

Physico- chemical properties of pineapple variety N36 harvested and stored at different maturity stages

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Article history

Received: 23 May 2012

Received in revised form:

21 June 2012

Accepted: 27 June 2012

Keywords

N36

colour

pH

titratable acidity

pulp

total soluble solid (TSS)

sugar content

Abstract

The aim of this study is to determine colour changes during storage and physico- chemical properties of peel, core and crown extracts of pineapple variety N36 for maturity indices of 1, 2 and 3. The L* (lightness), a* (redness) and b* (yellowness) values for peels increased significantly ($p \leq 0.05$) at each maturity stage during seven days storage. pH of pineapple peel, core and crown extracts were in the range of 3.24 to 3.84. The titratable acidity, percentage of pulp and Total Soluble Solid (TSS) of pineapple peel, core and crown extracts were in the range of 0.16 to 0.36%, 1.37 to 2.91% and 1.4 to 5.3°Brix, respectively. Fructose and glucose contents were significantly highest ($p \leq 0.05$) in pineapple core extract followed by pineapple peel extract and pineapple crown extract for maturity index 2. Significant difference ($p \leq 0.05$) was found in sucrose content between pineapple core and peel extracts with 8.92% and 3.87%, respectively for maturity index 3. However, sucrose was not detected in pineapple crown extract. Pineapple core extract was significantly higher ($p \leq 0.05$) amount of total sugar content compared to pineapple peel and crown extracts for all maturity indices.

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Introduction

Pineapple or *Ananas comosus* (L.) Merr., holds the third rank in the world tropical fruit production only preceded by banana and citrus (De Poel *et al.*, 2009). Malaysian Pineapple Industry Board (MPIB) reported that for year 2008, Johor produced the highest yield of pineapple with 143,963.00 metric tons followed by Kelantan and Kedah with 8,209.60 and 1,121.17 metric tons, respectively. For year 2009, four main pineapple varieties planted in Malaysia were Morris (48%), Josaphine (25%), Sarawak (9%) and N36 (8%) (MPIB, 2010). However, pineapple variety N36 is only planted in one large area with six thousand acres at Simpang Renggam, Johor, Malaysia. This variety is mainly used for canned products.

Pineapple fruits, harvested at different maturity stages, are not of uniform quality (Dhar *et al.*, 2008). Rosnah *et al.* (2009) reported that many researchers have identified indicators of fruit maturity based on measurement of size, weight or density, physical attributes; such as colour, firmness and moisture content; as well as other chemical attributes such as starch, sugar or acid contents or morphology

evaluation. These indicators have been used to determine the harvest times of fruit with acceptable flavour characteristics and structural integrities (McGrath and Karahadian, 1994).

The post harvest wastage of pineapple at the retail market is substantially high (Fernando and de Silva, 2000). Hence, alternatives to its efficient utilization are necessary (Correia *et al.*, 2007). Ketnawa *et al.*, (2009) reported that pineapple peel is a potential source for the extraction of beneficial bioactive compounds due to the large amount of waste after processing. This waste still retains a considerable amount of soluble sugars, as well as high fibre and low protein contents (Correia *et al.*, 2004). Rosma *et al.* (2005) reported that pineapple waste which consists of peel, core and unwanted parts of pineapples contain up to 6.14% of carbohydrate, minerals especially magnesium and 0.6% of crude protein, thus undoubtedly a valuable fermentation substrate for both single cell protein (SCP) and metabolites production.

Studies on different pineapple species such as Mauritius (Fernando and de Silva, 2000; Wijesinghe and Sarananda, 2002), Josaphine (Rosnah *et al.*, 2009), MD2 (Wardy *et al.*, 2009) and Red Spanish

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and Smooth Cayenne (Bartolomé *et al.*, 1995) have been conducted. However, research on pineapple variety N36 has not been carried out. Therefore, this study was undertaken to determine colour changes of the N36 pineapple of maturity indices 1, 2 and 3 during storage at room temperature and to determine physico-chemical properties of pineapple peel, core and crown extracts of maturity indices 1, 2 and 3.

