



## Antioxidant and Colour in Selected Local Fruits

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### ABSTRACT

Fruit pigments are associated with the presence of antioxidants. This study determined the content of antioxidant components (total phenolic content (TPC), ascorbic acid, beta carotene and lycopene) and colour in selected local fruits (papaya, watermelon, dragon fruit, wax apple, and jackfruit). The TPC, ascorbic acid, beta carotene and lycopene were determined spectrophotometrically. Ascorbic acid content was determined using the 2,6-Dichlorophenolindophenol (DCPIP) titration method. Colour was assessed by tristimulus colorimetry based on the reflection spectrum. Total soluble solids (TSS) were also determined. Papaya has TPC (61.86 mg GAE/100 g), ascorbic acid (31.14 mg/100 mL), lycopene (4.82 mg/100 g), beta carotene (19.98 mg /100 g), TSS (10.17 °Brix) and colour profile L\*(41.30), a\*(24.07), b\*(26.48), chroma value (35.79) and hue angle (47.70°). Wax apple has TPC (94.20 mg GAE/100 g), ascorbic acid (11.13 mg/100 mL), lycopene (1.62 mg/100 g), TSS (10.00 °Brix) and colour profile L\*(63.42), a\*(0.42), b\*(7.64), chroma value (7.66) and hue angle (86.69°). Dragon fruit has TPC (179.985 mg GAE/100 g), ascorbic acid (5.94 mg/100 mL), beta carotene (3.98 mg/100 g), TSS (10.30 °Brix) and colour profile L\*(21.45), b\*(0.66), chroma value (6.86) and hue angle (5.52°). Jackfruit has TPC (75.16 mg GAE/100 g), lycopene (2.31 mg/100 g), beta carotene (9.25 mg/100 g), TSS (20.43 °Brix) and colour profile L\*(71.74), a\*(5.79) and hue angle (82.98°). Watermelon has ascorbic acid (19.28 mg/100 mL), lycopene (36.55 mg/100 g), beta carotene (14.37 mg/100 g) and colour profile b\* (12.36), chroma value (26.98) and hue angle (27.22°). The a\* value has a significant positive correlation ( $p < 0.05$ ) with the content of ascorbic acid, lycopene, and beta carotene while the chroma value shows a negative correlation with the total phenolic content ( $p < 0.05$ ). The b\* value showing a negative correlation with the total phenolic content ( $p < 0.05$ ). Local fruits can be a good source of nutrient, phytochemicals, and antioxidants.

**Keywords:** Ascorbic acid, beta carotene, colour, lycopene, phenolic

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### INTRODUCTION

Plants rich in bioactive compounds play an important role in human nutrition and health (Noordin, Noor & Aizat, 2020; Ugasman, Hui & Wan Ahmad, 2023). With the increased consumption of fruits and vegetables in

raw and processed form, most plant-based diets rich in fruits and vegetables can reduce the risk of developing chronic diseases (Jideani et al., 2021). Antioxidants are biologically active compounds capable of eliminating reactive free radicals, such as hydrogen peroxide, superoxide radicals, and hydroxyl radicals (AlFaris et al., 2021). Antioxidant can prevent or delay body cell damage caused by free radicals (Cai et al., 2018).

Colour of fruits can be attributed to the presence of natural antioxidant pigments such as anthocyanidins, flavonoids, and carotenoids (Lu et al., 2021). Previous study reported that purple fruit is correlated with chelating activity and betalains, while orange fruit is correlated with phenolics, ascorbic acid, carotene, and DPPH (du Toit et al., 2018). Antioxidant capacity and mechanism of natural pigments to a certain extent, can be used as a basis for better use of natural pigments (Lu et al., 2021). In this study the analysis of the antioxidant components (total content of phenolic (TPC), ascorbic acid, beta carotene and lycopene) was carried out and, its relationship with the descriptive colour (of the edible parts) of selected local fruits in Malaysia, namely papaya, watermelon, dragon fruit, wax apple and jackfruit were determined.

