

Physicochemical and sensory properties of selected ‘cempedak’ (*Artocarpus integer* L.) fruit varieties

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Abstract

‘Cempedak’ (*Artocarpus integer* L.) is an aromatic exotic tropical fruit that can be widely found in Malaysia during season. The pulp yield and several physicochemical properties of five varieties of ‘cempedak’ (CH27, CH28, CH29, CH30 and CH33) were determined. The latter included total soluble solids, titratable acidity, pH, color, organic acids, sugars and carotenoid contents. Sensory evaluation of the five ‘cempedak’ varieties was conducted using Hedonic test, in which the assessed attributes include color, taste, texture and overall acceptability. Results indicate that CH33 yield the highest percentage (35.8%) of edible portion (fruit pulp), while CH27 shows the highest titratable acidity (0.52%). CH30 had the lowest L^* value (52.41), and highest intensity of color in terms of redness (32.45) and yellowness (65.27) values. All ‘cempedak’ varieties were highest in sucrose content (12.28-20.02 g/100 gFW) compared to fructose (5.70-6.72 g/100 gFW) and glucose (4.94-5.52 g/100 gFW), while malic acid (0.43-0.70%) was the highest organic acid as compared to citric acid (0.24-0.60%) and succinic acid (0.20-0.33%). All the ‘cempedak’ varieties studied have high content of α -carotene (2.30-45.27 μ g/100 gFW), followed by β -carotene (2.30-12.23 μ g/100 gFW), with CH28 having the highest content. From the five varieties of ‘cempedak’ fruit examined, it was found that CH28 ranked the highest in terms of sensory properties, namely taste, texture and overall acceptability.

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Keywords

‘Cempedak’

Physicochemical properties

Sugar composition

Organic acid composition

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Sensory assessment

Introduction

Artocarpus integer L., also known as *A. champeden* (Thunb.) Merr., belongs to the family Moraceae (Lim *et al.*, 2011). Depending on the country and language, ‘cempedak’ as it is called in Malaysia, is known with different vernacular names such as ‘Champada’ in Thailand and ‘Sonekadat’ in Myanmar (Janick and Paull, 2008). In Brunei, the fruit is locally known as ‘Tibadak’ (Lim *et al.*, 2011).

The fruit of ‘cempedak’ is similar to jackfruit (*Artocarpus heterophyllus*), yet smaller in size and stronger in smell (Subhadrabandhu, 2001). It is round in shape, with skin that is either greenish, yellowish or brownish in color and has studs on its rind (Chong *et al.*, 2008). Chong *et al.* (2008) also described ‘cempedak’ pulp as soft and golden yellow to orange in color. The flesh of the ‘cempedak’ fruit can either be consumed fresh or deep fried into

fritters, processed into a refreshing juice, dried into chips or creamed to make cakes (Lim *et al.*, 2011). Unripe ‘cempedak’ fruit is consumed as a vegetable and cooked in coconut milk, and eaten along with other vegetables, or in soup (Janick and Paull, 2008; Subhadrabandhu, 2001). The seed of ‘cempedak’ fruit is roasted or boiled in salty water; or dried and ground to make flour for baking (Lim *et al.*, 2011; Janick and Paull, 2008; Subhadrabandhu, 2001).

Some properties of ‘cempedak’ fruit such as moisture, ash, fat, protein, fiber and carbohydrate contents have been determined by different researchers (Lim *et al.*, 2001). Subhadrabandhu (2001) reported that the moisture and protein content of ‘cempedak’ were 58-85% and 3.5-7%, respectively. It is also high in fiber (5-6%) and low in fat (0.5-2.0%) (Subhadrabandhu, 2001). ‘Cempedak’ fruit has been reported to contain malic, citric and succinic acids, while having a high level of sucrose (Lee *et al.*,

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2013).

The 'cempedak' fruit bulb is a yellow or orange in color depending on the variety, and hence there is a need to determine its pigments profile especially in terms of carotenoid content. Carotenoids are a group of natural pigments that participate in many important nutritional functions. Foods rich in carotenoids such as β -carotene protect against vitamin A deficiency and anemia (McLaren and Frigg, 2001). Consumption of foods rich in these and other carotenoids (e.g. lutein, zeaxanthin, lycopene) protects against cancer, diabetes, heart disease, other non-communicable diseases and degenerative processes that involve oxidative stress (Coyne *et al.*, 2005).