Materials and Methods

Raw materials

Pineapple variety N36 with different maturity indices of 1, 2 and 3 used in this study were freshly harvested from Peninsula Plantations Sdn Bhd at Simpang Renggam, Johor, Malaysia. They were harvested in the morning according to the visual peel colour as set up by Malaysia's Best standard produced by Federal Agricultural Marketing Authority (FAMA) whereby the requirements for pineapple are referred: maturity 1- all eyes are glossy bluish dark green with reddish bractea, maturity 2 - all scales green with tinge of yellow between the scales at the base, the bracts are dry and whitish and maturity 3 - one to two scales are yellowish green at the base.

Colour measurement

Pineapples were kept at room temperature for a week. The pineapples were divided into bottom, middle and upper parts as described by Rosnah *et al.* (2009). Analysis of peel colour was carried out at the respective maturity index 1, 2 and 3 from day 1 to day 7. The pineapple peel colour at the bottom, middle and upper parts were measured by the L*, a*, b* colour space (also referred to as CIELAB) using a chromameter (CR-400, Minolta, Osaka, Japan). Expression of colour was characterized as L* (lightness) and a*, b* (chromaticity coordinates). The chromaticity coordinates represent colour directions as follows: +a* (red direction), -a* (green direction), +b* (yellow direction), -b* (blue direction). At least three readings were taken at each part of each fruit and the average values were recorded.

Extraction of pineapple peel, core and crown

Pineapple peels were crushed using fruit juice processor with ratio of pineapple peel to purified water 1: 1. The extract was filtered through a muslin cloth. Then, the pineapple peel extract was centrifuged at 360 x g for 10 min. The clear supernatant was collected and used for analysis. Pineapple core and crown were also extracted using the same procedure.

Physico-chemical properties determination

pH

pH of pineapple peel, core and crown extracts were determined at room temperature using pH meter after being standardized with pH 4 and pH 7 buffers.

Total titratable acidity

Total titratable acidity of pineapple peel, core and crown extracts was determined by titration method following Amador (2008).

Pulp volume

Pulp of pineapple peel, core and crown extracts were determined using the centrifugal method (Zainal, 2001). A centrifuge tube containing 10 ml of pineapple peel, core and crown extracts was centrifuged at 360 x g for 10 min at room temperature. Pulp volume was measured as the volume of precipitate which was directly read from the graduate centrifuge tube and expressed as a percentage of the total pineapple peel, core and crown extract volume.

Total soluble solid

Total soluble solid (TSS) of pineapple peel, core and crown extracts were determined using an Abbe refractrometer. A drop of the pineapple peel, core and crown extracts were placed on its prism. The percentage of TSS was obtained from direct reading of the refractrometer.

Sugar content

Sugar content in pineapple peel, core and crown extracts were determined using an analytical High Performance Liquid Chromatography (HPLC), Waters model 600 instrument with a Refractive Index detector model 2414. Analytical grade acetonitrile and sodium hydroxide were purchased from Merck Sdn Bhd. Standard fructose, glucose and sucrose were purchased from Sigma Technologies Sdn Bhd. Acetonitrile and purified water (90: 10; v/v) was used as mobile phase. Sugar in the sample was quantified by comparing peak areas of the samples with those of the sugar standard. The chromatography run using a Carbohydrate High Performance 4 μ m (4.6mm x 250 mm cartridge) column at 18-22°C, flow rate of 1.3 ml/min. Injection volume was 20 μ l.

Relative sweetness for individual sugar

Relative sweetness for individual glucose, sucrose and fructose in pineapple peel, core and crown extracts was calculated according to the method by Byrne *et al.*, (1991) as follows: Glucose= glucose content x 0.74, Sucrose= sucrose content x 1, Fructose= fructose content x 1.73.

Statistical analysis

All data were expressed as mean ± standard deviation (n= 3 replicates). Data were analyzed using one-way ANOVA using SPSS 15.0. Duncan’s multiple-range test was used to determine the difference between means. A significant difference was considered at the level of $p \leq 0.05$.

Results and Discussion

Figures 1a, 1b and 1c show the L* values for bottom, middle and upper parts of pineapple for maturity indices 1, 2 and 3 from day 1 to day 7. The L* values for bottom part of pineapple for maturity indices 1, 2 and 3 from day 1 to day 7 were in the range of 39.92 to 52.01, 45.67 to 56.71 and 48.45 to 61.82, respectively. The L* values for middle part of pineapple for maturity indices 1, 2 and 3 from day 1 to day 7 were in the range of 33.68 to 44.76, 40.07 to 51.25 and 41.89 to 56.46, respectively. The L* values for upper part of pineapple for maturity indices 1, 2 and 3 from day 1 to day 7 were in the range of 23.65 to 40.86, 29.97 to 45.92 and 37.50 to 49.92, respectively. There were significant increased ($p \leq 0.05$) for L* values for each maturity stages measured from day 1 to day 7.

