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Canarium species: A review on the bioactive compounds and potential pharmacological benefits of *C. ovatum, C. album* and *C. odontophyllum*

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Abstract

This review critically synthesizes current evidence on available pieces of evidence on the botanical characteristics, traditional uses, pharmacognostic constituents, and potential pharmacological properties of Canarium species, specifically *Canarium ovatum, Canarium album, Canarium odontophyllum*. Belonging to the family Burseraceae, *C. ovatum* is a tropical tree species native to the Philippines, where it serves as an economically significant crop, particularly in the Bicol region—the center of the Philippines' pili nut industry. There are various reports about the high amount of bioactive compounds in the kernels, pulp oil, and leaf extracts of the plant, such as polyphenols, tocopherols, phytosterols, and bioactive peptides. These constituents exhibit a varying range of biological activities, such as antioxidant, antibacterial, antihypertensive, anticancer, and immunomodulatory effects, as demonstrated in different in-vitro and in-vivo studies.

This review combines current research findings on the nutritional and pharmacological potential of *C. ovatum* to highlight its value as a functional food and a promising source of bioactive compounds for therapeutic and pharmacological applications.

Overall, this review study aims to consolidate current research on the nutritional composition and potential pharmacological activities of *C. ovatum, C. album, and C. odontophyllum,* emphasizing their value as promising sources of novel bioactive molecules for modern pharmacological applications.

Keywords: *Canarium ovatum*; *Canarium album; Canarium odontophyllum;* Bioactive compounds; Pharmacological benefits; Nutritional properties

1. Introduction

Canarium ovatum Engl, is a dioecious tree native to the Philippines, particularly found in regions like Bicol, Samar, and Leyte (Food and Agriculture Organization [FAO] & University of the Philippines Los Baños [UPLB], 2023) [1]. It is widely known for its economic value, especially as a source of resin and edible kernel seeds that are rich in unsaturated fats. More recently, however, it has started to gain international attention not just for industrial use, but also as a promising functional food (FAO & UPLB, 2023) [1].

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New advances in pharmacology have established the presence of several bioactive components in *C. ovatum*, such as polyphenols, tocopherols, and phytosterols, offering notable antioxidant and anti-inflammatory qualities (Pham & Dumandan, 2020) [2]. Moreover, bioactive peptides exhibiting ACE inhibition are found to present new opportunities for treatment and prevention of hypertension via the Pili nut (Gamba et al., 2023) [3]. Such a combination of nutrition and medicinal quality positions *C. ovatum* as a top contender in the international markets of functional foods and phytopharmaceuticals.

Figure 1 Morphological features of *Canarium ovatum* (Pili): (A) fresh fruits on the tree and (B) external and internal structure of the fruit and kernel. [32]

Another plant from the same species, *Canarium album* (Lour.) Raeusch. *(C. album)*, commonly referred to as Qingguo in Chinese or known as Chinese olive or White olive, belongs to the Burseraceae family, which distinguishes it from the European olive (*Olea europaea* L.) that is classified under the Oleaceae family.

This species is an evergreen tree that can grow up to 30 meters and is native to the southeastern regions of China. According to He (2015) [4], Qingguo is mainly grown in the Guangdong and Fujian provinces of China. It is known for its amazing adaptability, thriving in diverse environmental conditions such as saline and alkaline soils as well as on rocky hillside terrains.

Originating from Southeast China, *Canarium album* produces a useful fruit characterized by a high concentration of polyphenols and strong antioxidant properties, leading to its successful introduction across various tropical and subtropical Asian regions, including Vietnam, Malaysia, and Japan (Mei et al., 2017) [5]. While there are numerous ways of distinguishing the unique flavor of the Chinese olive, there has been a growing focus on promoting its use as a nutritious food product, which has largely been driven by the need for healthy diet options (Yu et al., 2021) [6].

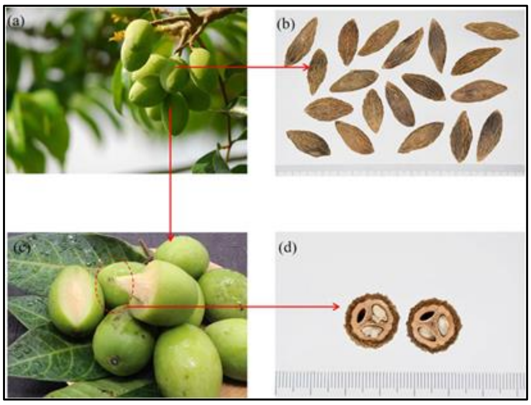

Figure 2 Plant images of Chinese olive. (A) The whole plant. (B) Dried fruit. (C) Fresh fruit. (D) Cross section of kernel. (Images adapted from Yu et al., 2023). [7]

In addition to the Pili nut's significance, another tropical species warrants attention for its similar nutritional and pharmacological properties. *Canarium odontophyllum* Miq., commonly known as Dabai or "Sarawak olive," is a Burseraceae tree native to the tropical rainforests of Borneo, particularly in Sarawak and Sabah part of East Malaysia

It produces seasonal fruits that are normally consumed and widely studied for their nutritional value and medicinal effects (Ringgit et al., 2025; Khoo et al., 2019) [8,9].