The Department of Agriculture, Malaysia, has identified 37 varieties of 'cempedak' (DOA, 2011). From the literature, DOA (2001) and DOA (2011) listed out the properties of the various varieties. However, there is scarce information on its carotenoid profile, apart from 80 $\mu\text{g}/100$ gFW total carotenoid content reported by Tee *et al.* (1997) and DOA (2001). With detailed analysis, varieties to be cultivated can be focused on certain variety for different aspects.

The objective of this study was to determine the proportion of fruit pulp in a fruit bulb and the physicochemical properties including the organic acid, sugar and carotenoid profiles of selected 'cempedak' fruit varieties that are commonly found in Malaysia. Sensory evaluation was also performed based on color, taste, texture and overall acceptability of the 'cempedak'. An understanding of the physicochemical characteristics of these varieties should lead to better processing into juice and other products.

Materials and Methods

Materials

The five varieties of 'cempedak' fruits used in this study comprised of three varieties (CH27, CH29 and CH30) obtained from Taman Pertanian, Universiti Putra Malaysia, Selangor, and two varieties (CH28 and CH33) obtained from the Department of Agriculture, Serdang, Selangor. 'Cempedak' fruit (weighing 1.5-2 kg each) were slit in half, and fruit bulbs (aril) removed. The pulp from the bulbs was separated from the seed. The pulp (200 g in each bag) was vacuum-packed in transparent polyethylene plastic bag and stored in the dark at -20°C prior to analysis. The 'cempedak' pulp was packed according to batch of purchase, with 3 different purchases, and ten fruits per batch.

Edible portion

The proportion of 'cempedak' pulp (edible portion) was determined as the percentage of weight of 'cempedak' pulp (kg) over the total weight of fruit bulb (kg) used to obtain the pulp.

Preparation of samples for analysis

Thawed 'cempedak' pulp that was initially frozen was chopped (approximately 1 cm x 1 cm x 1 cm) and then homogenized at low speed using a commercial blender (HGB 2WTS 3, Waring, USA) into puree to obtain a representative sample for each test.

Total soluble solids (TSS)

The total soluble solids (TSS) of the homogenized 'cempedak' puree was measured by using a digital refractometer (MA887, Milwaukee Instruments, Inc., North Carolina, USA) ($0-85^{\circ}\text{Brix}$) (Chauhan *et al.*, 2001). A dropper was used to drop the clear puree onto the glass surface of the refractometer.

Titrateable acidity

Titrateable acidity was estimated according to Ali *et al.* (2011). Ten grams of 'cempedak' puree was mixed with 40 mL of freshly distilled water. The mixture was filtered and made up to 100 mL before titrated against 0.1 M NaOH solution until the color turned from clear to pink. Titrateable acidity is expressed as percent malic acid (%) as dominant acid detected in 'cempedak' is malic acid.

pH

The pH of 'cempedak' pulp was determined using a calibrated Delta 320 pH meter (Metler-Toledo, China) and based on the 'cempedak' filtrate obtained above.

Color of 'cempedak' puree

The color of 'cempedak' puree was evaluated using a Hunter Lab ColorFlex EZ Spectrophotometer (Hunter Associate Laboratory Inc., Reston, USA). Half of the quartz sample cup was filled with 'cempedak' puree. Color readings were expressed in L^* (lightness-darkness), a^* (greenness-redness) and b^* value (blueness-yellowness).

Sugar composition and content

A High-performance Liquid Chromatograph (HPLC) (Waters Corporation, Milford, Massachusetts, USA) equipped with an autosampler system (Waters 2695 Separation), a refractive index detector (Waters 2414), a Purovosphe[®] Star NH_2 column (259 x 4.6 mm particle size of 5 μm , Merck, Darmstadt, Germany) was used to determine the sugar content (Hunt *et al.*,

1977). The mobile phase was degassed HPLC grade acetonitrile and double distilled deionized water (80/20, v/v) and the injection volume for each run was 20 μ L, and the temperature set at 40°C.

