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Physicochemical properties and sensory acceptability of pineapples of different varieties and stages of maturity

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Abstract

Pineapples are an excellent source of vitamins and minerals and are usually eaten fresh due to the appealing flavour of the fruits. However, pineapples obtained from different varieties and stages of maturity possess different compositions and are of varying eating quality. Thus, the objective of this study was to determine the relationship between the physicochemical properties and the consumer acceptability of pineapples of different varieties and stages of maturity using Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA). The pH, total soluble solids (TSS), redness (*a* value), and yellowness (*b* value) of the pineapples increased significantly (P<0.05) as the maturity stage increased for all varieties (MD2, N36 and Moris) of pineapple. However, the titratable acidity, vitamin C content, and all texture properties of the pineapples decreased significantly (P<0.05) as the maturity stage increased. The TSS of the pineapples showed a strong positive correlation with the yellow colour (b value) (r = 0.965), red colour (a value) (r = 0.864), and pH (r = 0.803) at P<0.01. Based on the PCA result, pineapples at index 4 and index 5 were mostly influenced by the texture parameters. The HCA result revealed that the Moris and N36 varieties of pineapple at index 7 had the highest similarity in terms of the physicochemical properties and sensory acceptability. The physicochemical properties of the pineapples of different varieties and stages of maturity significantly affected the sensory acceptability.

1. Introduction

Pineapples (*Ananas comosus* L. Merr) are a non-climacteric fruit that belongs to the Bromeliaceae family. Malaysia is one of the major producers of pineapples along with South Africa, Mexico, Kenya, Australia, Hawaii, Philippines, Taiwan, and Thailand (Bartolome *et al.,* 1995). According to the Malaysian Pineapple Industry Board, in 2017, 70% of pineapple production was mainly distributed for the domestic fresh market, while the rest was processed for canning and beverages. Nine varieties (Moris, Moris Gajah, Maspine, Gandul, Yankee, N36, MD2, Josaphine and Sarawak) of pineapple are planted in Malaysia, and, among these varieties, Moris, N36 and MD2 are widely planted in the northern part of Malaysia for the fresh market.

Moris is a 'Queen' cultivar that has higher tolerance to stress, pests, and diseases compared to other pineapple cultivars. It has golden yellow flesh, spongy texture with high sugar content (12-14^{o}Brix) (De Silva *et al.,* 2008) and produces a pleasant smell and flavour when ripening. However, the conical shape and deep eyes make this cultivar unsuitable for the canning process due to the high waste generated, and consequently, lower yield. Therefore, the Moris cultivar is commonly distributed either for local markets or exported to other countries as fresh produce.

The N36 cultivar is produced through a breeding process between the "Spanish" (Gandul) and the "Smooth Cayenne" cultivar. It can be categorized as a robust cultivar due to its longer lifespan and greater resistance to the blackheart disorder compared to other cultivars. This cultivar contains high sugar (16-17^{o}Brix) and less acid (0.5-1.2% acidity) and is normally consumed fresh (Abdullah *et al*., 1996; Hassan *et al.,* 2010; Mohammad *et al.,* 2012). The cylinder shape properties of this cultivar make it suitable for the canning process.

The MD2 cultivar is a hybrid pineapple that is produced from a breeding process between the Smooth Cayenne PRI hybrids 58-1184 and 59-443 (Greig, 2004). This cultivar is the sweetest among the pineapple cultivars and has a longer shelf life (Thalip *et al.,* 2015).

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The flesh contains about 12-19°Brix of total soluble solids and is less acidic (0.05-0.3% acidity) and more aromatic compared to other pineapple cultivars (Achuonjei *et al.,* 2003; Wardy *et al.,* 2009; Ding and Syazwani, 2016).

According to George *et al.* (2016), the appearance, size, skin colour, and aroma of pineapples are the main criteria for the determination of their quality. The physicochemical properties of pineapples are affected by the variety and stage of maturity (Pauziah *et al.,* 2013). The colour of a pineapple's skin changes from dark green to yellowish or orange upon ripening. The harvesting of pineapples at different stages of maturity is dependent on their application. Pineapples can be eaten starting from Index 3 onwards. Index 3 pineapples have a dark green peel with 1 to 2 yellow 'eyes' at the bottom of the fruits and the number of yellow 'eyes' increase upon fruit maturation. Generally, pineapples at Index 3 to Index 6 (75% yellow 'eyes' from the bottom) are suitable for fresh consumption. For fully ripe pineapples (Index 7), the flesh is too soft and juicy and not suitable for fresh consumption. At this stage, the fruit is suitable for juice processing.

According to Seppä *et al*. (2013), fruit harvesting at different stages of maturity has a notable impact on the sensory quality of the fruit. As a non-climacteric fruit, pineapples ripen during plant growth but slowly decay after harvesting. Therefore, the optimum level of ripening stage is very important at the point of harvesting to ensure satisfactory fruit quality. Upon maturation, the total soluble solids (°Brix) and titratable acidity (%) of the pineapples were reported to increase from 1.8 to 2.5° Brix and 0.18 to 0.32%, respectively, for the N36 variety (Nadya *et al.,* 2012), 4.8 to 12.7°Brix and 0.20 to 1.44%, respectively, for the Sarawak variety (George *et al.,* 2016), and 8.6 to 18.0°Brix and 0.52 to 0.78%, respectively, for the MD2 variety (Ding and Syazwani, 2016). Knowing the physicochemical properties and consumer acceptability of different varieties of pineapples and maturity stages is crucial due to the high demand for fresh consumption. Therefore, the aim of this study was to determine the relationship between the physicochemical properties and the consumer acceptability of pineapples of different varieties and stages of maturity.

2. Materials and methods

Pineapple of three varieties (MD2, N36, and Moris) at four maturity stages (Index 4 (25% ripe), Index 5 (50% ripe), Index 6 (75% ripe), and Index 7 (100% ripe)) were obtained from the pineapple plantation at Tasek Gelugor, Penang, Malaysia. Metaphosphoric acid was purchased from R&M Chemicals (Essex, UK). Sodium hydrogen bicarbonate and sodium hydroxide were purchased from Fisher Scientific (New Hampshire, United States). 2,6-Dichlorophenolindophenol salt, L (+) ascorbic acid and phenolphthalein were purchased from Merck (Darmstadt, Germany), and acetic acid was purchased from Fluka Chemicals (Shanghai, China).