The tree can reach about 36 m in height with a trunk diameter of up to 85 cm and bears large pinnate leaves, while its oblong, dark purple to black fruits measure roughly 3–4 cm long and 2–3 cm wide, enclosing an oily pulp and a hard three-angled seed that are rich in balanced fatty acids and various phytochemicals such as phenolic compounds, flavonoids, tannins, saponins, terpenoids, and bioactive amides, which various authors (e.g., Ringgit et al., 2025, Saari et al., 2017; Basri et al., 2016; Khoo et al., 2019) [8,10,11,12] associate with antioxidant, antihyperglycemic, antimicrobial, vasorelaxant, and antiproliferative activities.

As compared to the Pili nut, the dabai fruit (*Canarium odontophyllum*) also consists of various edible components such as the skin, pulp, and kernel, all of which are rich in bioactive constituents such as polyphenols, anthocyanins, tocopherols, carotenoids, and phytosterols (Hamzah et al., 2022) [12]. Its pulp oil is notably high in unsaturated fatty acids, specifically oleic, linoleic, and palmitic acids, which contribute to its significant nutritional profile (Khoo et al., 2019; Kadir et al., 2021) [9,13]. Current pharmacological studies have revealed that these compounds have been shown to exert significant antioxidant activity, primarily through free radical scavenging and modulation of oxidative stress pathways (Kadir et al., 2021; Hamzah et al., 2022) [12,14]. Moreover, Dabai proteins have shown angiotensin I-converting enzyme (ACE) inhibitory activity from the bioactive peptides isolated, indicating that this fruit may serve as a valuable functional food for the management of hypertension (Khoo et al., 2019), just like the Pili nut. [9].

Figure 3 (a) Mature dabai fruits; (b) Dabai flesh (mesocarp) and hard seed (endocarp); (c) Length of the seed; (d) Width of the seed; (e) Longitudinal section of the seed; (f) Transverse section of the seed and the kernel. (Images from Hamzah et al, 2022 [12] and public sources). [33]

In light of these promising findings, there is a need to consolidate and critically analyze the current scientific evidence on the bioactive constituents and pharmacological potential of *C. ovatum, C. album* and *C. odontophyllum*. Ultimately, this paper aims to enhance the value of Canarium species as a promising functional food and a potential source of novel bioactive molecules for pharmacological use.

2. Methods

This review used a systematic search of existing literature to identify key studies regarding *Canarium* species, focusing on their bioactive components and medicinal effects. Online searches were conducted in major academic databases, including PubMed, Scopus, and Google Scholar. The search was limited to articles published between 2015 and first quarter of 2025 to capture recent scientific developments. Keywords and Boolean combinations such as *"Canarium ovatum"*, *Canarium album", "Canarium odontophyllum", "bioactive compounds"*, *"pharmacological benefits"*, and *"nutritional properties"* were used.

In order to maintain the accuracy of this literature review, peer-reviewed journal articles and studies published in the English language have been used in the course of analysis. While the primary focus remained on the nutritional components of Canarium species, research work that is related to the pharmacology of its non-nut parts like barks, wood, and resins was considered for inclusion, if it contributed any valuable information related to the objectives of the study. In order to carry out a holistic review of the available literature on this topic, more sources were sought by conducting a search through references cited in the chosen primary articles. Data collected from various studies have been analyzed based on specific bioactive compound types such as polyphenols, tocopherols, and peptides and their respective pharmacological actions including antioxidant, antihypertensive, and antimicrobial actions.

3. Review of Related Literature

3.1. Botanical/Taxonomic description & distribution

Canarium ovatum belongs to the Burseraceae family, a group that contains around 100 species, a number of which carry real economic weight. What tends to set *C. ovatum* apart from its relatives is the quality of the nutrients packed into its edible seeds. The tree itself is capable of reaching up to 30 meters in height and bears distinctive large, pinnate leaves along with small yellowish flowers that eventually give way to the seed-bearing fruit. Given its resilience against strong winds and capacity to thrive across a range of climates, the species presents a strong case for integration into agroforestry initiatives and sustainable production systems (FAO & UPLB, 2023) [1]. In terms of physical description, *C. ovatum* is a medium-sized evergreen. It commonly attains a height of around 20 meters with a trunk diameter near 50 centimeters, and it can be recognized by its leathery, imparipinnate leaves and the presence of persistent, elongated stipules (World Agroforestry, n.d.) [31].

Reproductive structures appear as axillary inflorescences close to the branch tips. They're made up of narrow bunches of unisexual flowers that have three parts each. The male ones stand out because of the cup-like calyx and six stamens. Female flowers have a larger calyx and a noticeable pistil that's about 7 mm in length (World Agroforestry, n.d.) [31].

Within that hard shell sits a single seed. The edible kernel, which is mostly cotyledon tissue, accounts for just a small portion of the total fruit weight roughly 4% to 17% (World Agroforestry, n.d.) [31].

Native to the Philippines, *C. ovatum* is extensively cultivated in the Bicol Region, an area recognized as both the center of its genetic diversity and the principal hub of production (Pham & Dumandan, 2015) [2]. Even as global interest in its nutritional profile continues to rise, the species has yet to be fully exploited as a resource. This gap highlights the need for a more thorough scientific exploration of its varied bioactive makeup (FAO & UPLB, 2023) [1]. Analyses of the fruit have already uncovered an array of bioactive constituents namely carotenoids, tocopherols, and phytosterols which are linked to antioxidant capacity and a spectrum of potential health-promoting effects (Pham & Dumandan, 2015; Dumandan et al., 2022) [2,22].

