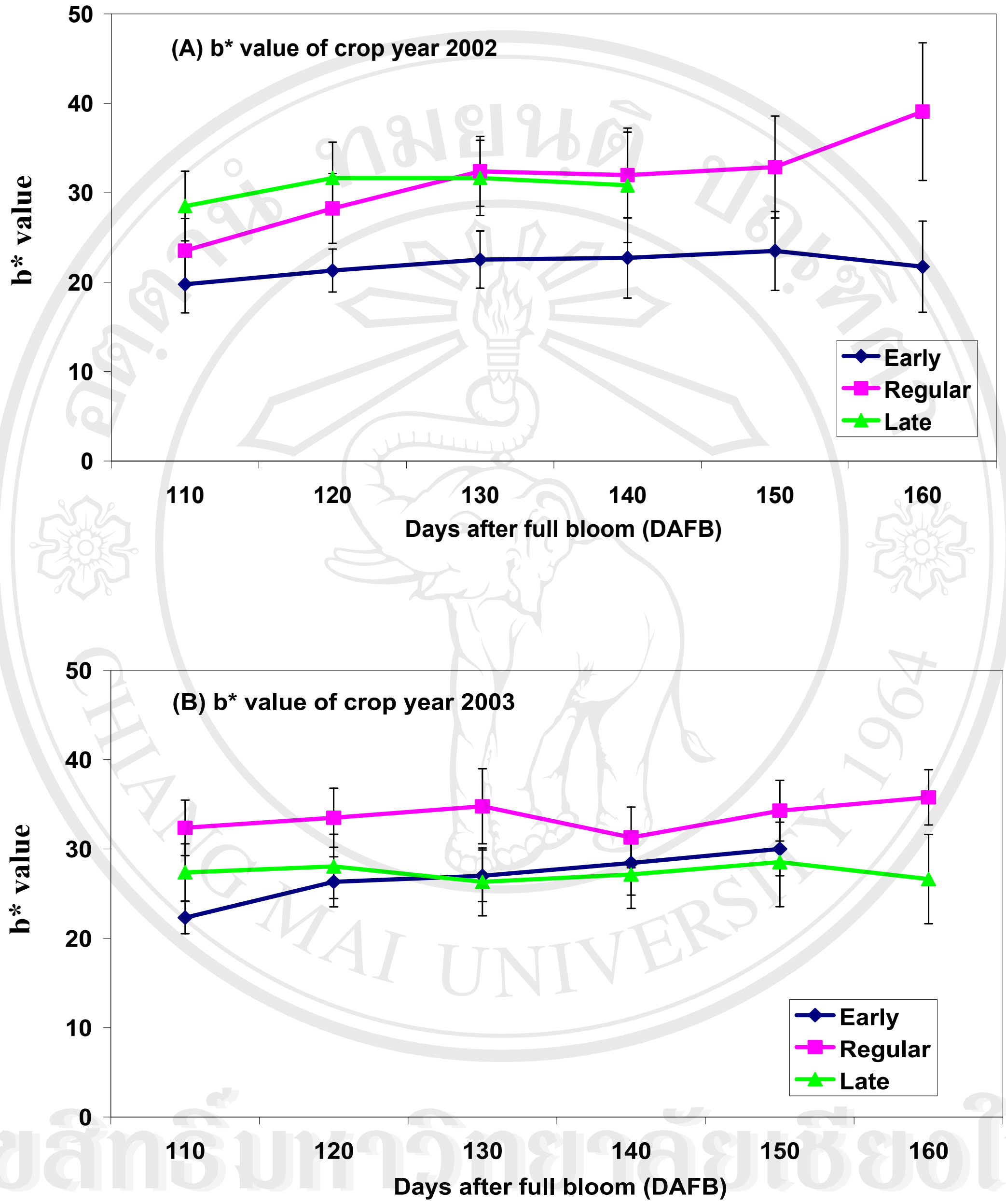


Figure 4.9 b* value of pineapple flesh from all crops at harvesting time for the years 2002 and 2003 (A and B).

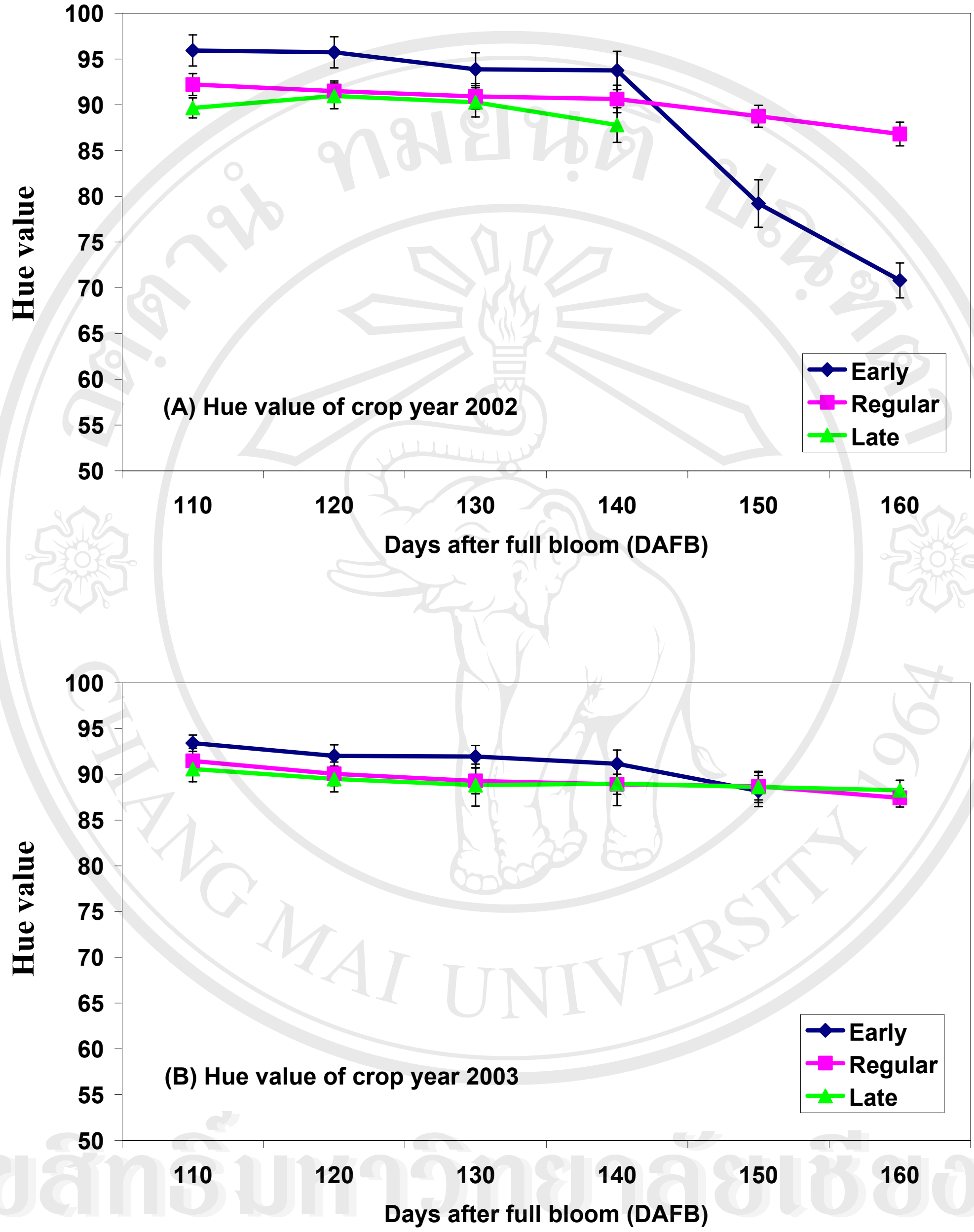


Figure 4.10 Hue angle of pineapple flesh from all crops at harvesting time for the years 2002 and 2003 (A and B).

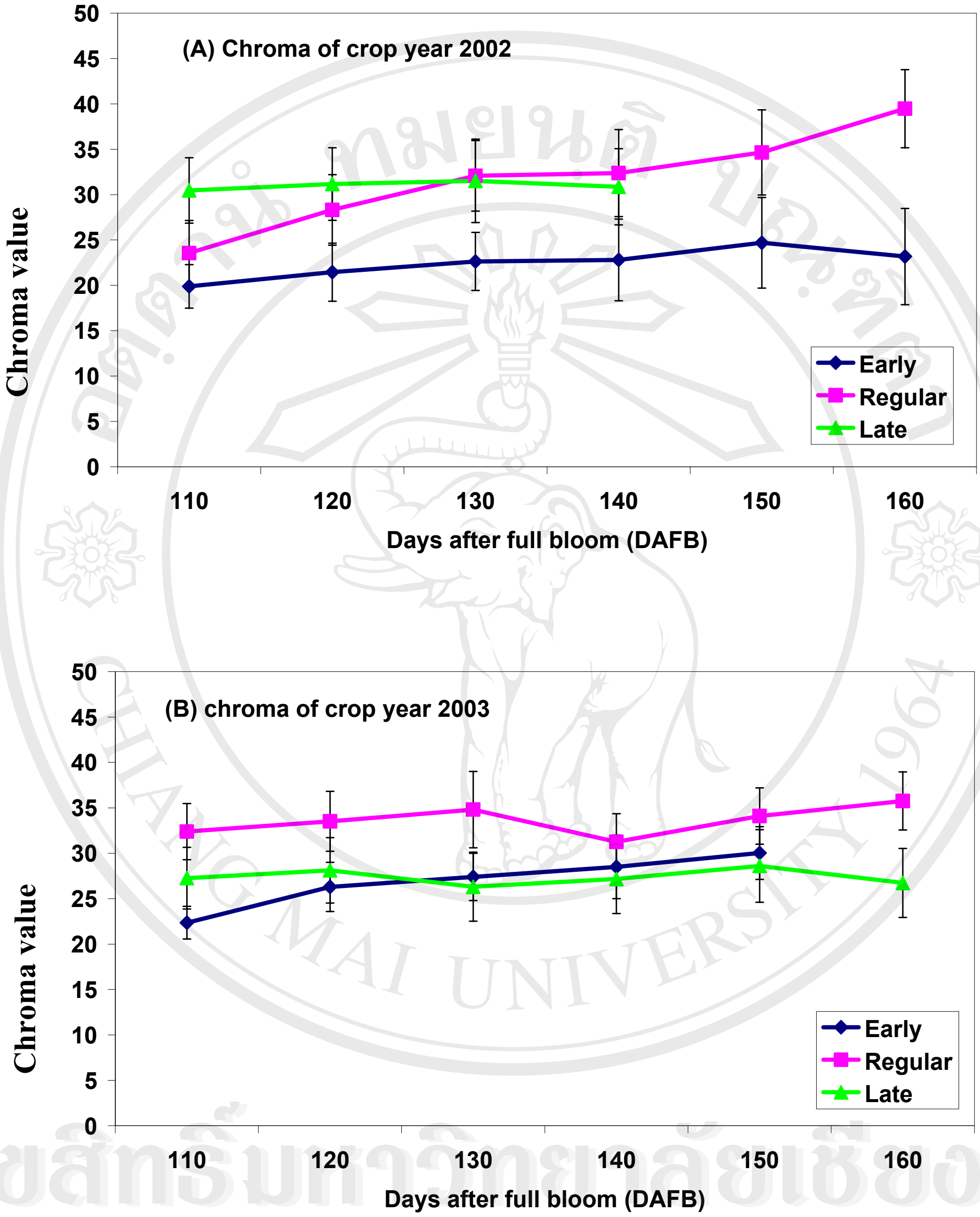


Figure 4.11 Chroma value of pineapple flesh from all crops at harvesting time for the years 2002 and 2003 (A and B).