2.1 Sample preparation

The crown of the pineapple was cut off prior to washing the fruit to remove dirt. The skin was peeled off, and the pineapple flesh was cut into small pieces (1.5 cm^3) using a sharp knife. After that, the pineapple juice was extracted using a centrifugal juice extractor (JE680, Kenwood, UK). The juice obtained was stored at 4°C prior to analysis.

2.2 Determination of physicochemical properties of pineapples

The pH and total soluble solids (TSS) were determined using a pH meter (S40 Seven MultiTM, Metter-Toledo, Switzerland) and a hand refractometer (Atago, Japan), respectively. The titratable acidity and vitamin C (ascorbic acid) content of the pineapples were measured according to the method described by George *et al.* (2016). The colour (*L* value (lightness), *a* value (redness), and *b* value (yellowness)) and texture profile analysis (TPA) of the pineapple flesh (1.5 cm^3) were measured using a Minolta colorimeter, CM-3500D (Osaka, Japan) (Nadzirah *et al.,* 2013) and Texture Analyser (Stable Micro System, Surrey, UK) (Selani *et al.,* 2014), respectively. The texture of the pineapples was measured by compression using a 36-mm cylindrical flat probe (P/36R), load cell 30 kg with a setting of 1 mm/sec test speed and 30% strain. All analyses were conducted in triplicate.

2.3 Sensory evaluation

A total of 40 untrained panellists (28 females and 12 males) with ages ranging between 20 and 22 years were involved in determining the acceptability of fresh pineapples using a 7-point hedonic scale (1 = dislike very much, 2 = dislike moderately, 3 = dislike slightly, 4 = neither like or dislike, 5 = like slightly, 6 = like moderately and 7 = like very much). Three varieties of pineapple at four maturity stages were cut into cubes (3 cm^3) and were labelled with a three-digit number prior to being served randomly to panellists (Mailgaard *et al.,* 2016). The panellists were asked to rate their acceptability in terms of the attributes of colour, aroma, texture, taste, and overall acceptability of all the pineapples. Plain water was provided for each panellist to rinse their mouth before and after sample testing. The

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sensory evaluation was conducted in two sessions with panellists being served less than six samples for each session. Sensory evaluation was conducted in individual booths in the sensory laboratory, Food Department, School of Industrial Technology, Universiti Sains Malaysia, Penang, Malaysia.

2.4 Statistical analysis

The physicochemical data were analysed through one-way and two-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 22. Two-way analysis of variance (ANOVA) was conducted to determine the interaction effect between the pineapple variety and the maturity stage for each variable (Table 1). Then, one-way analysis of variance (ANOVA) was conducted on the variables with no significance (P>0.05) in terms of the interaction effect, to evaluate the effects of the different varieties and maturity stages of pineapples on the physicochemical and sensory properties. Duncan's multiple-range test (P<0.05) was used to determine the significant difference between the means.

Table 1. F values and P values (two-way ANOVA) of the interaction between all pineapple varieties and stages of maturity on physicochemical properties and sensory acceptability attributes.

Variables	F-value	P-value
Lightness (L value)	2.019	0.102
Redness (a value) *	4.098	0.006
Yellowness (b value)	1.253	0.316
Total soluble solid (°Brix)*	6.700	0.000
pH*	135.947	0.000
Vitamin C*	375.128	0.000
Titratable acidity (% Citric acid)*	7.787	0.000
Hardness	2.121	0.088
Springiness	0.132	0.991
Cohesiveness	1.264	0.310
Gumminess	0.378	0.886
Chewiness	1.391	0.259
Colour*	15.741	0.000
Aroma*	7.625	0.000
Taste*	23.213	0.000
Texture*	2.551	0.020
Overall acceptability*	8.263	0.000

*There are significant interactions between the variety and maturity stage at P<0.05.

The correlations between all the parameters were analysed using the Pearson correlation test. Principal Component Analysis (PCA) was used to emphasize the variation and highlight the patterns in a dataset, and the classification of a sample on the basis of a set of measured variables into a number of different groups with similar characteristics in the same group was analysed using Hierarchical Cluster Analysis (HCA).

3. Results and discussion

Generally, fruits will pass through several stages, such as "development", "young" or "premature", "mature", "ripe", and "senescent". Pineapples are categorized as a non-climacteric fruit, and, therefore, the harvesting process only takes place when the fruit is mature. In addition, postharvest will not cause compositional changes or quality improvement of the fruit except de-greening and reduced acidity (Kader, 1992). The different maturity stages of pineapple have been classified into index 1 to index 3 (young or premature), index 4 (25% ripe), index 5 (50% ripe), index 6 (75% ripe) and index 7 (100% ripe). Harvesting at different maturity stages reveals the different pineapple compositions, physical properties, and sensory characteristics.

Table 2 shows the colour (lightness and yellowness) and textural properties of pineapples of different varieties (Moris, N36, and MD2) and maturity stages (index 4, index 5, index 6, and index 7). The increased maturity of the pineapples caused a change in the colour of the peel from green to yellow/orange, and the colour of the flesh from whitish to yellow/orange. The L value (lightness) of the pineapple flesh decreased significantly (P<0.05) as the maturity stage increased; however, the b value (yellowness) increased for all three varieties of pineapple. The synthesis of carotenoids and anthocyanins contributed to the development of the yellow or orange colour of the pineapple flesh. The MD2 pineapple variety had a significantly (P<0.05) higher b value (yellowness) compared to the Moris and N36 varieties for the maturity stages starting from index 4 (25% ripe) onwards.

