Physico-chemical characteristics of watermelon in Malaysia
(Nilai pemakanan dan ciri fiziko-kimia buah tembikai di Malaysia)

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Abstract
Watermelon (Citrullus lanatus) is a popular fruit among Malaysians. Red-fleshed seeded and seedless, and yellow-fleshed watermelons are mostly selected as a dessert and available throughout the year in local markets. Therefore, this study was focused to determine the nutritional and physico-chemical characteristics of these watermelons. Red-fleshed seedless watermelon contained 89.7 ± 4.3% moisture, while red-fleshed seeded and yellow-fleshed watermelon had 87.5 ± 2.6% and 87.0 ± 2.7% respectively. No significant differences were observed for most nutritional and physico-chemical analysis between samples. However, there were significant differences for colour determination (L*, a* and b*) and amount of sucrose among the samples. Yellow-fleshed watermelon showed L* = 50.0 ± 6.9, a* = 5.8 ± 2.0, b* = 32.6 ± 8.8, red-fleshed seedless showed L* = 43.4 ± 3.5, a* = 25.1 ± 4.4, b* = 15.2 ± 4.1 and red-fleshed seeded showed L* = 38.2 ± 5.1, a* = 19.4 ± 7.3, b* = 15.3 ± 6.6. Total sugar contents determined by high performance liquid chromatography (HPLC) showed that red-fleshed seedless, red-fleshed seeded and yellow-fleshed watermelon consisted of glucose, fructose and sucrose. Amount of total sugar for red-fleshed seedless, red-fleshed seeded and yellow-fleshed watermelon were 95.0 ± 25.2 mg/g, 113.8 ± 31.6 mg/g and 100.6 ± 25.5 mg/g respectively. There was positive and strong correlation between total soluble solid with total sugar (r² = 0.75). The results indicated that different varieties of watermelon had different nutritional contents and physico-chemical characteristics.

Keywords: nutritional analysis, physico-chemical, red-fleshed watermelon, yellow-fleshed watermelon

Introduction
In Malaysia, various watermelon cultivars and varieties contain seeds or are seedless, and have different sizes, shapes and colours of the flesh and skin. The colour of the skin ranges from light to dark greenish while the flesh colour can vary from pale pink, red or yellow to orange. The shape of the watermelon varies from round to oval shapes.

The quality and credibility of food mostly comes from the nutritional composition. According to the United States Department of Agriculture (USDA 2012), the moisture content of mature watermelon fruits is quite high, around 91% of the edible...
weight portion. Moisture content depends on the level of ripeness and can be increased up to 93%. Watermelon fruits are not ranked as a good source of protein and fat. The amount of protein and fat in watermelon is around three quarters of the weight of watermelon seeds (FAO 2010). Besides these, other nutrients such as minerals are important essential elements in our diet that are required in small quantities for optimum metabolism and to help regulate normal body processes. Watermelon is one of the important sources of potassium and other minerals (Sundia 2007). Potassium and calcium have the essential role of osmotic process in the body by controlling the electrolytic balance and the amount of body fluid to make the body pH more alkaline (MacWillian 2005).

Dietary fibres (DF) are easily found in vegetables and fruits, and help to maintain healthy digestion (Schofield 2008). Dietary fibres that are soluble in water are recognised as the soluble dietary fibres (SDF), while those insoluble in water are insoluble dietary fibres (IDF). A combination of soluble and insoluble fibres is the accumulation of DF in most plant foods. Dietary fibres are parts of carbohydrates that cannot be digested in the small intestine in humans. However, they are fully or partially fermented in the human large intestine (AACC 2000). Soluble dietary fibres will give a good benefit to the human body due to the hypoglycaemic and hypcholesterolemic effect (Ramulu and Udayasekhar 2003).

Since a lot of low quality watermelon fruits with pale flesh colour, below maturity stage and unsweetened have been marketed, consumers have increasingly lost confidence in these fruits. The internal quality of a watermelon fruit should be of a bright flesh colour and texture, free from defects, sweet and of optimum ripeness. In addition, the pH and acidity contributes to the essential quality of the physico-chemical properties. Unfortunately, these criteria cannot be assessed without cutting the fruit. However, fresh-cut watermelon has a lower quality level than a whole watermelon as it is often described with a loss of texture, colour and sweetness (Rushing et al. 2001).

The sweetness of watermelon is determined by the total sugar content and by the ratios among the main sugars (glucose, fructose and sucrose) (Brown and Summers 1985). The highest contribution of glucose and fructose in watermelon fruits happens during the early stages of the fruit development, while sucrose proportion is detected only three or four weeks after maturity (Elmstrom and Davis 1981; Brown and Summers 1985). In matured watermelon fruits, the proportions of sucrose and glucose are in the range of 20 – 40% of total sugars, while the proportion of fructose is in the range of 30 – 50% (Yativ et al. 2010). In addition to sweetness, fruit quality and maturity are also reflected by the total soluble solids content. Optimum quality of watermelon should have a sugar content (measured as total soluble solid/ºBrix) of 10 ºBrix or more (William 1999).

