Morphological and quality characteristics of genus of
Canarium L.: A review

N A H A Rashid 1,2, R Shamsudin1,2, S H Arifin1, W N Z Z Abdullah 3

1Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia
2Laboratory of Halal Services, Halal Products Research Institute, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia
3Department of Basic Science and Engineering, Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, Nyabau Road, 97008, Bintulu Sarawak, Malaysia
Email: rosnahs@upm.edu.my

Abstract. The genus Canarium L. comprises 75 species of aromatic trees which are found in the rainforests of tropical Asia, Africa and the Pacific. A literature review was conducted through published works to gather information on nutritional and ethnic values, colour, shape, fatty acid and also antioxidant activities of Canarium sp. The phytoconstituents which are present in most Canarium L. genus especially its fruit are mainly phenolic and fatty acid which are responsible for the actions. This novel compound serves as a contributor to the antioxidant capacity of Canarium fruit and thus, the genus can be recommended as a major source of natural antioxidants. However, this genus still can be categorised as underutilised fruit and little study is paid on its collection and comparison amongst species of Canarium L. species. Thus, the present review summarizes some such attributes of the Canarium L. genus.

1. Introduction
Canarium L. is a genus of approximately 75 species tropical and subtropical species belonging to the Burseraceae family and expand naturally across tropical Asia, Africa and Pacific [1]. The family comprises three tribes, Canariceae, Proteae, and Burserae. The Burseraceae family is well recognized in producing resins which beneficial in therapeutic, economic and cultural like myrrh, incense and copal [2]. Canarium L. trees occasionally shrubs with spirally and pinnate leaves. Canarium L. often produces edible kernels or nuts with several common names namely: Pacific almond, canarium nut, pili nut, Java almond, Kenari nut, galip nut, “nangai”, and “ngali”. Canarium indicum, Canarium odontophyllum Miq. and Canarium album L., Canarium ovatum, Canarium bengalense., Canarium Schweinfurthii are amongst the species comprised under this family and have a valuable bioactive compound that can be explored. In spite of the commercial potential of these indigenous Canarium L., this genus still can be categorised as underutilised fruit and little study is paid on its collection and comparison amongst species of Canarium L. species [3]. Therefore, this literature
review aims to gather information on nutritional and ethnic values, colour, shape, fatty acid and also antioxidant activities of Canarium sp.

2. Botanical Description
The following appropriate names of thirteen Canarium species at a level of high confidence are listed in a database of the Plant List (www. Theplantlist.org, 2019): C. aemulans Lauterb., C. agusanense Elmer, C. ahernianum Merr., C. album (Lour.) DC., C. album Leenh., Caliissimum Blume, C. amboinense Hochr., C. aneityense Guillaumin, C. angulatum Ridl., C. angustifolium (Blume) Miq., C. apoense Elmer, C. appendiculatum Lauterb. and C. asperum Benth [4]. The word Canarium derives from the Malay name ‘kanari’ [5]. According to Leenhouts, out of 52 recorded species under Canarium L., eight species can be found in the Malay Peninsula while 14 species are found in Borneo and are presented in Table 1 [5]. The species name typically is taken from the origin of the plant such as C. perlisanum and C. sumatranum but in some other cases, are somehow also indigenous to several other regions.

Table 1. List of Canarium L. in the Malaysia’s Peninsula and Borneo [5].

| Species               | Region                              |
|-----------------------|-------------------------------------|
| C. littorale          | Sumatra, Malay Peninsula, Java, Borneo. |
| C. latistipulatum     | Borneo (Sarawak and North Borneo)   |
| C. perlisanum         | Malay Peninsula (Perlis)            |
| C. patentinervium     | Sumatra, Malay Peninsula, Banka, Anambas Islands, Borneo |
| C. caudatum           | Sumatra, Malay Peninsula            |
| C. divergens          | North Borneo                        |
| C. odontophyllum      | Sumatra, Borneo, Philippines        |
| C. denticulatum       | Sumatra, Malay Peninsula (Perak), Java, Borneo, Philippines |
| C. megalanthum        | Sumatra, Malay Peninsula, Borneo    |
| C. pseudodecumanum    | South Sumatra, Banka, Borneo.       |
| C. decumanum          | East Borneo, Moluccas, New Guinea   |
| C. kostermansii       | Borneo (East Kutai)                 |
| C. pilosum            | Sumatra, Malay Peninsula, Borneo, Fiji Islands |
| C. merrillii          | North Borneo                        |
| C. dichotomum         | Sumatra, Borneo                      |
| C. fusco-calycinum    | Borneo (Sarawak)                    |
| C. pseudosumatranuni  | Malay Peninsula                      |
| C. sumatranum         | Sumatra, Malay Peninsula             |