Ten grams of 'cempedak' puree was treated with 100 mL of 85% methanol for 30 minutes at 80°C in a water bath (WNB 14, Memmert, Germany). The sample was then filtered through Whatman No. 1 filter paper and the 'cempedak' puree residue was then re-extracted twice using a total of 75 mL 85% methanol. The filtrates were pooled and the volume was reduced using a rotary vacuum evaporator and then made up to 10 mL with 85% methanol. The extract was then filtered through a Sep-Pak[®] C18 cartridge followed by filtration through a 0.45 μ m Minisart NY membrane filter (Sortorius Stedim Biotech GmbH, Germany). The filtrate was placed in a 1.5 mL amber vial for HPLC analysis.

A solution containing a mixture of standards (fructose, glucose and sucrose, each at 1% w/v concentration) was filtered as described for the sample extract and 20 μ L was injected into the HPLC to obtain the standard peak areas. A calibration curve was also obtained for each of the three sugars. The percentage of individual sugars (fructose, glucose and sucrose) was calculated using the calibration curves.

Organic acid composition and content

A High-Performance Liquid Chromatograph (Waters Corporation, Milford, Massachusetts, USA) an auto-sampler system (Waters 2695 Separation) integrated with Waters Empower 3 software and a wavelength detector (Waters 2487 Dual λ Absorbance) set at 210 nm was used to determine the organic acids profile of 'cempedak' puree. The column used to analyze the sample was a Purovspher[®] Star RP-18 end capped column (250 x 4.6 mm, the particle size of 5 μ m, Merck Darmstard, Germany) equipped with guard column (Merck, Darmstard, Germany).

Organic acid analysis was conducted using the method reported by Dolenc and Stampar (1997). Ten grams of 'cempedak' puree was mixed with 50 mL with deionized water and then clarified by centrifuge at 8000 rpm for 20 minutes at 4°C. This was followed by filtration of the extract using a 0.45 Minisart NY membrane filter (Sortorius Stedim Biotech GmbH, Germany), while 20 μ L was injected into the analytical HPLC column. Sulphuric acid (0.004 N) at pH 2.1 was used as the mobile phase, with the flow rate fixed at 0.8 mL min⁻¹ at 35°C. Galaturonic acid, oxalic and ascorbic acid was used to obtain the individual standard curve (with the concentration of 100 ppm each), and compared to detect the

predominant organic acids in 'cempedak'.

The 'cempedak' extracts was also analyzed using a Liquid Chromatography Tandem Mass Spectrophotometer, for further identification of organic acids in 'cempedak' puree. The AB Sciex 3200QTrapc Liquid Chromatography Tandem Mass Spectrophotometer (LCMS/MS) was coupled to Eksigent 110 Ultra High Performance Liquid Chromatography (UHPLC) system with Multiple Reaction Monitoring (MRM) method (Macwan et al., 2011). The column used in this experiment is Zorbax C18 (150 x 4.6 mm, 5 μ m). Mobile phases were 0.1% formic acid and 5 mM ammonium formate in water (solvent A) and 0.1% formic acid and 5 mM ammonium formate in acetonitrile (solvent B). The gradient programme was run with isocratic at 70% A: 30% B at 0.7 mL/min and column temperature of 40°C was applied. Column effluent was monitored at 280 nm, and mass spectra data were acquired by electrospray ionization (ESI) in negative ionization mode. An aliquot of 20 μ L was injected into the system per test. The LCMS/MS profiles of 'cempedak' varieties were plotted against 100 ppm of each organic acid standard (citric acid, maleic acid, malonic acid, quinic acid and succinic acid), in which the comparison is made using Multiple Reaction Monitoring (MRM). In principal, MRM could provide absolute structural specificity for the analyte and relative or absolute measurement of analyte concentration when stable, isotopically-labeled standards are added to a sample in known quantities (Bylund et al., 2007).

Carotenoid profile and content

The method used to determine the carotenoid profile was as described by Rodriguez-Amaya and Kimura (2004). 'Cempedak' puree (3 g) was mixed with 10 mL of distilled water and incubated for 30 minutes at room temperature. After that, 20 mL of cold acetone was added to the sample and left to stand for 15 minutes before the solution was filtered through a Whatman No. 1 filter paper using a Büchner funnel with pump suction. The residue was collected and placed in a mortar. A total of 15 mL cold acetone was added to the mortar and a pestle was used to grind the residue which was then filtered through a fresh Whatman No. 1 filter paper. This step was repeated twice and the filtrates were pooled.