Figures 2a, 2b and 2c show the a* values for bottom, middle and upper parts of pineapple for maturity indices 1, 2 and 3 from day 1 to day 7. The a* values for bottom part of pineapple for maturity indices 1, 2 and 3 from day 1 to day 7 were in the range of -0.67 to 5.82, 1.25 to 8.26 and 3.15 to 15.73, respectively. The a* values for middle part of pineapple for maturity indices 1, 2 and 3 from day 1 to day 7 were in the range of -4.77 to 2.72, -0.77 to 4.45 and 0.70 to 8.16, respectively. The a* values for upper part of pineapple for maturity indices 1, 2 and 3 from day 1 to day 7 were in the range of -10.27 to -0.31, -4.87 to 2.27 and -2.10 to 4.66, respectively. The bottom and middle part of pineapple maturity index 1 started to change colour at day 2 and day 5, respectively as indicated by +a values. The upper part of pineapple maturity index 1 remained green even until day 7 as indicated by -a value. The middle and upper parts of pineapple maturity index 2 started to change colour at day 2 and day 6, respectively as indicated by +a values. The upper part of pineapple maturity index 3 started to change colour at day 4 as indicated by +a value. There were significant increased ($p \leq 0.05$) in the a* values for each maturity stages measured from day 1 to day 7.

Figures 3a, 3b and 3c show the b* values for bottom, middle and upper parts of pineapple for maturity indices 1, 2 and 3 from day 1 to day 7. The

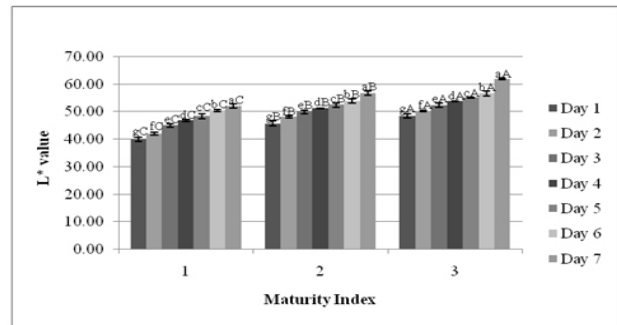


Figure 1a. Changes in L* values for bottom part of pineapple of maturity indices 1, 2 and 3 upon storage

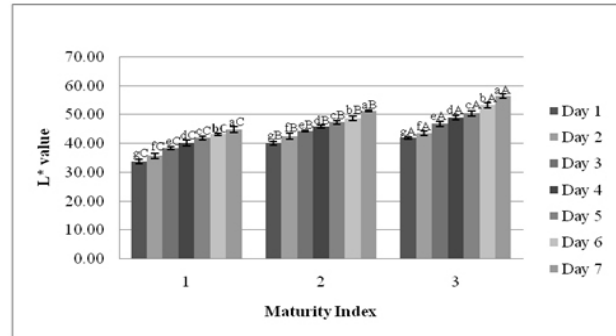


Figure 1b. Changes in L* values for middle part of pineapple of maturity indices 1, 2 and 3 upon storage

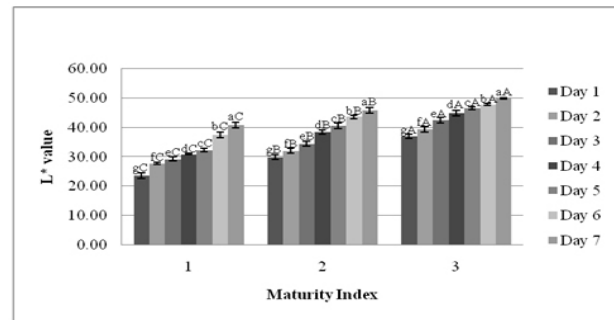


Figure 1c. Changes in L* values for upper part of pineapple of maturity indices 1, 2 and 3 upon storage