3. General Morphology
Canarium L. genus members consist of medium to broad buttressed trees up to 40–50 m (130–160 ft) tall and have alternately shaped, pinnate, spiral and stipulated leaves (Figure 1). At the base, the foliobes are oblique, whole, dentate or serrate at a margin, often thick and acuminate at apex. The secondary nerves extend towards the bottom. Tertiary nerves reticulate. The inflorescence is an axillary panicle.

The barks are greenish-gray, fawn or light-yellow-brown, usually smooth, scaly or dipped with many small lenticels (Figure 2). The outer bark is thin while the inner barks are rosy brown or reddish-gray, laminated, smooth and moist with a strong sticky or oily exudate. The stems are normally terete. At the root, terete is flattened to channeled swollen and carries 5-21 folioles. It includes 3 creamy petals. The androecium comprises a 6-stamen whorl. The stamens disk is 6 lobed. The gynaecium comprises of 3 carpels in a lobular ovary. The drupes sit on a persistent enlarged calyx, enclosing a woody stone [6].
The fruits are usually plum-shaped, drupe-like, almost always blue-black when ripe (white in South East Asian *Canarium album* and red in *Canarium euryphyllum*, rough, especially near base and apex, or glabrous; pericarp fleshy, sometimes fibrous pyrene stony, 3-celled, 1 or 2 cells sometimes slightly to almost entirely reduced (in the latter case endocarp quite rarely absent) (Figure 1). Cotyledons are palmatifid to 3, contortuplicate or folded [5].

![Figure 1. Greenish grey and scaly bark of Canarium odontophyllum [7].](image1)

3.1. Distribution
The *Canarium* L. genus (Burseraceae) is a very large genus of trees occurring in the tropical areas, one which is India [9]. It comprises approximately 100 species, which are distributed from India and Bhutan to Australia and New Guinea, with 75 species primarily distributed in central Asia and the Pacific, [5] but are mostly found in mainland Asia [1]. Roughly 55 species from the tropics of southeast Asia have a significant role to play in the rich use of their oils. The family is distributed across a range of tropical areas, free and low-level, including rainforests, deserts, dry deciduous forest kernels, fragrant resins and wood [10].

*Canarium* L. species are typically adapted to high rainfall areas, with well-distributed annual rainfall. Optimum rainfall for good growth and fruit production is around 2,000–3,000 mm [11], but
trees were recorded in precipitated areas up to 6,000 mm/year [12]. Canarium L. species naturally well grow on a broad variety of soil types [11, 13], ideally moist, rich, deep, crumbly, organically sandy loam land, with a pH of 4.5–6.5, but will tolerate alkalinity up to pH 7.4. Canarium L., though, can be contained in poorly drained woodland conditions [12].

Amongst these species, Galip (Canarium indicum), Chinese olive (Canarium ioalbum), Pili (Canarium ovatum) and African black olive (Canarium schweinfurthii) are the most commonly studied species as shown in Table 2.

| Canarium sp. | Indigenous region | Local name |
|-------------|------------------|------------|
| C. indicum  | At lowland forests of Melanesia (Papua New Guinea, Solomon Islands, Vanuatu) and parts of Indonesia [14]. | ‘Galip’, ‘Ngali’ or ‘Nangae’ nut |
| C. album L. | Southern China's tropical and subtropical regions [15] | ‘Ganlan’, ‘Qingguo’ |
| C. bengalense | Vietnam, China, Laos, Myanmar, Thailand and India-Assam [16] | ‘Dhuna Rata’, East Indian Copa |
| C. ovatum Engl. | Philippines (Bicol region) [17] | Pili nut |
| C. schweinfurthii Engl. | In eastern, west and central African equatorial forest regions [18] | African bush candle, .Aiele fruits,‘ube mgb’, ‘elemi’,Atili |
| C. odontophyllum Miq. | In the tropical rainforest of Sarawak, Malaysia | Sibu Olive, Sarawak olive, ‘dabai’ |