Petroleum ether (20 mL) was added to a 500 mL separatory funnel, followed by 1/3 of the total cempedak filtrate obtained above and 300 mL distilled water. After mixing, separation of phases was allowed to take place. The bottom colorless aqueous layer was discarded. Another 1/3 of the filtrate and 200

mL of distilled water were added to the separatory funnel. After mixing and phase separation, the bottom aqueous layer was again discarded. This step was repeated for the remaining 1/3 filtrate. The upper layer carotenoid extract which has a light yellow color (organic phase) was collected. The organic phase was evaporated to dryness at 35°C using a rotary evaporator. After that, 10 mL acetone was added to re-dissolve the residue, and some of the carotenoid solution was placed in a 1.5 mL amber vial.

High-Performance Liquid Chromatography (HPLC) separation was performed with an HPLC system (LC-20A7 Shimadzu Corp., Kyoto, Japan) equipped with degasser (DGU-20A5, Shimadzu Corp., Kyoto, Japan), auto-sampler (SFO-20A, Shimadzu Corp., Kyoto, Japan), a photodiode array detector (SPDM-20A) and a Zorbax C18 analytical column 5 µm (4.6 x 150 mm; Agilent Technologies, California, USA). The injection volume was 10 µL. The mobile phase was 70% (v/v) HPLC-grade acetonitrile, 20% (v/v) dichloromethane, 10% (v/v) HPLC-grade methanol. The detection wavelength, flow rate, column temperature and run time were 470 nm, 1.2 mL/min, 40°C and 15 min, respectively. Peak retention time and area of detected peaks in chromatogram from 'cempedak' variety were compared with individual standard curve of different carotenoids.

Sensory assessment

A Hedonic test was conducted to assess the color, taste, texture and overall acceptability of the pulp from different varieties of 'cempedak'. The test was carried out in sensory evaluation lab with partitioned booths and under adequate white lighting. A total of 40 untrained panelists from UCSI University participated in the sensory evaluation. The five freshly obtained ripe fruit samples (each variety one sample each) were used in the testing with coded samples presented in randomized order. A ballot paper was given to the participants and they were requested to evaluate the samples using a nine-point hedonic scale regarding samples' appearance, flavor, texture and overall acceptability.

Statistical analysis

Data obtained was analyzed using one-way ANOVA. Significant differences among the various parameters were determined using Tukey's test ($p < 0.05$). The statistical program used was Minitab software, release 17 (Minitab Inc., Pennsylvania, USA). The results were expressed as means \pm standard deviations of three replicates.

Results and Discussion

Pulp yield and physicochemical properties of 'cempedak' fruit varieties

The physicochemical properties of different 'cempedak' fruit varieties are presented in Table 1. The average pulp yield or proportion of the 'cempedak' varieties ranged between 20.5-35.8%, with CH33 having the highest proportion of pulp (1.8 fold more compared to the other varieties). The differences might be influenced by several factors, such as cultivar genotype and crop load (Gao *et al.*, 2012). The results obtained is in agreement with the findings by DOA (2001), who reported that CH28 variety has 21.1% pulp yield, while the CH33 variety has a higher pulp yield (35.8%). The information of pulp yield (edible fruit portion) is particularly relevant in the design or selection of appropriate packaging for fruit handling and storage, apart from addressing the needs of the food processing and beverage industries (Valero and Ruiz-Altisent, 2000).

There was no significant difference ($p > 0.05$) in the total soluble solids (TSS) content of all the 'cempedak' fruit varieties. From Table 1, the TSS values of the five 'cempedak' fruit varieties ranged from 34.0 to 34.8°Brix, and were in close approximation with the value (37°Brix, variety studied not stated) reported by Lee *et al.* (2013).

