PHYSICOCHEMICAL PROPERTIES OF THE TERAP FRUIT (*ARTOCARPUS ODORATISSIMUS* BLANCO)

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ABSTRACT

The genus *Artocarpus* belongs to the family of Moraceae with *Artocarpus altilis* (Breadfruit), *Artocarpus integer* (Chempedak) and *Artocarpus heterophyllus* (Jackfruit) being the common species in this genus. *Artocarpus odoratissimus* also known as Terap in Sarawak or Marang in English is found to be indigenous to the Borneo Island. This fruit is presently also being introduced to other Southeast Asian countries such as Philippines and Thailand. Terap is well-known for its sweet tasty flesh which is eaten raw and the seeds are normally steamed and used in some local dishes. The fruits are highly valued as a potential food source for local communities. However, their nutritional attributes and phytochemical properties are not fully explored particularly in Sarawak, Malaysia. Thus, the present study aims to evaluate the nutritional compositions and phytochemical properties of the *A. odoratissimus* fruit from Sarawak. Proximate analysis results obtained showed that the flesh had 75.90±0.75% moisture, 82.70±0.36% carbohydrate, 14.59±1.49% protein, 3.87±0.42% ash and 0.03±0.01% crude fiber. Terap fruit also possessed good mineral compositions with the trend of K > Ca > Na > Mg > P > Cu. Potassium was the major mineral component of the fruit ranging between 1237.16-1654.17 mg/100g. Terap is the sweetest fruit among all other *Artocarpus* species as fructose was found to be the most abundant sugar in the flesh (26.7±0.70 g/100 g) followed by glucose (25.38±0.45 g/100 g) and least amount being sucrose (4.38±0.21 g/100 g). Terap flesh was found to be an excellent source of vitamin B complex, with thiamine content (11.07±0.31 mg/100 g) being the highest. For the phytochemical attributes in Terap flesh, total phenolic content was 2.11-2.70 mg GAE/g, total flavonoid was 0.75-1.44 mg QUE/g and total antioxidant activity was 187.25-189.48 mg/mL. The present study supports the ethno-botanical uses of Terap by the local communities and the study sheds initial evidence on the potential for this fruit to be further explored and developed by nutraceutical and pharmaceutical industries, leading to enhancing the downstream application and product development of this indigenous fruit crop.

Keywords: Antioxidant, *Artocarpus odoratissimus*, indigenous, terap, marang

1. INTRODUCTION

Borneo is recognized as a land of diversity and rich heritage of flora as it is the widest island in the world. Sarawak, Malaysia, one of the parts in Borneo Island, is enriched with bountiful biodiversity consisted of approximately 3000 plant species (Soepadmo, 1995; Soepadmo & Saw, 2000). This tropical rainforest is abundant in diversity of beneficial indigenous plants and some of them are endemic species to the state of Sarawak. There are about 200 species are reported as endemic plants.

Generally, indigenous plant are fruits and vegetables that originate and naturally grow on the land or were introduced a long time ago from one place to another through natural processes or

human domestication (Abd Rahman, 2018). Indigenous plants have been exploited traditionally by various ethnics and indigenous people around the world. The knowledge on indigenous plants has been transferred over generations by the elders verbally thus local people gain benefits from its uses (Runi *et al.*, 2018). Local populace especially those living in the rural area highly depend on the indigenous plants to serve as good sources of nutrition, energy, minerals and medicine. Through exchanges of ethno-botanical knowledge and information among the communities in Sarawak, locals and tourists alike can now enjoy the goodness of many of these plants (Runi *et al.*, 2018).

Among these indigenous species, *Artocarpus odoratissimus* Blanco is one of the indigenous fruit species that is popular for its odour, hence gaining visibility in the local fruit industry. There have been increasing efforts made by several researchers to explore the potential of this fruit. *Artocarpus odoratissimus* species belongs to the genus *Artocarpus* from the Moraceae family. The synonyms of *A. odoratissimus* are *Artocarpus tarap* Becc., and *Artocarpus mutabillis* Becc. This fruit is known as Marang as its English name or Terap by the local communities in Sarawak and has various common names according to different regions and localities including *terap* (Malaysia), *pi-ien* (Bidayuh), *pingan* (Iban), and *keiran* (Kelabit). In other countries, the fruit is known as and *marang* (Sulu), *madang* (Lanao), *loloi* (Tagalog), and *khanun sampalor* (Thailand) (Subhadrabandhu, 2001). It is an indigenous crop to the Borneo Island states of Sabah and Sarawak (Malaysia), Kalimantan (Indonesia), and Brunei. Indigenous crops are defined as crops that are endemic and locally grown in a specific region (Haq, 2006). The plant is endemic to Borneo Island and also being cultivated at other countries such as Philippines (Soepadmo, 1995).