Papaya (*Carica papaya*) has high-value phytochemicals such as phytosterols, tocopherols, flavonoids, alkaloids, and carotenoids. Papaya is a good source of antioxidant and possess wound healing properties (Hassan et al., 2020). Papaya is eaten either raw or in processed form as jelly, sweets, jam, and pickles (Tan et al., 2020). Watermelon (*Citrullus lantus*) is an important horticultural plant that belongs to the Cucurbitaceae family. Asian countries account for approximately 81% of the total world watermelon production (Assefa et al., 2020). There are various nutraceutical potentials of watermelon and its importance as antioxidant, anti-cancer, cardiovascular protective, anti-inflammatory properties have been proven by *in vitro* and *in vivo* studies (Manivannan et al., 2020). Dragon fruit (*Hylocereus polyrhizus*), also known as pitaya or pitahaya, is a member of the cactus family Cactaceae and rich in nutrients (Al-Mekhlafi et al., 2021). Previous study reported that the pulp and skin extracts of dragon fruit inhibit the production of reactive oxygen species (ROS), reactive nitrogen species (RNS), inducible nitric oxide synthase (iNOS), and COX-2 (Saenjum, Pattananandecha & Nakgawa, 2021). Wax apple (*Syzygium samarangense*) or known as jambu madu originates from Malaysia, but it is widely cultivated in Southeast Asia. It contains various metabolites that have biological activities such as antioxidant, immunomodulatory, antibacterial activity, anticancer, anti-inflammatory, anti-hyperglycemic, and analgesics (Mukaromah, 2020). Jackfruit (*Artocarpus heterophyllus*) is widely cultivated in most tropical countries such as Bangladesh, India, Burma, Philippines, Pakistan, Sri Lanka, Malaysia, Thailand (Khan et al., 2021). Jackfruit has important nutrients, including phytochemicals, minerals, vitamins, carbohydrates, and proteins (Ranasinghe et al., 2019).

## MATERIALS AND METHODS

### Sample Preparation

Samples of papaya, watermelon, dragon fruit, wax apple, and jackfruit were purchased from the local market and selected based on the ready-to-consume maturity index. The sample was washed with distilled water and then finely ground using blender.

### Determination of Antioxidant Components

#### *Total Phenolic Content (TPC)*

A total of 1 g of sample was extracted using 10 mL of 80% methanol (80:20, v/v). Sample was heated in an oven at 40 °C for 24 hours according to the extraction method described by Singleton et al. (1999) with minor modifications, where fresh sample was used instead of dried sample (Nkolisa et al., 2019). The mixture was then concentrated with a rotary evaporator RV10 (IKA Evaporator, Germany) at 40 °C with 100 RPM. TPC was measured using the Folin-Ciocalteu (FC) reagent procedure as determined by Singleton et al. (1965). A total of 0.1 mL of diluted sample extract (1:10) was mixed with 0.5 mL of FC reagent together with 1.5 mL of sodium carbonate solution (7%). Distilled water was added to obtain a final volume of 10 mL. The mixture was heated

in an oven at 40 °C for 2 hours, and the spectrophotometric absorbance was recorded at 750 nm using a UV-Vis Spectrophotometer. The results are expressed in mg of gallic acid (Teh et al., 2022; Yenny et al., 2022) in 100 g fresh weight of the fruit sample (mg GAE/100 g).

#### *Ascorbic Acid Content*

Ascorbic acid content was determined using the 2,6- Dichlorophenolindophenol (DCPIP) titration method (Vahid, 2012). Indophenol dye liquid was prepared with 0.05 g of DCPIP mixed with 42 mg of sodium bicarbonate and 50 mL of distilled water in a 200 mL conical flask. A total of 10 g of sample was weighed, chopped, and squeezed then filtered using Whatman No. 1 into a conical flask to get the juice. A total of 5 mL of filtrate was extracted using metaphosphoric acid-acetic acid-sulfuric acid (3%) solution. Then, the solution was titrated with DCPIP dye and the volume of DCPIP used for each sample was recorded. The content of ascorbic acid in fruit samples was measured using the equation:

$$\text{Ascorbic acid content (mg/100 mL fruit juice)} = F \times (V - V_0) \times 100/SV$$

Where,

F = dye factor (mg/ascorbic acid/mL dye)