Literature reviews show that there have been numerous studies on watermelon, mostly on the red-fleshed seedless watermelon. However, there has been a limited study on the yellow-fleshed watermelon. Thus, the aim of this study was to determine the nutritional and physico-chemical properties of watermelons in Malaysia. The correlation between total sugars and total soluble solids were carried out to evaluate the relationship between these analyses.

Materials and methods
Three commercial watermelon varieties, namely, red-fleshed seedless (RS), red-fleshed seeded (RD) and yellow-fleshed (Y) were bought three times for each sample from Pasar Borong Selangor, Malaysia. The matured fruits were chosen according to the Federal Agricultural Marketing Authority (FAMA 2012) index of maturity. A total of
nine samples were obtained for each fruit following the Malaysian standard method of sampling fresh fruits MS 78:2002 (Malaysian Standard 2002).

**Chemical and reagents**
The following chemicals were purchased from Merck (Darmstadt, Germany): Anthrone reagent, glucose anhydrous, perchloric acid, analytical grade hydrochloric acid (HCl) and acetonitrile. Sulphuric acid (H$_2$SO$_4$), sodium hydroxide (NaOH) and petroleum ether were purchased from Fisher Scientific (Leicestershire, UK). Total dietary assay fibre kit and α-amylase, protease and amyloglucosidase solutions were purchased from Megazyme (Wicklow, Ireland). Other chemicals used included ethanol 95% (HmbG chemicals, Germany); diatomaceous earth-acid washed (Celite), MES-2-(N-Morpholino) ethanesulfonic acid and TRISTris(hydroxymethyl) aminomethane (Sigma Chemical Co., St. Louis, USA).

**Preparation of samples**
Fruits were washed with water and wiped with the tissue to dry the outer layer. They were then cut longitudinally from the stem-end to the blossom-end at the centre and sampled using the quartering technique by selecting different areas. The quartering technique for watermelon samples uses the principle of considering that each quarter should be representative of the whole fruit. Any symmetrical fruit should be cut into quarters, and one-quarter of each batch taken for analysis. The watermelons where cut into fourths, and two-fourths taken for a quarter, since each end may represent different parts of the fruit. Quarter watermelons were coarsely chopped and combined and the watermelon flesh diced into cubes of about 1 cm x 1 cm for analysis of moisture content. The rest of the watermelon flesh was homogenated using a blender (Waring Commercial, Torrington, CT, USA) and prepared for determination of the proximate composition, mineral, total soluble solid, pH, acidity of fruit and sugar contents. The colour of the fruits was measured at different locations of the flesh of each fruit. All outer layer skin, rind and seeds were discarded because only the edible portion of watermelon was used.

**Analysis of sample**

**Nutritional analysis**

1. **Proximate analysis**
Red-fleshed seedless, red-fleshed seeded and yellow-fleshed watermelons were analysed for proximate contents (crude protein, crude fat and ash) and total dietary fibre using AOAC International (AOAC 2000). Three replications were done for three independent measurements.

**i) Moisture content**
Moisture content was measured using an air-circulated oven (Memmert, Buchenbach, Germany) at 105 °C according to AOAC (2000) No. 925.09. Five grams of watermelon cubes were weighed into the dish and dried overnight. After drying, the dished was transferred into a desiccator to cool for approximately 45 min. This drying process was repeated until a constant weight was obtained. Moisture (M) is the disparity of the weight measured before and after drying as shown by the following equation:

\[
\text{Moisture (%) } = \frac{M_{\text{initial}} - M_{\text{dried}}}{M_{\text{initial}}} \times 100
\]

**ii) Crude protein**
The crude protein of the sample was analysed using Kjeldahl method according to AOAC (2000) No. 920.152. One gram of the homogenate fleshed watermelon was transferred directly into the digested tube and 15 ml concentrated sulphuric acid was added into all the tubes. The tube was digested using a fully auto Foss Digestor 2540 (Foss, Hillerod, Denmark) at 420 °C for 2 h and after cooled, was transferred into an automated distillation unit Kjeltec 8100 (Foss, Hillerod, Denmark). The amount of protein present was calculated using the
Physico-chemical characteristics of watermelon

equation from the nitrogen concentration of the food and multiplied with a conversion factor (6.25) and expressed in %:

\[ \text{Crude protein (\%)} = \% \text{nitrogen} \times \text{conversion factor (6.25)} \]

iii) Crude fat
The crude fat was determined using the Soxhlet method according to AOAC (2000) No. 991.36. Dried glass cups were weighed as W1. Two grams of homogenate watermelons were weighed in a porous thimble, placed in an extraction chamber of the thermal extraction heater machine, EM060100 (Cole-Parmer, Vernon Hill, USA) with a glass cup containing petroleum ether solvent suspended above for 8 h. The glass cup was then dried at 105 °C for 1 h, cooled in a desiccator for approximately 45 min and weighed as W2. The fat content was calculated using the following equation and expressed as g/100 g:

\[ \text{Crude fat (g/100 g)} = \frac{(W2 - W1)}{S} \times 100 \]

where W1 is the weight of dried glass cup, W2 is the weight of dried glass cup after extraction and S is the weight of the sample.