3.2. Nutritional values
Different fruits have different valuable compounds. However, besides due to lack of marketing, the public considers Canarium L. are inferior nutritionally. Kernels of C. indicum are very healthy [19] and are highly valued for their role in traditional food and health [5], usually are consumed fresh, dried or roast. Its nutritional value is high in oil, protein, vitamin and mineral content. A new flavone glycoside and six recognized cytoprotective compounds were extracted from the stem bark of C. bengalense. This may be due to traditional tumor and liver damage use of this plant [20]. C. odontophyllum is highly nutritious as it is rich in 339 kcal, 26.2 g fat, 3.8 g protein (100 g of dabai fruit), phosphorus fiber and minerals, potassium, calcium, magnesium and iron [21][9].

3.3. Ethnic values
There are many traditional ways of utilizing this genus being practiced by locals, ultimately contributing to a better quality of life. Normally, the kernel, the most useful component is processed into different food products. Kernel oil of C. indicum contains about 50% saturated fat (34% palmitic and 13% stearic), 38% monosaturated (oleic) and 14% polyunsaturated (linoleic). Therefore, this species could potentially be sold as cooking oil or blended with other oils. In Chinese folk medicine, C. album L. has long been applied in herbal treatment as a cure for dysentery, cough-hematemesis, snake venom, enteritis, and wellfish and alcohol toxicosis [22]. While in China, it is used to treat infections, inflammation, poisoning and detoxification [23]. C. bengalense extracts from its leaf and root showed anti-inflammatory, antiseptic and anti-asthmatic activity [20]. The species was reportedly useful in skin rashes and snake bites [24]. It is also investigated as Bangladesh's medicinal plants for influential biological activities [25] [26].

The pulp of C. ovatum, C. schweinfurthii and C. odontophyllum are commonly eaten raw after blanch. Another way is by dipping it with sugar, fish sauce, salt, pepper or other condiments. C. ovatum is also beneficial in the processing of flour, butter, baking goods, pasta and other items. The souvenir items usually are handcrafted using its shell whereas the nut is commonly used in pastries, candies and butter [27]. The pigment extracts of C. ovatum exocarps as a functional food colorant,
lead to further use of Pili pigment in the pharmaceutical and cosmetic industries as a natural colorant with functional properties. Edou et al. reported that the pulp and kernel of *C. schweinfurthii* contain about 30 to 50% of the oil used industrially for the production of shampoos and waxes and pharmacetically for the treatment of wounds and microbial infections [28]. Sometimes the fruit is used by traditional practitioners as a remedy for diabetes mellitus in southern Senegal [29] while in Congo and the Central African Republic, the plant is used in fever as stimulant, emollient, postpartum, constipation, malaria, diarrhea, sexual infections and rheumatism [30]. Meanwhile, high energy and fat content in dabai or *C. odontophyllum* potentially lead to local development of high-value products such as cold-storage pulp and fruit, mayonnaise, snacks, sauce and paste.

4. Quality Characteristics
This research provides a body of knowledge on the determination of different varieties or genotypes of *Canarium* sp. found that including *C. album* L. [31], *C. ovatum* Engl. [32], *C. schweinfurthii* Engl. [33][34][35] *C. odontophyllum* Miq. [36, 37] as presented in Table 3.

| *Canarium* L. | Fruit colour | Variety Name |
|---------------|--------------|--------------|
| *C. indicum*  | Take 5–8 months to reach maturity when they turn from green to blackish purple [5]. | - |
| *C. album* L. | Yellow to green | Determine according to different cultivars: Changde, Green Changying, Liangtoujian, Changying, Yangshi, Tanxiang, Zilaiyuan, Huiyuan, Maken22, and Tantou |
| *C. ovatum* Engl. | Green to yellowish-green when ripe. The pulp, which turns from green to dark purple to nearly black on ripening | Determine according to different provinces of Albay and physical characteristics: M.Orolfo, Magnaye, Laysa Laniuza, Magayon, Mayo, Orbase [32]. |
| *C. schweinfurthii* Engl. | Green when immature, turning black when ripe | 1. Determined based on width, length, weight, shape [33][34]  
2. Determined based on village area: Rizek, Nubatong, Kerke [35] |
| *C. odontophyllum* Miq. | When the fruit is fully mature, turn a darkning purple colour. | 1. Determined according to growing district: Sarikei, Kapit, Song, Kanowi [36]  
2. Determined according to different its shape: Large, Normal, Clear, Oval, Seluang and Round [37] |