Canarium album is thought to have first emerged in South China, where a history of cultivation and consumption stretches back over two thousand years. This species is a medium to large evergreen tree. The stem of this tree tends to grow vertically and is typically around 20-30 m high although many of them have reached as much as 40 m. The diameter of its stem could be up to 0.9 m with a smooth, light-brown bark which peels off in flakes. The species demonstrates strong ecological adaptability in coastal lowlands, on mountain slopes, and in hilly areas too. That said, most of the trees growing today are found in rather limited pockets, often in semi wild or completely wild conditions (Yu et al., 2021) [6]. China remains the top producer worldwide, with Fujian Province serving as the main growing hub. Planted area there now exceeds 140,000 acres. According to Jia et al. (2016) [16], the Chinese Olive has expanded far beyond the areas in Asia where it first existed. Currently there are large parts of Asia where you can now see it such as Vietnam & Japan on one side of the continent to Laos, Myanmar, Thailand, Philippines, Malaysia, Indonesia, India & Sri Lanka on the other side. The area of distribution of the Chinese Olive indicates the significance of this species culturally as well as its ability to settle in new habitats.

A study by Lai et al. (2017) [17] indicate that leaving the plant in the cold for too long can lead to frost damage, since it does not handle extreme temperatures well. Studies show that *Canarium album* could survive temperatures to about –3 °C. That is the lowest it can survive and can still make it.

Canarium odontophyllum Miq. is in the Burseraceae family occuring in the rainforests of Borneo. In East Malaysia, Sarawak and Sabah specifically, the tree goes by dabai or Sarawak olive. It grows in mixed dipterocarp forests. It is generally not found higher than about 800 meters up (Khoo et al., 2019; Saari et al., 2017) [9,10]. Although it is an extremely large evergreen tree reaching heights of 36 m, a trunk size of nearly 0.8 m across, it does produce pinnate leaves and buttressed roots. These characteristics enable this species to thrive in the upper canopy layers of Borneo's forest ecosystems (Saari et al., 2017) [10]. The tree produces oblong fruits on a seasonal basis. At maturity, the outer surface changes to a purple or almost black hue. The dimensions are around 3 to 4 cm in length by 2 to 3 cm in width.

Inside, the flesh is oily with palmitic and oleic acids. Even though the fruit holds cultural value, it is still not used as much as it could be in local diets (Ringgit et al., 2025; Khoo et al., 2019) [8,9].

Malaysian Borneo makes up the heart of its native distribution, but *C. odontophyllum* can also be found in areas of Indonesian Kalimantan and Brunei. Still, intentional cultivation for market purposes remains largely restricted to Sarawak, with a harvest window that falls between November and January (Ringgit et al., 2025) [8]. Phytochemical studies have turned up a mix of compounds in the leaves, stem bark, and fruit of this plant. Flavonoids, tannins, saponins, terpenoids, and different phenolics are all in there. Most researchers think this chemicals is what drives the plant's reported biological activities. A voucher specimen, UKMB 40052, confirm that this species belong to the genus *Canarium* L. (Saari et al., 2017; Basri et al., 2016) [10,11]. Based on the current body of research, there is no evidence pointing to any natural occurrence of this species in the Philippines, a fact that firmly establishes it as a pharmaceutical resource unique to the island of Borneo.

3.2. Traditional/Medicinal Uses

Ethnomedicine and Historical Context:

The *Canarium ovatum* tree, which is commonly called pili, is a native plant grown on a large scale across the Bicol Region. It is a major part of the Philippine landscape. Beyond just its role in the environment or in farming, the tree's economic worth and nutritional benefits are also widely recognized (Pham & Dumandan, 2015) [2]. Specific records of how *Canarium ovatum* is used as medicine are fairly hard to find in current research. Other species in the Canarium genus have actually been studied much more. For instance, *Canarium odontophyllum* is a part of people's diets in Borneo. They consume it because of the health benefits, and studies backs this up by showing the fruit has a high nutrient count and a lot of antioxidants. This is very different from *C. ovatum*, where medicinal documentation remains thin. (Hamzah et al., 2022; Salleh et al., 2022) [12,28].

Canarium album is still widely used in traditional Chinese healing practices today. Its role there is a great example of why the entire Canarium genus is considered so important to the medical field. A well-known use of this species is in Qinguo Wan. This traditional water-honey pill combines eight other plants into a single formula meant to treat pharyngitis. (Liu et al., 2021) [18]. These traditional practices are seen in many different countries and cultures. They suggest that the Canarium genus actually contains a wide range of medicinal properties. Because of this, these plants are increasingly viewed as both healthy "functional" foods and as possible sources for future medical treatments.

For generations, indigenous groups in Borneo have turned to *Canarium odontophyllum*, which is locally known as dabai. In Sarawak, the Dayak people include the fruit in their diet every season, mainly because they believe it helps with blood sugar and cholesterol levels (Kadir et al., 2020; Saari et al., 2017) [10,15]. Local medicinal practices actually involve more than just the fruit, frequently using the leaves, pulp, and bark of the tree. These various applications suggest that *C. odontophyllum* holds a lot of pharmacological potential. In particular, the plant is noted for its capacity to combat bacteria and lower inflammation (Basri & Sandra, 2016; Saari et al., 2017; Kadir et al., 2021) [10,13,25].

Rural communities in Borneo have always seen this plant as culturally and financially important. More recently, however, pharmacological studies have begun to support its medical uses, specifically for managing infections and regulating blood sugar or pressure (Basri & Sandra, 2016; Basri et al., 2018; Hamzah et al., 2022) [12,25,32]. Because of its history in traditional medicine, researchers are now looking more closely at the plant’s chemical makeup, specifically focusing on elements like saponins, flavonoids, and phenolic compounds. The goal is to see if these old health claims are actually true so the species can eventually be used to create modern medicines (Saari et al., 2017; Basri et al., 2018) [10,32].