iv) Total ash
Total ash was determined using the dry ashing technique according to AOAC (2000) No. 940.26. Clean silica crucibles were weighed as W1. Five grams of the homogenate watermelons were weighed in the crucibles (W2) and burnt in a high temperature muffle, Thermolyne 4800 furnace (Thermo Scientific, New York, USA) while maintaining temperature around 550 °C overnight. Then, the silica crucibles were cooled in a desiccator for approximately 90 min and weighed as W3. The result was calculated using the following equation and expressed as g/100 g:

\[ \text{Total ash (g/100 g)} = \frac{(W3 - W1/W2 - W1)}{S} \times 100 \]

v) Determination of carbohydrate
The total carbohydrate in watermelons was determined by differences and calculated as percent value after the deduction of 100 to moisture content, crude fat, crude protein, ash and total dietary fibre.

In addition, the available carbohydrate was determined as described by Clegg (1956) using anthrone reagent and glucose anhydrous as a standard. Approximately, 1 g of homogenate watermelon was weighed and 10 ml of distilled water was added. Then, 13 ml perchloric acid was mixed and filtered into a 250 ml volumetric flask. Then, 10 ml of the mixture was diluted to 100 ml with distilled water. One millilitre of diluted filtrate was transferred to a boiling tube. Then, 4 ml of the anthrone reagent was added into all tubes and the tubes were heated for 12 min. The tubes were rapidly cooled and the absorbance was read at 630 nm using spectrophotometer UV-Vis 2950 (Labomed Inc., Los Angeles, USA) against the blank. Total available carbohydrate was calculated using the following equation:

\[ \text{Total available CHO (% glucose)} = \frac{(25 - b)}{(a - w)} \]

where w is the weight of homogenate watermelon, a is the absorption of standard and b is the absorption of homogenate watermelon.

2. Analysis of sugar
The High Performance Liquid Chromatography (HPLC) method described by Yang et al. (2008) was used to determine the content of sugar (glucose, sucrose and fructose). One gram of homogenate watermelon was diluted with 10 ml deionised water and centrifuged using Biofuge Primo Heraeus (Fisher Scientific, Loughborough, UK) at 9,000 g for 5 min.
Then, the mixture was filtered with a 0.45 µm Nylon filter. The quantification of sugar was conducted using Jasco RI-1530 HPLC (Jasco Inc., Easton, USA) with refractive index detection, and the separation was carried out using a 5 µm Purospher Star NH2 column (250 mm x 4.6 mm) (Merck, Darmstadt, Germany). A mixture of acetonitrile:water (75:25 v/v) was used as a mobile phase with a flow rate of 1 ml/min. A mixture of sugar standards at a concentration 10 mg/ml containing fructose, glucose and sucrose was prepared.

3. Dietary fibre

Total dietary fibre (TDF) from the dried homogenate watermelons was analysed based on the methods of Lee et al. (1992) and Prosky et al. (1988) (AOAC 991.43) using Megazyme, the total dietary fibre assay kit.

i) Digestion

Two blank assays were run together with the homogenate watermelon sample to measure any contribution from the reagents to residue. Around 1.000 ± 0.005 g of dried homogenate watermelons were weighed in duplicate (M1 and M2), accurate to 0.1 mg into 400 ml tall-form beakers. Forty millilitres MES/TRIS pH 8.2 buffer solution was added to each beaker and stirred until completely dispersed. Then, 50 µl α-amylase solution was added and stirring was continued at low speed. Beakers were covered with aluminium foil and incubated at 95 – 100 °C in a shaker water bath, Hotech 902 (Hotech Instrument., New Taipei City, Taiwan) for 15 min with continuous agitation. After that, all beakers were removed from the water bath and cooled to approximately 60 °C. One hundred microlitres protease solution was added to each beaker and incubated for 30 min at 95 – 100 °C in a shaker water bath. The residue was washed and rinsed twice with 10 ml 70 °C H2O. The filtrate and water washings were combined and then transferred to a prepared 600 ml tall form beaker (reserved for the determination of soluble dietary fibre). By using vacuum, all residues were washed twice, each time with 15 ml portions of 78% ethanol, 95% ethanol and acetone. All crucibles containing residues were dried overnight at 105 °C. Crucibles, containing dietary fibre residues and Celite were weighed to the nearest 0.1 mg, and the residue weights were calculated by subtracting the weight of dry crucibles with Celite. One duplicate from each sample was used to determine protein using N x 6.25 as a conversion factor. The second duplicate was incinerated for ash analysis for five hours at 525 °C. The weight of the crucibles was subtracted with Celite to determine the ash weight.