4.1. Fruit color
Fruit skin color is an important indicator of external quality and maturity in common fruits as fruit appearance greatly influences consumer choice. Colour is an essential attribute to be considered in choosing certain food products, and can greatly affect customer acceptability. Table 3 summarizes the list of five Canarium L. with their colour attributes and variety name. C. album has a similar appearance to Mediterranean olives and turns yellowish-green [31]. C. ovatum or Pili pigment appears as red due to the presence of anthocyanin and its colour stability is maintained when at refrigerated temperature. In a study by Aril-dela et al., the Pili pigment extract imparted a uniform purplish color to the developed yogurt similar to a commercial blueberry yogurt. The successful application as the natural colorant of the extracted pigment from Pili exocarp produced a uniform purplish-pink color in yogurt [17]. To the naked eye, Pili nut kernel is light green-yellow in color. In a study conducted by Millena & Sagum, pulp colours are different amongst variety of pili nuts which lighter-yellowish, green-yellow, and darker –reddish or purplish pigment [32]. Different pH conditions can affect the colour changes. When the pulp becomes more acidic, it changes from light purple to bright red (intense red color), and from light purple to greenish when subjected to a more alkaline condition. C. schweinfurthii fruit appears green when immature, turning black when ripe. Meanwhile the immature C. odontophyllum fruit is white in color changes blue-black or dark purple when ripe.

4.2. Fruit shape and texture
Generally, the fruits are ovoid to elliptical. C. album L. possess elliptical, oblong, oval and obovate shape. The fruit shape index ratio ranged from 1.23 to 2.09 (Table 4), which was similar to previously reported results for C. odontophyllum fruit [38, 39] due to its high-water content, weight, and large fruit size. As C. indicum have ovoid drupe, C. schweinfurthii Engl. appears spherical and oblong, hence they can rather roll than slide.

Table 4. Physicochemical results of the different C. album cultivars.

| Cultivar       | Fruit shape index |
|---------------|-------------------|
| Huiyuan       | 1.23 ± 0.08i       |
| Zilaiyuan     | 1.51 ± 0.05fg     |
| Changying     | 1.81 ± 0.06c       |
| Maken22       | 1.6 ± 0.06e        |
| Green changying | 2.09 ± 0.08a    |
| Tanxian       | 1.45 ± 0.07gh     |
| Tantou        | 1.55 ± 0.07ef     |
| Liangtoujian  | 1.88 ± 0.12b       |
| Changde       | 1.72 ± 0.12d       |
| Yangshi       | 1.42 ± 0.05h       |

The Chinese olive fruit, C. album L. has strong sensory characteristics. A first bite, it is bitter and astringent and then it becomes fragrant, sour, and sweet after being chewed. Most of the time C. album L. is consumed fresh and sometimes it is also processed into beverages, candy, and preserves [40] [41]. Conversely, C. odontophyllum has a fine, creamy texture.

4.3. Oil content and fatty acid
Fats and oils are composed of molecules known as triglycerides, which are esters composed of three fatty acid units linked to glycerol. Purple or half-purple C. indicum fruit produced kernels with an oil content of approximately 76%. Oil content for purple and half-purple kernels was not significantly different but both of them are significantly higher oil content than green kernels which only 72.8 % (Table 5) [31].