b* values for bottom part of pineapple for maturity indices 1, 2 and 3 from day 1 to day 7 were in the range of 10.27 to 21.44, 10.42 to 21.63 and 18.92 to 39.21, respectively. The b* values for middle part of pineapple for maturity indices 1, 2 and 3 from day 1 to day 7 were in the range of 8.02 to 19.49, 10.42 to 21.63 and 12.65 to 32.11, respectively. The b* values for upper part of pineapple for maturity indices 1, 2 and 3 from day 1 to day 7 were in the range of 6.43 to 15.85, 7.24 to 20.01 and 11.04 to 22.45, respectively. The b* values significantly increased for each maturity stage from day 1 to day 7.

Colour of pineapple peel is an external factor or parameter that is used to determine the various stages of maturity (Joomwong, 2006). From this study, it was found that the a* and b* values increased because as the ripening progressed, the fruit become less green but gradually become more yellowish. In pineapple

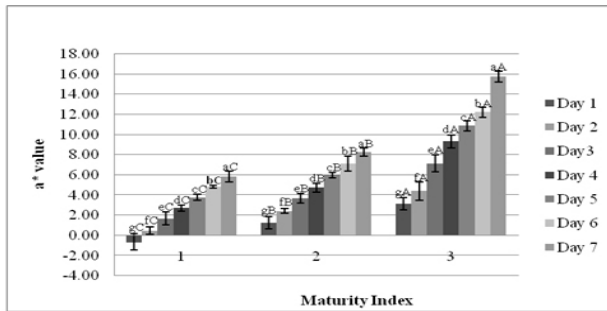


Figure 2a. Changes in a* values for bottom part of pineapple of maturity indices 1, 2 and 3 upon storage

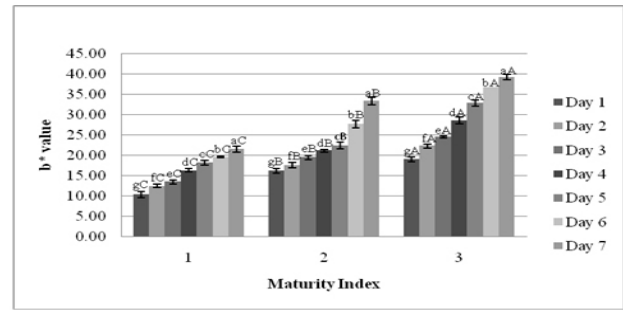


Figure 3a. Changes in b* values for bottom part of pineapple of maturity indices 1, 2 and 3 upon storage

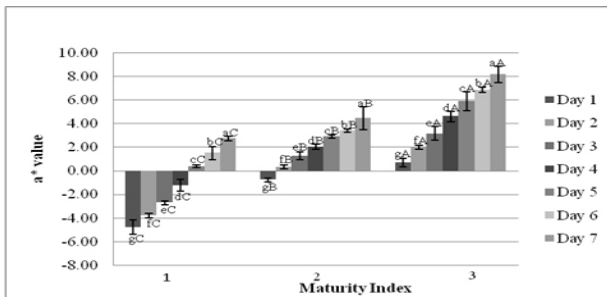


Figure 2b. Changes in a* values for middle part of pineapple of maturity indices 1, 2 and 3 upon storage

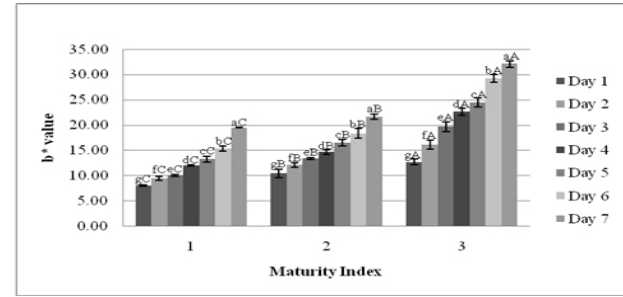


Figure 3b. Changes in b* values for middle part of pineapple of maturity indices 1, 2 and 3 upon storage