(d) Flesh translucency

Pineapple fruit with flesh translucency detected in fruits harvested at 120 DAFB when the fruit mature with acceptable quality. They were no incident of translucency fruit in the fruit harvested prior to the harvest date at 110 DAFB. When the fruit is fully mature with the highest sensory quality at 130 DAFB. The incident of fruit translucency was increase to about 10% to 20% (Figure 4.12, 4.13 and 4.14). The increase of flesh translucency could occur until 140 DAFB which is 20 days after harvesting date. However, there was no increase in percentages of translucent from the fruit that were prolonged on the field until 160 DAFB (Figure 4.12 and 4.13). This result supported the previous study by Srisang (2002) on the effect of fruit age in relation to the percentage of translucency. It was found that in the late crop, the percentage of fruit translucency was 11% at harvesting date and increase to 22% after one week in the field but no increase after 3 weeks of prolongs harvesting. Therefore, the translucent of the flesh may not be concomitant with ripening fruit because the percentages of fruit translucency were not increased when the ripening stage progress.

In this experiment, the percentage of translucent fruit average from each crop season was not significant differences. Although many attempts have been conducted in studying of factors related to pineapple fruit translucency. However, it can not be concluded the relationships between preharvest environmental factors and fruit translucency (Paull and Reyes, 1996; Chen and Paull, 2000; and Chen and Paull, 2001).

4.2.3 Conclusion

Shell color of pineapple fruit harvested in the late crop change faster than harvested in the early and regular crops. In the late crop, total chlorophyll of peel decreased while carotenoids of peel increased faster than other crops. Although, flesh carotenoids of different cropping seasons were not significant differences but they were different in b* and chroma values. The panelist rating the flesh color of the regular, early and late crops as yellow, slight yellow and pale yellow, respectively. The percentages of fruit translucency in different cropping seasons were not significant differences. The percentage of fruit translucency did not increase in the ripen fruit.

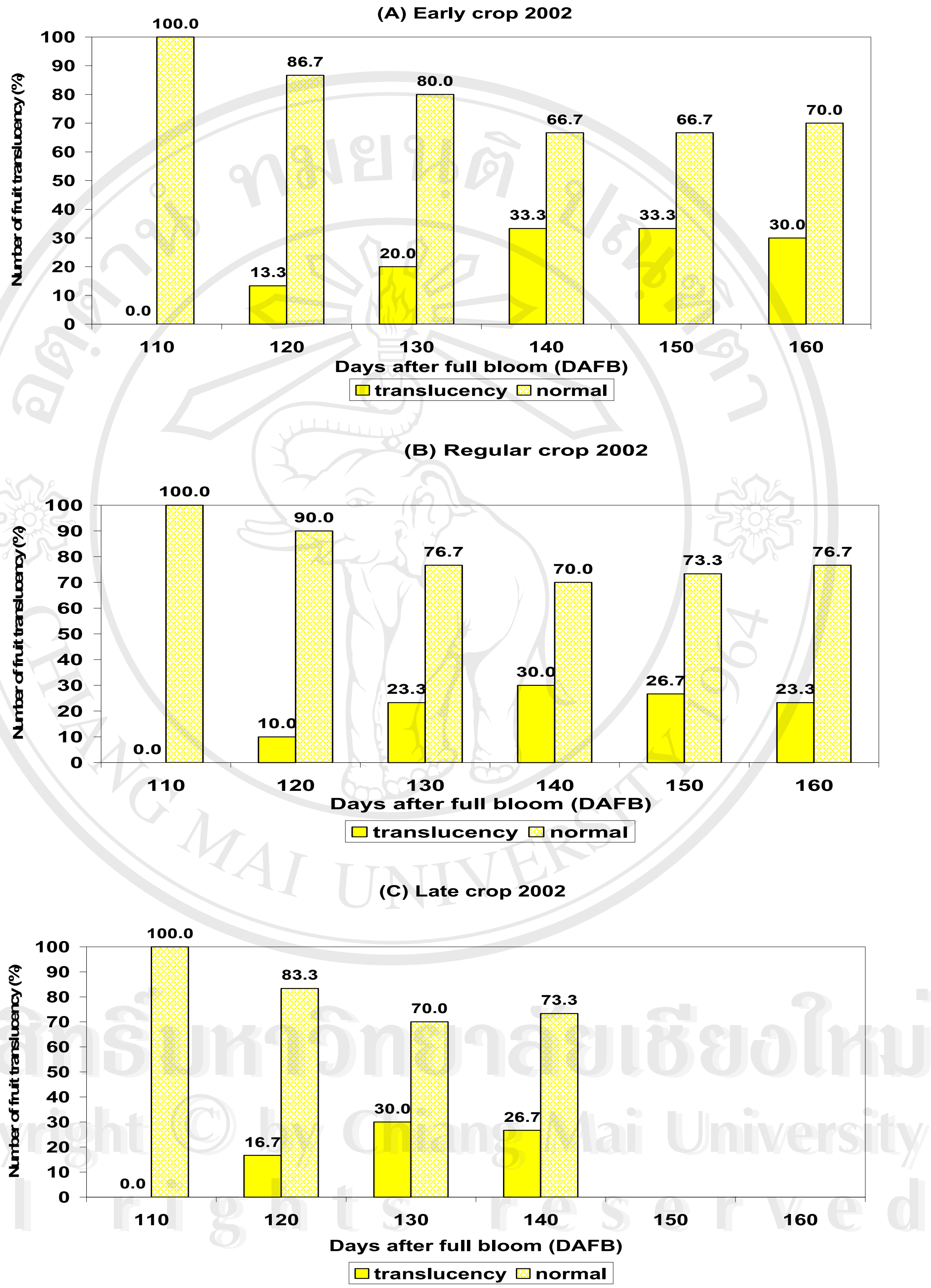


Figure 4.12 Percentage of translucency and normal fruit at each harvesting time of all crops for the year 2002.

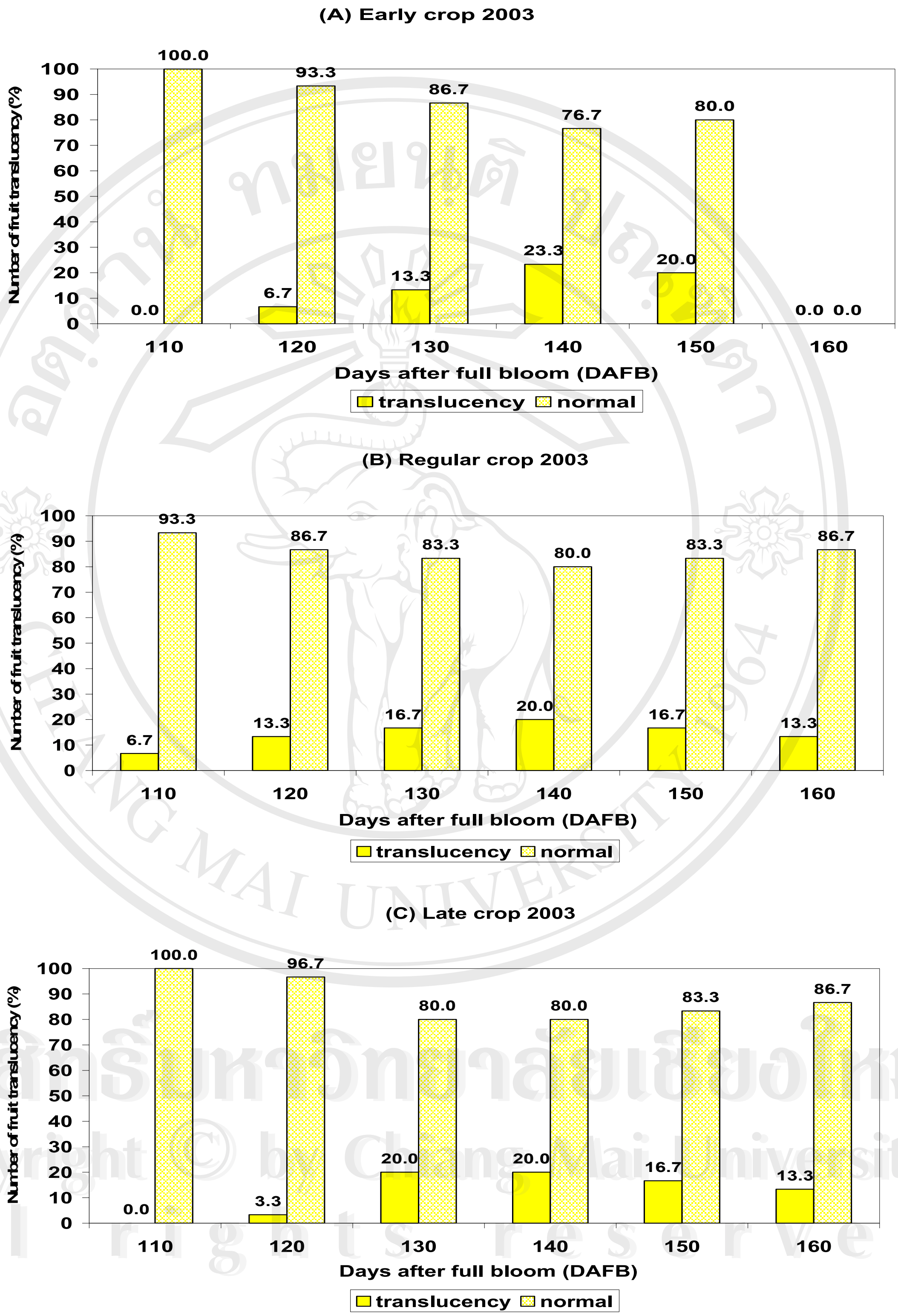


Figure 4.13 Percentage of translucency and normal fruit at each harvesting time of all crops for the year 2003.