iii) Insoluble dietary fibre determination

For the determination of insoluble dietary fibre, the digested sample from analysis of the total dietary fibre was used to filter through the crucibles into the filtration flask. The residue was washed and rinsed twice with 10 ml 70 °C H2O. The filtrate and water washings were combined and then transferred to a prepared 600 ml tall form beaker (reserved for the determination of soluble dietary fibre). By using vacuum, all residues were washed twice, each time with 15 ml portions of 95% ethanol. All crucibles containing residues were dried overnight at 105 °C. Crucibles containing the dietary fibre residues and Celite were weighed to the nearest 0.1 mg, and the residue weights were calculated by subtracting the weight of dry crucibles from Celite. One duplicate from each sample was used to determine protein using N x 6.25 as a conversion factor.
factor. The second duplicate was incinerated for ash analysis for five hours at 525 °C. The weight of the crucibles was subtracted with Celite to determine the ash weight.

iv) Soluble dietary fibre determination
For the determination of soluble dietary fibre, 320 ml of 95% ethanol at 60 °C was added to the filtrate from previous analysis in the pretreated tall beakers and left for one hour to precipitate form at room temperature. By using vacuum, all residues were washed twice, each time with 15 ml portions of 95% ethanol and acetone. All crucibles containing residues were dried overnight in 105 °C. Crucibles containing the dietary fibre residues and Celite were weighed to nearest 0.1 mg, and the residue weights were calculated by subtracting the weight of dry crucibles with Celite. One duplicate from each sample was used to determine protein using N x 6.25 as a conversion factor. The second duplicate was incinerated for ash analysis for five hours at 525 °C. The weight of the crucibles was subtracted with Celite to determine ash weight.

v) Calculation
Dietary fibre (DF) was determined in g/100 g using the following equation:

$$DF = \frac{\{R1 = R2\} - P - A - B}{\{M1 = M2\}/2} \times 100$$

where R1 and R2 are residue weights (mg) for duplicate samples; P and A are weights (mg) of protein or ash respectively, determined on the first and second residues; B is the blank weight (mg); and M1 and M2 are weights (mg) of samples. Blank (B) was determined in mg using the following equation:

$$B = (BR1 + BR2) - P - A$$

where BR1 and BR2 are residue weights (mg) for duplicate blank determination; P and A are weights (mg) of protein and ash respectively, determined on first and second blank residues. For insoluble dietary fibre and soluble dietary fibre determination, the above equation was used.

4. Minerals determination
The determination of minerals, sodium (Na), potassium (K), calcium (Ca) and ferum (Fe) was carried out according to the ashing procedure as described. Five millilitres concentrated HCl was added into the silica basin before being dried over water bath. Then 2 ml concentrated HCl was added to dissolve the ash and filtered using filter paper (Whatman No. 42) into a 100 ml volumetric flask. All watermelon residues were washed thrice with hot water and diluted to 100 ml. The Atomic Absorbance Spectrophotometer instrument GBC 904 (GBC Scientific Instrument, Hampshire, USA) was set up (Table 1) and computer software prepared as given in the operating manual. The calibration curve for each of the minerals was prepared using the standard solutions. Three readings were obtained for each sample solution.

Physico-chemical analysis
1. Measurement of colour
The colour measurements of fleshed watermelons were conducted using a colorimeter Minolta C300 (Minolta, Kyoto, Japan). This colorimeter is based on the CIE (Commission Internationale de L'Eclairage) L*a*b* colour scale. This system uses three values (L*, a* and b*) to describe the precise location of a colour inside a three-dimensional visible colour space. L* is defined as lightness ranging from 0 (black) to 100 (whiteness), a* is the positive value for reddish and negative value for greenish colours and b* is the positive value for yellowish and negative value for bluish colours. Calibration was performed on the white colour tile prior to the sample analysis. Triplicate samples were analysed and the mean was calculated.
The pH and acidity value of watermelon

The pH and acidity values of the homogenate watermelons were determined according to Yau et al. (2010) with slight modifications using the Mettler Toledo FE20 pH meter (Mettler Toledo, Greinfensee, Switzerland). Before the analysis, the pH meter was calibrated using pH 4 and pH 8 buffers. Approximately, 10 ml of homogenate watermelon was added with 40 ml distilled water. The pH meter electrode determined the pH value under stirring until the pH meter reached a constant value. Then the mixture of watermelon was titrated with 0.1 M sodium hydroxide (NaOH) solution until it reached pH = 8.1. All experiments were conducted at room temperature and three replications of all of the three independent measurements were carried out. The % acidity was calculated using the following equation from the NaOH titration value (0.1 M NaOH was equivalent to 0.0064 g citric acid) and was expressed as % acidity of citric acid.

\[ \text{Titratable acidity (\%) = \frac{\text{Titre} \times \text{acid factor (0.0064) \times 100}}{10 \text{ ml}} } \]

3. Total soluble solid

The total soluble solid content was determined using a digital refractometer Atago PR100 (Atago, Tokyo, Japan) and the result expressed as °Brix. The instrument was calibrated with a 10% sucrose solution. Approximately 1 g of homogenate watermelon was taken and determined in the refractometer. All experiments were conducted at room temperature and three replications of all three independent measurements were carried out.

