Phytochemical content and antioxidant properties of Bornean wild durian from Sabah

N Juarah¹, N Surugau², N A Rusdi ¹, M F Abu-Bakar³, M Suleiman ¹

¹Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Jalan UMS, 88400, Kota Kinabalu, Sabah, Malaysia
²Faculty of Science and Natural Resources, Universiti Malaysia Sabah, Jalan UMS, 88400, Kota Kinabalu, Sabah, Malaysia
³Faculty of Applied Science and Technology, Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Johor, Malaysia

*Corresponding author: nurizzahjuarah@gmail.com

Abstract. Borneo is the centre of diversity of the genus Durio (family: Malvaceae; local name: durian). Durian fruit is known to contain high amounts of the major bioactive compounds (as antioxidants) such as anthocyanins, carotenoids, polyphenols and flavonoids. Two types of wild durian species, namely Durio kinabaluensis Kosterm. & Soegeng (durian tupoloh) and Durio oxleyanus Griff. (durian sukang) were studied. The 80% methanolic extracts of flesh, seed and peel (mesocarp and exocarp) were analysed for antioxidant activities, total phenolic and total flavonoid content. The antioxidant activities were determined using three parameters; 2,2-diphenyl-1-picrylhydrazyl radical assay (DPPH), 2,2′-Azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) radical cation assay, and Ferric reducing antioxidant power assay (FRAP). Durio kinabaluensis mesocarp extract displayed the highest antioxidant properties and total phenolic content. The non-edible parts of both durians (seed and peel) exhibited higher phytochemical contents and antioxidant properties compared to the flesh parts. This data may contribute to the pharmaceutical applications, health benefit information of wild durians and helps in popularising the potential of these fruits in international markets and ultimately protects them from extinction.

1. Introduction
Durian is one of the unique fruits to Southeast Asia [1] where the genetic centre of the genus Durio is in Borneo. A total of 19 species are distributed and some minor species are cultivated on a small scale [2]. Out of 19 species found in Borneo, 14 durian species are found in Sabah [3]. Durio kinabaluensis Kosterm. & Soegeng is locally known as “durian tupoloh” is adapted to high altitude, grown from the foothills of the Crocker Range and Mount Kinabalu, mainly outside park boundaries [4]. This species also called as “durian kinabalu” and endemic in Sabah. The information on its nutritional and health benefits are yet to be reported [4]. While Durio oxleyanus Griff., locally known as “durian sukang” in Sabah [4] or “kerantongan” in Indonesia [3], is indigenous in Borneo, Peninsular Malaysia and Sumatra [4]. This species grows in lowland mixed dipterocarp forest [4].

Malaysian fruit resources include both cultivated and wild species [5]. The widely cultivated durian species is D. zibethinus. These species have been studied and reported to have high potential sources of antioxidants [1] and analysed for its volatile compositions using gas chromatography-mass spectrometry [6]. Besides that, the phytochemical contents and antioxidant capacity of different parts
Durian contains a high amount of phenolic compounds such as phenolic acids, flavonoids [15], anthocyanins [8], and other bioactive components such as carotenoids [16]. These phytochemicals contribute to several biological properties such as anti-inflammatory, antioxidant and antimicrobials [17]. The durian’s leaf and root were traditionally used to treat skin diseases and swellings [18]. Other than that, the durian’s flesh from several durian cultivars from Malaysia, Thailand and Indonesia were reported to have high folate content, which can be used as natural sources of folate supplements in healthy diet [19]. A review on durian fruits of *D. zibethinus* reported that the fruits could treat infertility in polycystic ovarian syndrome (PCOS). Thus, durian can be a good source of medicinal compounds which can be used in medicinal applications.

Borneo offers a huge diversity of wild edible underutilised fruits that are yet to be explored and commercialized. A few of this underutilised fruit have been investigated and now known to provide health benefits due to their phytochemicals and antioxidants contents [9]. However, scientific data about the health benefits of most of the wild fruits in Borneo is lacking. Thus, the objectives of this work were to determine the phytochemical content (total phenolic and total flavonoid content) and the bioactivity assessment based on the DPPH, ABTS and FRAP assay on *Durio kinabaluensis* and *D. oxleyanus*. To the best of our knowledge, this is the first paper presenting the phytochemical contents and antioxidant properties of these two wild fruits.