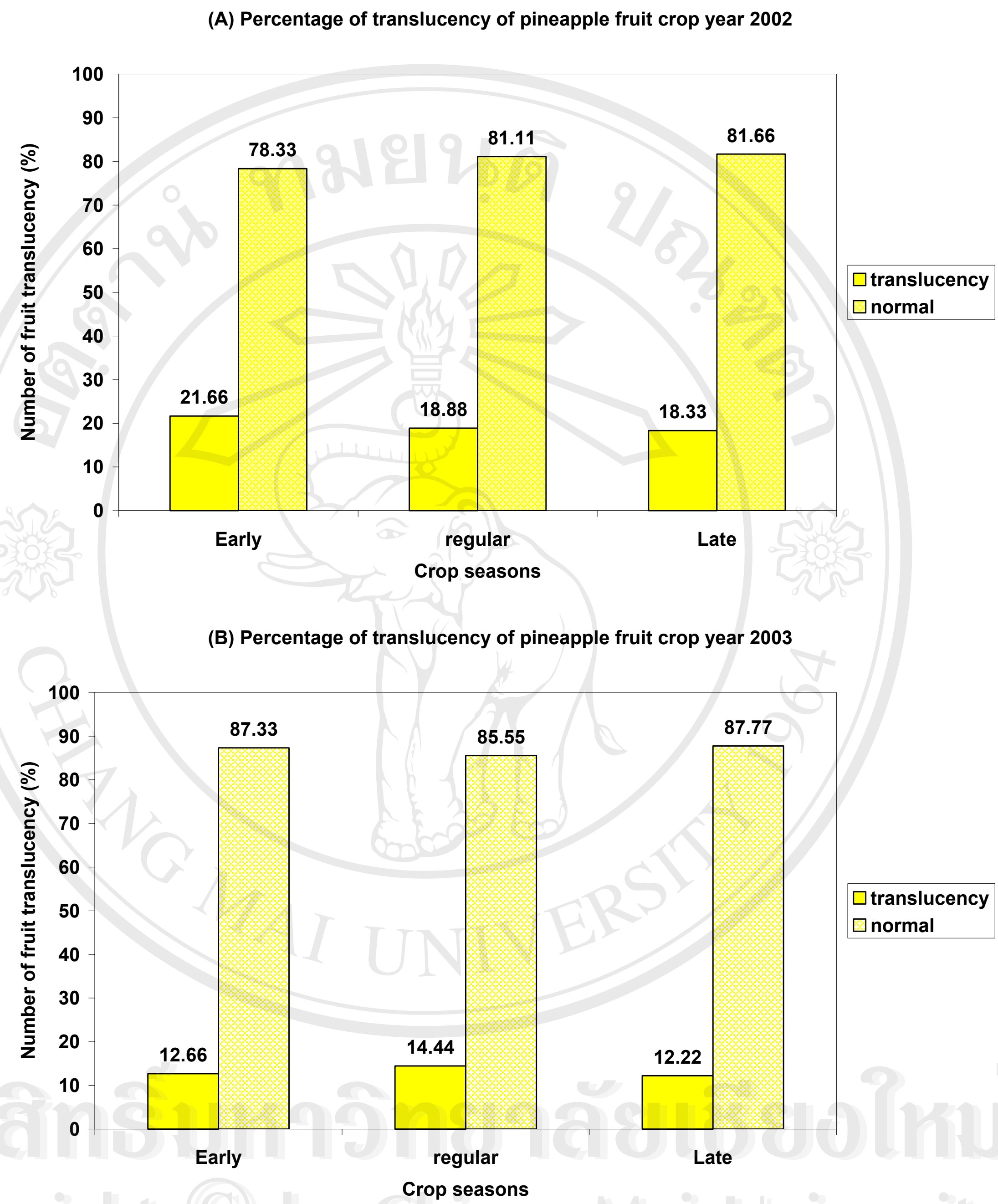


Figure 4.14 Percentage of translucency and normal fruit of all crops for the years 2002 and 2003.

4.3.1 Experiment 2: Assessment of physico-chemical attributes of pineapple fruit

4.3.1 Materials and methods

(a) Samples

A total of 240 pineapple fruits cv. Smooth Cayenne after Experiment 1 was used for this experiment. The harvesting and transportation procedures were similar to those described in Experiment 1.

(b) Analysis texture qualities of pineapple flesh

Slices of 3 cm thickness from basal, medial and top parts of each pineapple fruit were measured for flesh texture. The maximum force (Newton) to rapture the pulp tissue (after removal of shell) was determined 3 measurements on each slice at inner, middle and outer positions with a stable micro systems TA-TXT2i texture analyzer (Texture Technologies Crop, UK) equipped with 6 mm cylinder probe (P/6) type penetrating at a velocity of 10 mm/s to a final dept of 15 mm.

(c) Analysis of chemical attributes of pineapple fruits

Pineapple juice was prepared from 10 gram of each slices and used for chemical analysis. The juice was analyzed for total soluble solids (TSS), pH and titratable acidity (TA). TSS was measured with a digital refractometer PR-101 (ATAGO Company, Tokyo, JAPAN). The pH was measured at room temperature using Satorious Professional Meter PP–50 Operation Manual pH Meter. TA was determined by titrating 10 ml juice with 0.1 M NaOH to pH 8.2. The titratable acidity was expressed as a percentages of citric acid (mole equivalent = 0.064). Sugar concentration was analyzed with high performance liquid chromatography (HPLC) model “10AD Series” (Shimadzu, Kyoto, Japan). The HPLC was operated under the following conditions;

Column: Inertsil NH_2 (4.6.I.D.× 250mm), GL Science, Japan.
Mobile phase: Acetronitrile: water (83:17)
Detector: reflective index detector (RID)
Flow rate: 1.5 ml/min
Column Oven temperature: 35°C

(d) Analysis of crude fiber of pineapple flesh (AOAC, 2000)

Pineapple flesh from 3 slices (50 grams) was blended, 100 ml hot water was added and boiled for 10 min. 12.5 ml NaOH 50% solution was boiled and mixed about 5–15 min. The flesh fiber was washed and drained flowing on the net (30 meshes) then dried in hot-air oven at 100°C for 2 hrs. Dry residue was weighed and calculated for % crude fiber.

Crude fiber (%) = dry weight of fiber × 100 weight of sample

(e) Analysis of moisture content of pineapple flesh (AOAC, 2000)

The moisture content was determined by drying a weighed about 20-50 grams of homogenized pineapple flesh at 70°c for 76 hrs and reweighing. The percentage moisture content was calculated as following:

Moisture content (%) = flesh weight- dry weight/flesh weight × 100

(f) Data analysis

Analysis of Variance (ANOVA) with Randomized Complete Block (RCB) using pineapple fruits as a block was performed by SPSS® program (SPSS, Illinois, U.S.A.). Tukey's Least Significant Difference (LSD) was used to test the significant difference at 95 % confidential of each variable.

4.3.2 Results and discussion

(a) Analysis of texture qualities of pineapple fruits by Texture Analyzer

The flesh firmness declined during fruit maturation. During harvesting time at 110-130 DAFB the flesh firmness of all part and position of late crop declined to lower value than other crops in both years (Figure 4.15 - 4.16 and Table 4.2-4.3). After fruit harvested at 130 DAFB the flesh firmness began to loose and the flesh fiber tend to resist to the puncture force and cause the measurable firmness to increase until overripe. Therefore after ripe the texture of the flesh become more tough.

Firmness detection of inner and middle position of all part of fruit in early crop showed decrease firmness until the 3 rd harvest which was 130 DAFB and the fruit were fully ripe (Table 4.2-4.3) while late and regular crop the firmness decline more rapidly within the 2nd harvest at 120 DAFB. For inner position the fruit firmness already decline to the minimum point at first harvest. This pattern of decreasing in firmness also expressed in medial and top parts of fruit in each harvest crop. The rapid in decreasing in firmness of late crop may indicate that the crop was mature and ripe sooner than other crop. The flesh firmness of outer position of all parts in late crop was declined prior to regular and early crop in both years. Fruit of late crop developed during high temperature during the monthly of July to November. The high temperature may hasten fruit ripening of the crop.

Flesh firmness at inner and outer positions of the basal, medial and top parts were higher than the middle position. The flesh texture of inner and outer positions were hard become they are different in structure of parenchyma tissues near inflorescence axis (Okimoto, 1948) and shell structure, respectively. The firmness of middle positions was low because the tissue was homogeneous and composed of fruitlet which is fleshy ovary and sepal tissue. The flesh firmness of basal part was lower than others due to the pineapple fruit comprises of many fruitlets where maturity gradient exist within fruit. Fruitlet in the lower portion of the fruit are more mature than the upper portion (Tay 1977; Ramlah, 1981; Abdullah and Rohaya, 1997) and trend to be ripe faster than others (Miller and Hall, 1953).

Although the flesh firmness values were varied within each part and position but it was interesting to note that the firmness value variation was lowest at the middle position of fruit indicated by the SD value (±0.7) (Table A4.7-A4.12). Therefore the middle position could be the best position to represent the precise measurement of firmness of the fruit.

Table 4.2 Flesh firmness of all parts and positions of pineapple fruit crop year 2002

H+ Crop	Stage	Basal			Medium			Top		
		Inner	**Middle**	**Outer**	**Inner**	**Middle**	**Outer**	**Inner**	**Middle**	**Outer**
Early	110 D	13.85^{h}	12.79^{h}	21.49^{f}	14.00^{f}	12.95^{j}	18.99^{f}	15.56^{f}	14.06^{h}	19.11^{g}
	120 D	13.44^{gh}	11.40^{fg}	14.80^{d}	12.60^{de}	12.35^{i}	15.42^{e}	13.54^{e}	13.06^{g}	16.56^{f}
	130 D	11.83^{e}	10.99^{f}	11.86^{c}	12.22^{cd}	11.18^{g}	12.48^{c}	12.54^{d}	11.68^{f}	12.04^{e}
	140 D	11.41^{de}	9.78^{bc}	9.62^{ab}	10.08^{a}	9.61^{bc}	10.24^{ab}	10.41^{ab}	9.91^{bc}	9.63^{abc}
	150 D	10.87^{bcd}	9.99^{cd}	9.14^{a}	9.98^{a}	9.71^{cd}	10.10^{ab}	10.11^{a}	9.95^{bc}	10.10^{bcd}
	160 D	11.35^{de}	9.91^{cd}	9.32^{a}	10.16^{a}	9.85^{cd}	9.63^{ab}	10.63^{abc}	10.52^{de}	10.18^{bcd}
Av. SD		± 3.26	± 2.90	± 3.15	± 1.83	± 1.67	± 4.17	± 2.57	± 1.86	± 4.33
Regular	110 D	13.15^{g}	14.24^{i}	26.78^{g}	13.09^{e}	13.30^{j}	22.87g	19.36^{g}	14.04^{h}	21.44^{h}
	120 D	12.31^{f}	11.06^{f}	17.78^{e}	11.84^{c}	10.52^{ef}	12.74^{c}	12.71^{de}	10.64^{de}	11.98^{e}
	130 D	10.97^{cd}	9.26^{a}	11.88^{c}	9.83^{a}	9.18^{ab}	10.21^{ab}	10.68^{abc}	8.79^{a}	9.10^{ab}
	140 D	10.77^{bc}	8.96^{a}	11.35^{c}	9.90^{a}	8.98^{a}	9.98^{ab}	9.98^{a}	8.40^{a}	8.82^{a}
	150 D	9.98^{a}	9.39^{ab}	17.45^{e}	9.71^{a}	9.11^{a}	12.17^{c}	10.46^{abc}	8.37^{a}	10.33^{cd}
	160 D	12.43^{f}	10.17^{cde}	15.04^{d}	10.73^{b}	9.42^{abc}	10.38^{ab}	11.41^{c}	9.64^{b}	9.17^{ab}
Av. SD		± 1.46	± 2.01	± 6.35	± 1.51	± 1.72	± 4.83	± 3.71	± 2.33	± 4.75
Late	110 D	10.88^{bcd}	11.81^{g}	14.17^{d}	10.95^{b}	11.76^{h}	13.97^{d}	12.98^{de}	11.00^{e}	12.20^{e}
	120 D	11.06^{cd}	10.49^{e}	12.22^{c}	12.45^{d}	10.16^{de}	10.69^{b}	12.62^{d}	10.30^{cd}	10.98^{d}
	130 D	10.39^{ab}	10.36^{de}	11.13^{bc}	11.76^{c}	10.63^{f}	9.92^{ab}	10.92^{abc}	9.98^{bc}	10.07^{bcd}
	140 D	11.17^{cd}	10.23^{cde}	10.50^{abc}	11.75^{c}	9.78^{cd}	9.49^{a}	11.26^{bc}	9.48^{b}	9.46^{abc}
	150 D	-	-	-	-	-	-	-	-	-
	160 D	-	-	-	-	-	-	-	-	-
Av. SD		± 0.97	± 1.09	± 2.29	± 1.45	± 1.04	± 2.01	± 1.48	± 1.04	± 1.34
All SD		± 1.43	± 1.55	± 5.53	± 1.60	± 1.60	± 4.11	± 2.87	± 1.98	± 4.09