Artocarpus odoratissimus is an evergreen tree that is wild crafted and can be found in secondary forests. This mid-canopy tree can grow up to 40 m tall and has a diameter of 40-45 cm low buttresses trunk. The bark produces white sticky latex. The twigs are long, and has yellowish to reddish colour hair with 4-10 mm thickness (Lim, 2012). The fruit is large, with a length averaging about 16-17 cm, a diameter of approximately 13 cm, weighing almost 1 kg. The young fruit is green and turns yellowish brown as it ripens. The fruit shape is roundish oblong, covered with short, brittle spines. The flesh is white coloured, and has a strong aromatic smell with juicy flesh (Coronel, 1998; Lim 2012). The middle core of this fruit has flesh clinging on it, containing seed sized at 8 mm x 15 mm (Galang, 1955; Lim, 2012).

This entire tree and its parts have been found to be useful to the local consumers. The ripen fruit flesh are juicy, has a strong odour and aromatic taste which is suitable to be eaten raw (Tang *et al.*, 2013). Besides, the seeds of *A. odoratissimus* have a nutty flavour and can be consumed after it is roasted and boiled to soften the texture (Lim, 2012). Apart from the fruit, the roots are boiled to extract the water which is believed by the Ibans in Sarawak, Malaysia to cure diarrhea, while the leaves can treat venomous stings of centipedes and scorpions (Lim, 2012). These ethno-botanical features of *A. odoratissimus* as well as the nutritional values of this fruit have induced the interest to study this valuable fruit.

Due to the increasing demand for the fruit of *A. odoratissimus*, the state government of Sarawak, Malaysia believes that the fruit has great potential for commercialization. This is in line with the State's mission in popularizing indigenous crops for commercial cultivation, while tapping into the tremendous scope for accessing national and international markets. However, there has been limited documentation on the nutritional and phytochemical investigations of *A. odoratissimus* fruit particularly in Sarawak. Despite the potential importance of *Artocarpus odoratissimus* especially in its nutritional and pharmaceutical values, documented details on the nutrient and

phytochemical attributes are still lacking. Therefore, the objective of this study is to evaluate the nutritional compositions and phytochemical properties of the flesh of *A. odoratissimus*.

2. MATERIALS AND METHODS

2.1. Survey and sampling collection

The fruits of *A. odoratissimus* were collected and bought at the local market Pasar Utama Bintulu (3.1705° N, 113.0405° E), Bintulu, Sarawak, Malaysia. The fruits were collected from the months of June 2018 to January 2019. The chosen fruits were healthy and free from diseases and pests. The fruits were brought to the laboratory and immediately inspected and cleaned with distilled water to remove the debris.

2.2. Sample preparation

The fruits were cleaned and the flesh, seed, skin, and pedicel parts were separated. All the separated parts were divided into three divisions. Firstly, fresh samples were used directly for the determination of moisture content. Secondly, the oven dried samples were dried at 50°C until content weight were obtained and homogenized for analyses of proximate and mineral composition. The freeze dried samples were used for analysis of phytochemical compositions. All the processed samples were kept in an air-tight container prior to analyses.

2.3. Proximate composition analysis

The moisture content was determined by the method of oven drying based on AOAC (2000) official method 934.06. Samples weighing 2.0 g were cut into smaller pieces and spread evenly across a pre-weighed drying dish. Flesh samples were dried to a constant mass at 50°C. Ash content was determined by incinerating air dried samples in muffle furnace (method 930.05, AOAC, 2000). Crude fiber was determined in accordance to the (AOAC, 2000) method 993.19 by using Fibertec Hot Extraction Unit (FOSS Fibertec 2010 Hot Extractor). Crude protein was determined by the Kjeldahl method following the AOAC (2000) method 955.04. Soxhlet extraction was done via the Foss Tecator Soxtec 2055 Manual Extraction Unit for the determination of crude fat of *A. odoratissimus* based on the AOAC official method 920.39 Available carbohydrate was calculated according to (James, 1995) using the subtracting method. The calculation was performed based on the following formula:

Carbohydrate (%) = 100% – [Ash (%) + Crude protein (%) + Crude fat (%) + Crude fiber (%)

2.4. Mineral content analysis

Th mineral contents of *A. odoratissimus* in fruit parts for Potassium (K), Calcium (Ca), Sodium (Na), Magnesium (Mg), Phosphorus (P), Copper (Cu) and Ferum (Fe) were determined using atomic absorption spectrum (AAS) (AA800 Perkin-Elmer, Germany) according to the AOAC method 975.03 (AOAC, 1990).