V = volume (mL) of the dye used for titration in the sample

V<sub>0</sub> = volume (mL) of dye used in blank sample

SV = volume of sample used

#### *Lycopene Content*

A total of 1 gram sample was extracted in a mixture of 10 mL of acetone: n-hexane at a ratio of 4:6, and the mixture was left in an ice bath for 10 minutes. Then, it was centrifuged at 1370 × g (3500 rpm) for 10 minutes (Eppendorf Centrifuge 5810-R, Germany). The supernatant was separated using a separatory funnel. The absorbance of the hydrophobic fraction was measured spectrophotometrically at wavelengths of 663, 645, 505 and 453 nm using a UV Vis spectrophotometer, with an acetone/n-hexane mixture as a blank (Aguirre & Cabrera, 2012). The concentration of lycopene was calculated using the equation proposed by Nagata and Yamashita (1992) as follows: lycopene content (mg/g) = - 0.0458(A663) + 0.204(A645) + 0.372(A505) - 0.0806(A453)

#### *Beta Carotene Content*

Beta carotene concentration was determined using a colorimetric assay (Biswas, Sahoo & Chatli, 2011). A total of 500 mg of sample was extracted twice using 5 mL of cold acetone, and the mixture was left in an ice bath for 15 minutes with occasional shaking. The mixture was shaken vigorously for 10 minutes and centrifuged at 1370 × g (3500 RPM) for 10 minutes. The supernatant was collected and filtered using Whatman filter paper No. 42. A total of 3 μL of the supernatant was used to record the absorbance at 449 nm using an Epoch microplate spectrophotometer (Biotek Instrument, USA).

### **Colour Determination**

A total of 50 g sample was measured and cut 5 cm horizontally. A colorimeter (Chroma Meter CR-400, Minolta Co. LTD, Japan) was used to measure color in the CIELAB calorimetry system (Tilahun, Taye & Jeong, 2017; Azali, Hashim & Teh, 2022). The colour components which are L\* (brightness), a\* (red-green), b\* (yellow-blue) were recorded while chroma and hue angle were calculated using equations.

### **Total soluble solids (TSS)**

The sample was cut into small pieces and squeezed to obtain juice. An Atago N-50E refractometer (Atago, Japan) was used to measure the TSS (Pourdarbani et al., 2020). The value obtained is interpreted as °Brix.

## Statistical Analysis

For statistical analysis, the JASP Team (2022) JASP program (Version 0.16. 3) was used. All experiments were performed in triplicate and all data are expressed as mean  $\pm$  standard deviation. Mean values were compared with one-way ANOVA with Tukey's Post hoc test (with  $p < 0.05$ ). Correlation of colour attributes and antioxidant components was evaluated using Pearson's correlation.

## RESULTS AND DISCUSSION

### Antioxidants

Antioxidant content including TPC, ascorbic acid, lycopene and beta carotene in the selected local fruits studied (papaya, wax apple, dragon fruit, jackfruit, and watermelon) is shown in Table 1.

Table 1 Antioxidant content in selected local fruits.

Sample	Total Phenolic Content (TPC) (mg GAE/100g)	Ascorbic Acid (mg/100mL)	Lycopene (mg/100g)	Beta Carotene (mg/100g)
Papaya	61.86 $\pm$ 3.43 <sup>d</sup>	31.14 $\pm$ 1.28 <sup>a</sup>	4.82 $\pm$ 0.21 <sup>b</sup>	19.98 $\pm$ 1.01 <sup>a</sup>
Wax apple	94.20 $\pm$ 1.93 <sup>b</sup>	11.13 $\pm$ 1.28 <sup>c</sup>	1.62 $\pm$ 0.37 <sup>d</sup>	13.22 $\pm$ 1.04 <sup>b</sup>
Dragon Fruit	179.99 $\pm$ 4.42 <sup>a</sup>	5.94 $\pm$ 2.22 <sup>d</sup>	1.72 $\pm$ 0.23 <sup>cd</sup>	3.98 $\pm$ 0.68 <sup>d</sup>
Jackfruit	75.16 $\pm$ 7.95 <sup>c</sup>	9.65 $\pm$ 1.28 <sup>cd</sup>	2.31 $\pm$ 0.14 <sup>c</sup>	9.25 $\pm$ 0.25 <sup>c</sup>
Watermelon	59.79 $\pm$ 1.83 <sup>d</sup>	19.28 $\pm$ 2.22 <sup>b</sup>	36.55 $\pm$ 0.13 <sup>a</sup>	14.37 $\pm$ 1.14 <sup>b</sup>

Mean  $\pm$  standard deviation.

<sup>a-d</sup> Different alphabet indicates significant differences between groups within the same column ( $p < 0.05$ ).