H+ crop= harvested crop

Table 4.3 Flesh firmness of all parts and positions of pineapple fruit crop year 2003

H+ Crop	Stage	Basal			Medium			Top		
		Inner	Middle	Outer	Inner	Middle	Outer	Inner	Middle	Outer
Early	110 D	18.05^{i}	14.18^{h}	28.18^{def}	19.83^{e}	15.77^{f}	27.69^{g}	25.38^{h}	17.56^{h}	26.93^{h}
	120 D	12.10^{def}	10.04^{f}	3.33^{f}	12.70^{d}	10.42^{de}	20.32^{f}	13.81^{g}	11.30^{g}	20.48^{f}
	130 D	10.69^{a}	8.31^{ab}	22.04^{bc}	10.81^{abc}	8.45^{a}	12.56^{b}	11.77^{cdef}	9.20^{bc}	11.25^{a}
	140 D	12.23^{ef}	8.56^{b}	20.52^{b}	11.54^{c}	8.70^{a}	10.98^{a}	12.13^{ef}	9.16^{bc}	14.59^{bcd}
	150 D	12.08^{def}	8.09^{a}	29.10^{def}	11.19^{bc}	8.74^{a}	14.81^{d}	11.59^{cdef}	8.77^{ab}	14.99^{cd}
	160 D	-	-	-	-	-	-	-	-	-
Av. SD		± 2.84	± 2.50	± 6.21	± 3.57	± 3.05	± 6.73	± 5.75	± 3.55	± 6.05
Regular	110 D	12.91^{g}	9.83^{ef}	34.27^{g}	11.80^{cd}	9.98^{cd}	20.70^{f}	11.54^{bcdef}	8.87^{ab}	17.92^{e}
	120 D	12.53^{fg}	9.26^{d}	26.96^{d}	21.15^{f}	8.94^{ab}	16.89^{e}	11.34^{bcde}	10.75^{f}	15.61^{d}
	130 D	11.89^{cde}	8.74^{bc}	27.58^{def}	10.81^{abc}	8.95^{ab}	15.46^{d}	10.97^{bc}	8.56^{a}	13.75^{bc}
	140 D	11.10^{ab}	8.74^{bc}	24.02^{c}	9.82^{a}	8.92^{ab}	15.46^{d}	9.36^{a}	8.60^{a}	14.29^{bcd}
	150 D	11.55^{bcd}	8.29^{ab}	24.47^{c}	10.11^{ab}	8.62^{a}	15.37^{d}	9.63^{a}	8.36^{a}	14.14^{bcd}
	160 D	12.11^{def}	9.11^{cd}	29.68^{def}	11.20^{bc}	9.33^{b}	18.02^{e}	11.00^{bcd}	8.80^{ab}	14.16^{bcd}
Av. SD		± 1.09	± 0.74	± 5.72	± 0.90	± 0.75	± 3.91	± 1.07	± 0.07	± 2.63
Late	110 D	13.71^{h}	10.76^{g}	28.88^{def}	12.79^{d}	10.53^{e}	14.38^{d}	12.35^{f}	9.93^{de}	13.98^{bcd}
	120 D	14.01^{h}	10.31^{f}	27.35^{de}	12.96^{d}	10.01^{cd}	14.97^{d}	11.62^{cdef}	9.69^{de}	14.18^{bcd}
	130 D	12.61^{fg}	10.14^{f}	29.88^{ef}	11.42^{c}	10.13^{cde}	12.97^{bc}	11.16^{bcd}	9.56^{cd}	13.13^{b}
	140 D	11.36^{bc}	9.49^{de}	22.60^{bc}	11.41^{c}	10.14^{cde}	14.46^{d}	10.76^{b}	9.83^{de}	13.85^{bcd}
	150 D	12.58^{fg}	9.87^{ef}	16.49^{a}	11.06^{bc}	9.90^{c}	14.00^{cd}	10.96^{bc}	9.90^{de}	15.67^{d}
	160 D	12.92^{g}	10.86^{g}	29.60^{def}	11.89^{cd}	10.20^{cde}	14.90^{d}	11.82^{def}	10.16^{e}	24.28^{g}
Av. SD		± 1.23	± 1.00	± 6.63	± 1.08	± 0.68	± 2.38	± 1.02	± 0.70	± 5.56
Av. SD		± 1.87	± 1.63	± 6.26	± 3.66	± 1.84	± 4.55	± 3.70	± 2.23	± 5.02

H+ crop= harvested crop

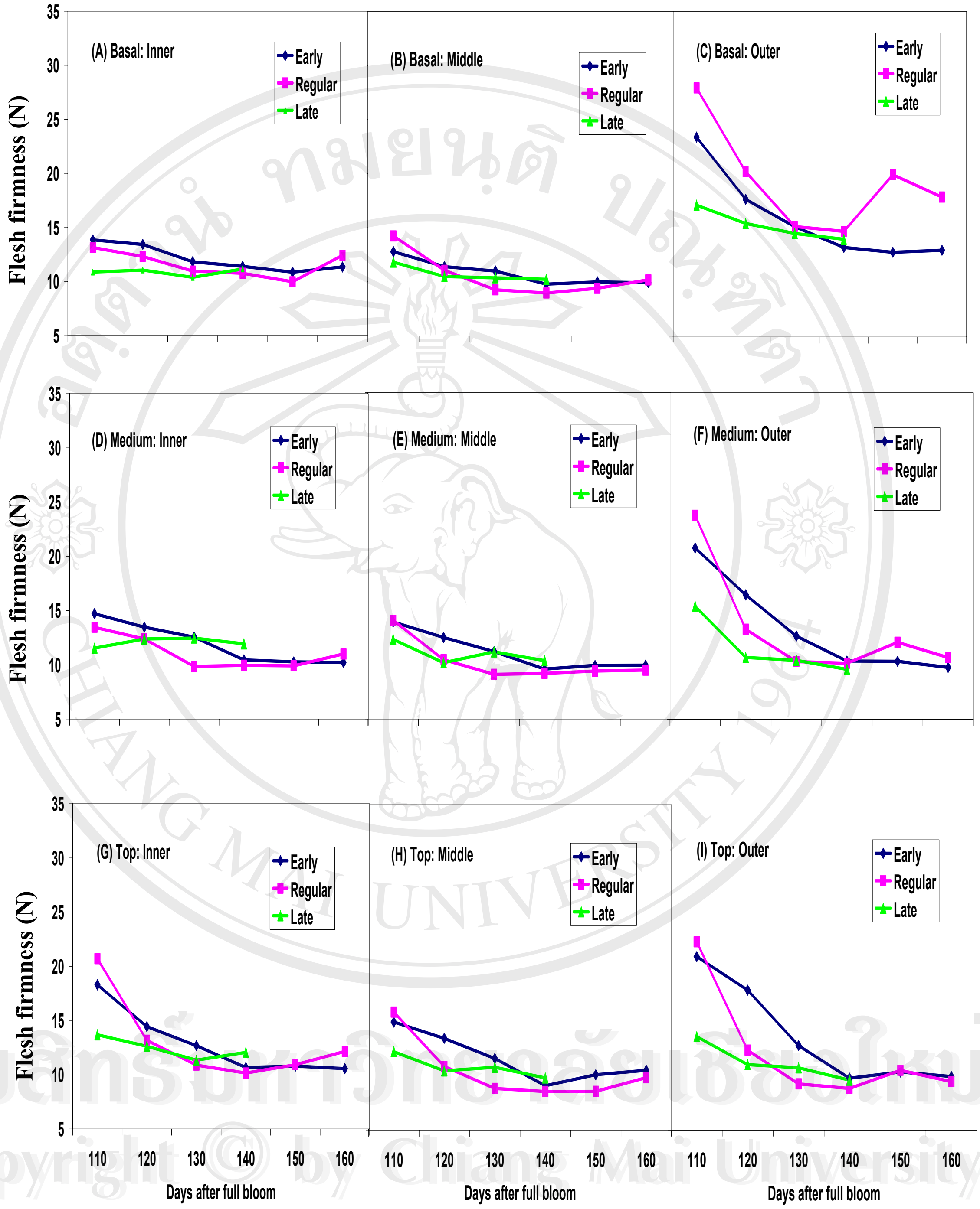


Figure 4.15 Flesh firmness of 3 parts (basal, medium, top) and 3 positions (inner, middle, outer) of all crops for the year 2002.