3.3. Phytochemistry / Chemistry

Table 1 Summary of quantity of each phytochemicals present in each Canarium species.

Specific Compounds	***C. ovatum***	***C. album***	***C. odontophyllum***
Phenolic Compounds	Present but not quantified	1,174.0 to 1,799.6 mg/100g	18.88 to 26.62 mg GAE/g
Fatty Acids	Up to 60.93% (oleic acid dominant)	73.3%	~44.4% to 47.72%
Amino Acids	Present (bioactive peptides), not quantified	Glutamic acid: 5.02 g Arginine: 3.19 g Aspartic acid: 2.47 g	-
Volatiles & Aromatic Compounds	-	-	Present but not quantified
Anthocyanins & Anthocyanidins	23 mg/g (skin)	-	523.3±22.36 mg/100g
Flavonoids	Qualitative (+++)	128.81 and 373.94 mg/100g	15.62 to 46.70 mg QE/g
Phenylpropanoid	Present, not quantified	Present but not quantified	-
Triterpenoid	Present (twigs), not quantified	Present but not quantified	
Carotenoids	β-carotene 56.89 mg/100g	-	Present but not quantified
Terpenoids	Present but not quantified	-	Present but not quantified
Phytosterols, Tocopherols, and Minor Lipids	Present but not quantified	-	+
Minerals	Present (bioavailability reported), not quantified	+	+

3.3.1. Qualitative Analysis (Classes Present):

Phenolic Compounds

Phenolic compounds, including phenols and tannins, are present in *C. ovatum* bark and leaf extracts (Balbuena et al., 2019) [19]. In *C. album,* phenolics—categorized into phenolic acids, flavonoids, and phenylpropanoids—are primarily responsible for therapeutic benefits and bitter flavor (Yu et al., 2023) [7]. For C. *odontophyllum*, semi-polar phenolic acids such as coumaric and anisic acid were identified in oil and oleoresin; further profiling revealed ellagic acid, vanillic acid, ethyl gallate, and syringic acid in pulp and peel (Khoo et al., 2019; Kadir et al., 2021; Hamzah et al., 2022). [9,12,14]

Fatty Acids

Fatty acids are major constituents of C. *ovatum* pulp and kernel oils, with oleic acid dominant (Millena & Sagum, 2018) [20]. *C. album* fresh kernels are rich in fatty acids (Yu et al., 2023) [7]. In C. *odontophyllum*, major fatty acids include palmitic, oleic, linoleic, and stearic acid, with minor ones such as lauric, myristic, α-linolenic, margaric, caprylic, and dihydroxystearic acid (Khoo et al., 2019). [9]

Amino Acids

C. ovatum kernel proteins (e.g., 11S globulin) yield bioactive peptides with antihypertensive and antioxidative activities (Gamba et al., 2023) [3]. *C. album* provides 18 amino acids (10 non-essential, including proline and aspartic acid; 8

essential, including threonine, valine, methionine) (Yu et al., 2023) [7]. No amino acid compounds were reported for *C. odontophyllum.*

Volatiles & Aromatic Compounds

Short-chain peptides (Trp-Ala-Pro, His-Met-Lys, Phe-Asn-Ser, Lys-Lys-Lys, Pro-Lys-Pro) were tentatively identified in *C. odontophyllum* oil and oleoresin (Khoo et al., 2019) [9]. No volatiles or aromatic compounds were reported for *C. ovatum* or *C. album.*

Anthocyanins & Anthocyanidins

Anthocyanidins are present in *C. ovatum* pulp and skin (Millena et al., 2018) [20]. The purple skin of *C. odontophyllum* contains anthocyanins, including malvidin-3,5-di-O-glucoside, cyanidin-3-O-glucoside, cyanidin-3-O-rutinoside, peonidin-3-O-glucoside, cyanidin, pelargonidin, and delphinidin (Kadir et al., 2021) [14]. No anthocyanins were reported for *C. album*.

Flavonoids

Flavonoids are detected in *C. ovatum* extracts (Cajuday et al., 2017) [21]. C. *album* contains diverse flavonoids (isoflavones, chalcones, dihydroflavonoids, flavonols and glycosides) across roots, stems, leaves, and fruit (Yu et al., 2023) [7]. *C. odontophyllum* fruit contains catechin, epicatechin, epicatechin gallate, epigallocatechin gallate, apigenin, prenyl-naringenin, sophoraflavanone B, and neobavaisolavone (Kadir et al., 2021; Khoo et al., 2019, Hamzah et al., 2022) [9,12,13].

Phenylpropanoid

Phenylpropanoids are present in *C. album*, which contains simple phenylpropanoids, lignans, and coumarins (Yu et al., 2023) [7]. In *C. odontophyllum*, syringic acid has been identified as a key phenylpropanoid in both the pulp and the oil extracts [14].

Triterpenoid

Triterpenoids (α- and β-amyrin, lupenone, β-amyrone) are present in *C. ovatum* pulp oil, leaves, and twigs (Dumandan et al., 2022; Ragasa et al., 2015) [22, 23]. In *C. album*, triterpenoids are the most prevalent terpenoids, biosynthesized from six isoprene units (Yu et al., 2023) [7]. No triterpenoids reported for *C. odontophyllum*.