Ash was used to extract the minerals. Two milliliters of concentrated HCl was added and left to evaporate on hot plate in a fume chamber. After the samples were totally evaporated, 10 mL of 20% HNO_3 was added and evaporated until the volume became half. The sample solutions were

then filtered using Whatman Paper No. 2 and marked up to 100 mL with distilled water. The extracted sample solutions were used for the analyses.

2.5. Vitamin analysis

The vitamin content in the flesh of *A. odoratissimus* fruit for vitamins A, B1 (thiamin), B2 (riboflavin), B3 (niacin), B5 (pantothenic acid), B6 (pyridoxine), B7 (biotin), B9 (folicacid), B12 (cyanocobalamin), D, E and K was determined according to the AOAC method 974.29 (AOAC, 2000). Vitamin C in the flesh was determined according to AOAC method 967.21. The flesh samples were dried at 45°C and grounded prior to analysis. Ascorbic acid was determined by the Indophenol titration method with a Vitamin C solution of known concentration as a standard. The samples were sent to the BP Food and Environment Industrial Testing Laboratory, Malaysia for determination of the other vitamin content.

2.6. Sugar analysis

The glucose, fructose and sucrose contents in A.odoratissimus flesh were determined using HPLC system according to AOAC method 923.09 (AOAC, 2000). The samples were dried at 45°C and grounded prior to analysis. The samples were sent to the BP Food and Environment Industrial Testing Laboratory, Malaysia for determination of the sugar content. The mobile phase for the determination of sugar content was 75% acetonitrile (HPLC grade) and 25% ultra-pure water. The sugar content was identified by comparing the retention time of standard and samples and further quantified by peak area measurement using software.

2.7. Phytochemical analysis

2.7.1. Determination of total phenolic content (TPC)

The total phenolic content in dried extracts of methanol obtained from freeze dried samples was determined spectrophotometrically using the Folin-Ciocalteu's reagent (Shukla *et al*., 2012). 1 mL methanolic solution of extract (1 mg/mL) or standard solution of gallic acid (10, 20, 40, 60, 80, 100 µg/mL) was added to 2.5 mL of 10% Folin-Ciocalteu's reagent dissolved in distilled water and incubated for 5 min. After the 5 min incubation, 2 mL of 7.5% Na_2CO_3 solution was added to the mixture, incubated in dark for 30 min at 24°C, and the absorbance was measured at 765 nm with an UV-VIS spectrophotometer. A Blank reagent containing 1 mL methanol, 2.5 mL of 10% Folin-Ciocalteu's reagent and 2 mL of 7.5% Na_2CO_3 solution was also prepared. The results were calculated using the calibration curve of gallic acid and the total phenolic content was expressed as milligrams of gallic acid equivalents per gram extract (mg GAE/g dried extract).

2.7.2. Determination of total flavonoid content (TFC)

The total flavonoid content was also determined spectrophotometrically at 510 nm with slight modifications (Zhishen *et al.*, 1999). 1 mL of methanolic solution of extract (1 mg/mL) or standard solutions of quercetin (10, 20, 40, 60, 80, 100 µg/mL) was added into 0.5 mL of 5% $NaNO_2$ solution and 0.5 mL of 10% $AlCl_3$ solution. After 5 min, 2 mL of 4% NaOH solution was added and incubated for 15 min at room temperature and the absorbance was measured against the blank at 510 nm with an UV-VIS spectrophotometer. A Blank reagent was prepared by adding the entire reagent without adding sample or standard. A calibration curve was constructed using

standard quercetin and the total flavonoid content was expressed as milligrams of quercetin equivalents per gram extract (mg QE/g dried extract).