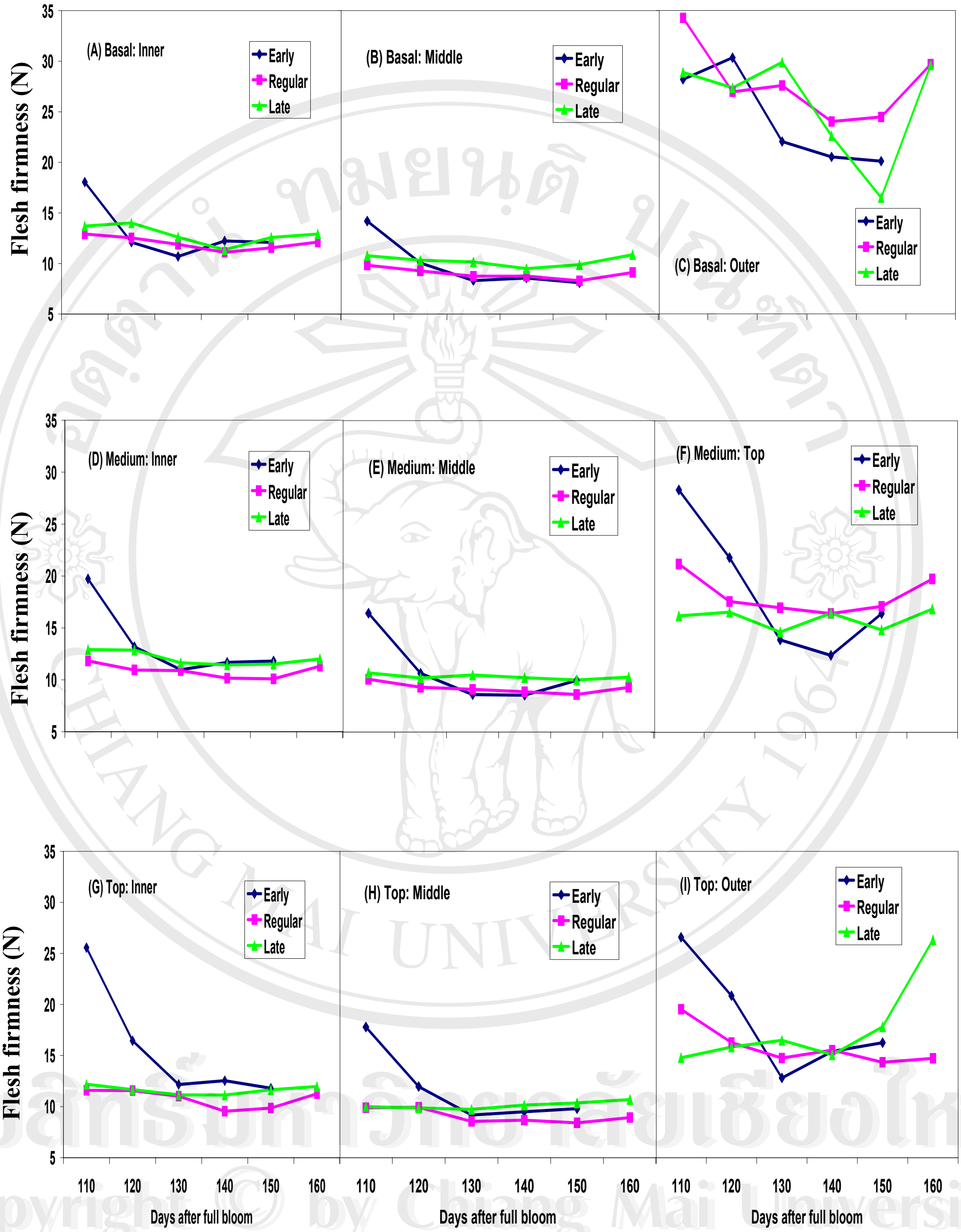


Figure 4.16 Flesh firmness of 3 parts (basal, medium, top) and 3 positions (inner, middle, outer) of all crops for the year 2003.

(b) Chemical attributes

Total soluble solids of pineapple flesh in all crops increased prior a week to ripen at 120 DAFB and slightly increase but not significant different in those fruits harvesting during at 130 DAFB to 160 DAFB (Figure 4.17A-B, Table A4.13 and A4.14). TSS of the late crop was higher than the early and regular crops in both years (Figure 4.17A-B, Table A4.13 and A4.14). TSS of fruit harvested in regular crop of year 2002 was lower than crop of year 2003 (Figure 4.17A-B). Incident of high rainfall in May which was a month before harvesting in crop year 2002 may reduce TSS content.

Bartholomew and Paull (1986) reported that the TSS content of fruit related to the light levels during fruit maturation. They pointed out that the fruit initiated in the late summer when the temperature is high will be large in size. Because it matures through winter when light intensity is substantially reduced. The final TSS of fruit will be low. Fruit with the highest TSS were initiated in winter, giving a small fruit, but matures through spring and early summer when light level are high, giving a large production of TSS. Comparing with our results, the solar radiation during crop development of early crop fruit was lowest in the both years (2293.5MJmm^{-3}, 2376.05MJmm^{-3}) compare to solar radiation in the regular and late crop (3005.1MJmm^{-3}, 2802.4MJmm^{-3} and 2479.9MJmm^{-3}, 2752.6MJmm^{-3}). The early crop fruit also mature during lower temperatures compared to other crop which may cause the early crop to low TSS content at harvest period. Although during development of the regular crop, the solar radiation level was the highest but the day temperature during fruit development was also very high (37-38°C) (Figure 3.1) which may reduce the TSS accumulation and show lower TSS accumulation than late crop.

The acidity, expressed as grams of citric acid per 100 g fresh weight, similar to total soluble solids, fruit harvested in late crop was higher than harvested in early and regular crops (Figure 4.17C-D, Table A4.13 and A4.14). The high acid content of the late crop may due to the decrease in temperatures on field during harvest. Similarly, high acid content of the late crop were reported by Smith (1984). Titratable acid in all crops did not significant decrease during 60 days of harvesting period.

The TSS and acid content are the factors influence eating quality. Smith (1988a, 1988b) reported that TSS gave the average highest correlation with the eating quality among nine parameters tested. However the significant correlation occurs only with the fruit harvested in early crop with TSS above 14%. Although the late crop in our experiment had high TSS content than other crops but it was also contain high level of acid which cause reduce the TSS/TA ratio (Table 4.4, Figure 4.18A-B) and gave sour taste and the panelist trend to gave lower eating quality score (acceptability) than regular crop (Figure 4.20A-B). However, TSS/TA ratio of all crop were not below 22 (Table A4.13-4.14). Singleton and Gortner (1965) point out the fruit sample having TSS/acid ratio higher than the average ratio of 22–23 tend to the better received by consumers than those below this average.

It showed be note that the pineapple grow in northern Thailand in subtropical climate, unlike in Australia or Hawaii, the temperature in cool season was not below 15 °C therefore the average TSS of all crop were not different and were above 12% and were all acceptable in range around scale 6 except the early crop fruit which developed during cool season show less sweet and less acid resulted in flat taste while late harvested crop showed sour taste cause inferior taste than the regular crop in season. Regular crop had less acid and gave highest TSS/TA ratio and also showed to better eating quality.

The pH value was increased with maturity but no significant differences. The pH value in of three harvested crops were ranging from 3.4-4.5 with close to the pH value as the fruits approach the fully ripe stage that reported by Teisson and Pineau (1982), ranging from 3.7 - 3.9. The pH value in late crop was lower than other crops agree with total titratable acidity of each crop (Figure 4.18C-D).

The results from our experiment, total sugars content of pineapple fruit harvested in the regular crop in the year 2004 was 13.84-16.63% compared to 15% of the early crop and 11% in the late crop of pineapple grown in Australia (Leverington, 1968). The total sugar in our experiment composed of 9.2–11.76% sucrose, 2.13–3.24% fructose and 2.11–2.88% glucose (Table 4.5, A4.15 and Figure 4.19). The proportion of sucrose, fructose and glucose were 5.5: 1.3: 1.1 with similarly to reported by Wills *et al*., (1998); Dull (1971) and Chen and Paull (2000).

During pineapple fruit development, glucose and fructose are the predominant sugars until 6 week before harvesting sucrose begin to accumulate rapidly and ultimately exceeded the glucose and fructose concentration. Glucose and fructose remained relatively constant throughout development (Morris and Arthur, 1984) and (Chen and Paull, 2000). In this experiment, sucrose was accumulated at ripening stage and higher than fructose and glucose during harvested time.

Table 4.4 Chemical attributes of pineapple fruits harvested at 130 DAFB from all crops for the years 2002 and 2003. (Data given in Appendix B)

Harvested crop	Year	TSS (%)	TA (%w/v)	TSS/TA ratio	pH
Early	2002	12.53[a]	0.48[a]	31.09[b]	4.28[c]
Regular	2002	12.60[a]	0.49[a]	29.74[b]	3.54[b]
Late	2002	14.56[b]	0.67[c]	22.50[a]	3.19[a]
Early	2003	12.44[a]	0.59[b]	21.15[a]	4.03[b]
Regular	2003	14.53[b]	0.51[a]	30.47[c]	3.78[a]
Late	2003	15.35[c]	0.65[c]	24.50[a]	3.79[a]

[/] Significantly differences at 95% internal tested by Tukey's Least Significant Different with randomized completed bock (RCB) design.

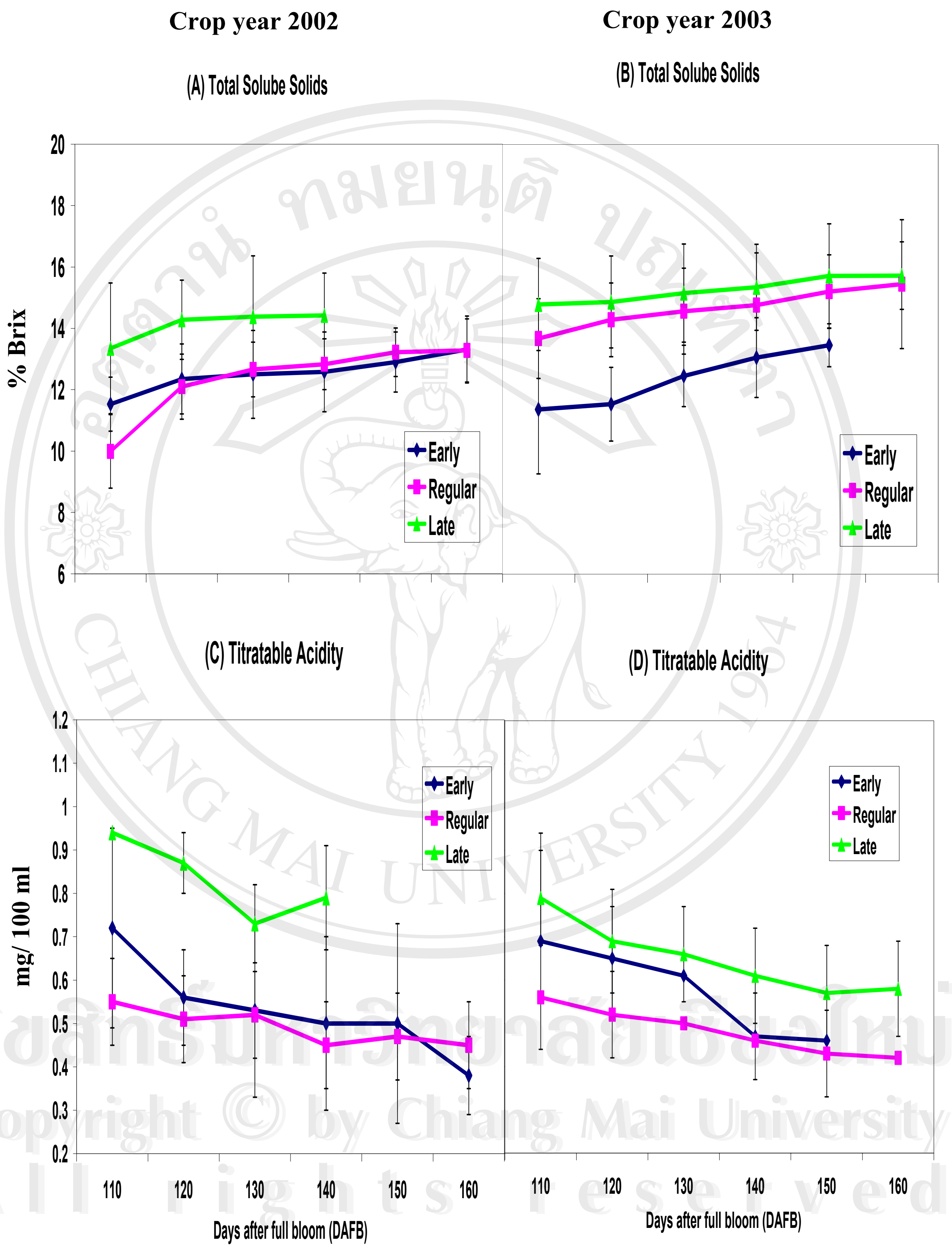


Figure 4.17 Total soluble solids and titratable acidity of flesh pineapple of all crops for the years 2002 and 2003.