Carotenoids

Carotenoids are present in C. *ovatum* oil (Pham & Dumandan, 2015) [2]. *C. odontophyllum* peel, pulp, and seed contain all-trans-β-carotene, 15-cis-β-carotene, 13-cis-β-carotene, 9-cis-β-carotene, di-cis-β-carotene, all-trans-lutein, 9-cis-lutein, 13-cis-lutein, and apocarotenoids (hydroxy-apocarotenal and isomers) (Kadir et al., 2021; Khoo et al., 2019) [9,14]. No carotenoids reported for C. *album*.

Terpenoids

Terpenoids are present in *C. ovatum* extracts (Terrazola et al., 2025) [24]. *C. odontophyllum* oil and oleoresin contain triterpenes and sesquiterpenes (oleanolic acid, glycyrrhet-aldehyde, oleanonic aldehyde, kauralexin A2, bixin aldehyde, cincassiol B, phaseollin, lacinilene C); leaf extracts also contain terpenoids (Khoo et al., 2019; Basri & Sandra, 2016) [9,25]. No terpenoids reported for *C. album*.

Phytosterols, Tocopherols, and Minor Lipids

C. ovatum oil contains phytosterols, tocopherols (vitamin E), and minor lipids (Pham & Dumandan, 2015) [2]. *C. odontophyllum* oil/oleoresin contains sphingolipids (phytosphingosine, sphinganine, dimethyl-safingol), phospholipids, mono-, di-, and triglycerides, plant sterols (lanosterol and its hydroxyl forms), and tocopherols (α- and γ-tocopherol) (Khoo et al., 2019; Kadir et al., 2021; Hamzah et al., 2022) [9, 12, 15]. No such compounds reported for C. *album*.

Minerals

C. ovatum contains K, Ca, Mg, P, Fe, Zn, Cu (Millena et al., 2018) [20]. *C. odontophyllum* contains Ca, Na, K, Mg, P, Fe (Hamzah et al., 2022) [12]. *C. album* contains the same essential minerals (Yu et al., 2023) [7].

3.3.2. Quantitative Analysis (Yields, % Composition):

Phenolic Compounds

In *C. ovatum*, research by Millena and Sagum (2018) [20] indicates presence of phenolic compounds, though specific quantification of syringic acid is not established for this species. In *C. album*, gallic acid (166 mg/100 g FW) and ellagic acid (87.8 mg/100 g FW) accounted for 32.9% and 17.4% of total phenolics, respectively (Yu et al., 2023) [7]. The total phenolic content (TPC) in *C. odontophyllum* is not uniform across the different parts of the plant. For instance, the peels show a range from 18.88 to 26.62 mg GAE/g (Hamzah et al., 2022) [12]. In comparison, fresh pulp was found to contain 267.0 ± 4.24 mg GAE per 100 grams (Kadir et al., 2021) [14]. Scientists also noted that the defatted pulp has about 4.404 ± 0.09 mg GAE/g extract (Kadir et al., 2021) [14]. Besides the general TPC levels, syringic acid was identified in the oil of the dabai pulp at 2.11 ± 0.03 μg/mL (Kadir et al., 2021) [14].

Fatty Acids

C. ovatum kernel contains 67.2–74.1% fat and its pulp contains 20.2–31.7% fat, with oleic acid being the most abundant fatty acid (Millena & Sagum, 2018; Pham & Dumandan, 2015) [2, 20]. In *C. album*, 13 fatty acids were identified, with unsaturated fats at 73.3% of total; linoleic (41.8%) and oleic (30.5%) dominate, followed by palmitic (18.0%) and stearic (7.8%) (Yu et al., 2023) (Yu et al., 2023) [7]. For *C. odontophyllum*, fresh pulp fat content ranges from 21.16–25.76 g/100 g (up to 37.07%); the oil composition comprises saturated (~47.65%), monounsaturated (~40.38%), and polyunsaturated (~13.11%) fatty acids (Khoo et al., 2019; Kadir et al., 2021) [9, 13, 15]. Individual values for dabai oil are reported as: palmitic 41.62%, oleic 39.68%, linoleic 12.85%, and stearic 4.31% (Khoo et al., 2019; Kadir et al., 2021) [9, 15].

Amino Acids

No detailed amino acid quantification is available for *C. ovatum* (Gamba et al., 2023) [3]. In *C. album*, the most abundant amino acids per 100 g kernel are glutamic acid (5.02 g), arginine (3.19 g), and aspartic acid (2.47 g) (Yu et al., 2023) [7].

Volatiles & Aromatic Compounds

No quantitative data on volatiles/aromatics for *C. ovatum* or *C. album*. For *C. odontophyllum*, compounds were identified based on relative abundance (peak intensity) without absolute mass quantifications or percentage yields (Khoo et al., 2019) [9].

Anthocyanins & Anthocyanidins

Anthocyanidins are present in the pulp and skin of *C. ovatum* (Millena et al., 2018) [20]. No quantitative data is currently available for *C. album*. In *C. odontophyllum*, the high TPC of the fresh pulp (267.0 ± 4.24 mg GAE/100 g) reflects a significant presence of anthocyanins and other phenolics (Kadir et al., 2021) [14]. Specifically, the total monomeric anthocyanin content in defatted dabai pulp (which includes the peel) is 523.3 ± 22.36 mg/100 g extract (Kadir et al., 2021) [14].