Hosseini Bai et al. tested the roasting method, resulting in no changes in fatty acid composition or excessive kernel color development [42]. Thus, both roasted and raw kernels have beneficial health effects. Comparing amongst the fruit component and variety of C. odontophyllum respectively, the
dabai kernel contains the highest percentage of protein and fat while the highest protein content was found in Kanowit purple dabai fruit as it is a good source of unsaturated fatty acids [43]. The high nutritional value combined with high fatty acid content suggests that dabai fruit is highly suitable for commercial use, especially as a source of healthy oil and functional foods [37]. Overall, the dominant fatty acid among the Canarium species are oleic and palmitic acids but for C. album, linoleic acids are the major fatty acids. Dabai pulp is rich with polyunsaturated fatty acids characterized by both linoleic and linolenic fatty acids [37]. In comparing amongst the variety of dabai, Bulat genotype was the most potential with an extremely high polyunsaturated fatty acid ratio. Meanwhile, pulp and kernel of C. ovatum may be considered as superior sources of mono-unsaturated fatty acids in Canarium L. species [32].

| Fruit colour   | Oil content (%) dw |
|----------------|--------------------|
| Purple         | 76.59 (0.57)a      |
| Half-purple    | 76.26 (0.68)a      |
| Green          | 72.29 (1.22)b      |

Values are means (SE) for oil content (Tukey’s test) and means for kernel weight (Mann-Whitney U-tests).

### 4.4. Antioxidant activities

Activities with antioxidants have been reported in C. ovatum, C. album, C. odontophyllum, and C. schweinfurthii. Pigment extract by spectrophotometric analysis C. ovatum show that high phenolic and flavonoid content were found, specifically anthocyanins, which also showed high antioxidant activity determined by DPPH and FRAP assays. The thick, semi-solid dark purple paste extracted from the exocarp has been discovered to have an antioxidant action attributable to phytonutrients, particularly anthocyanin [17] and the study increases the pulp's nutritional content, an important source of dietary fiber and essential fatty acids.

C. album is considered a good source of polyphenols and major fruit antioxidant due to its phenolic content. This is due to the fruit's genetic background rather than climatic conditions and agronomic practice. Phenolic compounds are essential for sensory qualities, lead to fruit astringency [44] and are potentially vital for body health. The differences in the total phenolic content between fruits could be partly due to environmental factors during fruit growth and fruit development. Extraction of tannin from the leaves, twigs and stem barks of C. album L. showed powerful antioxidant activity was shown in the radical DPPH scavenging activity and ferric reduction of dried tannin [45]. Novel compounds from this species include brevifolin, hyperin and ellagic acid, showing free radical activity in the DPPH assay [46].

C. odontophyllum skin is a major antioxidant source because of its high phenolic compounds as well [47] while its kernels have the lowest phenolic content. Purple dabai fruits from Kapit has been found to contain the highest total phenolic, flavonoid and anthocyanin content and to show natural antioxidant potential compared to red dabai fruit with significantly lower total phenolic, flavonoid and anthocyanin content [36]. The distinction can be closely related to the geographical location which is less exposed to pollutants, thus having a positive influence on the phytochemical properties of dabai fruits. Total Phenolic Content and Total Flavanoid Content of C. album fruits have been reported to be higher than C. odontophyllum [48].

The phytochemical analysis on C. Schweinfurthii only shown carbohydrates, flavonoids and steroids in ethanol extract. In a separate study, Vitamin C and E exhibited remarkable but varying antioxidant activities in different extracts and the highest levels were obtained in methanol extract (Table 6) [49]. This species may act as an alternative medicine to cancer sufferers, diabetes, hypertension and other cardiovascular diseases. The essential oil of C. schweinfurthii Engl. was analised for the antioxidant activity with the DPPH assay and by β-carotene bleaching, which resulted in significantly antioxidant activity at 150 μg / ml activity of both tests [50].
Table 6. Antioxidant properties of \textit{C. schweinfurthii} fruit extracts

| Solvents  | Total phenol | Ferric reducing power | DPPH | Total flavonoids | Vitamin C | Vitamin E |
|-----------|--------------|-----------------------|------|------------------|-----------|-----------|
| n-Hexane  | 416.14±2.71c | 106.28±8.13d          | 48.15±4.13a | 1.83±0.00c       | 32.85±1.03c | 487.2±17.21a |
| Acetone   | 412.03±6.63d | 232.03±15.07c         | 32.27±1.05b | 1.68±0.02d       | 31.32±0.03d | 451.4±15.62b |
| Methanol  | 620.31±15.82a | 358.96±21.72a         | 13.61±1.26d | 3.06±0.15b       | 34.21±1.01b | 338.0±13.15c |
| Water     | 598.47 ±13.9b | 284.11±13.21b         | 17.28±0.17c | 2.71±0.34b       | 45.31±2.14a | 338.0±13.15c |