### TPC

TPC in dragon fruit is the highest (179.99 mg GAE/100 g), differs significantly ( $p < 0.05$ ) compared to papaya (61.86 mg GAE/100 g), wax apple (94.20 mg GAE/100 g), jackfruit (75.16 mg GAE/100 g) and watermelon (59.79 mg GAE/100 g). Papaya showed a significant difference ( $p < 0.05$ ) with other samples except watermelon. In a previous study, TPC in dragon fruit showed a higher value of 277.60 mg GAE/100 g (Saenjum, Pattananandecha & Nakagawa, 2021). Biswas et al. (2021) reported lower TPC in wax apple (46.32 mg GAE/100 g) compared to this study. Meanwhile, TPC in the study of Dieng et al. (2017) in watermelon showed almost the same value which is 63.33 mg tannic acid equivalent /100 g dry extract. Maisarah et al. (2013) reported higher (272.66 mg GAE/100 g) TPC in papaya. Shafiq et al. (2017) observed higher (239.87 mg GAE/100 g) TPC in jackfruit. This difference range of TPC in plants is attributed to intrinsic and extrinsic influences (Tomás-Barberán & Espín 2001). The complex nature of compounds, the methods of extraction and analysis used contribute to the differences observed (Koca & Karadeniz 2009).

### Ascorbic Acid

Papaya showed the highest ascorbic acid value (31.14 mg/100 mL) significantly ( $p < 0.05$ ) compared to wax apple (11.13 mg/100 mL), dragon fruit (5.94 mg/100 mL), jackfruit (9.61 mg/100 mL) and watermelon (19.28 mg/100 mL). The content of ascorbic acid in jackfruit shows a significant difference ( $p < 0.05$ ) with other fruits except wax apple and dragon fruit. The ascorbic acid content of papaya in this study can be compared with the

study of Rayhan et al. (2019) with almost the same value of 30.00 mg/100 g. While Souza et al. (2008) showed that the content of ascorbic acid in papaya was higher in the range of 59.90 mg/100 g up to 112.40 mg/100 g. Based on the study of Luu et al. (2021) the content of ascorbic acid in dragon fruit showed a value almost the same as this study which is 6.00 mg/100 g while the study of Ruzainah et al. (2009) showed a higher value (8.00 to 9.00 mg/10 g). As for jackfruit, the study of Cantillo-Zacarias et al. (2021) showed a value almost the same as this study which is 6.80 mg/100 g. Chou and Sin (2012) reported lower (8.63 mg/ 100 g) content in watermelon. While Esua et al. (2017) reported higher (21.63 mg/ 100 g) content in wax apple. According to Najwa and Azrina (2017), variation in vitamin C (ascorbic acid) content in fruit samples can be attributed to many pre-harvest and handling factors including environment. Exposure of fruits to light has a strong influence on the chemical composition of fruits, especially vitamin C.

Based on the Recommended Nutrient Intake (RNI 2017) for Malaysia, the intake of ascorbic acid (vitamin C) that needs to be taken is 30.00 to 35.00 mg/day for children and 70.00 mg/day for adults. In addition, the World Health Organization and the Food and Agriculture Organization (WHO/FAO 2004) recommend a daily intake of 45.00 mg for all groups aged 10 and over. An intake of 45.00 mg/day will ensure that a measurable amount of ascorbate will be present in the plasma of most individuals and will be available to supply tissue needs for metabolism. The findings of this study prove that local fruits, especially papaya can be source of vitamin C with high content of ascorbic acid.

### *Lycopene*

Watermelon showed the highest lycopene content (36.55 mg/100 g) with a significant difference ( $p < 0.05$ ) compared to other selected local fruits studied while wax apple recorded the lowest value (1.62 mg/100 g). Papaya had 4.82 mg/100 g lycopene with a significant difference ( $p < 0.05$ ) compared to dragon fruit (1.72 mg/100g) and jackfruit (2.31 mg/100 g). A study by Suwanaruang (2016), reported a comparable lycopene content in papaya (4.53 mg/100 g). In fact, there are many previous studies on the content of lycopene in papaya that have been done with varying values such as 230.00 to 421.20  $\mu\text{g}/100\text{ g}$  (Lara-Abia et al., 2021), 1.44 to 3.39 mg /100 g (Souza et al., 2008), 1.02 mg/100 g (Rayhan et al., 2019) and 10.92 mg/100 g (Desai et al., 2018). Meanwhile, Suwanaruang (2016) study on the lycopene content of watermelon showed a lower value of 14.43 mg/100 g, compared to this study. Charoensiri et al. (2009) reported lower content in wax apple (17.10  $\mu\text{g}/100\text{ g}$ ), dragon fruit (Vietnam variety, white colour) (3.40  $\mu\text{g}/100\text{ g}$ ), and undetected in jackfruit. Fruits rich in lycopene include tomatoes, watermelon, and many other natural sources of dietary lycopene. Lycopene is an important and healthy carotenoid found in red fruits. It gives the characteristic red colour to the plant and has many health benefits. In this study, watermelon is the main sample that has a red pigment based on the colour evaluation based on Table 2 which shows the value of  $L^*$ ,  $a^*$  and  $b^*$  components.