The acidity of a fruit is generally assessed by its titratable acidity (TA) and pH values. The TA of the 'cempedak' varieties ranged from 0.33% to 0.52% (Table 1). There was no information in the literature on the TA of 'cempedak'. The pH of the cempedak fruit under study ranged from pH 5.7-6.0 with no significant differences ($p > 0.05$) found between the varieties (Table 1). A lower pH of 5 has been reported in an earlier work (Lee *et al.*, 2013). The differences may be due to the different stages of ripening and also the variety of 'cempedak' fruit studied. The pH value influences microbial growth, the rate of fruit deterioration and determines the degree of post-harvest processing deterioration (Bates *et al.*, 2001). Thus, with an average pH value of pH 5.8, 'cempedak' fruit should be of mild acidic condition, and would require acidification to pH < 4.5 prior to thermal preservation at temperatures below 100°C.

Color of puree

Color directly affects the appearance and the consumer acceptability of fruit. Table 1 shows the different color properties of the 'cempedak' puree from different varieties. It is clear that each 'cempedak' variety has a distinct color properties. The L^* values ranged from 52.41-64.46, with CH30

Table 1. Physicochemical properties of different 'cempedak' varieties

'Cempedak' variety	Edible portion(%)	Total soluble solids (TSS) (^o Brix)	**Titratable acidity (TA) (%)	pH	<i>L</i> *	<i>a</i> *	<i>b</i> *
CH27	20.5±1.2 ^c	34.3±0.7 ^a	0.52±0.01 ^a	5.7±0.2 ^a	64.46±2.14 ^a	20.01±2.09 ^b	55.24±3.63 ^b
CH28	21.1±2.0 ^c	34.4±0.1 ^a	0.37±0.09 ^b	5.8±0.1 ^a	61.51±1.61 ^a	11.38±0.70 ^c	50.97±5.11 ^b
CH29	23.0±2.0 ^c	34.6±0.2 ^a	0.43±0.07 ^b	5.7±0.3 ^a	57.27±4.32 ^{ab}	17.99±2.13 ^b	52.60±1.12 ^b
CH30	28.1±2.8 ^b	34.0±0.4 ^a	0.33±0.05 ^b	5.8±0.1 ^a	52.41±6.00 ^b	32.45±2.10 ^a	65.27±2.54 ^a
CH33	35.8±2.6 ^a	34.8±0.3 ^a	0.37±0.05 ^b	6.0±0.2 ^a	61.30±1.46 ^{ab}	10.17±0.70 ^c	49.35±3.41 ^b

*Each value represents the mean of triplicate samples ± standard deviation. Values within the same column with different superscript (a-c) are significantly different at $p \leq 0.05$, as measured by Tukey's HSD test.

** Malic acid was used to express titratable acidity.

Table 2. Sugar content (g/100 gFW) in different varieties of 'cempedak'

'Cempedak' variety	Fructose	Glucose	Sucrose	Total sugar
CH27	6.12±0.28 ^{ab}	5.52±0.46 ^{ab}	20.02±1.88 ^{aA}	31.66±2.48 ^a
CH28	5.68±0.54 ^{ab}	4.94±0.44 ^{ab}	16.66±2.52 ^{abA}	27.30±1.64 ^{ab}
CH29	5.88±0.48 ^{ab}	5.10±0.56 ^{ab}	18.82±0.56 ^{aA}	29.80±1.66 ^a
CH30	5.70±0.72 ^{ab}	5.14±0.56 ^{ab}	12.28±0.68 ^{abA}	23.10±0.9 ^b
CH33	6.72±0.20 ^{ab}	5.46±0.46 ^{ab}	19.44±2.28 ^{aA}	31.62±1.76 ^a

* Each value represents the mean of triplicate samples ± standard deviation. Values within the same column with different superscript (a-b) and values within the same row (different sugar) with different superscript (A-B) are significantly different at $p \leq 0.05$, as measured by Tukey's HSD test.

having the lowest *L** value, indicating it is the darkest among the varieties and the difference can be detected visually. On the contrary, CH27 and CH28 varieties are among the lightest varieties, with high value of *L** (64.46 and 61.51, respectively), however, the difference cannot be observed visually.

For *a** values, it is observed that CH30 has the highest value (32.45), indicating it is more reddish compared to the rest of 'cempedak' varieties with *a** values ranging from 10.17-32.45, with CH28 and CH33 having the lowest *a** value of 11.38 and 10.17, respectively.