2. Materials and methods

2.1. Sample collection and preparation

The durian fruit season in Malaysia normally starts from June until August. The most ideal for durian production is when the annual rainfall exceed 2000 mm with a short dry weather period [20]. Thus, the fruits of *D. oxleyanus* as shown in Figure 1(a) and (b) was collected on August 14, 2019 at 6° 07’ 60.00” N, 116° 15’ 60.00” E. *D. kinabaluensis* as shown in Figure 2(a) and (b) was collected on August 23, 2019 at 5° 39’ 0” N, 117° 07’ 0” E. The specimens were identified by Mr Joel Bin Dawat from the Systematic Botanic Section, Sepilok Forest Research Centre, Sabah (5° 52’ 26.3” N, 117° 56’ 59.1” E). The specimens are in the process of depositing in BORNEENSIS (BORH), Universiti Malaysia Sabah, Malaysia. The fruits of *D. oxleyanus* are difficult to open as it has harder, and thick peel as compared to *D. kinabaluensis*. *D. oxleyanus* fruit has greenish peel while *D. kinabaluensis* has yellowish peel. The durian fruits were cleaned and separated into flesh, seed and peel (mesocarp and exocarp). The samples then freeze-dried for 1 week and grounded using waring blender (Waring, Japan) to get fine powders. The ground samples were stored in a freezer at temperature of -80 °C until used.
Figure 1. Durio oxleyanus. (a) Long with slightly curved green to yellowish spine, (b) Pale yellow flesh covering the golden-brown seeds.

Figure 2. Durio kinabaluensis. (a) Slightly lobed, yellowish conical spine, (b) Creamy white to pale yellow flesh, covering the light brown seeds.

2.2 Sample extraction
One gram of the ground samples (flesh, seed, exocarp and mesocarp) were extracted using 80% of methanol (HmbG, Germany) in 60 ml amber vials with a ratio of 1:10. The vial then agitated on an orbital shaker (200 rpm) for 24 hours. The sample mixture was filtered using filter paper (Whatman No. 5). The supernatant fluid was decanted into a clear vial. The vials containing the extracts then placed in a small black storage container and stored in a freezer (-80 °C). The experiments were carried out in a dark with a minimum presence of light. The percentage yield was calculated based on the equation (1)

\[
\text{\%} = \left( \frac{\text{Weight of the extract (mg)}}{\text{Weight of the sample (1000 mg)}} \right) \times 100
\]  

(1)

2.3 Total phenolic content (TPC)
Folin-Ciocalteu’s method [12] with a slight modification was performed in determining the content of total phenolic compounds in durian samples. The crude extracts or gallic acid (10 µl) were mixed with Folin-Ciocalteu reagent and Na2CO3 solution in the ratio of 2:15:15. The mixture was left for 90 minutes in the dark and the measurement was taken using microplate reader (Thermo Scientific, Sweden) at 725 nm. The results were expressed as mg gallic acid equivalent in 1 g of sample (mg GAE/g) as shown in equation (2).
Gallic acid equivalent (mg/g) = C1 × V/m

Where C1 = reading from the standard curve (mg/ml), V = extract volume (ml) and m = weight of extract (g)

2.4 Total flavonoid content (TFC)
The colourimetric assay [12] was performed to determine the total flavonoid in the sample extracts with quercetin as the standard. The extract or quercetin (25 µl) was mixed with distilled water, 5% NaNO2, 10% of AlCl3 and 1 M solution of NaOH. The measurement at 510 nm was taken using a microplate reader (Thermo Scientific, Sweden). The standard curve of quercetin was established using several concentrations (0.4 – 0.05 mg/ml). The quercetin equivalent was calculated based on the equation (2). The final results were expressed as mg QE/g sample.