As the pineapple maturity stages increased, all the texture parameters, such as hardness, springiness, cohesiveness, gumminess, and chewiness, decreased significantly (P<0.05) for all pineapple varieties (Moris, N36, and MD2) (Table 2). The loosening and disintegration of the cell wall due to the conversion of insoluble pectin into a soluble form during fruit maturation contributed to the softer texture (Nikolic and Mojovic, 2007; Sane *et al.,* 2007; George *et al.,* 2016). The texture of the MD2 variety was softer compared to the Moris and N36 at the maturity stage of index 4 (25% ripe). However, no significant difference (P>0.05) was observed in terms of the hardness for all three varieties at index 6, and index 7. The results revealed that different varieties of pineapple did not significantly influence the texture properties of springiness, cohesiveness, gumminess and chewiness.

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Table 2. Colour (lightness and yellowness) and texture profile of pineapples at different varieties and stages of maturity.

Variables	Pineapple varieties	Maturity stages			
		Index 4 (25% ripe)	Index 5 (50% ripe)	Index 6 (75% ripe)	Index 7 (100% ripe)
Colour (L and b)					
Lightness (L value)	Moris	69.73±1.43^{Aa}	65.05±1.49^{Ab}	59.67±0.44^{Bc}	50.71±1.07^{Bd}
	N36	69.86±1.58^{Aa}	68.97±2.82^{Aa}	63.07±2.38^{Ab}	54.70±1.60^{Ac}
	MD2	66.06±1.73^{Ba}	60.72±1.52^{Bb}	53.30±0.88^{Cc}	45.15±2.30^{Cd}
Yellowness (b value)	Moris	26.47±1.19^{Bd}	32.12±1.38^{Bc}	40.06±1.56^{Bb}	46.73±1.54^{Ba}
	N36	24.53±1.93^{Bd}	29.06±1.43^{Cc}	37.12±1.41^{Cb}	42.20±1.64^{Ca}
	MD2	33.20±0.83^{Ad}	38.4±1.59^{Ac}	43.22±2.04^{Ab}	50.44±2.26^{Aa}
Texture profile					
Hardness (g)	Moris	2875.99±2.25^{Aa}	2538.75±1.84A^{Bb}	1117.20±1.62^{Ac}	986.69±1.36^{Ad}
	N36	2883.17±1.63^{Aa}	2541.78±2.10^{Ab}	1115.87±2.20^{Ac}	986.30±1.22^{Ad}
	MD2	2856.66±2.57^{Ba}	2536.22±1.98^{Bb}	1115.27±0.91^{Ac}	972.02±2.14^{Ad}
Springiness (mm)	Moris	0.52±0.01^{Aa}	0.47±0.01^{Ab}	0.42±0.01^{Ac}	0.37±0.02^{Ad}
	N36	0.52±0.01^{Aa}	0.47±0.02^{Ab}	0.42±0.02^{Ac}	0.37±0.01^{Ad}
	MD2	0.53±0.01^{Aa}	0.49±0.01^{Ab}	0.43±0.02^{Ac}	0.38±0.01^{Ad}
Cohesiveness	Moris	0.67±0.02^{Aa}	0.62±0.02^{Ab}	0.56±0.01^{Ac}	0.43±0.02^{Ad}
	N36	0.66±0.02^{Aa}	0.61±0.02^{Ab}	0.55±0.02^{Ac}	0.42±0.01^{Ad}
	MD2	0.67±0.02^{Aa}	0.61±0.02^{Ab}	0.53±0.02^{Ac}	0.40±0.01^{Ad}
Gumminess (g)	Moris	503.01±0.82^{Aa}	480.92±0.72^{Ab}	442.31±0.87^{Ac}	375.20±0.99^{Ad}
	N36	503.07±0.11^{Aa}	480.75±0.66^{Ab}	442.25±1.15^{Ac}	373.84±2.32^{Ad}
	MD2	502.24±1.06^{Aa}	480.56±0.96^{Ab}	441.54±0.71^{Ac}	374.35±1.01^{Ad}
Chewiness (g.mm)	Moris	346.62±1.15^{Aa}	301.36±0.67^{Ab}	286.39±1.21^{Ac}	236.00±1.61^{Ad}
	N36	344.78±1.64^{ABa}	301.31±0.92^{Ab}	286.27±1.00^{Ac}	236.16±0.91^{Ad}
	MD2	343.68±1.02^{Ba}	300.95±0.88^{Ab}	287.06±1.69^{Ac}	235.29±0.89^{Ad}

Means ± Standard deviation, SD (n=3). Values with different small superscript letters, $^{a\text{-}d}$ within the variable in the same row are significantly different at $P<0.05$. Capital superscript letters, $^{A\text{-}C}$ within the variable in the same column are significantly different at $P<0.05$.

With an increase in the stage of maturity, the yellowness (b value) (Table 2) and redness (a value) (Table 3) increased for all pineapple varieties, except for N36; the increment of redness (a value) was significant ($P<0.05$) at index 5 onwards. A previous study by Ding and Syazwani (2016) reported that an increase in maturity increases the sugar content and intensity of the yellowness of pineapples while reducing the acid content, and vitamin C content of the pineapple flesh. The results (Table 3) show that the total soluble solids (TSS) increased significantly ($P<0.05$) with the increase in the stage of maturity for all varieties of pineapple. Previous studies also reported similar findings for other pineapple varieties, such as Sarawak (George *et al.,* 2016) and Queen (Truc *et al.,* 2008). The TSS value of pineapples increases due to the conversion of starch by ADP-glucose pyrophosphorylase, β-amylases, and sucrose phosphate synthase to sugars, such as glucose, sucrose, and fructose upon ripening (mature green, index 4) to ripe yellow/orange (index 7)) (Fernando and De Silva, 2000; Kittur *et al.,* 2001; Zhu *et al.,* 2017). The accumulation of sugar resulting from starch synthesis upon fruit ripening might be related to the darker colour of the pineapple flesh, which is indicated by an increase in the redness (*a* value) of the fruit. The MD2 variety had the highest TSS value compared to both Moris and N36 at all maturity stages. This showed that the MD2 variety had a sweeter taste from an early stage of maturity (index 4, 25% ripe).