3.3.3. Flavonoids

C. ovatum pulp total phenolic content is 267.0 ± 4.24 mg GAE/100 g, indicating a high level of phenolic compounds including flavonoids (Kadir et al., 2021) [14]. Isolated flavonoids from *C. album* include quercetin, kaempferol, hyperin, isoquercetrin, luteolin-7-O-glucoside, brevifolin, amentoflavone, and sitoindoside I; quantitative yields are not specified (Yu et al., 2023) [7]. Catechin and epigallocatechin are found in high amounts within the peels of *C. odontophyllum*, even though the specific percentage yields for each weren't listed on their own. In terms of the total flavonoid content, these peels generally show a range between 15.62 and 46.70 mg quercetin equivalent/g. (Hamzah et al., 2022) [12].

3.3.4. Phenylpropanoid

When testing the oil extracts of *C. odontophyllum*, syringic acid was measured at 2.11 ± 0.03 μg/mL (Kadir et al., 2021) [14]. Quantitative data for phenylpropanoids in *C. ovatum* and *C. album* were not reported.

3.3.5. Triterpenoid

Concentrations of triterpenoids in *C. ovatum* were not quantified (Dumandan et al., 2022) [22]. *C. album* triterpenoids include 3-epi-α-amyrin, urs-12-ene-3α,16β-diol, urs-12-ene-3β,16α-diol, β-amyrin, 3-epi-β-amyrin, and olean-12-ene-3α,16β-diol; quantitative data not provided (Yu et al., 2023) [7]. No quantitative data for *C. odontophyllum*.

Carotenoids

Exact mass quantifications for *C. ovatum* carotenoids are not detailed. In *C. odontophyllum*, a "moderate amount" of β-carotene was reported (Khoo et al., 2019) [9], and apocarotenoids detected at moderate levels by relative abundance; no absolute yields established (Khoo et al., 2019) [9]. No quantitative data for C. *album*.

Terpenoids

No quantitative values for *C. ovatum*. For *C. odontophyllum*, terpenoids were tentatively identified by LC-MS based on relative abundance; precise quantitative yields or mass measurements are not established (Khoo et al., 2019) [9]. No quantitative data for *C. album*.

Phytosterols, Tocopherols, and Minor Lipids

No quantitative values for C. *ovatum* (Pham & Dumandan, 2015) [2]. For *C. odontophyllum*, vitamin E (α-tocopherol) in dabai pulp oleoresin is 0.13 ± 0.02 mg/100 g, and dabai kernel oil contains ~12.04 mg/100 g (Kadir et al., 2021) [15]. Exact mass quantifications for phytosterols and other minor lipids are not established; they were detected by relative abundance (Khoo et al., 2019) [9]. No quantitative data for C. *album*.

3.3.6. Minerals

For *C. ovatum*, mineral bioavailability values are reported (Mg 54.4–90.3%, Ca 13.7–40.9%), but not absolute concentrations (Millena et al., 2018). C. *album* fresh fruit contains K (587 mg/100 g), Ca (226.2 mg/100 g), and Mg (186 mg/100 g) (Yu et al., 2023) [7]. For *C. odontophyllum*, values vary: Chew et al. reported Ca (16.00–67.88 mg/100 g FW), Na (7.26–11.19 mg/100 g FW), K (3.64–7.19 mg/100 g FW); Hoe and Kueh reported K (810 mg/100 g), Ca (200 mg/100 g), Mg (106 mg/100 g), P (65 mg/100 g) for the edible portion.

4. Pharmacological activities / Efficacy evidence

4.1. Antibacterial Activity

4.1.1. Canarium ovatum

The antibacterial activity of *Canarium ovatum* has been demonstrated using extract-based and nanotechnology approaches. Dumandan et al. (2022) [22] reported that saponified diethyl ether extract (SDEE) of pili pulp oil showed activity against gram-negative bacteria (Escherichia coli, Salmonella typhi), with zones of inhibition of 10.3 mm and 11.7 mm and MICs of 40 μg/mL and 35 μg/mL, respectively, but no activity against gram-positive bacteria (*Staphylococcus aureus*, *Bacillus cereus*) or *Pseudomonas aeruginosa*. Activity was attributed to triterpenoids (α-, β-amyrin) and phytosterols identified via GC-MS.

Arya et al. (2017) [26] showed that *C. ovatum* leaf extract-mediated silver nanoparticles (AgNPs) exhibited significant antibacterial activity against Pseudomonas aeruginosa (disc diffusion), with the extract acting as a reducing and stabilizing agent. Overall, activity depends on phytochemical composition and formulation, with lipid extracts selective for gram-negative bacteria and nanoparticle systems enhancing efficacy.

4.1.2. Canarium odontophyllum

In 2016, Basri and Sandra found that *Canarium odontophyllum* leaf extracts using either acetone or methanol, could kill MRSA (*Staphylococcus aureus*) at levels of 156.25 μg/mL and 312.5 μg/mL. The most important part of the study showed that these extracts made the antibiotic oxacillin eight times more powerful. Because it attacks bacteria in a way that is similar to vancomycin, it has a lot of promise as a supportive treatment for staph.

The key to the plant's medicinal strength is really just its natural mix of tannins, flavonoids, and phenolics. It's actually quite different from *C. ovatum*, though. While *C. ovatum* is usually the better pick for Gram-negative bacteria, *C. odontophyllum* is more of a specialist at taking down MRSA.