2.7.3. Total antioxidant activity

- Ferric Reducing/Antioxidant Power Assay (FRAP)

  The FRAP assay was performed according to (Benzie & Strain, 1999) with slight modifications. The working FRAP reagent consisted of 10 mM 2,4,6-tripyridyl-s-triazine (TPTZ) solution, 20 mM $FeCl_3$.6H2O and 300 mM acetate buffer (pH 3.6) in a 1:1:10 ratio prior to use in water bath at 37°C. 100 µL of extract solution was mixed with 900 µL of FRAP reagent. The mixture was left to stand for an incubation period of 4 minutes at 37°C. After that, the reading of absorbance was taken spectrophotometrically at 593 nm against the blank. The calibration standard curve was determined using Trolox with standard series from 1 to 4 µg and the volume was made up to 300 µL with distilled water. FRAP values were calculated and expressed as milligrams of Trolox equivalent per gram extract (mg TE/g).

- Free - radical scavenging assay (DPPH)

  The scavenging acidity of the *A. odoratissimus* fruit extracts was determined using 2, 2-diphenyl-1-picrylhydrazyl (DPPH) as a free radical assay. Scavenging activity on DPPH was assessed according to the method reported by (Shukla *et al.*, 2012) with a slight modification. 1 mL methanolic solution of each extracts (20, 25, 50, 100, 150, 200 µg/mL) was added to 3 mL working solution of DPPH (0.1 mM DPPH in methanol) and incubated in the dark. After 30 min, the absorbance of all extracts were read at 517 nm with an UV-VIS spectrophotometer and compared to that of standard Trolox with similar concentrations. 1 mL of methanol with 3 mL working solution of DPPH served as blank. The % inhibition was calculated as:

  Inhibition = [(Absorbance of blank − Absorbance of sample or standard after 30 min) / (Absorbance of blank after 30 min)] x 100

  The EC50 value in methanol extracts of freeze dried samples and standard Trolox were calculated by plotting a graph of % inhibition versus concentration.

3. RESULTS AND DISCUSSION

3.1. Proximate content of *Artocarpus odoratissimus* flesh

Fruits have been a part of human diets over the years. They contain high water content, carbohydrates, sugars, vitamins, minerals and organic acids which are required by the body to function well (Onibon *et al.*, 2007). Apart from commercial fruits, indigenous fruits also possess ample nutrition which is useful for local consumers especially those from rural areas. The fruit of *A. odoratissimus* has always been used for its juicy flesh. The results of proximate compositions of *A. odoratissimus* fruits are presented in Table 1.

The proximate content of flesh was categorically represented as carbohydrate > moisture > crude protein > ash > crude fat > crude fibre. The present moisture content of flesh was slightly higher than the reported values (67.5-73.4%) by (Tang *et al.*, 2013) in Brunei. Relatively higher moisture content is important in fruits for their stability and quality. The flesh contained

14.59±0.19% of protein, indicating that this fruit can be an alternative source of protein for rural communities. The present protein values in flesh were relatively higher than the previous observation by (Tang *et al.*, 2013) with values of 1.31-1.51%.

For the flesh, the crude fat content in the present study was similar to the crude fat in *A. heterophyllus* (0.2%). Whereas flesh of *A. champeden* (2.4-3.5%) possessed higher crude fat content as compared to flesh of *A. odoratissimus* in this study. The amount of fats present in the flesh and seeds of *A. odoratissimus* is available for the use of the body to generate body cells, regulate normal body temperature and aid the body system in the absorption of vitamin A, D, E and K.

The present fiber content in the flesh was relatively lower (0.03%) than the reported values (0.9-1.13%) (Tang *et al.*, 2013). Crude fiber in the flesh of *A. champeden* (4.6-7.6%) and *A. heterophyllus* (5.6%) were relatively higher compared to flesh of *A. odoratissimus* as recorded in previous studies (0.90-1.13%) and the present (0.03±0.01%) study. Additionally, higher carbohydrate content was recorded in the flesh at the ranges of 82.27-83.41%. The carbohydrate content in the flesh was relatively higher compared to previous studies (12.0-25.2%) in *A. odoratissimus* and other *Artocarpus* species including *A. champeden* (16.2-28.3%) and *A. heterophyllus* (9.4-25.4%). The higher carbohydrate in the flesh shows that this fruit contains higher sugar compostion and can potentially serve as an energy source for consumers.