Statistical analysis

Statistical analysis was carried out using the Statistical Package of Social Sciences (SPSS) for Windows, version 20 software (IBM, New York, USA). All data were reported as mean ± standard deviation from triplicate analyses. One-way analysis of variance (ANOVA) accompanied with Tukey’s and Pearson correlation were conducted to identify the significant differences between samples \((p < 0.05)\) and the relationship between samples.

Results and discussion

Nutritional composition of watermelon

Table 2 shows the proximate composition among watermelon fruits. Moisture content of watermelon was around 87 – 90%. Red-fleshed seedless watermelon had the highest moisture content. However, the range values of moisture content for the red-fleshed and yellow-fleshed watermelons were comparatively lower than for red-fleshed watermelon reported previously (Yau et al. 2010; USDA 2012). According to the Federal Agricultural Marketing Authority (FAMA), the unripe watermelons were much heavier due to the higher moisture content. The weight of the fruit becomes lighter when it reaches the complete maturity stage where the moisture content of the fruit increases.

<table>
<thead>
<tr>
<th>Element</th>
<th>Flame type</th>
<th>Lamp (mA)</th>
<th>Wavelength (nm)</th>
<th>Slit width (nm)</th>
<th>Range (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>Air-Acetylene</td>
<td>5.0</td>
<td>589.6</td>
<td>0.5</td>
<td>0.5 – 1.5</td>
</tr>
<tr>
<td></td>
<td>Air-Acetylene</td>
<td>5.0</td>
<td>330.4</td>
<td>0.5</td>
<td>100 – 300</td>
</tr>
<tr>
<td>K</td>
<td>Air-Acetylene</td>
<td>6.0</td>
<td>769.9</td>
<td>0.5</td>
<td>1 – 4</td>
</tr>
<tr>
<td>Ca</td>
<td>Nitrous oxide-Acetylene</td>
<td>10.0</td>
<td>422.7</td>
<td>0.5</td>
<td>1 – 4</td>
</tr>
<tr>
<td>Fe</td>
<td>Air-Acetylene</td>
<td>7.0</td>
<td>248.3</td>
<td>0.2</td>
<td>2 – 8</td>
</tr>
</tbody>
</table>

Conditions specified are for GBC atomic absorption spectrophotometer 904 (Sources: Athanasopoulos 1990; Shaw 1990)
Physico-chemical characteristics of watermelon

Table 2. Nutritional composition of red-fleshed seedless (RS), red-fleshed seeded (RD) and yellow-fleshed (Y) watermelons based on edible weight basis

<table>
<thead>
<tr>
<th>Parameters</th>
<th>RS</th>
<th>RD</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>89.65 ± 4.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>87.46 ± 2.58&lt;sup&gt;a&lt;/sup&gt;</td>
<td>87.03 ± 2.67&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>0.76 ± 0.81&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.81 ± 0.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.76 ± 0.17&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>0.16 ± 0.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.18 ± 0.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.21 ± 0.06&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>0.36 ± 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.24 ± 0.07&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.28 ± 0.03&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total CHO (different) (%)</td>
<td>10.6 ± 3.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.08 ± 2.65&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.71 ± 2.28&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total Available CHO (%)</td>
<td>11.41 ± 3.12&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.27 ± 3.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.96 ± 1.61&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total Dietary Fibre (%)</td>
<td>0.56 ± 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.63 ± 0.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.54 ± 0.05&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Insoluble dietary fibre (%)</td>
<td>0.34 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.35 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.30 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Soluble dietary fibre (%)</td>
<td>0.24 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.26 ± 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.24 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Calcium (mg/100 g)</td>
<td>7.26 ± 1.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.43 ± 0.99&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.00 ± 1.44&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sodium (mg/100 g)</td>
<td>1.25 ± 0.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.22 ± 0.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.32 ± 0.15&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Potassium (mg/100 g)</td>
<td>130.52 ± 26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>143.91 ± 8.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>130.71 ± 17&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ferum (mg/100 g)</td>
<td>0.47 ± 0.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.41 ± 0.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.47 ± 0.15&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

All figures were obtained from means ± SD of three replications. Means with different letters are significantly different at <i>p</i> < 0.05

Reduces. High moisture content of fruits will have an effect on the flesh crispness of watermelons (Sargent 2000).

Protein, fat and total carbohydrate by different and total available carbohydrate contents of red-fleshed seedless, red-fleshed seeded and yellow-fleshed watermelon showed no significant difference among samples. Fat and protein contents were similar with the findings of Inuwa (2011). The low proportion of carbohydrate, fat and protein in watermelon consequently responded to low calorie and energy source of fruits. The amount of total available carbohydrate and total carbohydrate by different had a higher percentage compared to the value reported by WHO (2005). This situation maybe due to low moisture content and accumulation of sugar during maturity stages of watermelon samples.