4.2. Anticancer Activity

4.2.1. Canarium ovatum

By testing the bark, pulp, and leaves of *Canarium ovatum* in a lab, researchers have been exploring whether the plant can help fight cancer. A 2025 study led by Terrazola found that an ethanol-based leaf extract was particularly effective against HCT116 colorectal cancer cells, showing an IC_{50} of 94.43 mg/L. [24]. The extract also showed a very strong antioxidant effect at 11.44 mg/L. This suggests the plant might combat cancer by dealing with free radicals. These various health benefits are likely caused by the presence of steroids, tannins, saponins, and alkaloids within the tree (Terrazola et al., 2025) [24].

Research by Cajuday et al. (2017) discovered that ethanol extracts from the pulp can actually stop fertilization and prevent new blood vessels from forming [21]. In their sea urchin and CAM experiments, they found an IC_{50} of 0.369 mg/mL for these effects. The bark also appears to be quite potent, but it works differently. According to Balbuena et al. (2019), bark extracts can stop cells from dividing and even cause damage to chromosomes. They used Allium cepa and sea urchin tests to confirm this, recording an IC_{50} value of 0.54 mg/mL [19].

Due to its unique chemical makeup, *C. ovatum* can effectively neutralize free radicals and stop cells from multiplying or forming new blood vessels.

4.2.2. Canarium odontophyllum

The anticancer potential of *Canarium odontophyllum* has been explored using colorectal cancer models. Basri et al. (2016) [11] found that the acetone stem bark extract exhibited cytotoxic effects against HCT 116 cells, with an IC_{50} value of 25 ± 5.20 µg/mL after 48 hours. The extract also showed selective toxicity toward cancer cells compared to normal colon fibroblasts (CCD-18co). Evidence of apoptosis was confirmed through Annexin V-FITC/PI assay, while DNA damage was demonstrated using the alkaline comet assay.

Similar observations were reported by Ishak et al. (2023) [27], who documented antiproliferative activity against both HCT 116 and HT 29 cell lines, with an IC_{50} value of 61.24 µg/mL. These effects have been linked to the presence of bioactive compounds such as flavonoids, tannins, phenolics, and terpenoids.

Compared with *C. ovatum*, *C. odontophyllum* shows a more selective cytotoxic profile in colorectal cancer models. The consistent observation of apoptosis and DNA damage highlights its potential relevance for further mechanistic studies.

4.3. Anti-hypertensive Activity

4.3.1. Canarium ovatum

The antihypertensive activity of *Canarium ovatum* is mainly associated with angiotensin I-converting enzyme (ACE) inhibition. Gamba et al. (2023) [3] demonstrated that peptides derived from the 11S globulin fraction of pili nut kernel achieved up to 99.73% ACE inhibition, exceeding the activity of captopril and enalapril. This effect is believed to involve interaction with the ACE active site, resulting in decreased angiotensin II formation.

Cajuday et al. (2024) [34] reported that the ethanolic leaf extract exhibited 78.48% ACE inhibition (IC_{50} = 63.71 µg/mL), a value considered comparable to captopril. While similar activity has been observed across different plant parts, the current evidence is still largely limited to in vitro models. The activity has been linked to peptides, flavonoids, phenolics, and antioxidant compounds such as carotenoids and tocopherols, suggesting that both enzyme inhibition and oxidative stress reduction may play a role.

4.3.2. Canarium odontophyllum

In Canarium *odontophyllum*, antihypertensive effects have been associated with vasorelaxation. Basri et al. (2018) [32] reported that aqueous leaf extract induced vasodilation in rat thoracic aorta. However, when tested using endothelium-denuded aortic rings, no significant inhibition of calcium-induced contractions was observed following stimulation with phenylephrine (PE) or potassium chloride (KCl). This points to a mechanism that may not depend on calcium channels, although further clarification is still needed.

4.4. Antioxidant Activity

4.4.1. Canarium ovatum

Multiple in vitro studies have demonstrated the antioxidant activity of Canarium *ovatum*. Terrazola et al. (2025) [24] reported strong DPPH radical scavenging activity in ethanolic leaf extract (IC_{50} = 11.44 mg/L), attributed to flavonoids, tannins, and phenolic compounds. Dumandan et al. (2022) [22] also observed antioxidant activity in saponified diethyl ether extracts of pili pulp oil using DPPH and lipid peroxidation assays, with results comparable to α-tocopherol. Identified compounds included triterpenoids and phytosterols based on GC-MS analysis.

Cajuday et al. (2017) [21] reported similar findings, noting strong scavenging activity and reducing power using both DPPH and FRAP assays. Pili oil has likewise been shown to contain carotenoids, tocopherols, and sterols that contribute to its antioxidant properties (Pham & Dumandan, 2015) [2]. Overall, the activity appears to be driven by a combination of phenolics, triterpenoids, and lipid-soluble antioxidants.

4.4.2. Canarium odontophyllum

The antioxidant activity of *Canarium odontophyllum* varies depending on the plant component studied. Salleh et al. (2022) [28] reported high activity in dabai extracts, with the Sibu skin fraction showing the highest potency (EC_{50} = 198.76 ± 1.06 μg/mL).

Evidence from in vivo studies further supports this observation. Kadir et al. (2021) [13] showed that dabai pulp oil increased antioxidant enzyme levels (SOD, GPx, CAT) while reducing lipid peroxidation (MDA) in hypercholesterolemic rats. The activity was associated with triterpenoids and phytosterols such as β- and α-amyrin, stigmasterol, and campesterol. In addition, Khoo et al. (2019) [9] identified phenolic acids, flavonoids, lignans, triterpenes, and apocarotenoids, suggesting possible synergistic interactions.