### *Beta Carotene*

The content of beta carotene in papaya is significantly ( $p < 0.05$ ) (19.98 mg/100 g) the highest followed by watermelon (14.37 mg/100 g), wax apple (13.22 mg/100 g), jackfruit (9.25 mg/100 g) and dragon fruit (3.98 mg/100 g). The beta carotene content of papaya in this study is comparable with the study by Dotto and Abihudi (2021) (20.80 mg/100 g), while the study by Lara-Abia et al. (2021) showed a lower value which is between 120.3 to 233.2  $\mu\text{g}/100\text{ g}$ . Meanwhile, the study of Moo-Huchin et al. (2017) stated that the beta carotene content in dragon fruit from Mexico is higher with a range of 1.41 to 19.83 mg beta carotene/100 g. Charoensiri et al. (2009) reported lower content in wax apple (between 17.40 to 22.10  $\mu\text{g}/100\text{ g}$ ), jackfruit (26.40  $\mu\text{g}/100\text{ g}$ ), and watermelon (616.00  $\mu\text{g}/100\text{ g}$ ). Beta carotene is a natural carotenoid that exists as a pigment where it plays an important role in protecting the body's cells and thus acts as a powerful antioxidant. According to Jeyakodi, Krishnakumar and Chellappan (2018), the amount of conjugated double bonds containing carotenoids changes the wavelength of light that can be absorbed resulting in them varying in colour from red, orange, to yellow.

## Colour

Previous studies have shown a correlation between the colour measurements of the CIELAB system, which defines a three-dimensional colour space and represents colour stimuli as achromatic ( $L^*$ ) and bichromatic signals representing blue-yellow ( $b^*$ ) and red-green ( $a^*$ ), and for determining the presence of bioactive compounds such as carotenoids, anthocyanins and other phenolics, betalains and chlorophyll in plants (Delazio, Israr & Klatzky, 2017; Solano-Doblado et al., 2020). The values of  $L^*$ ,  $a^*$ ,  $b^*$ , chroma and hue angle for the samples studied are shown in Table 2.

Table 2 Values of  $L^*$ ,  $a^*$ ,  $b^*$ , chroma and hue angle based on CIELAB

Sample	$L^*$	$a^*$	$b^*$	Chroma Value	Hue Angle (°)
Papaya	41.30±3.06 <sup>b</sup>	24.07±0.65 <sup>a</sup>	26.48±1.56 <sup>b</sup>	35.79±1.36 <sup>b</sup>	47.70±1.61 <sup>b</sup>
Wax apple	63.40±4.17 <sup>a</sup>	0.42±0.26 <sup>b</sup>	7.64±1.23 <sup>d</sup>	7.66±1.22 <sup>d</sup>	86.69±2.26 <sup>a</sup>
Dragon Fruit	21.45±0.61 <sup>c</sup>	6.83±0.26 <sup>b</sup>	0.66±0.06 <sup>c</sup>	6.86±0.27 <sup>d</sup>	5.52±0.41 <sup>d</sup>
Jackfruit	71.74±7.07 <sup>a</sup>	5.79±5.49 <sup>b</sup>	46.66±2.56 <sup>a</sup>	47.23±2.53 <sup>a</sup>	82.98±6.62 <sup>a</sup>
Watermelon	31.91±0.63 <sup>b,c</sup>	23.98±1.95 <sup>a</sup>	12.36±1.54 <sup>c</sup>	26.98±2.37 <sup>c</sup>	27.22±1.61 <sup>c</sup>

Mean ± standard deviation.