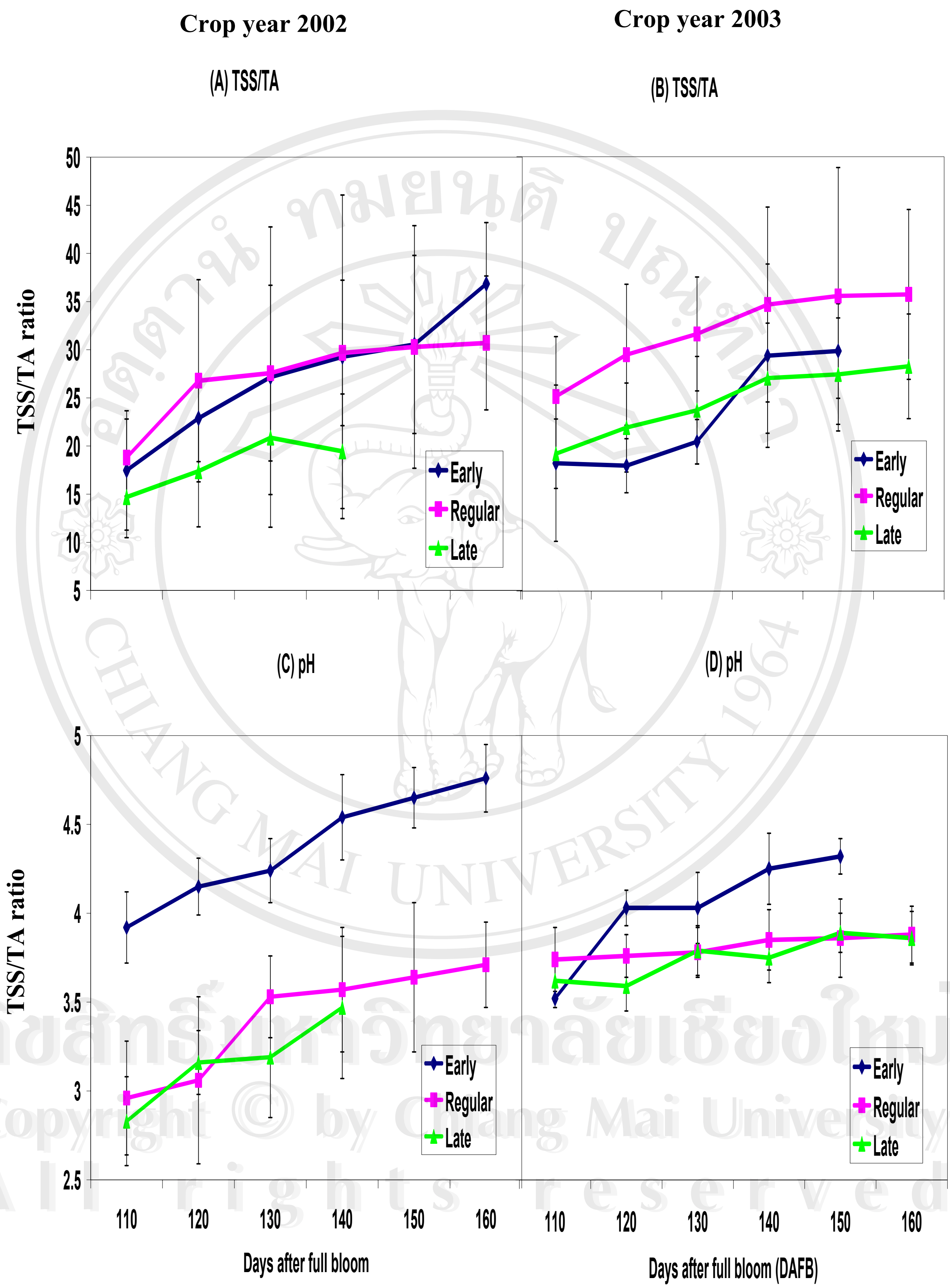


Figure 4.18 TSS/TA ratio and pH of pineapple fruit of all crops for the years 2002 and 2003.

Table 4.5 Chemical properties and sugars contents of pineapple fruits at 130 DAFB of the regular crop for the year 2004. (Data given in Appendix B)

Part	TSS[ϕ]	TA[θ]	TSS/TA ratio	pH	Sugar (% w/w fresh weight)*				
					Suc	Fru	Glu	Red	TS
Basal	13.10[b]	0.313	41.75[ab]	3.72[c]	10.29[a]	2.80[b]	2.33[a]	5.13[b]	15.42[a]
Medial	12.35[b]	0.345[ab]	35.78[bc]	3.70[c]	9.59[a]	2.93[c]	2.49[b]	5.43[d]	15.02[b]
Top	12.25[c]	0.406[c]	30.13[c]	3.68[c]	9.40[b]	2.62[c]	2.12[a]	4.74[b]	14.14[b]
All	12.56[abc]	0.355[ab]	35.89[ab]	3.70c	9.76[ab]	2.78[bc]	2.31[a]	5.10[b]	14.86[ba]

[+]Harvested at 130DAFB (Days after full bloom)

[ϕ]Total Soluble Solids

[θ] Titratable acidity

∗ Suc: Sucrose; Fru: fructose; Glu: Glucose; Red: Reducing sugar (Fructose+ Glucose); TS: Total Sugar (Fructose+Glucose+sucrose)

/ significant different at 95% interval tested by Tukey's Least significant Different with Randomized complete Block (RCB) design.

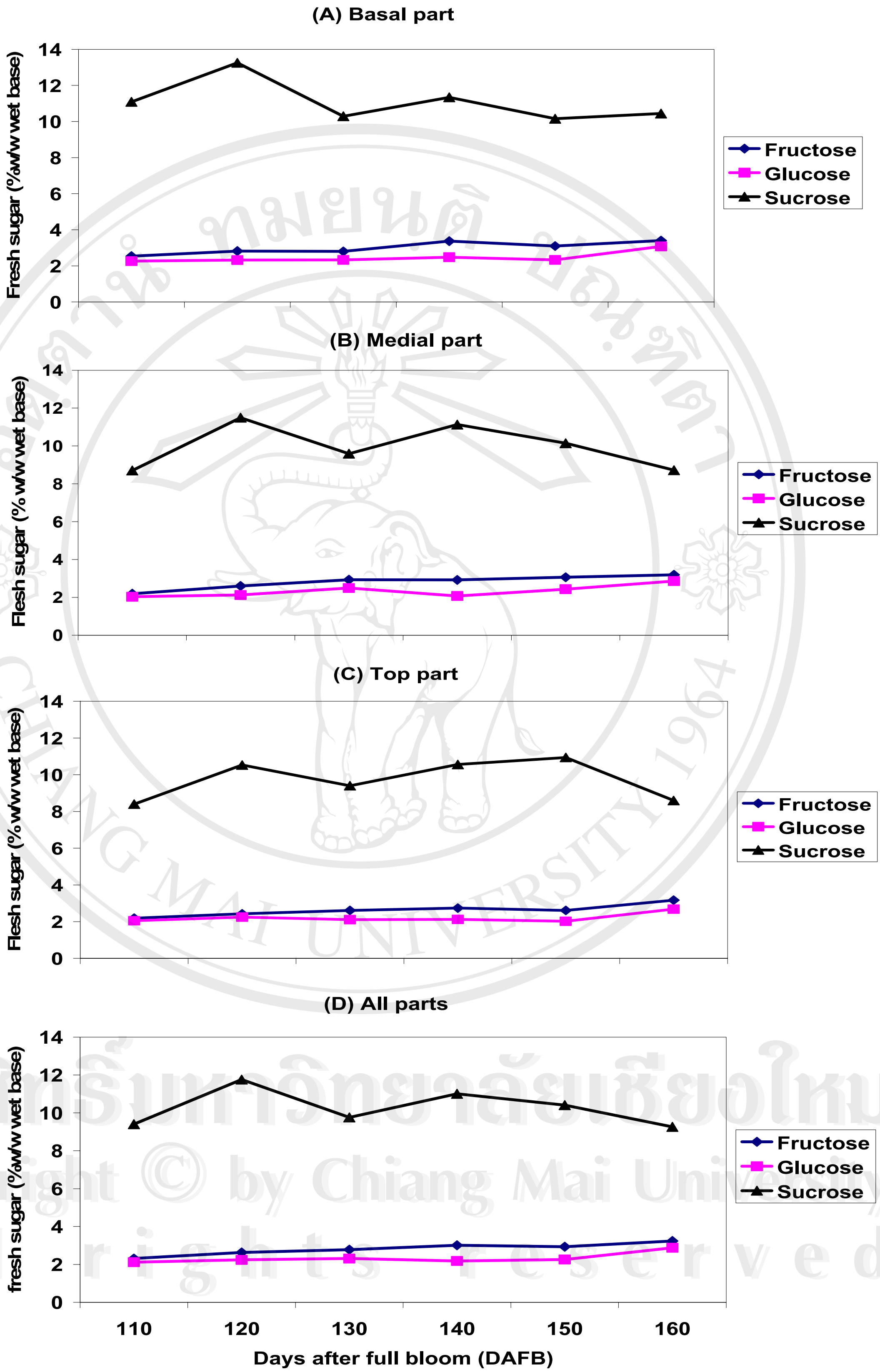


Figure 4.19 Changes in sugar contents of the regular crop for the year 2004.