Citric acid is the major organic acid found in pineapples and contributes to the tart flavour of the fruit. An increase in the stage of maturity of the pineapples significantly ($P<0.05$) increased the pH value and decreased the titratable acidity (TA) for all varieties (Table 3). The results show that, as the pineapple fruit ripens, the titratable acidity decreased from 0.49% to 0.36%, 0.46% to 0.26%, and 0.33% to 0.12% for the Moris, N36 and MD2 varieties, respectively. The decline in titratable acidity upon ripening was due to the utilization of acid during respiration as a respiratory substrate and for the generation of ATP (adenosine triphosphate) (Fernando and De Silva, 2000; Lee and Lee, 2000). The decrease in titratable acidity was parallel to the loss of citric acid in the Smooth Cayenne variety of pineapple (Saradhuldhat and Paull, 2007). In this study, the TSS/TA ratio ranged from 25.86 to 47.14 for Moris, 26.52 to 63.85 for N36, and 41.51 to 108.94 for the MD2. Therefore, the MD2 variety has a higher TSS/TA ratio and is sweeter and less sour, and the aroma is

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more intense compared to the Moris and N36 varieties.

The results show that, at the increased stages of maturity, the vitamin C (ascorbic acid) content for all pineapple varieties had significantly (P<0.05) reduced (Table 3). The reduction in vitamin C content in pineapples upon ripening is associated with the oxidative destruction and ascorbic acid dehydrogenase activity (Kamol *et al.,* 2014; Muhammad *et al.,* 2014). The MD2 variety showed significantly higher vitamin C compared to the Moris and N36 for all stages of maturity. Another study (Lu *et al.,* 2014) also found that the MD2 pineapple variety contained the highest ascorbic acid compared to 26 pineapple genotypes from China.

The different varieties and stages of maturity of the pineapples influenced consumer acceptability (Table 4). Generally, the colour of the peel and flesh of the pineapple is closely related to its taste and texture. Light yellow represents an unripe pineapple with sour taste and firmer texture, whereas dark yellow or orange represents an overripe pineapple with a tangy taste and very soft texture. The sensory results show that consumers preferred a yellow colour of index 5 (50% ripe) and index 7 (100% ripe) for the Moris variety. Increased stages of maturity lead to an increase in the pineapple aroma by means of odour-active volatile compounds, such as esters, lactones, aldehydes, ketones, alcohols, carbonyl acids, hydrocarbons, phenol, and sulphur (Hassan *et al.,* 2011). The sensory score for aroma was significantly higher in the Moris and N36 varieties at index 7 (100% ripe) compared to index 4 (25% ripe). However, consumers preferred the aroma of the MD2 variety at index 5 (50% ripe) compared to other stages of

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Table 3. Color (redness), total soluble solids, pH, titratable acidity and vitamin C of pineapples at different varieties and stages of maturity.

Variables	Pineapple varieties	Maturity stages			
		Index 4 (25% ripe)	Index 5 (50% ripe)	Index 6 (75% ripe)	Index 7 (100% ripe)
Redness (a value)	Moris	1.28±0.50^{g}	2.46±0.19^{ef}	3.30±0.21^{d}	4.26±0.13^{c}
	N36	0.97±0.27^{g}	1.32±0.62^{g}	2.08±0.32^{f}	3.61±0.06^{d}
	MD2	2.72±0.18^{e}	3.49±0.41^{d}	4.80±0.46^{b}	6.42±0.41^{a}
Total soluble solids (°Brix)	Moris	12.67±0.06^{i}	14.53±0.21^{f}	15.43±0.21^{e}	16.97±0.15^{b}
	N36	12.20±0.20^{j}	14.17±0.15^{g}	15.73±0.15^{d}	16.60±0.10^{c}
	MD2	13.70±0.10^{h}	15.18±0.07^{e}	16.50±0.20^{c}	17.43±0.15^{a}
pH	Moris	3.92±0.02^{g}	4.16±0.02^{c}	4.20±0.01^{b}	4.23±0.01^{a}
	N36	3.45±0.01^{j}	3.74±0.02^{i}	3.99±0.01^{e}	4.03±0.01^{d}
	MD2	3.85±0.01^{h}	3.97±0.01^{f}	4.16±0.01^{c}	4.25±0.01^{a}
Titratable acidity (% Citric acid)	Moris	0.49±0.01^{a}	0.45±0.01^{b}	0.41±0.01^{c}	0.36±0.02^{d}
	N36	0.46±0.01^{b}	0.40±0.02^{c}	0.32±0.01^{e}	0.26±0.01^{f}
	MD2	0.33±0.01^{e}	0.28±0.02^{f}	0.21±0.01^{g}	0.12±0.02^{h}
Vitamin C (mg/100 g)	Moris	25.60±0.55^{c}	19.84±0.55^{e}	16.21±0.39^{f}	13.37±0.38^{g}
	N36	21.16±1.13^{d}	16.94±0.54^{f}	13.55±0.07^{g}	13.07±0.64^{g}
	MD2	56.33±0.573^{a}	35.83±0.56^{b}	26.24±0.55^{c}	21.43±0.21^{d}

Means ± Standard deviation, SD (n=3) values with different small superscript letters, $^{a-j}$ within the variable are significantly different at P<0.05.

Table 4. Sensory acceptability of pineapples at different varieties and stages of maturity.