<sup>a-d</sup> Different alphabet indicates significant differences between groups within the same column ( $p < 0.05$ ).

Table 2 shows that jackfruit had significantly ( $p < 0.05$ ) the highest  $L^*$  value (71.74±7.02) compared to the other samples studied. This shows that jackfruit has the highest brightness compared to wax apple (63.42), papaya (41.30), watermelon (31.91), and dragon fruit (21.45). As for the  $a^*$  value, all samples have a positive  $a^*$  value where the colour is towards red based on the CIELAB space. However, the  $a^*$  values for papaya and watermelon are not significantly different ( $p > 0.05$ ) (24.07 and 23.98, respectively). While wax apple, dragon fruit and jackfruit show low  $a^*$  values (0.42, 6.83 and 5.79, respectively). For the  $b^*$  value, all samples show a positive  $b^*$  value showing the colour towards yellow. Jackfruit recorded the highest  $b^*$  value ( $p < 0.05$ ) showing the yellowest colour then followed by papaya (26.48), watermelon (12.36), wax apple (7.64) and dragon fruit (0.66) with significant difference ( $p < 0.05$ ) for each sample. The chroma value of jackfruit is the highest (47.23) significantly ( $p < 0.05$ ) compared to other samples. This shows that jackfruit had a higher red colour saturation than papaya (35.79) and watermelon (26.98) while wax apple and dragon fruit have a much lower chroma value which are 7.66 and 6.86, respectively. The hue angles for wax apple and jackfruit were not significantly different ( $p > 0.05$ ) (86.69° and 82.98°). Papaya, watermelon, and dragon fruit showed a significant difference in hue angle values ( $p < 0.05$ ) with values of 47.70°, 27.22° and 5.52°, respectively.

Colour is one of the most relevant indicators in detecting fruit ripeness and is proven to be directly related to its intrinsic properties such as sugar levels (Meulebroeck, Thienpont & Ottevaere, 2016). It was found that chlorophyll gives the green colour to most vegetables, while carotenoids are generally responsible for the orange or yellow colour (Cömert, Mogol & Gökmen, 2020). The blue, purple and red colours of fruits and vegetables reflects to the anthocyanins in their tissues. Ong et al. (2006) reported that the hue angle values of jackfruit pulp increased significantly with maturity, associated with increased beta carotene content in the fruit pulp.

## Correlation between Antioxidants and Colour

Correlation between  $L^*$ ,  $a^*$ , and  $b^*$  values with TPC, ascorbic acid content, lycopene, and beta carotene content is shown in Table 3. The correlation between  $L^*$  values for selected local fruits is not significant ( $p > 0.05$ ) with

TPC, ascorbic acid content, lycopene, and beta carotene content. The value of  $a^*$  shows a significant positive correlation ( $p < 0.05$ ) with the content of ascorbic acid, lycopene, and beta carotene. The high  $a^*$  value in papaya and watermelon shows the high content of ascorbic acid, lycopene, and beta carotene. Therefore, the value of  $a^*$  can determine the level of content in antioxidant components based on the correlation. In addition, the  $b^*$  value only has a significant negative correlation ( $p < 0.05$ ) with TPC only and does not have a significant correlation ( $p > 0.05$ ) with other antioxidant components. This is also the same with the correlation of chroma value with antioxidant components where chroma value only has a significant negative correlation ( $p < 0.05$ ) with TPC only. So, the level of total phenolic content in fruits can also be identified through the value of  $b^*$  and chroma in the CIELAB colour space system. However, the hue angle value does not have a significant correlation with the antioxidant component.

Table 3 Correlation between  $L^*$ ,  $a^*$ , and  $b^*$  values with TPC, ascorbic acid content, lycopene, and beta carotene content.

	$L^*$	$a^*$	$b^*$	Chroma Value	Hue Angle (°)
<b>TPC</b>	-0.463 (0.082)	-0.507 (0.054)	-0.575 (0.025)*	-0.675 (0.006)*	-0.505 (0.055)
<b>Ascorbic acid</b>	-0.143 (0.612)	0.817 (<0.01)*	0.212 (0.447)	0.416 (0.123)	-0.037 (0.895)
<b>Lycopene</b>	-0.371 (0.170)	0.645 (0.009)*	-0.163 (0.563)	0.113 (0.690)	-0.365 (0.181)
<b>Beta carotene</b>	0.140 (0.618)	0.627 (0.012)*	0.231 (0.407)	0.363 (0.183)	0.279 (0.314)

Pearson's  $r$  (p value). \* $p < 0.05$ .