(d) Crude fiber analysis

The average crude fiber content was 0.33 mg/100g fresh weight (Table 4.6) and not significant different in all crops. This result for crude fiber was close to found that by Akamine (1976), Nakasone and Paull (1998) were 30-0.61 and 0.5 mg/100g fresh weight, respectively but it has lower than reported by Smith (1993) was 2.0 mg/100g fresh weight. The difference in method used may affected crude fiber content.

(e) Moisture content

The moisture content of pineapple fruit was not significant difference in all crops. The average moisture content was 88 to 90% (Table 4.6) that agree with previous reported Salunkhe and Desai (1984) and Smith (1993). It was found that pineapple fruit contains 80 to 86% water. The moisture content of pineapple flesh showed high values in all crops.

4.3.3 Conclusion

The flesh firmness of fruit from all cropping seasons showed significantly differences in all parts and positions and during harvesting time at 110-130 DAFB. Flesh firmness of the late crop was lower than other crops. Total soluble solids and titratable acidity in the late crop was higher than other crops but TSS/TA ratio and pH were lower than other crops. The crude fiber and moisture contents of fruit from all cropping seasons were not significant differences.

Table 4.6 Moisture content (%) and crude fiber (%) of pineapple fruit from all crops for the year 2002

Part	Stage (DAFB)$^{+}$	Moisture content (%)			Crude fiber (%)		
		Early	Regular	Late	Early	Regular	Late
Basal	110	94.97^{f}	91.61^{e}	87.67^{bcd}	0.357^{abcd}	0.330^{abc}	0.386^{d}
	120	90.29^{de}	88.54^{bcde}	86.58^{bcd}	0.360^{abcd}	0.335^{abc}	0.376^{cd}
	130	89.37^{cde}	87.82^{bcd}	86.24^{abc}	0.378^{cd}	0.331^{abc}	0.355^{abcd}
	140	89.06^{cde}	87.72^{bcd}	85.13^{ab}	0.312^{a}	0.336^{abc}	0.324^{ab}
	150	88.87^{bcde}	87.03^{bcd}	-	0.311^{a}	0.321^{a}	-
	160	83.05^{a}	83.03^{a}	-	0.372^{bcd}	0.343^{abcd}	-
Medial	110	96.02^{i}	92.05^{h}	89.53^{defgh}	0.335^{abc}	0.336^{abc}	0.359^{cd}
	120	91.12^{gh}	88.93^{cdefg}	87.56^{bcde}	0.382^{d}	0.307^{a}	0.364^{cd}
	130	90.59^{fgh}	88.45^{cdefg}	87.20^{bcd}	0.383^{d}	0.308^{a}	0.338^{abc}
	140	90.26^{fgh}	88.72^{cdefg}	86.82^{bc}	0.325^{abc}	0.335^{abc}	0.312^{ab}
	150	90.01^{efgh}	85.61^{b}	-	0.309^{a}	0.310^{a}	-
	160	84.43^{a}	88.00^{bcdef}	-	0.353^{bcd}	0.332^{abc}	-
Top	110	96.24^{g}	92.25^{h}	89.72^{def}	0.389^{bcd}	0.344^{abcd}	0.404^{d}
	120	91.82^{gh}	89.51^{cdf}	89.24^{bcd}	0.388^{bcd}	0.321^{ab}	0.378^{bcd}
	130	91.40^{gh}	89.03^{bcd}	88.49^{bcd}	0.392^{cd}	0.337^{abc}	0.384^{bcd}
	140	91.32^{gh}	88.78^{bcd}	88.14^{b}	0.327^{abc}	0.352^{abcd}	0.341^{a}
	150	90.81^{fg}	88.23^{bc}	-	0.342^{abcd}	0.326^{abc}	-
	160	86.47^{a}	88.25^{bc}	-	0.359^{abcd}	0.389^{bcd}	-
All	110	95.74^{i}	91.97^{h}	88.97^{def}	0.361^{bcd}	0.337^{ab}	0.383^{d}
	120	91.08^{gh}	88.99^{def}	87.79^{bcd}	0.377^{cd}	0.321^{a}	0.373^{cd}
	130	90.45^{fg}	88.43^{cde}	87.31^{bc}	0.385^{d}	0.325^{a}	0.359^{bcd}
	140	90.21^{fg}	88.41^{cde}	86.70^{b}	0.321^{a}	0.341^{ab}	0.326^{a}
	150	89.89^{efg}	88.96^{bc}	-	0.319^{a}	0.319^{a}	-
	160	84.65^{a}	86.43^{b}	-	0.362^{bcd}	0.355^{bc}	-

4.4 Experiment 3: Change of sensory quality and ripening of pineapple fruit

4.4.1 Material and methods

(a) Samples

Twenty pineapple fruits were hand peeled and cut transversely into three slices from each fruit and each slice was cut into 8–10 segments. All segments were mixed and served in a random order on white dishes coded with a three-digit random number and rated by panelists.

(b) Evaluation sensory attributes of pineapple fruits

Ten sensory attributes color, sweetness, sourness, aroma, firmness, softness, watery, dryness, fibrousness and acceptable were evaluated by 10 trained panelists (seven females/three males, aged 24-45 years) at harvest. Evaluation was scored in a scaling test by using 10-point scale (0 = dislike extremely; 5 = neither like nor dislike; and 10 = like extremely).

(c) Data analysis

Data were statistically analyzed by an analysis of variance (ANOVA) and mean separation was by Duncan's multiple range test at $P \leq 0.05$. Significant differences were indicated by different letters in the same row.

4.4.2 Results and discussion

(a) Sensory quality of pineapple

Color score of pineapple flesh trend to increase during harvesting period and the score of the regular crop trend to showed higher score than other crops. The panelists express the color score of the regular crop as bright yellow and the early crop as slightly yellow, while the late crop as pale yellow. Although the statistical analysis of the color score of each crop not showed significant difference evaluated by panelist but the score of b* value measured by colorimeter show significant difference higher values in the regular crop than other crops throughout harvest period. Rating by panelist may not consistent because of the panelist could not compare the ranging score of each crop in the same time.

Regular crop was higher sensory qualities score of sweet taste than the other crops (Figure 4.20) but not significant differences. Sourness of the late crop was higher score than other crops and agrees with high TA content of crop in this experiment. Panelist pointed out that the late crop tasted sour although it shows the highest TSS and the early crop was flat taste.

Firmness, softness, watery, dryness, fibrousness, aroma and acceptable scores of all crops in both years were not significant differences (Figure 4.21). Aroma of the late crop increase prior than other crops in year 2002 inline with more advance ripening of their crop.

Acceptability of pineapple fruit of the regular crop trend to showed higher score than other crops at 130 DAFB (Table 4.7, Figure 4.20). In this experiment, panelists were able to distinguish the sweet taste of the regular crop together with its better color score therefore the acceptable score trend to showed higher than other crops. However, it was not significant difference which may due to the inconsistent of scoring of the panelist.

Table 4.7 Sensory qualities of pineapple fruit at each harvesting date from all crops for the years 2002 and 2003.

Assay	Stage (DAFB)$^{+}$	2002			2003		
		Early	Regular	Late	Early	Regular	Late
Color	110	3.26^{a}	5.80^{b}	4.35^{a}	3.60^{a}	4.60^{ab}	3.80^{a}
	120	4.00^{a}	5.83^{b}	5.30^{ab}	5.30^{ab}	5.90^{b}	4.60^{ab}
	130	4.40^{a}	6.20^{b}	5.80^{ab}	5.35^{ab}	6.20^{b}	5.60^{ab}
	140	6.10	6.20	6.20	6.35	6.95	5.48
	150	6.10	6.95	-	6.40	7.28	7.10
	160	6.70	7.35	-	-	7.35	7.40
Sweetness	110	4.00	4.50	4.20	4.40	4.75	4.20
	120	4.60	5.45	5.40	4.80	5.00	4.30
	130	4.90	5.85	5.65	5.15	5.90	4.50
	140	5.00^{a}	5.90^{ab}	6.60^{b}	6.10^{ab}	6.10^{ab}	5.55^{ab}
	150	5.10	6.50	-	6.40	6.10	5.45
	160	5.70	7.20	-	-	6.45	6.20
Sourness	110	5.00	5.65	6.10	4.50	5.00	5.25
	120	4.15^{b}	5.25^{b}	5.20^{b}	2.30^{a}	4.10^{b}	4.90^{b}
	130	3.00^{ab}	3.75^{abc}	4.90^{c}	2.40^{a}	3.75^{abc}	4.50^{bc}
	140	2.45^{a}	3.30^{abc}	4.65^{c}	2.15^{a}	3.00^{ab}	4.10^{bc}
	150	2.40^{ab}	2.30^{ab}	-	2.10^{a}	2.95^{ab}	3.60^{b}
	160	2.35	2.10	-	-	2.60	2.85
Aroma	110	3.95^{a}	3.65^{a}	5.60^{b}	3.80^{a}	4.15^{a}	4.30^{ab}
	120	4.45^{a}	4.05^{a}	6.45^{b}	4.30^{a}	4.45^{a}	4.85^{a}
	130	5.80	5.25	6.50	5.30	5.10	5.20
	140	5.90^{a}	5.60^{a}	8.70^{b}	5.75^{a}	5.65^{a}	5.40^{a}
	150	6.10	6.00	-	6.05	6.15	5.95
	160	6.55	6.35	-	-	6.15	6.20
Acceptable	110	4.00^{abc}	4.70^{bc}	4.20^{abc}	3.10^{a}	5.30^{c}	3.30^{ab}
	120	5.30	5.50	5.60	5.40	5.50	4.90
	130	5.60	6.10	5.90	5.60	6.50	5.60
	140	6.00	6.50	5.40	5.80	6.10	6.00
	150	5.60	6.30	-	5.30	5.80	5.80
	160	5.10	5.70	-	-	5.40	5.70

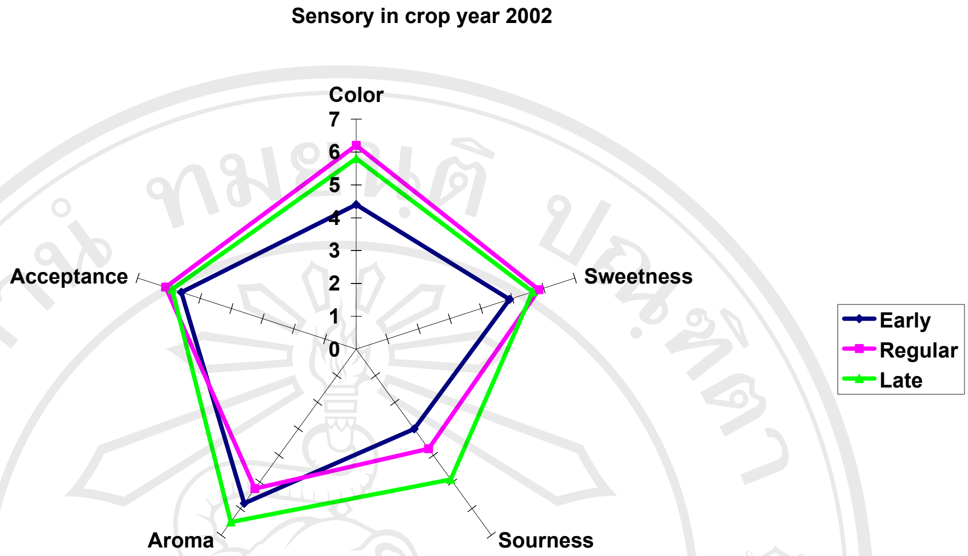
Different letter in the same row indicate significant differences, $P \leq 0.05$