Sensory attributes	Pineapple varieties	Maturity Stages			
		Index 4 (25% ripe)	Index 5 (50% ripe)	Index 6 (75% ripe)	Index 7 (100% ripe)
Color	Moris	4.57±0.94^{cd}	5.87±0.73^{a}	5.17±0.95^{b}	5.53±1.22^{ab}
	N36	3.73±0.83^{e}	4.03±1.22^{de}	4.57±0.90^{cd}	4.60±0.97^{cd}
	MD2	4.63±0.93^{c}	5.23±1.30^{b}	4.53±1.36^{cd}	2.90±0.80^{f}
Aroma	Moris	3.70±0.88^{e}	5.23±0.90^{bc}	5.67±1.27^{ab}	5.90±1.12^{a}
	N36	3.67±0.99^{e}	4.10±0.96^{de}	4.10±0.99^{de}	4.40±1.33^{d}
	MD2	4.03±0.85^{de}	5.10±0.88^{c}	4.13±1.17^{de}	4.43±0.77^{d}
Texture	Moris	4.93±1.14^{bc}	5.83±0.83^{a}	5.13±1.11^{b}	4.37±1.35^{cd}
	N36	4.23±1.10^{de}	5.07±1.31^{b}	4.83±0.99^{bcd}	4.37±1.35^{cd}
	MD2	4.37±0.93^{cd}	5.00±1.14^{bc}	3.67±0.99^{e}	3.63±1.10^{e}
Taste	Moris	4.23±0.86^{cd}	6.03±0.76^{a}	4.07±1.26^{ef}	3.90±1.21^{ef}
	N36	3.90±0.96^{ef}	5.30±1.29^{b}	5.30±0.99^{b}	4.67±1.06^{c}
	MD2	5.67±0.84^{ab}	5.70±0.92^{ab}	3.60±0.93^{f}	2.93±1.05^{g}
Overall acceptability	Moris	4.63±1.10^{de}	5.90±0.88^{a}	5.27±1.39^{bc}	4.30±1.18^{def}
	N36	4.03±0.85^{ef}	4.83±0.95^{cd}	4.13±1.17^{ef}	4.07±1.11^{ef}
	MD2	5.53±1.07^{ab}	5.43±1.04^{ab}	3.73±1.05^{f}	3.90±0.99^{f}

Means ± Standard deviation, SD (n=40) values with different small superscript letters, $^{a-g}$ within the variable are significantly different at P<0.05.

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Table 5. Correlation coefficient (Pearson) of physicochemical properties and sensory acceptability attributes of all pineapples at different varieties and stages of maturity.

Variables	pH	TSS	TA	Vitamin C	Lightness (L)	Redness (a)	Yellowness (b)	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Colour	Aroma	Texture	Taste	Overall acceptability
pH	1.000																
TSS (°Brix)	0.803**	1.000															
TA	-0.463	-0.779**	1.000														
Vitamin C	-0.224	-0.348*	-0.094	1.000													
Lightness (L)	-0.756**	-0.931**	0.807**	0.240	1.000												
Redness (a)	0.761**	0.864**	-0.853**	-0.015	-0.960**	1.000											
Yellowness (b)	0.807**	0.965**	-0.806**	-0.198	-0.976**	0.943**	1.000										
Hardness	-0.703*	-0.900**	0.610*	0.543	0.832**	-0.702*	-0.860**	1.000									
Springiness	-0.697*	-0.915**	0.563	0.642*	0.841**	-0.686*	-0.849**	0.945**	1.000								
Cohesiveness	-0.647*	-0.916**	0.688*	0.512	0.916**	-0.784**	-0.890**	0.889**	0.962**	1.000							
Gumminess	-0.657*	-0.902**	0.635*	0.519	0.898**	-0.754**	-0.880**	0.897**	0.968**	0.994**	1.000						
Chewiness	-0.693*	-0.935**	0.633*	0.553	0.876**	-0.746**	-0.878**	0.867**	0.971**	0.974**	0.969**	1.000					
Colour	0.330	-0.003	0.425	0.015	0.141	-0.153	-0.045	0.076	0.036	0.179	0.124	0.035	1.000				
Aroma	0.657*	0.492	-0.006	-0.242	-0.440	0.404	0.515	-0.390	-0.472	-0.379	-0.416	-0.510	0.658*	1.000			
Texture	-0.025	-0.395	0.682	-0.080	0.589*	-0.562	-0.488	0.433	0.348	0.521	0.488	0.342	0.637*	0.322	1.000		
Taste	-0.214	-0.335	0.339	0.340	0.567	-0.498	-0.438	0.506	0.441	0.526	0.510	0.371	0.540	0.044	0.718**	1.000	
Overall acceptability	0.028	-0.347	0.432	0.429	0.443	-0.295	-0.332	0.533	0.465	0.538	0.510	0.382	0.609	0.382	0.796**	0.747**	1.000

*Values are significant different a $P<0.05$. ** Values are significant different at $P<0.01$. °Brix (total soluble solids), TA (titratable acidity).

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maturity. The texture of the pineapples became less firm and watery as the stage of maturity increased. The results revealed that most consumers preferred the texture of the Moris variety at index 5 (50% ripe) where the acceptability score was 5.83. Consumers gave the highest taste score (6.03) for the Moris variety at index 5 (50% ripe). However, it is not significant to MD2 at index 4 (25% ripe) and index 5 (50% ripe) with the acceptance taste score of 5.67 and 5.70, respectively. This could be due to the balance of the sweet and sour taste of the Moris at index 5 and MD2 pineapples at index 4 and index 5. Meanwhile, the taste score was significantly lower for the MD2 pineapple at index 7 (100% ripe). An increased maturity stages at index 6 and index 7, the acceptability score significantly (P<0.05) reduced due to the less sour and tangier taste, and fermented flavour. For overall acceptability, consumers preferred to consume the Moris pineapple variety at index 5 (50% ripe) and the MD2 variety at index 4 (25% ripe) and index 5 (50% ripe).

Table 5 shows the correlation coefficient of the physicochemical properties and sensory acceptability attributes of all pineapples at different varieties and maturity stages. The results show that there is a highly positive correlation (P<0.01) between the total soluble solids (TSS) with pH (r = 0.803), redness (a value) (r = 0.864), and yellowness (b value) (r = 0.965), where increased TSS reduced the acidic taste and induced redness and yellowness of the pineapple flesh. However, a negative correlation (P<0.01) between the TSS and titratable acidity (r = -0.775), vitamin C (ascorbic acid) content (r = -0.348), lightness, (L *value*) (r = -0.931), and all texture parameters (hardness (r = -0.900), springiness (r = -0.913), cohesiveness (r = -0.918), gumminess (r = -0.902), and chewiness (r = -0.935)) was observed for all pineapples. Fully ripe pineapples with a higher TSS value contained less vitamin C and had a soft texture as well as less springiness, cohesiveness, gumminess, and chewiness. The overall acceptability of pineapples of different varieties and maturity stages was positively correlated with the colour acceptance (r = 0.609), texture acceptance (r = 0.796), and taste acceptance (r = 0.747) at P<0.01. This shows that the consumer acceptability of Moris, N36, and MD2 pineapples are depended on the colour, texture, and taste properties.