The study of Cömert, Mogol and Gökmen (2020) looking at the relationship between the colour of fruits and vegetables with one of the antioxidant capacities, proving that the colour of fruits and vegetables shows the presence of different pigmented components, as can be seen in this study. Their study showed that most fruits and vegetables with hue angle values above  $180^\circ$  and below  $20^\circ$ , have high antioxidant capacity ( $>10$  mmol TE/kg fresh weight). The study of Patras et al. (2011) also stated that carrots and tomatoes that are rich in carotenoids are in the same group as lettuce that is rich in chlorophyll, while onions, grapes and broccoli are characterized by low levels of antioxidant capacity. However, their study did not show any significant correlation between colour and antioxidant capacity. Thus, the  $L^*$  value is not sufficient to distinguish fruits and vegetables according to colour, because it only shows the level of brightness (Cömert, Mogol & Gökmen, 2020). It can also be seen that generally consumers prefer bright coloured (red, blue, or purple) fruits and vegetables because of their potential health benefits through antioxidant compounds in their structure. Hence, the relationship between the colour of fruits and vegetables and their nutritional composition becomes an important matter. This study relates the colour of selected fruits with antioxidant content with some limitations.

### Total Soluble Solids (TSS)

Based on the TSS content shown in Table 4, jackfruit showed the highest value of  $20.43^\circ$ Brix significantly ( $p < 0.05$ ) compared to papaya, wax apple, dragon fruit and watermelon. Compared to the study of Balamaze, Muyonga and Byaruhanga (2019), the TSS content of jackfruit in their study was slightly higher compared to this study (in the range of  $20.90 - 24.3^\circ$ Brix). Meanwhile, the TSS content of papaya in this study is slightly above the minimum required for papaya commercialization ( $10^\circ$ Brix) (Salinas, Hueso & Cuevas, 2021). The TSS of wax apple is comparable to a previous study on Thai wax apple ( $9.73^\circ$ Brix) (Mothina & Yapwattanaphun, 2017). Meanwhile, the TSS content recorded in dragon fruit in a previous study was between  $11.31$  to  $13.09^\circ$ Brix (Budiastra & Dzikri, 2022). In the same study, the TSS content is directly proportional to the fruit harvesting time where the TSS value increases with the age of the dragon fruit when harvested. On the other hand, the TSS content in watermelon was lower compared to this study (in the range of  $7.60 - 13.20^\circ$ Brix) (Yoo

et al., 2012). An accumulation of soluble solids occurs in fruits after harvest, because of physiological processes that lead to starch and pectin breaking down into smaller soluble molecules. Therefore, the high content of dissolved solids observed in jackfruit can be attributed to the high content of starch and pectin compared to other fruits.

Table 4 Content of total soluble solids (TSS) in selected local fruits.

Sample	TSS (°Brix)
Papaya	10.20±0.00 <sup>c</sup>
Wax apple	10.00±0.00 <sup>d</sup>
Dragon Fruit	10.23±0.00 <sup>b</sup>
Jackfruit	20.43±0.03 <sup>a</sup>
Watermelon	10.10±0.00 <sup>c</sup>

Mean ± standard deviation.

<sup>a-d</sup> Different alphabet indicates significant differences between groups within the same column ( $p < 0.05$ ).

## CONCLUSION

This study found that papaya had the highest content of ascorbic acid (31.14 mg/100 mL) and beta carotene (19.98 mg/100 mL) compared to the other local fruits studied. TPC was found to be more abundant in dragon fruit (179.99 mg GAE/100 g) while watermelon had the most lycopene content (36.55 mg/100 g). Through the analysis of colour determination, this study proved that the selected local fruits studied have red colour pigment that can be linked to the content of carotenoids (lycopene and beta carotene). This study also found a correlation between colour and specific antioxidant components, namely a positive correlation of red colour ( $a^*$ ) with the content of ascorbic acid, lycopene, and beta carotene ( $p < 0.05$ ), a negative correlation of yellow colour ( $b^*$ ) and chroma value with the amount phenolic content ( $p < 0.05$ ). In addition, jackfruit showed the highest value of TSS (20.43 °Brix). Hence, local fruits can be a good source of nutritional components, phytochemicals, and antioxidants.

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