2.5 Antioxidant assessment based on free radical scavenging method (DPPH)
The scavenging activity of the extracts was estimated using of 2,2-diphenyl-1-pycrol-hydrazil (DPPH) as a free radical [13]. The sample extracts or standard were mixed with 0.1 mM of 80% methanolic DPPH solution (Merck, Germany) in the ratio of 1:2 in the dark. After 30 minutes, the absorbance was measured at 519 nm using a microplate reader (Thermo Scientific, Sweden). The percentage of inhibition of the DPPH radical was calculated according to equation (3). The results were expressed as IC50 value (the concentration of sample that able to scavenge 50% of the DPPH free radical). A standard curve of Trolox established and the results were expressed as mg TE/g.

\[
\% = 1 - \left( \frac{\text{Sample reading} - \text{Empty sample reading}}{\text{DPPH reading}} \right) \times 100
\]

2.6 ABTS•⁺ decolourization assay
ABTS assay was performed by reacting the sample with ABTS radical cation [13]. The ABTS working solution was prepared by reaction between 15 ml of ABTS solution (7.4 mM) with 264 µl potassium persulfate (2.6 mM) and left for 12 hours in the dark. The working solution was diluted to get an absorbance of 0.7 ± 0.02 units at 734 nm. The sample extracts or standard was mixed with the working solution in the ratio of 1:2 in the dark. After 30 minutes, the absorbance was taken using a microplate reader (Thermo Scientific, Sweden) at 734 nm. The percentage of scavenging was calculated based on equation (3). The graph of percentage against concentration for each of the extracts was constructed to get the IC50 value (the concentration of sample that scavenge 50% of the radical). A standard curve of Trolox was constructed using several concentrations. The results were expressed as mg Trolox equivalent in 1 g of dried sample (mg TE/g).

2.7 Determination of ferric reducing antioxidant potential (FRAP)
The FRAP assay was conducted according to [21] with slight modification. FRAP reagent was freshly prepared on the day of assay. The working FRAP reagent was produced by mixing 300 mM acetate buffer (pH 3.6), 10 mM 2,4,6-tris (1-pyridyl)-5-triazine (TPTZ) solution, and 20 mM FeCl3.6H2O in the ratio of 10:1:1, respectively. The sample extracts (20 µl) or Trolox were mixed with the FRAP reagent (180 µl) in the dark. After 30 minutes, the absorbance was taken using microplate reader (Thermo Scientific, Sweden) at 593 nm. A standard curve of trolox was constructed (0.02, 0.04, 0.06, 0.08, 0.1 mg/ml). The results were expressed as mg TE/g sample.

2.8 Statistical analysis
All of the analysis was done in triplicates. All results were reported as mean ± standard deviation using Statistical Product and Service Solutions (SPSS) software version 17.0. The data were analysed by analysis of variance (ANOVA) with Least Significant Difference (LSD) and Duncan Test was conducted to identify the significant difference between parts of the durian fruits (p < 0.05).
3. Results and discussion

3.1. Extraction yield, total phenolic and flavonoid content present in different parts of durian fruit

Based on the sample extraction, the highest percentage yield was found in the flesh of *D. kinabaluensis* and *D. oxleyanus* with 45.5 and 39.8 %, respectively. Meanwhile, the lowest percentage yield was found in mesocarp of *D. kinabaluensis* with 7.1 % (Figure 3).

The phenolic and flavonoid compounds have been reported to contribute to the antioxidative properties of fruits due to their hydroxyl group [3, 5, 6]. Based on the Figure 4, the phytochemical contents of both durian fruits were in the range from 205.16 to 3.86 mg GAE/g in total phenolic content while 376.93 to 0.28 mg QE/g in total flavonoid content. The highest total phenolic content was found in the mesocarp of *D. kinabaluensis* followed by the exocarp of *D. oxleyanus* with 205.16 ± 11.61 and 161.03 ± 5.97 mg GAE/g sample respectively. The highest total flavonoid content was found in exocarp of *D. oxleyanus* with 376.93 ± 21.58 mg QE/g, followed by 210.52 ± 18.30 mg QE/g of *D. kinabaluensis*’s seed.