Previously, total carbohydrate, soluble and insoluble dietary fibre contents in red seedless watermelon were reported as 0.6%, 0.3% and 0.3% (Ramulu and Udayasekhara 2003). This study found that total dietary fibre content in the red-fleshed seedless, red-fleshed seeded and yellow-fleshed watermelon ranged from 0.54 – 0.63%, soluble fibre was around 0.25% and insoluble dietary fibre ranged between 0.30% and 0.35%. This study also showed that the soluble and insoluble dietary fibre expressed as percentage to the total dietary fibre were balanced, ranging from 40 – 50% and consequently, benefits the digestion system and helps to prevent metabolic diseases. Thus, the high intake of red-fleshed and yellow-fleshed watermelons in a daily diet will be beneficial to balance and fulfil the dietary fibre guidelines.

Moreover, there were significant differences among samples for ash content. The possible reason for the differences could be from minerals content in samples. There was no difference in the amounts of mineral concentration between the red-fleshed watermelons in this study which was in agreement with the findings of Abdullahi (2014). However, the amount of calcium in red-fleshed seedless watermelon in this study showed significant differences with the red-fleshed seeded and yellow-fleshed watermelon. According to Crisosto and Mitchell (2002), there are a lot of factors that affect and fluctuate mineral composition in raw fruits and vegetables. Besides that,
the distribution of vascular tissue, seed and peel also have an effect on the mineral concentrations. In mature fruits, higher mineral concentration is mostly found in the skin and seed (Saure 2005). Thus, different varieties of watermelon are also affected by this factor and watermelon can be considered as one of the most important edible fruits with high nutritional value.

**Sugar composition**

*Figure 1*(a) shows the chromatogram of fructose, sucrose and glucose standards and *Figures 1* (b), (c) and (d) shows the chromatograms of sugar content of the fruits. From the analysis, each standard chromatogram has a good separation. The first peak detected was fructose followed by glucose and sucrose. The fructose, glucose, sucrose and total sugar parameters are shown in *Table 3*. Yellow-fleshed watermelon had the highest amount of fructose (51.4 mg/g edible weight). However, red-fleshed seeded variety had the highest amount of total sugar (113.8 mg/g edible weight). The amount of sugars present among RS and Y were in the order of fructose >glucose >sucrose. For

![Chromatogram of fructose, sucrose and glucose standards](image1)

![Chromatogram of red-fleshed seedless watermelon](image2)
Physico-chemical characteristics of watermelon

Figure 1. (c) Chromatogram of red-fleshed seeded watermelon and (d) Chromatogram of yellow-fleshed watermelon

Table 3. The fructose, glucose, sucrose and total sugar parameters among red-fleshed seedless (RS), red-fleshed seeded (RD) and yellow-fleshed (Y) watermelons of edible weight

<table>
<thead>
<tr>
<th>Sample</th>
<th>Fructose (mg/g)</th>
<th>Glucose (mg/g)</th>
<th>Sucrose (mg/g)</th>
<th>Total sugar (mg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS</td>
<td>46.55 ± 18.83a</td>
<td>31.22 ± 13.6a</td>
<td>15.93 ± 8.71a</td>
<td>95.04 ± 25.22a</td>
</tr>
<tr>
<td>RD</td>
<td>49.59 ± 10.92a</td>
<td>29.51 ± 14.5a</td>
<td>34.93 ± 13.55b</td>
<td>113.78 ± 31.58a</td>
</tr>
<tr>
<td>Y</td>
<td>51.43 ± 15.86a</td>
<td>33.91 ± 12.2a</td>
<td>15.3 ± 5.12a</td>
<td>100.59 ± 25.45a</td>
</tr>
</tbody>
</table>

All figures were obtained from means ± SD of three replications. Means with different letters are significantly different at $p < 0.05$. 
red-fleshed seeded watermelon, the order was fructose > sucrose > glucose. Among these watermelons, there were significant differences for the sucrose content with RD containing the highest.

Since the progress of fruit initial development, fructose and glucose were the most active sugars due to the main presence of α-galactosidase and acid invertases. During this phase, reducing-sugars such as sucrose are not present yet (Lanchun et al. 2010; Snowdon 2008). According to Yativ et al. (2010), sucrose is the highest soluble sugar accumulated in the watermelon varieties starting from the third week of pollination onwards, although variations in accumulation of reducing-sugars throughout maturing have been reported. Thus, the percentage of sugar content will be increasing with the ripening process of the fruit (Wills et al. 2004). According to Yau et al. (2010), watermelon containing highest amount of fructose content is in excellent condition since the degree of sweetness of fructose is higher than sucrose.