With respect to *b**, CH30 has the highest value of *b** (65.27), as compared to the other varieties studied (which ranged from 49.35-55.24), indicating that it is distinctively more yellowish compared to the rest. These color values are in agreement with DOA (2001), who describes the color of CH27, CH30 and CH33 as pale yellow, yellowish orange and orange, respectively, while CH28 and CH29 are both yellow in color. As suggested by Sojak and Glowacki (2010), genotypic features and weather conditions (precipitation and sun exposure) also contributes to the color of fruit.

Sugar composition and content

Fruit sweetness is an important aspect of fruit quality and is highly dependent on its sugar composition (Lee *et al.*, 2013). Sucrose, glucose and fructose are the main sugars found in fruits of commercial importance. Table 2 tabulates the sugar composition and content of different 'cempedak' varieties.

The sucrose, fructose and glucose contents of the 'cempedak' pulp flesh ranged from 12.28-20.02 g/100 gFW, 5.70-6.72 g/100 gFW and 4.94-5.52 g/100 gFW, respectively. Among these three types of sugar, sucrose is the most dominant sugar. Lee *et al.* (2013) found that the content of sucrose, glucose and fructose contents in 'cempedak' fruit were 18.19 g/100 mL, 7 g/100 mL and 5 g/100 mL, respectively. In terms of total sugar, it was found that CH30 has lower sugar content (23.10 g/100 gFW) as compared to other varieties studied. This result was in agreement with the lowest total soluble solids value, however there was no significant differences observed ($p > 0.05$) among the TSS of different varieties studied.

The lower sugar content may also be due to varietal differences and perhaps different ripening stage of

Table 3. Organic acid content (g/100 gFW) in different varieties of 'cempedak'

'Cempedak' variety	¹ Ascorbic acid	² Citric acid	¹ Galacturonic acid	² Malic acid	¹ Oxalic acid	² Succinic acid
CH27	0.02±0.00 ^a	0.38±0.0 ^b	0.02±0.00 ^a	0.56±0.03 ^{ab}	0.02±0.00 ^b	0.31±0.12 ^a
CH28	0.01±0.00 ^b	0.57±0.06 ^a	0.02±0.00 ^a	0.70±0.08 ^a	0.02±0.00 ^b	0.32±0.08 ^a
CH29	0.01±0.00 ^b	0.51±0.11 ^{ab}	0.02±0.00 ^a	0.55±0.08 ^{ab}	0.03±0.00 ^a	0.30±0.02 ^a
CH30	0.02 ±0.00 ^a	0.24±0.02 ^b	0.02±0.00 ^a	0.43±0.02 ^b	0.03±0.00 ^a	0.33±0.05 ^a
CH33	0.01±0.00 ^b	0.60±0.05 ^a	0.00±0.00 ^b	0.64±0.08 ^{ab}	0.03±0.0 ^a	0.20±0.04 ^a

¹Values obtained from HPLC; ² Values obtained from LCMS/MS. Each value represents the mean of triplicate samples ± standard deviation. Values within the same column with different superscript (a-b) are significantly different at p≤0.05, as measured by Tukey's HSD test.

the sample studied. As sucrose was most abundant, it indicates the lowest tendency toward non-enzymatic browning reactions during processing (Vásquez-Caicedo *et al.*, 2002). On the other hand, low fructose contents (that has high sweetness potency) may not have effect on the sweetness sensation.

Organic acid composition and content

Fruits contain a wide variety of organic acids. Generally, these organic acids are widely distributed in fruits and originate from biochemical processes or from the activity of some microorganisms such as yeasts and bacteria. It functions to determine the palatability of fruits, together with sugar (Vásquez-Caicedo *et al.*, 2002).