There were significant differences in TPC and TFC values between the outer layer (exocarp) and the inner layer (mesocarp) of both durian peel. Meanwhile, the lowest phenolic and flavonoid contents were found in both durians’ flesh with 5.04 ± 0.07 mg GAE/g and 0.45 ± 0.08 mg QE/g in *D. oxleyanus* and 3.86 ± 0.078 mg GAE/g and 0.45 ± 0.08 mg QE/g in *D. kinabaluensis*.

The previous research on methanolic extracts of the flesh of *D. kutejensis* and *D. zibethinus* reported on the lower TPC with 1.83 and 1.68 mg GAE/g, respectively [9]. Low TPC and TFC also stated on the methanolic extracts of *D. zibethinus*’s flesh (monthong) with 4.3 mg GAE/g and 1.7 mg CE/g [22]. Another research had also reported on the total phenolic and total flavonoid content of ethanolic extract for the peel of two *D. zibethinus* cultivars (durian medan and monthong). Both durians’ peel displayed high TPC and TFC with the value of 245.38 mg GAE/g and 472.80 mg rutin/g for durian medan while 148.34 mg GAE/g and 310.30 mg rutin/g for durian monthong [12].
Figure 4. Phytochemical contents in different parts of durian fruit.

Notes: Data presented in mean ± standard deviation with n=3, different letters showed there is significant different at P < 0.05 between durian’s parts in total phenolic and total flavonoid content.

3.2. Antioxidant activity of wild durian fruits

The mesocarp of *D. kinabaluensis* had the highest scavenging activity against DPPH and ABTS radicals as it had the lowest concentration to scavenge the radicals (12.23 ± 0.21 and 11.60 ± 1.27 µg/ml, respectively). It was followed by the seed of *D. kinabaluensis* which have IC$_{50}$ of 20.37 ± 0.40 and 10.00 ± 0.60 µg/ml in scavenging DPPH and ABTS radicals (Table 1). Meanwhile the exocarp and the seed of *D. oxleyanus* showed high antioxidant activity compared to its mesocarp and flesh with IC$_{50}$ value of 23.00 ± 0.50 and 27.87 ± 0.45 µg/ml in DPPH assay and 12.40 ± 1.31 and 16.43 ± 1.40 µg/ml in ABTS assay. The flesh from both *D. kinabaluensis* and *D. oxleyanus* showed the lowest antioxidant activity as they had a high amount of concentration needed to scavenge 50% of the radicals which were 3982.30 ± 300.84 and 2079.83 ± 39.99 µg/ml, respectively.

There were several studies reported on the highest amount of the antioxidant activities in the non-edible parts of the fruits compared to their flesh. For example, the seed and kernel of *Artocarpus odoratissimus* and *Mangifera pajang* had a high antioxidant capacity compared the flesh parts [21]. The peel and the seed extracts from several *Artocarpus* species had higher scavenging activity than pulp extracts [23] and the seed of *Ceri Terengganu* had higher antioxidant properties compared to its flesh [24]. The ethanolic extract of *D. zibethinus*’s seed and the peel exhibited higher antioxidant properties in DPPH assay compared with the leaves with IC$_{50}$ of 44.17 and 54.14 mg/l, respectively [14].

| Table 1. The IC$_{50}$ of sample parts and positive controls in scavenging DPPH and ABTS radical. |
| --- |
| Durian species and standards | Sample parts | IC$_{50}$ DPPH (µg/ml) | IC$_{50}$ ABTS (µg/ml) |
| --- | --- | --- | --- |
| *D. oxleyanus* (Sukang) | Flesh | 3982.30 ± 300.84$^a$ | 2079.83 ± 39.99$^a$ |
| | Seed | 27.87 ± 0.45$^c$ | 16.43 ± 1.40$^c$ |
| | Mesocarp | 40.70 ± 1.90$^d$ | 19.50 ± 0.55$^f$ |
| | Exocarp | 23.00 ± 0.50$^e$ | 12.40 ± 1.31$^e$ |
| *D. kinabaluensis* (Tupoloh) | Flesh | 3441.10 ± 138.71$^b$ | 2757.03 ± 560.50$^b$ |
| | Seed | 20.37 ± 0.40$^e$ | 10.00 ± 0.60$^f$ |
| | Mesocarp | 12.23 ± 0.21$^f$ | 11.60 ± 1.27$^f$ |
| | Exocarp | 60.70 ± 5.32$^g$ | 81.10 ± 2.89$^d$ |
| Trolox | - | 8.44 ± 0.43 | 7.47 ± 0.90 |
Ascorbic acid 8.7 ± 0.53

Notes: Data presented in mean ± standard deviation with n=3, different letters showed there is significant different at P < 0.05.