Physico-chemical properties of watermelon

1. Measurement of colours

The colour values of red-fleshed seedless, red-fleshed seeded and yellow-fleshed watermelon are presented in Table 4. There were significant differences ($p < 0.05$) among the samples in parameters of $a^*$ and $b^*$ values. Yellow-fleshed watermelon had the highest values for $L^*$ (49.99 ± 6.92), followed by red-fleshed seeded watermelon (43.44 ± 3.48) and red-fleshed seeded watermelon (38.2 ± 5.09). Yellow-fleshed watermelon also had the lowest value for $a^*$ (5.77 ± 2.00) and the highest value for $b^*$ (32.59 ± 8.77). From the analysis, red-fleshed seeded watermelon had darker red colour compared to the red-fleshed seedless watermelon. This might be due to the presence of seeds and antioxidative compounds. According to Thompson (2003), the flesh of watermelon can contain many black or brown seeds which will affect the colour of the flesh. Other than that, during storage, the intensity of red colour of watermelon will be higher and consequently, contribute to the increased synthesis of lycopene (Collins et al. 2006; Perkins-Veazie and Collins 2003). Colour of fruits is one of the vital parameters for identifying the maturity stage of the fruits (Yau et al. 2010).

2. The pH and acidity of watermelon

The pH and titratable acidity of red-fleshed seedless, red-fleshed seeded and yellow-fleshed watermelon ranged from 5.4 – 5.6 and 0.07 – 0.09% acidity of citric acid as shown in Table 5. The values showed that there were no significant difference among samples. According to FAO (2010) and Salman-Minkov and Trebitsh (2008), watermelon is not affected by cold temperature, and it only ripens while it is still attached to the plant. The pH value of the fruit will remain stable during maturing, and the acid content of the fruit does not change after harvesting (Yau et al. 2010).

Table 4. The colour parameters among the red-fleshed seedless (RS), red-fleshed seeded (RD) and yellow-fleshed (Y) watermelons

<table>
<thead>
<tr>
<th>Sample</th>
<th>Colour parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$L^*$</td>
</tr>
<tr>
<td>RS</td>
<td>43.44 ± 3.48</td>
</tr>
<tr>
<td>RD</td>
<td>38.2 ± 5.09</td>
</tr>
<tr>
<td>Y</td>
<td>49.99 ± 6.92</td>
</tr>
</tbody>
</table>

All figures were obtained from means ± SD of three replications. Means with different letters are significantly different at $p < 0.05$. 
Physico-chemical characteristics of watermelon

However, the high effect of acidity is an additional factor of delayed ripening in fruits (Soteriau et al. 2014). The low value of titratable acidity shows that these watermelons do not produce a sour flavour during storage (Azudin et al. 1989). The pH and the titratable acidity of the watermelon flesh are usually observed as the quality properties that contribute to fruit taste and it depends on the optimal balance between sourness from the acidity and sweetness. Thus, amount of titratable acidity will affect the intensity of sweet flavour of the fruit.

3. Total soluble solid of watermelon
Total soluble solid was measured using a refractive index and strongly described as the sweetness measurement (Maynard 2001). Besides that, it is also considered as the ripening standards for certain fruits such as melons, grape and citrus. However, the amount of soluble solid in flesh will be reduced due to the storage conditions and rainy season (Yau et al. 2010). This study showed that the amount of total soluble solid (TSS) (Table 4) for red-fleshed seedless, red-fleshed seeded and yellow-fleshed watermelons were 9.24 ± 1.03, 10.46 ± 1.89 and 9.91 ± 0.98 ºBrix respectively. No significant differences were detected among samples. Consequently, in this study, the amount of soluble solid indicated that the fruits were in good condition and fully matured. According to Tlilli et al. (2011), fully ripened watermelons should have a soluble solid value of more than 8 ºBrix.

### Table 5. The pH, titratable acid and total soluble solid among the red-fleshed seedless (RS), red-fleshed seeded (RD) and yellow-fleshed watermelon (Y)

<table>
<thead>
<tr>
<th>Sample</th>
<th>pH</th>
<th>Titratable acidity (% acidity of citric acid)</th>
<th>Total soluble solid (ºBrix)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS</td>
<td>5.6 ± 0.34a</td>
<td>0.07 ± 0.02a</td>
<td>9.24 ± 1.03a</td>
</tr>
<tr>
<td>RD</td>
<td>5.5 ± 0.43a</td>
<td>0.09 ± 0.02a</td>
<td>10.46 ± 1.89a</td>
</tr>
<tr>
<td>Y</td>
<td>5.36 ± 0.11a</td>
<td>0.08 ± 0.01a</td>
<td>9.91 ± 0.98a</td>
</tr>
</tbody>
</table>

All figures were obtained from means ± SD of three replications. Means with different letters are significantly different at p <0.05

Consequently, the total sugar content will be increasing with the ripening process of the fruit. The high value of this correlation showed the strong relationship between the total soluble solid and total sugar as reported by Soteriou et al. (2014) and Yativ et al. (2010). This indicated that the high value of total soluble solid can be

### Correlation between total soluble solid and total sugar

The correlation between the total soluble solid and total sugar among watermelons was highly significant ($r^2 = 0.75, p <0.01$) (Figure 2). The high value of the total soluble solid was in linearity with the high amounts of total sugar. According to Soteriou et al. (2014), total soluble solids in the watermelons are influenced by the level of maturity.