Table 1. Proximate constituents (%) of Artocarpus odoratissimus flesh and comparison with other commercial *Artocarpus* species

Species	Moisture	Ash	Crude protein	Crude fat	Crude fibre	Carbohydrate	Trend
A. odoratissimus	75.90±0.75 (74.65-77.23)	3.87±0.42 (3.03-4.30)	14.59±1.49 (13.13-17.51)	0.26±0.09 (0.10-0.40)	0.03±0.01 (0.02-0.04)	82.70±0.36 (82.27-83.41)	C > M > P > A > F > Fi
*A. odoratissimus**	67.9-73.4	0.6-0.8	1.31-1.51	-	0.90-1.13	12.0-25.2	M > C > P > Fi > A
*A. champeden***	62.3-73.4	2.5-3.9	4.9-5.8	2.4-3.5	4.6-7.6	16.2-28.3	M > C > Fi > P > A> F
*A. heterophyllus****	83	2.2	1.6	0.2	5.6	9.4-25.4	M > C > Fi >A > P > F

*(Tang *et al.*, 2013), **(Lim *et al.*, 2011), ***(Janick & Paull, 2008)

3.2. Minerals composition of *Artocarpus odoratissimus* flesh

Minerals are important constituents in the determination of nutritional value in the fruit. The value of macronutrients and micronutrients of the flesh are presented in Table 2. The edible portion of *A. odoratissimus* which is the flesh contains a relatively higher value of ash (3.03-4.30%). The ash content of the flesh confirms that it contains high mineral values. The *A. odoratissimus* fruits possess appreciable quantities of K, P, Na, Ca, Mg, and Cu which are useful for human health. The trend of nutrients in the flesh of *A. odoratissimus* was K > Ca > Na > Mg > P > Cu. However, the trend of the elements may vary even in similar *Artocarpus* species. *Artocarpus champeden* and *A. heterophyllus* were reported to have lower Na content than Ca in flesh (Lim *et al.*, 2011; Tiwari & Vidyarthi, 2015; Sy Mohamad *et al.*, 2019). The species composition and locality may also have effects on the nutritional attributes of the plant (Wardlaw, 2003).

As in many other fruits, K is the most abundant mineral in the A. odoratissimus fruit parts. In the edible portion of the fruit, the flesh contains high concentrations of K with 1210.40±28.00 mg/100 g. The K concentration in the present study was six times higher for the flesh than

the reported value for flesh (176-298 mg/100 g) by (Tang, 2013). This higher K content in *A. odoratissimus* fruit can potentially serve as a significant source of K which is vital in controlling blood pressure and body fluid balance (Wardlaw, 2003). K also is relatively important for heart health. Numerous studies have also reported the potential of K in reduction of blood pressure, thus mitigating the risks of other non-communicable diseases including hypertension, cardiovascular diseases and stroke (Whelton, 2014).

The second most abundant mineral content in *A. odoratissimus* fruit is Ca (916.81±23.70 mg/100 g). The fruit can provide appreciable amount of Ca content which is important for bone and teeth formation and strength, muscle contraction and blood clotting (Hadji, 2015). The Mg content in *A. odoratissimus* was found to be 150.93±2.78 mg/100 g. The values of Mg obtained from the present study for the flesh were comparatively higher than the reported study by (Tang *et al.*, 2013)which was 14.8-31.3 mg/100 g. Mg is an essential constituent for building a healthy diet for the body. The importance of Mg includes regulating optimum biochemical activity in human bodies and is required as a co-factor in enzymatic reactions (Schwalfenberg & Genuis, 2017).

The P level was recorded low in the fruit flesh. Phosphorus is known to be an essential element for the metabolic process and healthy bone development (Wardlaw, 2003; Penido & Ulon, 2012). The Na value obtained for the flesh was 182.33±15.53 mg/100 g. An adequate intake of Na is vital for cellular homeostasis and balancing body fluids (Maron *et al.*, 2015).

Cu was found in trace quantity in all parts of the *A. odoratissimus* fruit. The present study shows that Cu in the flesh was 0.89±0.03 mg/100 g. The concentrations of Cu in *A. odoratissimus* fruits were found to be within the limits of the recommended maximum level allowed in food based on the Malaysian Food Regulations (Akta Makanan, 1985) limit of 4.00 mg/ 100 g. No traces of Fe were found in the flesh of the fruit.