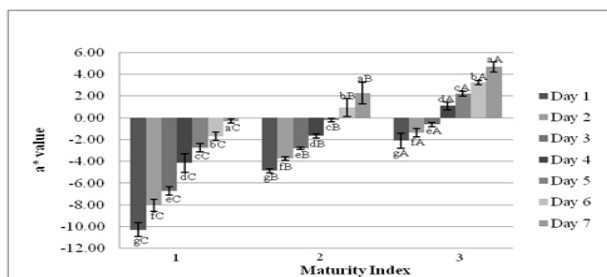


Figure 2c. Changes in a* values for upper part of pineapple of maturity indices 1, 2 and 3 upon storage

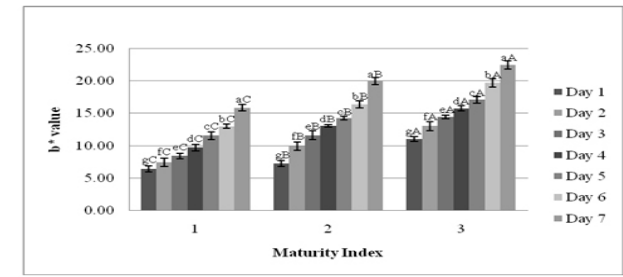


Figure 3c. Changes in b* values for middle part of pineapple of maturity indices 1, 2 and 3 upon storage

maturity index, the yellowish colour increases starting from peduncle and progress to the upper part of the fruit as the maturity stage increases (Rohana *et al.*, 2009). They reported that although pineapple is considered as a non-climacteric fruits, the peel acts as a climacteric due to the increase in peel colour after harvesting. The L^* , a^* and b^* values increased because the colour of the pineapple peel intensified during the storage period. The result of present study is similar with Wijesinghe and Sarananda (2002) on colour changes of Mauritius pineapple during storage.

pH, titratable acidity, percentage of pulp, total soluble solid and percentage of sugar content of pineapple peel, core and crown extracts are shown in Tables 1, 2 and 3. It was found that pH and titratable acidity of pineapple peel and core extracts increased as the maturity index increases. Instead, pH and titratable acidity of pineapple crown extract decreased as the maturity index increases. pH of the pineapple peel, core and crown extracts which were in the range of 3.24 to 3.84 indicated that the extracts

were acidic. The highest significant titratable acidity in the pineapple peel, core and crown extracts were 0.31 (maturity index 3), 0.29 (maturity index 3) and 0.36 (maturity index 1), respectively.

pH is an internal ripeness indicator (Vinson *et al.*, 2010). Rosnah *et al.* (2012) reported that pH of water apple cultivar Kristal Taiwan fruit was in the range of 3.84 to 4.12. It means that pineapple peel, core and crown extracts are sourer than water apple cultivar Kristal Taiwan fruit. pH is an important factor in fruit processing industry (Moneruzzaman *et al.*, 2008). According to Wardy *et al.* (2009), fruit titratable acidity increased with maturity of fruit which was in agreement with this finding for the pineapple peel and core extracts. In contrast, the titratable acidity of the pineapple crown extract decreased with maturity. This was Tafti and Fooladi (2006) suggested that acid content increase during maturation in warm condition. The decrease in the titratable acidity of pineapple crown extract was complied with Othman (2011) who reported that the decrease in acidity during the ripening of pineapple was due to the loss

Table 1. Physico-chemical properties of pineapple peel extract of maturity indices 1, 2 and 3

Assay	Maturity Index		
	1	2	3
pH	3.47 ± 0.00 ^c	3.78 ± 0.01 ^b	3.84 ± 0.00 ^a
Titrateable acidity (%)	0.16 ± 0.00 ^c	0.23 ± 0.00 ^b	0.31 ± 0.00 ^a
Pulp (%)	2.02 ± 0.02 ^c	2.23 ± 0.01 ^b	2.31 ± 0.01 ^a
Total soluble solid (°Brix)	1.80 ± 0.00 ^c	2.20 ± 0.00 ^b	2.50 ± 0.00 ^a
Total sugar (%)	6.74 ± 0.21 ^c	7.26 ± 0.10 ^b	7.37 ± 0.08 ^a
Glucose (%)	2.18 ± 0.09 ^a	2.18 ± 0.08 ^a	1.68 ± 0.02 ^b
Sucrose (%)	2.58 ± 0.08 ^c	3.04 ± 0.08 ^b	3.87 ± 0.03 ^a
Fructose (%)	1.98 ± 0.16 ^b	2.04 ± 0.07 ^a	1.82 ± 0.02 ^c