![Figure 2. Correlation between total sugar and total soluble solid](image)

*Correlation between total soluble solid and total sugar*

*Consequently, the total sugar content will be increasing with the ripening process of the fruit. The high value of this correlation showed the strong relationship between the total soluble solid and total sugar as reported by Soteriou et al. (2014) and Yativ et al. (2010). This indicated that the high value of total soluble solid can be*
explained by the amount of the total sugar in ripened watermelons.

**Conclusion**

This study showed that moisture content, protein, fat, total carbohydrate by different and total available carbohydrate contents of red-fleshed seedless, red-fleshed seeded and yellow-fleshed watermelons have no significant differences ($p > 0.05$) among samples. Total dietary fibre content in the red-fleshed seedless, red-fleshed seeded and yellow-fleshed watermelons ranged from 0.53 – 0.63%, the soluble fibre was around 0.25% and insoluble dietary fibre ranged from 0.25 – 0.34% respectively. The pH and titratable acidity of red-fleshed seedless, red-fleshed seeded and yellow-fleshed watermelons ranged from 5.4 – 5.6 and 0.07 – 0.09% acidity of citric acid respectively. Yellow-fleshed watermelon showed the highest values for $L^*$ and $b^*$ values compared to red-fleshed seedless watermelon and red-fleshed seeded watermelon. Despite that, yellow-fleshed watermelon had the lowest value for $a^*$. The amounts of the total soluble solid for red-fleshed seedless, red-fleshed seeded and yellow-fleshed watermelons were 9.24, 10.46 and 9.91 ºBrix respectively. Yellow-fleshed watermelon had the highest amount of fructose although red-fleshed seeded had the highest amount of total sugar among samples. Hence, the correlation between the total soluble solid and total sugar among samples was highly significant ($r = 0.75$, $p < 0.01$) and the total soluble solid will influence the amount of total sugar in the ripened watermelon.

**Acknowledgments**

Authors would like to thank the Malaysian Agricultural Research and Development Institute (MARDI) and Faculty of Medicine and Health Sciences, Universiti Putra Malaysia (UPM) for providing the scholarship, chemicals, equipments and infrastructures in accomplishing this study.

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Abstrak

Tembikai (Citrullus lanatus) merupakan buah-buahan yang popular dalam kalangan rakyat Malaysia. Tembikai merah tanpa biji, tembikai merah berbiji dan tembikai kuning sering dipilih sebagai pencuci mulut dan mudah didapati sepanjang tahun. Kajian ini memberi tumpuan untuk menentukan nilai pemakanan, fiziko-kimia dan ciri-ciri penggalak kesihatan buah tembikai. Tembikai merah tanpa biji mengandungi 89.7 ± 4.3% kelembapan, manakala tembikai merah berbiji dan tembikai kuning mempunyai 87.5 ± 2.6% dan 87 ± 2.7% kelembapan masing-masing. Tiada perbezaan yang signifikan untuk analisis pemakanan dan fiziko-kimia antara sampel. Walau bagaimanapun, terdapat perbezaan yang signifikan bagi penentuan warna \( L^* \), \( a^* \) dan \( b^* \) dan kandungan sukrosa antara sampel. Tembikai kuning mempunyai ciri penentuan warna \( L^* = 50.0 \pm 6.9; a^* = 5.8 \pm 2.0; b^* = 32.6 \pm 8.8 \), manakala tembikai merah tanpa biji mempunyai ciri penentuan warna \( L^* = 43.4 \pm 3.5, a^* = 25.1 \pm 4.4; b^* = 15.23 \pm 4.1 \) dan tembikai merah berbiji mempunyai ciri penentuan warna \( L^* = 38.2 \pm 5.1; a^* = 19.4 \pm 7.3; b^* = 15.3 \pm 6.6 \). Jumlah penentuan gula menggunakan kromatografi cecair berprestasi tinggi (HPLC) menunjukkan jumlah kandungan gula untuk tembikai merah berbiji, tembikai merah tanpa biji dan tembikai kuning terdiri daripada glukosa, fruktosa dan sukrosa. Jumlah keseluruhan gula adalah 95.0 ± 25.2 mg/g untuk tembikai merah tanpa biji, 113.8 ± 31.6 mg/g untuk tembikai merah berbiji dan 100.6 ± 25.5 mg/g untuk tembikai kuning. Terdapat korelasi yang positif dan kuat antara jumlah pepejal larut dengan jumlah gula \((r^2 = 0.75)\). Kesimpulannya, varieti tembikai memberikan kandungan nutrien dan ciri-ciri fiziko-kimia yang berbeza.