Figure 1 shows the Principal Component Analysis (PCA) plots of the physicochemical properties and sensory acceptability score of 12 pineapples of different varieties (Moris, N36, and MD2) and maturity stages (index 4, index 5, index 6, and index 7). The principal component analysis explained 80.16% of the variance of the data set in two dimensions, F1 (61.99%) and F2 (18.17%). The PCA plot was used to determine the pattern and the relationship of the pineapple attributes (physicochemical and sensory acceptability), with selected eigenvalues of each factor loading was more than 1.0. In this study, the eigenvalue for factor loading 1 (F1) and factor loading 2 (F2) was 11.158 and 3.271, respectively. According to Liu *et al.* (2003), a factor loading with a value of 0.3-0.5 shows low correlation, 0.5-0.7 is a medium correlation, while 0.7-1.0 is a high correlation. As shown in Figure 1, the first dimension (F1) categorised pineapple according to their physicochemical properties. Pineapples at index 4 and index 5 (Moris, N36, and MD2 varieties with maturity less than 50% ripe) were located at the right of the F1 and were mainly characterized by cohesiveness (0.979), gumminess (0.966), lightness, L (0.960), chewiness (0.949), springiness (0.948), hardness (0.933), titratable acidity (0.747) and vitamin C (ascorbic acid) (0.450) properties. In contrast, pineapples with maturity above 50% ripe (Moris, N36 and MD2 varieties at index 6 and 7) were located at the left of the F1 and were mainly characterized by total soluble solids (°Brix) (-0.959), yellowness, b value (-0.947), redness, a value (-0.860), and pH (-0.724) properties. Pineapples in the second dimension (F2) of the PCA was based on sensory acceptability scores. Moris (index 5, 6 and 7) and MD2 (index 5) were located at positive values of the F2, is characterized by high colour, aroma, taste, texture, and overall acceptability scores with factor loadings of 0.883, 0.812, 0.545, 0.741, and 0.725, respectively. Meanwhile, other pineapples located at the negative values of the F2

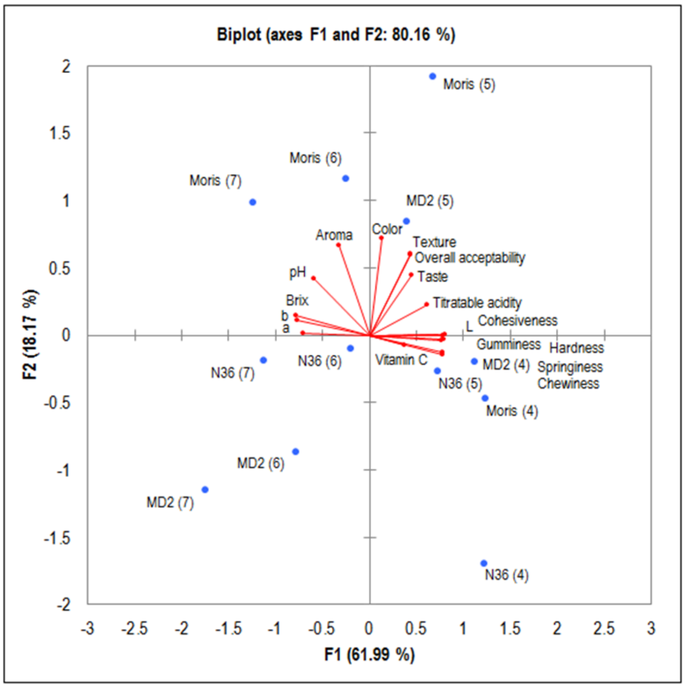

Figure 1. Principal Component Analysis (PCA) plots of 12 pineapples at different varieties and stages of maturity. Moris (4) to Moris (7) – Moris variety at index 4 to index 7; N36 (4) to N36 (7)– N36 variety at index 4 to index 7; MD2(4) to MD2 (7)– MD2 variety at index 4 to index 7.

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were characterized by the low scores in sensory acceptability attributes.

The PCA plot shows that, as the pineapples ripen, the changes in their physicochemical properties, such as lightness (L value), hardness, springiness, cohesiveness, gumminess, chewiness, titratable acidity, and vitamin C, are more apparent than the other factors that influence the sensory acceptability (colour, taste, texture, and overall acceptability). The acceptability of the pineapple's aroma score was influenced by the total soluble solids (°Brix) and the pH value, which lead to the sweet taste and sour aroma of the pineapple, while the overall acceptability of the pineapple was mostly influenced by the acceptance of colour, taste, and texture attributes. The texture was the main factor that characterized all the pineapples at index 4 and index 5, while the pH, total soluble solids (°Brix), redness (*a* value), and yellowness (*b* value) had the most influence on the pineapples at index 6 and index 7. Index 4 pineapples (25% ripe) were more influenced by their texture parameters, which were indicated by the highest value for hardness, springiness, gumminess, and chewiness. Moris and MD2 pineapples at index 5 (50% ripe) had a higher acceptability score (> 5) for the colour, taste, and texture attributes, while the Moris pineapple at index 6 and index 7 had higher aroma acceptability compared to the Moris pineapple at index 4 and index 5.