Table 3 shows the organic acid composition and content of the different 'cempedak' varieties which was detected by both HPLC and LCMS/MS. As some organic acids, namely citric acid, malic acid and succinic acid, have close retention times and could not be identified by HPLC, further analysis was done using LCMS/MS. It can be concluded that malic acid (0.43-0.70 g/100 gFW) was the most abundant organic acid in the five 'cempedak' fruit varieties. In addition, there were also considerable quantities of citric acid (0.24-0.60 g/100 gFW) and succinic acid (0.20-0.33 g/100 gFW). A small quantity (0.02-0.03 g/100 gFW) of oxalic acid was obtained in all the 'cempedak' varieties. Lee *et al.* (2013) who reported the presence of 0.96 g/100 mL of malic acid, 0.87 g/100 mL of citric acid, 0.518 g/100 mL of succinic acid and 0.02 mg/100 mL of oxalic acid in 'cempedak' fruit

The ascorbic acid content that ranged from 0.01-0.02 g/100 g (10-20 mg/ 100 g) is in agreement with 13.3 mg/100 gFW and 17.7 mg/100 gFW vitamin C, as reported by Tee *et al.* (1997) and DOA (2001), respectively. However, the cempedak variety used in their study was not stated. The content of the

investigated organic acids in 'cempedak' fruit was diverse and depends on fruit variety. Apart from the six organic acids mentioned above, trace amounts of other not identified acids were also present.

Carotenoid profile and contents

Among health-promoting compounds, carotenoids function as antioxidants, reduction of risk in cancer and cardiovascular diseases (Concurso *et al.*, 2012). Carotenoids are among the most abundant naturally occurring pigments in fruits. Yellow or orange colored fruit are an excellent source of carotenoids mainly β-carotene, but also α-carotene, lutein, violaxanthin, lycopene and neoxanthin (Yano *et al.*, 2005). The carotenoid composition and contents of different 'cempedak' varieties are presented in Table 4. In general, it can be concluded that the most dominant carotenoid found in all 'cempedak' fruits studied was α-carotene (2.30-45.27 μg/100 gFW), followed by β-carotene (2.30-12.23 μg/100 gFW) (Table 4). The most varied was the contents of α-carotene, which was 19.6 fold more in CH28 than the content found in CH33. It is also interesting to note that CH29, CH30 and CH33 varieties have lutein content of 0.67 and 0.20 μg/100 gFW, respectively. Lutein was not detected in CH29, CH30 and CH33, probably due to varietal differences or their values are below the detection limit of the method used in quantification.

A wide variation of neoxanthin (0.30-3.40 μg/100 gFW), lycopene (0.23-1.97 μg/100 gFW) and cryptoxanthin (0.10-3.30 μg/100 gFW) were observed, suggesting that there are considerable levels of diversity in the carotenoid content in different varieties of 'cempedak'. The characteristics of cultivars, climate and conditions for growing vegetable crops may produce fruits whose carotenoid profile can differ considerably. Abu Bakar *et al.*

Table 4. Carotenoid content ($\mu\text{g}/100 \text{ gFW}$) in different varieties of 'cempedak'

'Cempedak' variety	α -Carotene	β -Carotene	Cryptoxanthin	Lutein	Lycopene	Neoxanthin
CH27	12.80 \pm 2.33 ^b	10.67 \pm 0.06 ^d	1.50 \pm 0.27 ^b	0.67 \pm 0.06 ^a	0.87 \pm 0.06 ^b	2.93 \pm 0.18 ^{ab}
CH28	45.27 \pm 3.74 ^a	3.73 \pm 0.12 ^c	3.30 \pm 0.17 ^a	0.20 \pm 0.00 ^b	0.23 \pm 0.06 ^c	0.30 \pm 0.00 ^b
CH29	7.63 \pm 1.65 ^b	12.23 \pm 1.50 ^a	0.23 \pm 0.05 ^c	0.00 \pm 0.00 ^c	0.43 \pm 0.06 ^c	2.00 \pm 1.15 ^{ab}
CH30	42.13 \pm 3.97 ^a	8.23 \pm 1.12 ^b	0.10 \pm 0.00 ^c	0.00 \pm 0.00 ^c	1.10 \pm 0.20 ^b	0.67 \pm 0.05 ^{ab}
CH33	2.30 \pm 0.46 ^c	2.30 \pm 0.17 ^{cd}	0.10 \pm 0.00 ^c	0.00 \pm 0.00 ^c	1.97 \pm 0.15 ^a	3.40 \pm 0.26 ^a

*Each value represents the mean of triplicate samples \pm standard deviation. Values within the same column with different superscript (a-c) are significantly different at $p \leq 0.05$, as measured by Tukey's HSD test.