5. Conclusions

This review highlights the fact that only about 10% of the total \textit{Canarium L.} species have been studied for botanical description, morphology and quality characteristics. Indeed, as compared to many other genera in this family, \textit{Canarium L.} is still very much understudied. The collection diversity of certain quality attributes such as fruit colour, shape, texture, oil and fatty acid content as well as some phytoconstituents such as phenolic and flavonoid related to antioxidant activities reviewed in this work demonstrates that there is much to be discovered in this family. The comparison amongst species of \textit{Canarium L.} especially its ethical values and nutritional values reveal the importance of these underutilized fruits and further investigation should be performed on food product value-added and comparison on isolated bioactive compounds amongst \textit{Canarium L.} species to develop a certified novel herbal product that would benefit the local people.

Acknowledgment

The authors would like to thank the Ministry of Higher Education of Malaysia, for providing financial support under the Fundamental Research Grants Scheme (FRGS) (Project Number: 07-01-19-2201FR) and the Sarawak Biodiversity Centre for approved and issued the R&D permit.

Supplementary Materials: The following are available online at http://www.journals.hh-publisher.com/index.php/AAFRJ//xxx/s1, Figure 1, Figure 2, Figure 3, Figure 4-SHA, List of Tables_SHA

References

[1] Weeks A, Daly D C, Simpson B B 2005 The phylogenetic history and biogeography of the frankincense and myrrh family (Burseraceae) based on nuclear and chloroplast sequence data \textit{Mol. Phylogenet. Evol.} 35 85-10

[2] Paparozzi, E T 2005 Plant resins chemistry evolution ecology and ethnobotany \textit{Hort. Sci.} 40 3 508-508

[3] Wiart C 2006 Medicinal plant of asia pacific-drugs for the future World Scientific Publishing Co. Pte. Ltd. British Library Cataloguing in Publication Data 380

[4] GenusCanarium 2019 http://www.theplantlist.org

[5] Leenhouts P W 1956 Burseraceae \textit{Flora Malesiana} 5 251-286.

[6] Stickman 1972 Tree flora of malaya \textit{J. Nat.l Prod.} 1 126-127

[7] Ding P 2011 Dabai (Canarium odontophyllum Miq.), Postharvest biology and technology of tropical and subtropical fruits: Volume 3: Cocona to mango. Woodhead Publishing Limited.
doi: 10.1016/B978-1-84569-735-8-50003-6.

[8] Canarium fruit and section image. 2020. Retrieved 18 August 2020, from https://www.discoverlife.org/mp/20p?see=L_BBGI01&res=640

[9] Kueh H S 2003 Indigenous fruits of Sarawak (Sarawak: Lee Miing Press Sdn. Bhd)

[10] McGregor A 1991 A review of the world production and market environment for macadamia nuts. Retrieved from http://agris.fao.org/agrissearch/search.do?recordID=US9635253

[11] Carlos J T, Dawes S N 1990 South Pacific tropical nut cultivation: status and outlook. Institute of Research Extension and Training, University of the South Pacific Apia Western Samoa

[12] Bourke R M 1996 Edible indigenous Nuts in Papua New Guinea. In: Stevens et al. (eds), South Pacific Indigenous Nuts ACIAR. ACIAR Proceedings No. 69 Canberra Australia pp 45–55

[13] Evans B R 1991 The agronomy on Ngali nut (Canarium spp.) in Solomon Islands. Research Bulletin No 9 Division of Research. Dodo Creek Research Station Honiara Solomon Islands pp 27

[14] Thomson L, Evans B, Elevitch C 2006 Canarium indicum var. indicum and C. harveyi (canarium nut) D Burseraceae (tonguewood family) Traditional trees of Pacific Islands: their culture, environment and use, permanent agriculture resources (Holualoa, Hawai’i USA) pp 209-228

[15] He, C 2015 Canarium album (Lour.) Rauesch (Qingguo, Chinese Olive) 10.1007/978-3-211-99448-1_34

[16] Wu Z Y, Raven P H, Hong D Y 2008 In flore of China. Science Press (Beijing and Missouri Botanical Garden Press) St. Louis pp 108-110