The FRAP assay is based on the ability of the antioxidants in the extract to act as reductant by donating electron to reduce ferric iron (Fe³⁺) to ferrous iron (Fe²⁺). Based on the Figure 5, the mesocarp of *D. kinabaluensis* showed the highest FRAP value compared other sample parts, followed by *D. kinabaluensis*’s seed, *D. oxleyanus*’s exocarp, seed and mesocarp, *D. kinabaluensis*’s exocarp, *D. oxleyanus*’s flesh and *D. kinabaluensis*’s flesh (Figure 5).

The previous research stated that there was a positive correlation between the phenolic compounds and the flavonoids present in the extracts with its antioxidant capacity [18, 19, 20]. In this study, the non-edible parts from both *D. kinabaluensis* and *D. oxleyanus* had higher antioxidant activities compared to their flesh part. This might be due to their high total phenolic and flavonoid content. Phenolic compounds are secondary metabolites involved in the defence system of the plant against pest, predators, and microorganisms [17, 22]. Thus, the high phenolic compounds found in the non-edible parts of durian fruits may occur due to the production of non-essential secondary metabolites for self-protection. Other than antioxidants, phenolic compounds also function as antimicrobial agents. For example, tannic acid, epigallocatechin gallate, rutin, and eugenol showed high antibacterial activity against *Staphylococcus epidermidis* and *Pseudomonas aeruginosa* which can be used as supplements in antibiotic application [29].

![Figure 5](image-url)  

**Figure 5.** Antioxidant properties of different parts of *D. oxleyanus* and *D. kinabaluensis*.

Notes: Data presented in mean ± standard deviation with n=3, different letters showed there is significant different at P < 0.05 between durian’s parts in DPPH, ABTS and FRAP assay.

All sample result was expressed in mg TE/g sample.

The non-consumable parts of durian such as the seed and peel are usually considered as waste products. Thus, researchers have been interested in studying the potential use of durian by-products to improve environmental concern and waste management. There are several studies reported on the potential application of non-edible parts of durian. The natural biopolymer from *Durio zibethinus*’s seed has been proven effective to be used as nutrient medium and stabilizer for spray dried probiotic...
bacteria, *Lactobacillus plantarum*. This is due to the presence of several important components such as polysaccharides, amino acids and fatty acids [30]. The preliminary works on the potential use of durian rind as an alternative raw non woody-based material for pulp and paper industry were also reported [31]. Other than that, the incorporation of carboxymethyl cellulose extracted from the durian rind can be used as a blending agent to improve the properties of rice starch-based film [32] and the potential of durian peel as a sorbent to remove acid dye were also reported [33].

4. Conclusion

In this paper, 80% of methanolic extracts have been analysed for phytochemicals content and antioxidant activities. The mesocarp and seed of *D. kinabaluensis* may contribute to the potential sources of natural antioxidants due to high phytochemicals (phenolic and flavonoid contents) and high antioxidant properties. The findings in this study might help to promote the fruits’ potential in nutraceutical and food application. The phenolic compounds from these byproducts can be used as functional food ingredients or to be used as additional supplements for health benefits. Since the phenolic content was found higher in the peels, identifying the phytochemicals could also help in the pest management strategies. However, more research needed to be done on the potential of the components in the durians non-edible parts to be applied in various products. Investigations on anticancer properties and phytochemical profiling of wild durian in Borneo are in progress.