Table 2. Mineral composition (mg/100 g) of Artocarpus odoratissimus flesh

Mineral composition (mg/100 g)						References
K	P	Na	Ca	Mg	Cu	
1210.40±28.00 (1237.16-1654.17)	98.12±2.51 (93.15-101.15)	182.33±15.53 (68.46-184.91)	916.81±23.70 (586.80-1156.66)	150.93±2.78 (107.58-184.91)	0.89±0.03 (0.63-1.00)	Present study
176-298	-	1.15-1.70	0.48-1.35	14.8-31.3	0.39-0.59	[11]

3.3. Sugar composition and content in flesh of *Artocarpus odoratissimus*

Basically *A. odoratissimus* is the sweetest fruit of the *Artocarpus* genus. The sweet juicy flesh is a favourite for many people in Borneo Island. The flesh also consists of higher carbohydrate content (82.70±0.36%) which is related to higher sugar composition. The major source of energy comes from carbohydrate which can be further categorized into three main sugars. The three main sugars are sucrose, glucose and fructose which were all found to be the prime constituents in the flesh of *A. odoratissimus*. The sugar content of *A. odoratissimus* is presented in Table 3 and Figure 1. Quantitative measurements of sugar content influences total sweetness. In the sweetness category, fructose has been reported to be at least 1.73 times sweeter than sucrose (Hanover & White, 1993). From the analysis of the study, fructose was found to be the most abundant sugar composition in the flesh with a range of 26.7±0.70%. The fructose composition in this study was comparatively higher than reported values (6.9-13.7%) by (Tang *et al.*, 2013). The flesh consisted of higher fructose than the *A. heterophyllus* flesh which was 4.53% (Chowdhury *et al.*, 1997).

Fructose comprised the larger portion of total sugars ranging from 26.0-27.4 g /100 g followed by glucose ranging from 25.4-26.3 g/100 g. A positive correlation was observed for both fructose and glucose values.The fructose and glucose composition in *A. odoratissimus* flesh ranged ~47% and ~45% respectively while sucrose consisted of 8% of total sugars (Figure 1). Sugar compositions in other *Artocarpus* species varied from *A. odoratissimus*. A similar composition of sugar content was recorded in *A. heterophyllus*. On the contrary, the trend of sugar compositions in *A. champeden* showed that it possessed higher sucrose than the fructose and glucose contents. As for non-reducing sugar composition (sucrose), the level of sucrose in *A. odoratissimus* (4.38±0.21 g/100) was lower than in *A. champeden* (20.02±1.88 g/100 g). The trend of sugar content in *A. odoratissimus* for the present study was fructose > glucose > sucrose. A similar trend was reported for *A. odoratissimus* fruit sugar content by (Shahrir *et al.*, 2013) in Sarawak. Generally, the glucose/fructose ratio is the key indicator for determining the palatability of the fruit flesh (Kelebek *et al.*, 2011). In the *A. odoratissimus* fruits studied, the measured glucose/fructose ratio was 0.95 and this is in line with the reported ratio by (Tang *et al.*, 2013) in Brunei. This value is important to determine the correct amount of sugar accepted by our body whereby excess of fructose may cause fructose malabsorption.

Table 3. Sugar content (g/100 g) in flesh of *Artocarpus odoratissimus* and comparison with other commercial Artocarpus species

Species	Non-reducing Sucrose	Reducing		G/F ratio	Total sugar
		Glucose	Fructose		
A. odoratissimus	4.38±0.21 (4.60-5.00)	25.38±0.45 (25.40-26.30)	26.7±0.70 (26.00-27.40)	0.95	57.35±1.91 (56.00-58.70)
A. odoratissimus [11]	0.3-11.2	5.8-13.7	6.9-13.7	0.95	13.00-38.6
A. champeden [28]	20.02±1.88	5.52±0.46	6.12±0.28	0.90	31.66±2.48
A. heterophyllus [25]	1.49	2.06	4.53	0.45	8.08

Values are expressed as mean ± standard deviation and values in bracket are the range.