[17] Aril-dela C, Bungihan J.V, Cruz T E E, Sagum R S 2017. Canarium ovatum Engl. (Pili) exocarp crude extract as functional food colorant incorporated in yogurt developed product Food Res. 2 1 89–98 https://doi.org/10.26656/fr.2017.2.1.173

[18] Orwa C A, Mutua K, Jammadass R, Anthony R S 2009 Agroforestry Data base. A Tree reference and selection guide version 4.0. Retrieved 8th of December 2016

[19] Evans B R 1991 The production, processing and marketing of Ngali nut (Canarium spp.) in Solomon Islands. Report to UK Overseas Development Administration London. Dodo Creek Research Station Honiara Solomon Islands pp 37

[20] Le H, Ha D, Minh C, Kim T, Van Kiem P, Thuan ND, Na M 2012 Constituents from the stem barks of Canarium bengalense with cytoprotective activity against hydrogen peroxide-induced hepatotoxicity Arch. Pharm. Res. 35 1 pp 87-92

[21] Tan, Chin Xuan and Azlan, Azrina (2016) Nutritional, phytochemical and pharmacological properties of Canarium odontophyllum Miq. ( dabai ) fruit. Pertanika Journal of Scholarly Research Reviews 2 1 pp 80-94 ISSN 2462-2028

[22] Mogana R, Wiart C 2011 Canarium L.: A phytochemical and pharmacological review J. Pharm. Res. 8 9

[23] Zhiyong H, Wenshui X, Chen J 2008 Isolation and structure elucidation of phenolic compounds in Chinese olive (Canarium album L.) fruit Eur. Food Res. Technol 226 1191-1196

[24] Sarkar M, Devi A 2017 Analysis of medicinal and economic important plant species of Hollongapar Gibbon wildlife sanctuary Assam Northeast India Trop. Plant Res. 4 3 486-495 https://doi:10.22271/tpr.2017.v4.i3.065

[25] Sharmin T, Rahman MS, Tahia F 2017 Investigation of biological activities of Jasminum matthewii Afr. J. Pharm. Pharmac. 11 3 38-44 https://doi.org/10.5897/AJPP2016.4697

[26] Sharmin T, Rahman M S, Mohammadi H 2018 Investigation of biological activities of the flowers of Lagerstroemia spectosa the Jarul flower of Bangladesh BMC Complementary and
[27] Philippines, Department of Agriculture (Phil-DA) 2011 Pili Technoguide. Retrieved on September 24, 2014 from Phil-DA Website: http://bicol.da.gov.ph/attachments/article/28/Pili%20Technoguide.pdf

[28] Edou E P, Abdoul-Latif F M, Obame L C, Mewono L, Agnaniet H 2012 Volatile constituents of Canarium schweinfurthii Engl. essential oil from Gabon Int. J. AgriScience 2 200–203

[29] Kamthouing P, Kahpui S M, Djomeni P D, Tédong L, Asongalem E A, Dimo T 2008 Antidiabetic activity of methanol/methylene chloride stem bark extracts of Terminalia superba and Canarium schweinfurthii on streptozotocin-induced diabetic rats J Ethnopharmacol. 104 3 306-309

[30] Koudou J, Abena AA, Ngaissona P, Bessière J M 2005 Chemical composition and pharmacological activity of essential oil of Canarium schweinfurthii Fitoterapia 76 7-8 700-3

[31] Chang Q, Su M H, Chen Q X, Zeng B Y, Li H H, Wang W 2017 Physicochemical properties and antioxidant capacity of chinese olive (Canarium album L.) cultivars J. Food Sci. 82 6 1369-1377 doi: 10.1111/1750-3841.13740

[32] Millena C G, Sagum R S 2018 Physicochemical characterization and fatty acid profiling of different Philippine pili nut (Canarium ovatum , Engl.) varieties J. Am. Oil Chem.’ Soc. 953 325–336. https://doi.org/10.1002/aocs.12028

[33] Nyam M A, Wonang D L, Akueshi C O 2009 Phytochemical screening and Antimicrobial Studies on Canarium schweinfurthii, (‘Atili’)fruits and oil Nig J Botany 22 247-53

[34] Maduelosi N J, Angage S S 2015 Characterization of African Elemi Canarium schweinfurthii. Int. J Adv Res Chem Sci 2 34-6