Means ± sd (n= 3 replicates) within each row with different superscript are significantly different (p≤ 0.05)

Table 2. Physico-chemical properties of pineapple core extract of maturity indices 1, 2 and 3

Assay	Maturity Index		
	1	2	3
pH	3.24 ± 0.01 ^c	3.37 ± 0.00 ^b	3.59 ± 0.00 ^a
Titrateable acidity (%)	0.19 ± 0.00 ^c	0.24 ± 0.01 ^b	0.29 ± 0.01 ^a
Pulp (%)	1.37 ± 0.17 ^c	1.43 ± 0.05 ^b	1.86 ± 0.01 ^a
Total soluble solid (°Brix)	4.50 ± 0.15 ^c	4.08 ± 0.04 ^b	5.30 ± 0.00 ^a
Total sugar (%)	12.68 ± 0.17 ^c	13.33 ± 0.10 ^b	13.46 ± 0.12 ^a
Glucose (%)	2.31 ± 0.10 ^b	2.56 ± 0.09 ^a	2.32 ± 0.07 ^b
Sucrose (%)	8.37 ± 0.09 ^c	8.53 ± 0.08 ^b	8.92 ± 0.09 ^a
Fructose (%)	2.00 ± 0.07 ^b	2.24 ± 0.05 ^a	2.22 ± 0.07 ^a

Means ± sd (n= 3 replicates) within each row with different superscript are significantly different (p≤ 0.05)

Table 3. Physico-chemical properties of pineapple crown extract of maturity indices 1, 2 and 3

Assay	Maturity Index		
	1	2	3
pH	3.97 ± 0.00 ^a	3.94 ± 0.00 ^b	3.92 ± 0.00 ^b
Titrateable acidity (%)	0.36 ± 0.00 ^a	0.30 ± 0.00 ^b	0.28 ± 0.00 ^c
Pulp (%)	2.91 ± 0.00 ^a	2.41 ± 0.00 ^b	1.38 ± 0.01 ^c
Total soluble solid (°Brix)	1.40 ± 0.00 ^c	1.60 ± 0.00 ^b	2.00 ± 0.00 ^a
Total sugar (%)	1.25 ± 0.03 ^c	1.33 ± 0.06 ^b	1.40 ± 0.04 ^a
Glucose (%)	0.48 ± 0.03 ^b	0.51 ± 0.05 ^a	0.53 ± 0.02 ^a
Sucrose (%)	ND	ND	ND
Fructose (%)	0.78 ± 0.01 ^c	0.83 ± 0.04 ^b	0.87 ± 0.02 ^a

Means ± sd (n= 3 replicates) within each row with different superscript are significantly different (p≤ 0.05)

Table 4. Yellowness and relative sweetness for individual sugar of pineapple peel, core and crown extracts of maturity indices 1, 2 and 3

Maturity	Yellowness (b*)	Relative sweetness for individual sugar								
		Glucose			Sucrose			Fructose		
		Peel	Core	Crown	Peel	Core	Crown	Peel	Core	Crown
Index 1	10.27	1.61	1.71	0.36	2.58	8.37	ND	3.45	3.48	1.36
Index 2	10.42	1.61	1.89	0.38	3.04	8.53	ND	3.55	3.90	1.44
Index 3	18.92	1.24	1.72	0.39	3.87	8.92	ND	3.17	3.86	1.51

b* is yellowness values of pineapple peel of maturity index 1, 2 and 3 measured at day 1

in the dominant citric acid. Besides, the acidity was decreased because they are used as a respiratory substrate and generation of ATP (Lee *et al.*, 2010). Titrateable acidity of the pineapple peel and core extract increased while titrateable acidity of the pineapple crown extract decreased with maturity was in accordance with Moradshahi *et al.*, (1977) who found that the photorespiration in pineapple crown

was associated by an equal loss of total acid at the higher temperatures and by a decrease in CO₂ uptake with increased temperature.