Table 4.7 Sensory qualities of pineapple fruit at each harvesting date from all crops for the years 2002 and 2003.(continue)

Assay	Stage (DAFB)+	2002			2003		
		Early	Regular	Late	Early	Regular	Late
Firmness	110	4.10	3.90	4.00	3.75	4.05	3.90
	120	4.20	3.60	3.60	3.70	3.50	3.50
	130	3.40	3.10	3.25	3.80	3.20	3.20
	140	2.55	3.05	2.70	2.50	3.05	3.10
	150	2.35	2.45	-	2.45	2.55	2.45
	160	2.40	2.30	-	-	2.60	2.30
Softness	110	3.00[a]	3.05[a]	4.40[b]	2.95[a]	3.25[a]	3.05[a]
	120	3.30	3.57	4.30	3.30	3.62	3.57
	130	3.65	3.95	5.15	3.72	3.55	3.65
	140	4.92	4.60	5.70	5.27	4.40	4.70
	150	4.75	5.35	-	5.35	5.15	5.00
	160	5.00	5.00	-	-	4.65	5.35
Watery	110	5.00	4.80	6.50	5.50	5.50	4.80
	120	5.75	5.90	6.50	6.15	5.65	5.75
	130	6.40	6.05	7.00	6.25	6.25	5.90
	140	6.35[a]	6.85[a]	8.40[b]	6.35[a]	6.45[a]	6.85[a]
	150	6.75	6.80	-	7.10	7.00	7.00
	160	6.20	7.10	-	-	7.25	7.10
Dryness	110	4.20	3.65	3.40	3.60	3.55	3.65
	120	3.20	2.95	3.10	3.05	3.35	3.20
	130	2.75	2.65	2.40	3.00	2.85	2.65
	140	2.20	2.00	2.20	2.40	2.35	2.00
	150	2.00	1.65	-	2.00	1.95	1.65
	160	1.75	1.45	-	-	1.70	1.55
Fibrousness	110	6.60	6.20	6.85	6.50	6.55	6.30
	120	6.40	6.00	6.10	6.00	6.30	6.20
	130	6.00	5.75	5.50	5.40	6.25	6.05
	140	5.15	5.85	5.20	5.05	5.70	5.85
	150	5.00	5.00	-	4.90	5.55	5.00
	160	4.60	4.85	-	-	5.15	4.75

Different letters in the same row indicate significant differences, P≤0.05

(A)



(B)

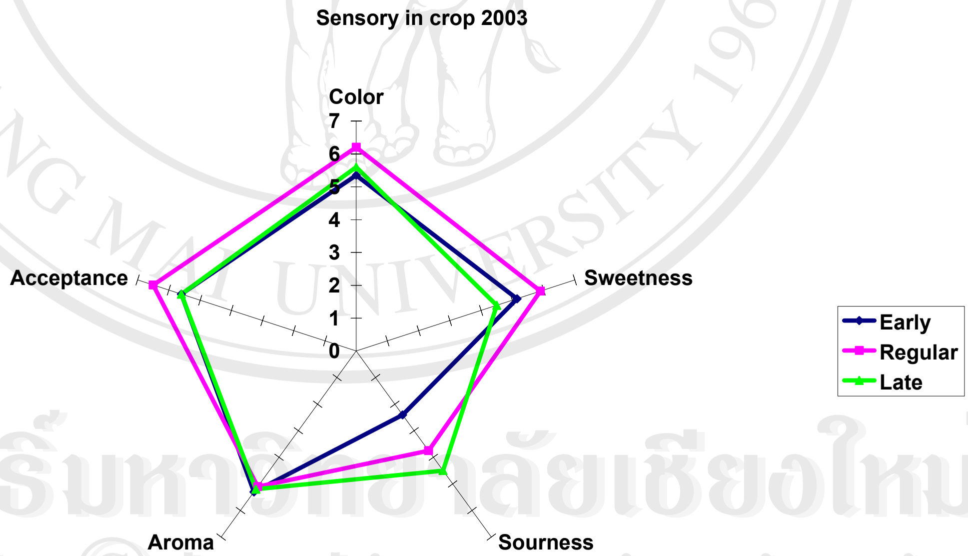
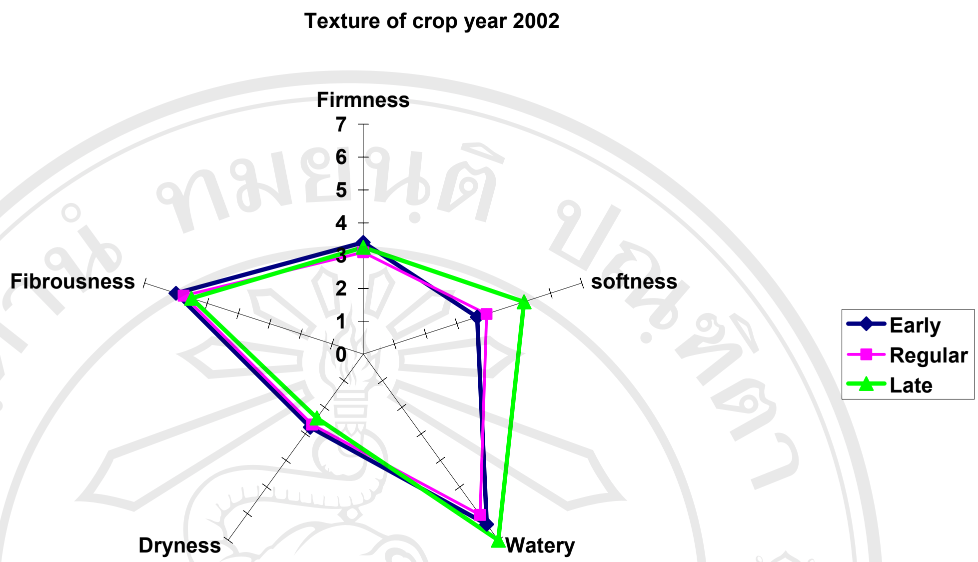


Figure 4.20 Spider plots of five sensory attributes (flavor) of pineapple at 130 DAFB of all crops for the years 2002 (A) and 2003 (B).

(A)



(B)

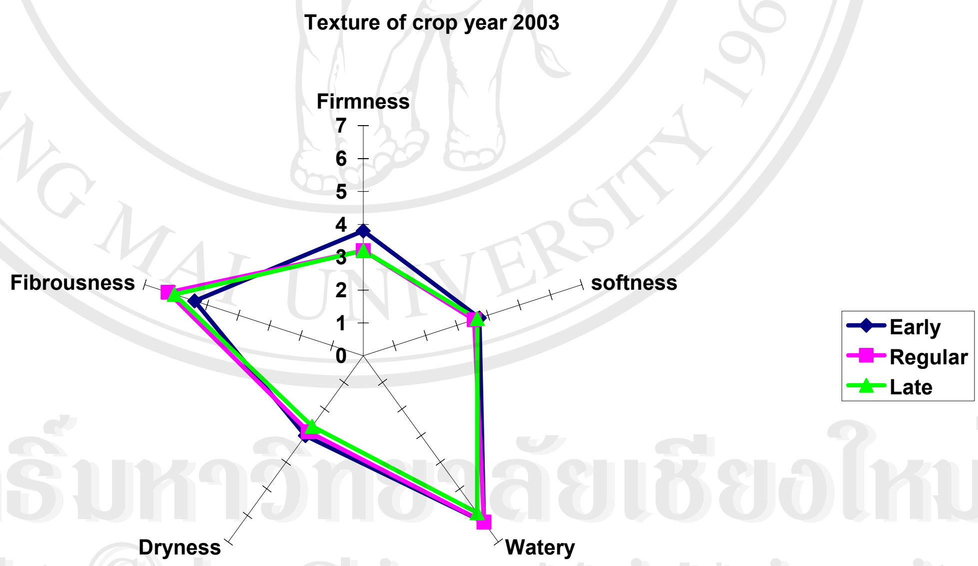


Figure 4.21 Spider plots of five sensory attributes (texture) of pineapple at 130 DAFB of all crops for the years 2002 (A) and 2003 (B).

(b) Fruit ripening

Pineapples like other non-climacteric fruit although maturation and ripening of fruit is indicated by the maximum accumulation of sugar or TSS and decrease in acid rather than the change in firmness and aroma. The pineapple fruit from all 3 seasons when harvested at 110 DAFB, their TSS content were not yet increased to its maximum and the acid were high. However, in this experiment of TSS in all crops were risen to their peak in second harvested at 120 DAFB indicate the fruit were ripe (Figure 4.17). Further more in all crops the TSS/TA ratio was sharply increase in second or third harvested of 120 and 130 DAFB which indicate the full ripe stage. However in the early crop, the TSS rise to the peak while the fruit are in green color (Figure 4.2 and 4.17). Therefore, the color criteria in the case of pineapple are not good index of ripening as were described in literature (Smith, 1984). In the late crop although the fruit color had change and TSS were increased to the peak at 120 DAFB but due to its high acid of this crop, the panelist gave the higher score at 130 DAFB.

In conclusion, the fruit from all three crops could be ripe at 120 DAFB and harvested period can cover for 20 days until 140 DAFB. During 140-160 DAFB the flesh texture is declined which indicate that fruit was over-ripe (Table A4.6, 4.7) but the levels of TSS, TA and pH values were sustained. For the late crop which the fruit development during high temperature, the field life were shorten to 140 DAFB the fruit were deteriorate due to incidence of rain income during harvesting in year 2002.

Thailand is located in the tropical region and the temperature among summer; rainy season and winter are not much different. Although, in the winter season the night is cool but day temperature is high. The monthly mean temperature is of 31°C. Therefore, the TSS and TSS/TA ratio of all season crops stay high value and had lower acid content compare to the fruit growing in sub-tropic and temperate zone. In Taiwan which located in the sub-tropic, there is a clear temperature different between summer and winter. During winter monthly the average temperature is around 17°C and fruit contain high acid and lack sweetness (Chang, 1988; Lin and Chang, 2000).

4.4.3 Conclusion

The regular crop was higher score of acceptable than other crops which may relation to high score of color and sweetness. The late crop was inferior quality when ripe. Their flesh was pale yellow and had sour-sweet taste. The early crop also showed inferior flesh quality because the fruit had light sweet taste and had low acid content. The fruit from all three crop season could be ripe at 120 DAFB and harvested period can cover for 20 days until 140 DAFB.