5. Acknowledgements

The authors would like to acknowledge and express gratitude to Universiti Malaysia Sabah for providing the grant research on phytochemicals, antioxidant and anticancer properties of wild durian in Borneo, NIC (SDN 0050). Thanks also to Sabah Biodiversity Council for giving the access license certification to collect and conduct research on selected durian fruits in Sabah and Madam Andi Maryani A Mustapeng from Systematic Botanic Section, Sepilok Forest Research Centre for assisting in the identification of durian samples. The authors are thankful to the Faculty of Science and Natural Resource and Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Malaysia for providing laboratory facilities and technical assistance during this study.

References

[1] Ashraf M A, Maah M J and Yusoff I 2010 Estimation of antioxidant phytochemicals in four different varieties of durian (*Durio zibethinus* Murray) fruit *Middle-East J. Sci. Res.* 6 465-471

[2] Kanzaki S, Yonemori K, Sugiura A and Subhadrabandhu S 1998 Phylogenetic relationships of the common durian (*Durio zibethinus Murray*) to other edible fruited *Durio* spp. by RFLP analysis of an amplified region of cpDNA *J. Hortic. Sci. Biotechnol.* 73 317–321

[3] Reksodihardjo W S 2016 The species of *Durio* with edible Fruits *Econ. Bot.* 16 270–282

[4] Lim T K 2016 *Edible Medicinal and Non-Medicinal Plants vol 1* (New York: Springer) pp 556-563

[5] Choo K 1995 Collection and evaluation of under-utilized tropical and subtropical fruit tree genetic resources in Malaysia diversity of under-utilized fruit tree species in Malaysia in *JRCAS International Symposium Series* 27–38

[6] Chin S T, Nazimah S A H, Quek S Y, Man Y B C, Rahman R A and Hashim D M 2007 Analysis of volatile compounds from Malaysian durians (*Durio zibethinus*) using headspace SPME coupled to fast GC-MS *J. Food Compos. Anal.* 20 31–44

[7] Evary Y M, Nugroho A E, and Pramono S 2019 Comparative study on DPPH free radical scavenging and alpha-glucosidase inhibitory activities of ethanolic extracts from different parts of durian plant (*Durio zibethinus murr.*) *Food Res.* 3, 463–468

[8] Arancibia-Avila P, Toledo F, Park Y S, Jung S T, Kang S G, Heo B G, Lee S H, Sajewicz M, Kowalska T and Gorinstein S 2008 Antioxidant properties of durian fruit as
influenced by ripening *LWT - Food Sci. Technol.* 41 2118–2125

[9] Khairul Ikram E H, Khoo H E, Mhd Jalil A M, Ismail A, Idris S, Azlan A, Mohd Nazri H S, Mat Diton N A and Mohd Mokhtar R A 2009 Antioxidant capacity and total phenolic content of Malaysian underutilized fruits *J. Food Compos. Anal.* 22 388–393

[10] Chingsuwanrote P, Muangnoi C, Parengam K, and Tuntipopipat S 2016 Antioxidant and anti-inflammatory activities of durian and rambutan pulp extract *Int. Food Res. J.* 23 939–947

[11] Aruan D G R, Barus T, Haro G and Simanjuntak P 2019 Toxicity and antioxidant activities of extract of n-hexane, H2O, and ethyl acetate from the leaves of durian, *Durio zibethinus L.* *Rasayan J. Chem.* 12 947–950

[12] Muhtadi M and Ningrum U 2019 Standardization of durian fruit peels (*Durio zibethinus Murr.*) extract and antioxidant activity using DPPH method *Pharmaciana* 9

[13] Li Wang X L 2014 Antioxidant activity of durian (*Durio zibethinus Murr.*) shell in vitro *Asian Journal of Pharmaceutical and Biological Research* 3 1713–1718

[14] Gabule Ang A M, Reyes Nalda C M D and Sabejon S E 2018 Brine shrimp lethality and antioxidant activity of the leaf, rind and seed ethanolic extracts of *Durio zibethinus L.* *Asian J. Biol. Life Sci.* 7 105–111

[15] Venkatesh P, Hariprasat K, Soumya V, Francis M P, and Sankar S 2010 Isolation and aphrodisiac screening of the fruits of *Durio zibethinus* Linn *Asian J. Biol. Sci.* 3 1-17