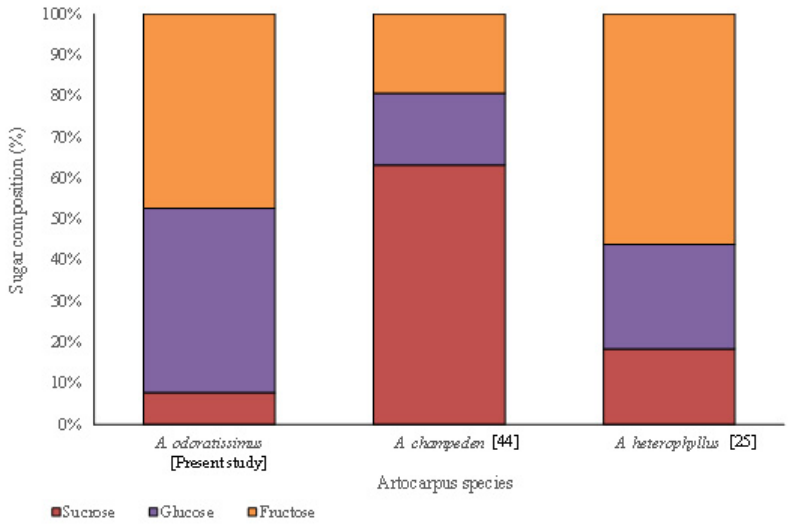

Figure 1. Sugar composition (%) in *Artocarpus* species

3.3. Vitamin composition in flesh of *Artocarpus odoratissimus*

The flesh of *Artocarpus odoratissimus* is an excellent vitamin source to the human diet especially in supplying the human body with B vitamins. This study shows that the flesh of *A. odoratissimus* consist predominantly of vitamin B1 (Thiamin) (11.07±0.31 mg/100 g), followed by vitamin B3

(Niacin) (0.93±0.06 mg/100 g), vitamin B9 (Folic acid) (0.50±0.00 mg/100 g) and the least amount of vitamin B2 (Riboflavin) (0.27±0.06 mg/100 g) and vitamin C (0.33±0.06 mg/100 g). This trend and composition were different from other *Artocarpus* species where higher vitamin C has been recorded in *A. champeden* (90.33 mg/ 100 g) (Abdullah *et al*., 2013) and *A. heterophyllus* which is rich in Vitamin A (175-540 mg/100 g) (Arora & Parle, 2016). As for other vitamins analysed such as vitamin A, B5, B6, B7, B12, D, E, and K, the values were not detected in the flesh of *A. odoratissimus*. This is the first documentation of vitamin composition in *A. odoratissimus* flesh. The variation of vitamin content may be due to the flesh colour and composition of the *Artocarpus* species fruit. Basically the flesh of *A. champeden* and *A. heterophyllus* are yellow while *A. odoratissimus* is white.

Table 4. Comparison of vitamin contents (mg/100 g) in the flesh of Artocarpus odoratissimus to other commercial Artocarpus species

Vitamins	*Artocarpus odoratissimus* (Present study)	*Artocarpus champeden**	*Artocarpus heterophyllus***
Vitamin A	n.d.	-	175-540
Vitamin B1 (Thiamin)	11.07±0.31 (10.80-11.40)	-	0.03-0.09
Vitamin B2 (Riboflavin)	0.27±0.06 (0.20-0.30)	-	133
Vitamin B3 (Niacin)	0.93±0.06 (0.90-1.00)	-	-
Vitamin B9 (Folic acid)	0.50±0.01 (0.50-0.52)	-	-
Vitamin C	0.33±0.06 (0.30-0.40)	90.33 ± 28.01	7.0-10.0

Values are expressed as mean ± standard deviation and values in bracket are the range
***Abdullah *et al*., 2013; **Tiwari & Vidyarthi, 2015; Arora & Parle, 2016**

3.4. Phytochemical properties of different parts of the Artocarpus odoratissimus fruit

3.4.1. Total phenolic content (TPC) and total flavonoid content (TFC)

Total phenolic content of *A. odoratissimus* was determined by the reaction of oxidation-reduction using Folic-Ciocalteu reagent. The values of TPC were expressed in milligrams gallic acid equivalent to 1 gram dried sample (mg GAE/ g). The TPC of the fruit was 2.35±0.18 mg GAE/ g. The previous study by (Bakar *et al*., 2015) reported that a higher value of TPC was found in the skin (42.38±0.20 mg GAE/ g) and the least value of TPC was found in the flesh (3.53±0.33 mg GAE/ g). The results of both studies support that the A. odoratissimus fruit is rich in phenolics that might contribute to high antioxidant activities (Jagtap & Bapat, 2010). Thus, as the fruits reach maturity stage, the amount phenolic also increases (Duenas *et al*., 2009).