It was found that percentage of pulp in pineapple peel and core extracts as summarized in Tables 1 and 2 was highest in maturity index 3 followed by maturity index 2 and 1 which was in an agreement with Dhar *et al.* (2008). However, percentage of pulp in pineapple crown extract was the highest in maturity index 1 followed by maturity indices 2 and 3. TSS in the pineapple peel, crown and core extracts increased as the maturity index increases which was similar to Dhar *et al.* (2008) and Othman (2011) and was in the range of 1.4 to 5.3°Brix. From this study, it was found that the peel colour had a linear relationship with TSS as indicated by the increasing trend of TSS and peel colour with the storage period. TSS is another important quality factors that attributes for many fresh fruits because solids include the soluble sugars sucrose, glucose and fructose as well as acids (Tehrani *et al.*, 2011). According to Moneruzzaman *et al.* (2008), during maturation and ripening of fruit there are changes in total soluble solid. The total soluble solid increases from mature green stage to yellow ripe stage.

It was found that glucose, sucrose and fructose were detected in pineapple peel and core extracts. However, only glucose and fructose were detected in pineapple crown extract. Percentage of glucose in pineapple peel, core and crown extracts were in the range of 1.68 to 2.81%, from 2.31 to 2.56%, and from 0.48 to 0.51%, respectively as shown in Tables 1, 2 and 3. Percentage of sucrose in pineapple peel and core extracts was in the range of 2.58 to 3.87% and from 8.37 to 8.92%, respectively. Percentage of fructose in pineapple peel, core and crown extracts were in the range of 1.82 to 2.04%, from 2 to 2.24% and from 0.78 to 0.87%, respectively. The pineapple core extract contain the highest total sugar in maturity index 3 (13.46%) followed by maturity index 2 (13.33%) and maturity index 1 (12.68%). These results are in agreement with the explanation from Ersoy *et al.* (2007) and Wijesinghe and Sarananda (2002) that sugar content and its quantity changed in fruits may depend upon the fruit maturity stages. The result showed that there was increment of total sugar content in pineapple peel, core and crown extracts during the storage-ripening period.

Sugar is an important factor of fruit quality. The composition of sucrose, glucose and fructose plays a key role in determining the sweetness in tomato, papaya, peach and apple (Zhang *et al.*, 2011). From this study it was found that sucrose was the major sugar present in the pineapple waste extract. This

result is in agreement with Masniza *et al.* (2000) who reported that pineapple contains 12-15% sugar of which two-third or majority is in the form of sucrose and the rest are glucose and fructose.

Table 4 shows the relationship of yellowness (b^*) of pineapple peel and relative sweetness for individual glucose, sucrose and fructose of pineapple peel, core and crown extracts of maturity indices 1, 2 and 3. It was found that the relative sweetness for individual sucrose of pineapple peel and core extracts increased with the progressive of pineapple peel yellowness. The relative sweetness for individual glucose and fructose of pineapple crown extract was also increased with the progressive of pineapple peel yellowness. However, the relative sweetness for individual glucose and fructose of pineapple peel and core extracts increased during maturity index 2 and decreased during maturity index 3. The fructose in pineapple peel extract increased and decreased during maturation is similar with guava which increased during ripening and subsequently decreased in the over-ripe fruits (Rosnah *et al.*, 2012). The reduction in fructose could be due to its utilization in synthesis of sucrose which increased with fruit maturity (Ladaniya and Mahalle, 2011).

Sweetness is an important indicator of fruit quality and highly correlated with ripeness in most fruit (Ersoy *et al.*, 2007). Byrne *et al.* (1991) reported that the sweetness of fruit is highly dependent on sugar composition because sugar differs in their relative sweetness. According to Ishtiaq *et al.*, (2010), yellowness (b^*) of the fruit is accompanied by a progressive sweetness of the fruit pulp due to the formation of sugars resulting probably from starch hydrolysis.

Conclusion

From this study, it can be concluded that colour of the pineapple peel changes during one week storage as indicated by increasing in the L^* , a^* and b^* values. The color became less green but more yellow with storage-ripening period. The physico-chemical properties of the pineapple peel, core and crown extracts differed according to maturity. These findings would be useful for many purposes such as guideline for pineapple industry to identify the maturity of pineapple more accurately for harvesting purpose and the usage of pineapple waste in enzyme production and fermentation process.

Acknowledgements

Special thanks to Ministry of Higher Education, Malaysia for funding this project under Fundamental

Research Grant Scheme [600-RMI/ST/FRGS/Fst(32/2010)] and also Peninsula Plantation Sdn Bhd, Simpang Renggam, Johor, Malaysia for supplying pineapple for this project

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