[35] Ma N, Oe O, Dawang S A survey of some varieties of canarium schweinfurthii (atili) grown in some parts of Jos East LGA, Plateau State, Nigeria and their antibacterial activities J. Microb. Lab. Sci. 1 1 12

[36] Chew L Y, Prasad K N, Amin I, Azrina A, Lau C Y 2011 Nutritional composition and antioxidant properties of Canarium odontophyllum Miq. (Dabai) fruits J. Food Compos. Anal. 24 4–5 670-677 https://doi.org/10.1016/j.jfca.2011.01.006

[37] Chua H P, Nicholas D. Yahya M N A 2015 Physical properties and nutritional values of dabai fruit (Canarium odontophyllum) of different genotypes J. Trop. Agric. Food. Sci. 431 pp 1–10 doi: 10.13140/2.1.2944.3366

[38] Azlan A K, Hock N P, Khoo E, Abdul-Aziz N, Mohamad A, Ismail A, Amom Z 2010 Comparison of fatty acids, vitamin E and physicochemical properties of Canarium odontophyllum Miq. (dabai) olive and palm oils J. Food Compos. Anal. 23 8 pp 772–776 doi: 10.1016/j.jfca.2010.03.026

[39] Ding P, Tee Y K 2011 Physicochemical characteristics of dabai (Canarium odontophyllum Miq.) fruit Fruits 66 1 pp 47–52 doi: 10.1051/fruit/2010040.

[40] He Z, Xia, W 2007 Analysis of phenolic compounds in Chinese olive (Canarium album L.) fruit by RPHPLC-DAD-ESI-MS Food Chem 105 3 pp 1307–11

[41] Kuo C-T, Liu T H, Hsu T H, Lin FY, Chen HY 2015 Antioxidant and antiglycation properties of different solvent extracts from Chinese olive (Canarium album L.) fruit Asian Pac. J. Trop. Med. 8 12 pp 1013–1021

[42] Hosseini B, Darby S, Nevenimo I, Hannet T, Hannet G, Poienou D, Grant M, Brooks E, Walton P, Randall D, Wallace H M 2017 Effects of roasting on kernel peroxide value, free fatty acid, fatty acid composition and crude protein content PLOS ONE 12 9 e0184279 https://doi.org/10.1371/journal.pone.0184279

[43] Azrina A, Nadiah N M N, Amin I 2010 Antioxidant properties of methanolic extract of Canarium odontophyllum fruit Int. Food Res. J. 17 319

[44] Bajec M, Gary P 2008 Astrignency: mechanisms and perception Crit. Rev. Food Sci. Nutr. 48 858-75
[45] Zhang L, Lin Y 2008 Tannins from Canarium album with potent antioxidant activity. *Journal of Zhejiang University Science B* **9** 407–415 https://doi.org/10.1631/jzus.B0820002

[46] Ito M, Shimura H, Watanabe N, Tamai M, Hanada K, Takahashi A 1990 Hepatoprotective Compounds from Canarium album and Euphorbia nematoxypha. *Chem. Pharm. Bull* **38** 2201-2203

[47] Shakirin, F H, Prasad K N, Ismail A, Yuon L C, Azlan A 2010 Antioxidant capacity of underutilized Malaysian Canarium odontophyllum (dabai) Miq fruit. *J. Food Compos. Anal.* **23** 8 pp 777–781 doi: 10.1016/j.jfca.2010.04.008

[48] Liu H, Qiu N, Ding H, Yao R 2008 Polyphenols contents and antioxidant capacity of Chinese herbs suitable for medical or food uses. *Food Res. Int.* **41** 4 2008 pp 363-370

[49] Wahab A G, Adekunle A I, Elizabeth GA 2015 Phytochemical composition and antioxidative potential of Purple Canary (Canarium schweinfurthii). *The Pharma Innovation Journal* **2015** 4 1 49-52

[50] Obame L, Koudou J, Kumulungui B S, Ismael H N, Prosper E, Aboubakar S O, Alfred S T 2007 Antioxidant and antimicrobial activities of Canarium schweinfurthii Engl essential oil from Centrafrican Republic. *African Journal of Biotechnology* **6** 2319-2323