TFC content observed in the flesh of the fruit was 1.14±0.20 mg QUE/g. The TFC content in the skin part was reported by (Bakar *et al*., 2015) to be 36.78±0.28 mg GAE/ g) which is higher than in the flesh (1.23±0.09 mg GAE/g). Bakar *et al.* (2009) reported that bambangan also possessed a high phytochemical content in the skin and seed compared to the flesh part. Soong and Barlow (2004) also stated that the by-product of *A. heterophyllus* (jackfruit) such as the skin and seed showed higher phytochemical contents compared to the flesh of the fruit. Flavonoids have been reported for their effectiveness against cancer, and the ability to act as cardio protective agents, antioxidants, possess antibacterial properties, and protect the skin from UV radiation. It also has a great potential for application in pharmaceutical and medical industries (Ahmed *et al*.; Andreu *et al*., 2018; Meng *et al*., 2018).

3.4.2. Ferric Reducing/Antioxidant Power Assay (FRAP) properties

The FRAP value in the flesh was 40.84±0.12 µM TE/g. The trend of the previous study by Bakar *et*

al. (2015) report that the skin had higher FRAP properties which is 378.93±20.25 µM/g, followed by the seed (68.06±2.93 µM/g) and the flesh (17.92±0.74 µM/g).

3.4.3. DPPH properties

DPPH assay is used to analyse the potential of *A. odoratissimus* fruit extracts to scavenge free radicals. The antioxidant activity of fruit extracts of *A. odoratissimus* is presented in Table 5. The free-radical scavenging activity was measured through conversion of DPPH into stable DPPH-H formation that occur after the hydrogen radical or electron was accepted (Hatano, 1995). The present study shows that the sample extracts generated antioxidant colour from pale purple to dark purple due to the ability of hydrogen to donate electron. The present result indicated that A. odoratissimus fruit possess free radical scavenging activity. A lower EC50 value shows that the fruit extracts have greater antioxidant activity. The results of the present study are in line with the reported study.

Table 5. TPC, TFC, FRAP and DPPH properties of Artocarpus odoratissimus flesh

TPC (mg GAE/g)	TFC (mg QUE/g)	FRAP(µm TE/g)	DPPH (mg/mL)	References
2.35±0.18 (2.11-2.70)	1.14±0.20 (0.75-1.44)	40.84±0.12 (40.66-40.79)	188.48±0.65 (187.25-189.48)	Present study
3.53±0.33	1.23±0.09	17.92±0.74	-	[30]

Values are expressed as mean ± standard error (n=4) and values in bracket are the range

4. CONCLUSIONS

Artocarpus odoratissimus is an economically important indigenous crop that highly possesses nutritional and medicinal benefits. The demand for this fruit among consumers has increased largely due to its excellent and aromatic flavor and various ethnobotanical attributes. The increase in demand opens up opportunities for commercialization and is in line with the Sarawak state's mission in popularizing indigenous crops for commercial cultivation while tapping into the tremendous scope for access into national and international markets. The findings show that the fruit exhibited good proximate compositions. The flesh (82.70±0.36%) of *A. odoratissimus* contained high carbohydrate in line with a high total soluble solid value of 18.13°Brix. *Artocarpus odoratissimus* contained good mineral constituents with a varied trend of minerals according to the fruit parts. The trend was K > Ca > Na > Mg > P > Cu. Potassium was the major mineral component found in the fruit (905.61±18.89 mg/100g). The flesh of *A. odoratissimus* contained the highest level of sweetness as compared to other *Artocarpus* species. There were three main sugars observed to be present in this fruit which were fructose, glucose and sucrose with the total sugar content of 57.35±1.91 g/100 g. The flesh predominantly consist of reducing sugars with fructose at 26.7±0.7 g/100 gfollowed by glucose (25.38±0.45 g/100 g), while sucrose was the lowest amount of non-reducing sugars4.38±0.21 g/100 g. The flesh was also rich in vitamin B complex particularly vitamin B1, thiamine (11.07±0.31 mg/100 g).

From a broader perspective, the information gathered in this study highlights the potential uses of indigenous fruit crops such as Terap in food and health sectors due to its nutritional and phytochemical attributes. In future, more studies and research can be conducted to provide detailed information and documentation on the phytochemicals and physicochemicals of *A. odoratissimus*. Therefore, this could enhance the downstream application or product development of the *A. odoratissimus* fruit.

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