The dendrogram for the Hierarchical Cluster Analysis (HCA) of 12 pineapples of different varieties and maturity stages is shown in Figure 2. Pineapples were clustered based on their similarity (> 40%) to the physicochemical properties and sensory acceptability. Based on Figure 2, pineapples were divided into three clusters: A: Moris (index 5, index 6, and index 7) and N36 (index 6 and index 7), B: Moris (index 4) and N36 (index 4 and index 5), and C: MD2 (index 4, index 5, index 6, and index 7). The results show that Moris and N36 pineapples at index 7 had the highest similarity of 1.0 (100% similar), which indicate that both varieties had similar physicochemical properties and sensory acceptability. Moris and N36 pineapples at index 4 also showed a high similarity of 0.980. This could be proven through the results obtained from Tables 2 and 3, which show no significant difference (P>0.05) in yellowness, redness, or texture profiles between Moris and N36 at index 4. MD2 pineapples at index 6 and index 7 had the highest similarity of 0.968 compared to MD2 at index 4 and index 5. However, the MD2 variety at all maturity stages is in one cluster, which has high similarity in the physicochemical properties and sensory acceptability. This shows that the MD2 variety has a unique characteristic that differentiates it from the other pineapple varieties for all stages of maturity. Even though all these varieties are widely planted in Malaysia for the fresh market, pineapples contribute to 10% of the processed food market, which includes canning, jam, beverages, snacks, and confectionery. It is crucial to know that, even though they are different varieties, Moris and N36 have a similar fruit quality for food processing applications. The use of pineapples at similar physicochemical properties could provide the consistency of the end product quality, which is critical in the food industry. The unique properties of MD2, which is sweetest, less acidic, high in vitamin C, and more aromatic compared to Moris and N36, increase its demand for the domestic and exported fresh pineapple market in Malaysia, which is estimated to increase from 350,000 metric tonnes to 700,000 metric tonnes production per year by 2020 (Daily Express, 2014).

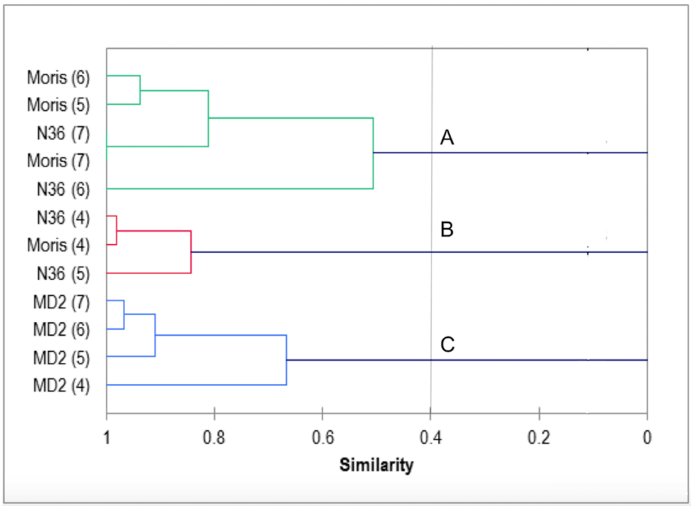

Figure 2. Cluster diagram of 12 pineapples at different varieties and stages of maturity showing the similarity in the physicochemical properties and sensory acceptability. Moris (4) to Moris (7) – Moris variety at index 4 to index 7; N36 (4) to N36 (7)– N36 variety at index 4 to index 7; MD2(4) to MD2 (7)– MD2 variety at index 4 to index 7.

4. Conclusion

The changes in the physicochemical composition of the Moris, N36, and MD2 pineapple varieties upon fruit maturation affected consumer acceptability. All pineapple varieties were highly acceptable as fresh consumption at Index 5 (50% ripe). The total soluble solids (TSS) content of all pineapple varieties had a high positive correlation (P<0.01) with yellowness (*b value*) (r = 0.965) upon fruit ripening. Conversely, an increased TSS content in the pineapples had a negative correlation (P<0.01) with all the texture parameters. Based on the Principal Component Analysis (PCA) results, sensory attributes, such as colour, taste, and texture, strongly affected the overall acceptability of the pineapples. The combination datasets allow interpretations of the similarities and differences in the Moris, N36, and MD2 pineapples. MD2 had different physicochemical and

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sensory acceptability compared to the Moris and N36 varieties as the MD2 variety was in a different cluster to the Moris and N36 varieties.

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References

Abdullah, H., Rohaya, M.A. and Abd. Aziz, I. (1996). Quality changes in pineapple (*Ananas comosus* cv. N36) stored at low temperature. *MARDI Research Journal,* 24(1), 39-47.

Achuonjei, P., Boschma, S., Happe, G., Hoogendoorn, B., Meekma, I., Pilkes, J. and Waardenburg, R. (2003). Ghana: sustainable horticultural export chain. Michigan: Michigan State University.

Bartolome, A.P., Ruperez, P. and Fuster, C. (1995). Pineapple fruit: morphological characteristics, chemical composition and sensory analysis of Red Spanish and Smooth Cayenne cultivars. *Food Chemistry*, 53, 75-79. https://doi.org/10.1016/0308-8146(95)95790-d

Daily Express. (2014). Demand for MD2 pineapple variety strong, likely to grow. Retrieved from Daily Express website: http://www.dailyexpress.com.my/news.cfm?NewsID=93194

Ding, P. and Syazwani, S. (2016). Physicochemical quality, antioxidant compounds and activity of MD-2 pineapple fruit at five ripening stages. *International Food Research Journal*, 23(2), 549-555.

De Silva, A.E., Kadir, M.A., Aziz, M.A. and Kadzimin, S. (2008). Callus induction in pineapple (*Ananas comosus* L.) cv. Moris and Josapine. *International Journal of Agricultural Research,* 3(4), 261-267. https://doi.org/10.3923/ijar.2008.261.267

Fernando, M.F.S.W. and De Silva, P.H.J.C. (2000). Postharvest handling of Mauritius pineapple (*Ananas comosus.* L. Merr) at ambient temperature. *Annals of the Sri Lanka Department of Agriculture, Sri Lanka*, 4, 359-366.

George, S.D., Razali, Z. and Somasundram, C. (2016). Physiochemical changes during growth and development of pineapple (*Ananas comosus* L. Merr. cv. Sarawak). *Journal of Agriculture Science and Technology,* 18(2), 491-503.

Greig, I. (2004). Pineapple wars redux. *Chronic Horticulture,* 44(2), 5.

Hassan, A., Wills, R., Atan, R.M., Othman, Z., Lam, P.F. and Smith, M. (2010). Blackheart disorder in fresh pineapple. *Fresh Produce,* 4(1), 29-35.