Table 5. Sensory assessment for different varieties of 'cempedak'

Sensory attributes	'Cempedak' variety				
	CH27	CH28	CH29	CH30	CH33
Color	6.9 \pm 1.3 ^a	6.3 \pm 1.4 ^{ab}	6.6 \pm 1.8 ^{ab}	6.9 \pm 1.8 ^{ab}	6.0 \pm 1.7 ^b
Taste	6.9 \pm 1.5 ^{ab}	7.4 \pm 1.37 ^a	6.7 \pm 2.0 ^{ab}	5.7 \pm 1.9 ^b	6.5 \pm 1.8 ^{ab}
Texture	6.4 \pm 1.7 ^{ab}	6.8 \pm 1.5 ^a	6.4 \pm 1.9 ^{ab}	5.7 \pm 1.9 ^b	6.2 \pm 1.8 ^{ab}
Overall acceptability	6.7 \pm 1.8 ^{ab}	7.0 \pm 1.47 ^a	6.4 \pm 1.9 ^{ab}	5.6 \pm 1.8 ^b	6.0 \pm 1.9 ^{ab}

* Each value represents the mean of 40 panelist \pm standard deviations. Values within the same row with different superscript (a-b) are significantly different at $p \leq 0.05$, as measured by Tukey's HSD test.

(2015) detected a total of 1.09 mg/g (109 mg/100 g) dry weight total carotenoid content in 'cempedak' flesh, in which the variety studied was not stated. However, the lower total carotenoid obtained in this study (10.07-53.03 $\mu\text{g}/100 \text{ gFW}$) was determined in fresh weight.

To the best of our knowledge, this is the first time that the entire carotenoid composition of 'cempedak' varieties has been studied in detail. It was reported that 'cempedak' has a total carotenoid of 80 μg per 100 gFW carotene in Malaysia Food Composition Database, with no further research on types of carotenoids found in 'cempedak'.

As a comparison, the carotenoid profile of jackfruit (*Artocarpus heterophyllus*), a fruit which is quite similar in appearance with 'cempedak', as determined by Tee and Lim (1991), was found to contain 95 $\mu\text{g}/100 \text{ gFW}$ lutein, 17 $\mu\text{g}/100 \text{ gFW}$ cryptoxanthin, 56 $\mu\text{g}/100 \text{ gFW}$ β -carotene and 56 $\mu\text{g}/100 \text{ gFW}$ other carotenoid. No lycopene and α -carotene were detected in jackfruit (Baliga *et al.*, 2011). The sum of carotenoid was found to be 223 $\mu\text{g}/100 \text{ gFW}$ and total RE 11 $\mu\text{g}/100 \text{ gFW}$ (Tee and Lim, 1991).

Sensory assessment of 'cempedak' fruit

Sensory evaluation in terms of the Hedonic test was conducted in order to evaluate the different aspects of sensory properties for selected 'cempedak' varieties (Table 5). All 'cempedak' varieties performed differently in terms of their sensory attributes. However, there was no significant differences ($p > 0.05$) among CH27, CH28 and CH29 varieties in terms of color, taste, texture and overall acceptability, with CH28 having the highest mean in taste, texture and overall acceptability.

Hence, it is suggested that 'cempedak' variety CH28 to be utilized in the production of 'cempedak' fruit juice and powder. It is the combined perception of texture and taste (sweetness) which determines the organoleptic quality and suitability of 'cempedak' for table and processing purposes, in addition of the physical and chemical properties of the 'cempedak' CH28.

Conclusion

The physicochemical and sensory properties of CH27, CH28, CH29, CH30 and CH33 'cempedak' was

studied. Each variety has its own unique properties: CH33 has the highest proportion of pulp, while CH30 was found to have the lowest titratable acidity and also the darkest, most reddish and yellowish among the five 'cempedak' varieties studied. They did not greatly differ between the varieties in terms of total soluble solids, sugar and acidity (pH). Generally, the five varieties of 'cempedak' was found to contain a high level of sucrose, followed by fructose and glucose, while the dominant organic acid was malic acid, followed by citric acid and succinic acid. The main carotenoid pigment was α -carotene, with β -carotene as the second most abundant carotenoid. In conclusion, CH28 was the best 'cempedak' variety to be processed into juice and powder, based on highest carotenoid content and consumers selection.

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