[16] Wisutiamonkul A, Promdang S, Ketsa S and Van Doorn W G 2019 Carotenoids in durian fruit pulp during growth and postharvest ripening *Food Chem.* 180 301-305

[17] Metsamuuronen S and Siren H 2019 Bioactive phenolic compounds, metabolism and properties: a review on valuable chemical compounds in Scots pine and Norway spruce 3

[18] Husin N A, Rahman S, Karunakaran R and Bhore S J 2018 A review on the nutritional, medicinal, molecular and genome attributes of Durian (*Durio zibethinus L.*), the King of fruits in Malaysia *Bioinformation*. 14 265-270

[19] Striegel L, Chebib S, Dumler C, Lu Y, Huang D and Rychlik M 2018 Durian Fruits Discovered as Superior Folate Sources *Front. Nutr.* 5 2-6

[20] Ketsa S, Wisutiamonkul A, Palapol Y and Paull R 2020 The Durian: botany, horticulture and utilization *Horticulture Review* 47 125-211

[21] Abu Bakar M F, Mohamed M, Rahmat A and Fry J 2009 Phytochemicals and antioxidant activity of different parts of bambangan (*Mangifera pajang*) and tarap (*Artocarpus odoratissimus*) *Food Chem.* 113 479–483

[22] Haruenkit R, Poovanodom S, Vearsilp S, Namiesnik J, Sliwka-Kaszynska M, Park Y S, Heo B G, Cho J Y, Jang H G and Gorinstein S 2010 Comparison of bioactive compounds, antioxidant and antiproliferative activities of Mon Thong durian during ripening *Food Chem.* 118 540–547

[23] Abu Bakar M F, Karim F A and Persisamy E 2015 Comparison of phytochemicals and antioxidant properties of different fruit parts of selected *Artocarpus* species from sabah, Malaysia *Sains Malaysiana* 44 355–363

[24] Looi S K, Zainol M K, Mohd Z Z, Hamzah Y and Mohdmaidin N 2020 Antioxidant and antibacterial activities in the fruit peel, flesh and seed of Ceri Terengganu (*Lepisanthes Alata*) leehn. *Food Res. J.* 4 1600–1610

[25] Kainama H, Fatmawati S, Santoso M, Papilaya P M, and Ersam T 2020 The Relationship of free radical scavenging and total phenolic and flavonoid contents of *Garcinia lasoar* PAM *Pharm. Chem. J.* 53 1151–1157

[26] Chavan J J, Gaikwad N B, Kshirsagar P R and Dixit G B 2013 Total phenolics, flavonoids and antioxidant properties of three *Ceropegia* species from Western Ghats of India *South African J. Bot.* 88 273–277

[27] Gan J, Feng Y, He Z, Li X and Zhang H 2017 Correlations between antioxidant activity
and alkaloids and phenols of Maca (Lepidium meyenii) J. Food Qual. 2017

[28] Lin et al 2016 An overview of plant phenolic compounds and their importance in human nutrition and management of type 2 diabetes Molecules 21 10

[29] Mandal S M, Dias R O and Franco L O 2017 Phenolic Compounds in Antimicrobial Therapy J. Med. Food 20 1031-1038

[30] LEE et al 2018 Dual Use of a Biopolymer From Durian (Durio zibethinus) seed as a nutrient source and Stabilizer for Spray Dried Lactobacillus Plantarum Front. Sustain. Food Syst 2 1-9

[31] Chen C, Chuang C, Liu M, Hsu W, Lin H, and Hsieh J 2010 Effects of total chlorine free (tcf) bleaching on the characteristics of chemi-mechanical (cmp) pulp and paper from malaysian durian (Durio zibethinus murr.) Rind J. Med. 26 55-64

[32] Suriyatem R, Auras R A, and Rachtanapun P 2019 Utilization of carboxymethyl cellulose from Durian rind agricultural waste to improve physical properties and stability of rice starch-based film J. Polym. Environ. 27 286-298

[33] Hameed B H and Hakimi H 2008 Utilization of durian (Durio zibethinus Murray) peel as low cost sorbent for the removal of acid dye from aqueous solutions Biochem. Eng. J. 39 338-343