Hassan, A., Othman, Z. and Sirivanich, J. (2011). Pineapple (*Ananas comosus* L. Merr). In Yahia, E.M. (Eds). Postharvest Biology and Technology of Tropical and Subtropical Fruits: Mangosteen to White Sapote, Vol. 4, p. 194-217. Cambridge: Woodhead Publishing. https://doi.org/10.1533/9780857092618.194

Kader, A.A. (1992). Quality and Safety Factors: Definitions and evaluation for fresh horticultural crops. In Postharvest technology of horticultural crops. Publication 3311, p. 185-189. USA: University of California, Division of Agriculture and Natural resources.

Kamol, S.I., Howlader, J., Sutra Dhar, G.C. and Aklimuzzaman, M. (2014). Effect of different stages of maturity and postharvest treatments on quality and storability of pineapple. *Journal of the Bangladesh Agricultural University*, 12(2), 251–260. https://doi.org/10.3329/jbau.v12i2.28679

Kittur, F., Saroja, N. and Tharanathan, R. (2001). Polysaccharide-based composite coating formulations for shelf-life extension of fresh banana and mango. *European Food Research and Technology,* 213(4-5), 306-311. https://doi.org/10.1007/s002170100363

Lee, D.H. and Lee, C.B. (2000). Chilling stress-induced changes of antioxidant enzymes in the leaves of cucumber: in gel enzyme activity assays. *Plant Science*, 159, 75-85. https://doi.org/10.1016/s0168-9452(00)00326-5

Liu, C.W., Lin, K.H. and Kuo, Y.M. (2003). Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. *Science of the Total Environment,* 313, 77–89. https://doi.org/10.1016/s0048-9697(02)00683-6

Lu, X.H., Sun, D.Q., Wu, Q.S., Liu, S.H. and Sun, G.M. (2014). Physico-chemical properties, antioxidant activity and mineral contents of pineapple genotypes grown in China. *Molecules,* 19, 8518-8532. https://doi.org/10.3390/molecules19068518

Mailgaard, M.C., Civille, G.V. and Carr, B.T. (2016). Sensory Evaluation Technique. 5th ed. USA: CRC Press

Mohammad, S., Ghazali, K.H., Che Zan, N., Mohd Radzi, S.S. and Abdul Karim, R. (2012). Classification of fresh N36 pineapple crop using image processing technique. *Advanced Materials Research*, 418-420, 1739-1743. https://doi.org/10.4028/www.scientific.net/amr.418-420.1739

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Muhammad, I., Ashiru, S., Ibrahim, I.D., Kanoma, A.I., Sani, I. and Garba, S. (2014). Effect of ripening stage on vitamin C content in selected fruits. *International Journal of Agriculture, Forestry and Fisheries*, 2(3), 60-65.

Nadya, H., Zainal, S., Nadzirah, K.Z., Siti Roha, A.M., Atikah, O. and Tengku Elida, T.Z.M. (2012). Physicochemical properties analysis of three indexes pineapple (*Ananas comosus*) peel extract variety N36. *APCBEE Procedia*, 4, 115-121. https://doi.org/10.1016/j.apcbee.2012.11.020

Nadzirah, K., Zainal, S., Noriham, A., Normah, I., Siti Roha, A. and Nadya, H. (2013). Physico-chemical properties of pineapple variety N36 harvested and stored at different maturity stages. *International Food Research Journal*, 20(1), 225-231. https://doi.org/10.1016/j.apcbee.2012.11.022

Nikolic, M.V. and Mojovic, L. (2007). Hydrolysis of apple pectin by the coordinated activity of pectic enzymes. *Food Chemistry*, 101(1), 1–9. https://doi.org/10.1016/j.foodchem.2005.12.053

Pauziah, M., Malip, M., Norhayati, M., Tham, S.L. and Ibrahim, M.A. (2013). Physical properties and chemical compositions of 'Maspine' pineapple at different stages of maturity. *Acta Horticulturae*, 1012, 165-170. https://doi.org/10.17660/actahortic.2013.1012.16

Sane, V.A., Sane, A.P. and Nath, P. (2007). Multiple forms of α-expansin genes are expressed during banana fruit ripening and development. *Postharvest Biology and Technology,* 45(2), 184–192. https://doi.org/10.1016/j.postharvbio.2007.03.003

Saradhuldhat, P. and Paull, R.E. (2007). Pineapple organic acid metabolism and accumulation during fruit development. *Science Horticulturae*, 112, 297-303. https://doi.org/10.1016/j.scienta.2006.12.031

Selani, M.M., Brazaca, S.G.C., dos Santos Dias, C.T., Ratnayake, W.S., Flores, R.A. and Bianchini, A. (2014). Characterisation and potential application of pineapple pomace in an extruded product for fibre enhancement. *Food Chemistry,* 163, 23-30. https://doi.org/10.1016/j.foodchem.2014.04.076

Seppä, L., Peltoniemi, A., Tahvonen, R. and Tuorila, H. (2013). Flavour and texture changes in apple cultivars during storage. *LWT- Food Science and Technology,* 54, 500-512. https://doi.org/10.1016/j.lwt.2013.06.012

Thalip, A.A., Tong, P.S. and Ng, C. (2015). The MD2 'Super Sweet' pineapple (*Ananas comosus*). *UTAR Agriculture Science Journal*, 1(4), 14-17.

Truc, T.T., Binh, L.N. and Muoi, N.V. (2008). Physico-chemical properties of pineapple at different maturity levels. 1st International Conference on Food Science and Technology, p. 130-134. Mekong, Vietnam.

Wardy, W., Saalia, F.K., Steiner-Asiedu, M., Budu, A.S. and Sefa-Dedeh, S. (2009). A comparison of some physical, chemical and sensory attributes of three pineapple (*Ananas comosus*) varieties grown in Ghana. *African Journal of Food Science,* 3(1), 22-25.

Zhu, X., Zhang, C., Wu, W., Li, X., Zhang, C. and Fang, J. (2017). Enzyme activities and gene expression of starch metabolism provide insights into grape berry development. *Horticulture Research,* 4, 17018. https://doi.org/10.1038/hortres.2017.18

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