Antioxidant capacity appears to depend on both the fruit part and its origin, with skin fractions consistently showing stronger effects. In some cases, the activity is comparable to or even exceeds that of *C. ovatum*.

4.5. Hepatoprotective and Lipid-Modulating Effects

4.5.1. Canarium album

Non-alcoholic fatty liver disease (NAFLD) is widely recognized as one of the most common chronic liver disorders, yet effective therapeutic options remain limited. Because of this, interest in plant-derived compounds has increased in recent years. Yeh et al. (2018) [29] reported that the ethyl acetate fraction of Chinese olive (CO-EtOAc) reduced lipid accumulation and liver damage in a high-fat diet (HFD)-induced NAFLD model. These effects were linked to changes in oxidative stress, inflammatory responses, and hepatic lipid metabolism.

4.5.2. Canarium odontophyllum

While hepatoprotective data for C. *ovatum* remain scarce, related evidence has been reported for Canarium *odontophyllum*. Kadir et al. (2021) [14] showed that both dabai pulp oil (DPO) and defatted dabai pulp (DDP) improved hepatic parameters in rats fed a high-cholesterol diet. Among the two, DDP produced more pronounced reductions in total cholesterol, LDL, and HMG-CoA reductase levels. Neither treatment caused changes in AST or ALT, suggesting no apparent hepatotoxicity. Histological observations also indicated improvements in steatosis. Syringic acid, identified through HPLC analysis, was proposed as one of the contributing bioactive compounds.

Additional findings were reported by Kadir et al. (2021) [15] who observed that dabai pulp oleoresin (DPL), obtained through supercritical CO_2 extraction, exhibited low peroxide and free fatty acid values and contained α-tocopherol. These characteristics support its potential use as a functional food component.

Current evidence points toward a lipid-modulating and hepatoprotective role for Canarium species, although the exact mechanisms remain to be clarified.

4.6. Immunomodulatory Activity

4.6.1. Canarium ovatum

The immunomodulatory effects of Canarium *ovatum* have been demonstrated in vivo. Salvador-Membreve et al. (2018) [30] reported that ethanolic pili pulp extract (COPE) enhanced delayed-type hypersensitivity responses, as reflected by increased footpad thickness. In addition, the extract elevated hemagglutination antibody titers and promoted lymphocyte proliferation, along with the formation of germinal centers in the spleen. No toxicity was observed even at higher doses. These findings indicate that the extract influences both cellular and humoral immune responses.

4.6.2. Canarium odontophyllum

Evidence of immunomodulatory activity has also been reported for Canarium *odontophyllum*. Saari et al. (2015) [10] observed that aqueous leaf extract administered to streptozotocin-induced diabetic rats reduced fasting blood glucose levels and increased splenic $CD3^+$ $CD4^+$ T lymphocytes. This suggests an immunostimulatory effect. Identified phytochemicals include flavonoids, tannins, saponins, terpenoids, and phenolic compounds.

It is important to note, however, that these findings are based on a Type 1 diabetes model with a relatively short duration of exposure (28 days). While the results are indicative of immune-related effects, further studies are needed to better define the underlying mechanisms.

Research Gap and Future Research

4.7. Research Gap and Future Research

4.7.1. Comprehensive Phytochemical Quantification

Although qualitative profiling of phytochemicals has been extensively reported, quantitative data remain limited. In *C. ovatum*, absolute mass values for triterpenoids, carotenoids, terpenoids, phytosterols, and minerals are often unavailable and are instead presented in terms of bioavailability. Similar gaps are evident in C. *album*, particularly for anthocyanins, carotenoids, and terpenoids. In *C. odontophyllum*, information on amino acid profiles, phenylpropanoids, and absolute quantification of volatile compounds, apocarotenoids, and minor lipids is still lacking, with most data reported only as relative abundance. The use of standardized extraction and analytical methods would help establish more consistent quantitative profiles.

4.7.2. Transition from In Vitro to In Vivo and Clinical Evaluations

Much of the current evidence remains limited to in vitro studies. For example, the antihypertensive activity of *C. ovatum* has largely been demonstrated through ACE inhibition assays. To strengthen clinical relevance, further in vivo investigations and well-designed clinical trials are needed. These should focus on efficacy, bioavailability, safety, and pharmacokinetics, which are essential for the development of Canarium-derived therapeutic agents and functional foods.

4.7.3. Unexplored Pharmacological Domains and Ethnomedicinal Validations

Gaps remain in the pharmacological evaluation of specific species. In particular, hepatoprotective and lipid-modulating effects of *C. ovatum* have not yet been directly studied. In addition, available ethnomedicinal data are still limited. Future research should include targeted in vivo studies, especially those based on its phytosterol and fatty acid composition, along with broader ethnobotanical documentation.

4.7.4. Elucidation of Mechanisms and Synergistic Applications

The molecular mechanisms underlying the reported bioactivities are not yet fully understood. Further studies are needed to clarify the pathways involved in the immunomodulatory and anticancer effects of *C. ovatum*, as well as the genotoxic activity of *C. odontophyllum* in colorectal cancer models. The application of advanced molecular approaches, along with investigations into potential synergistic effects with conventional therapies, including anti-MRSA activity, may provide deeper insight.

5. Discussion

The present review summarizes current evidence on the phytochemical composition and pharmacological potential of *Canarium ovatum*, *Canarium album*, and *Canarium odontophyllum*. These species contain bioactive compounds such as phenolics, flavonoids, fatty acids, tocopherols, and peptides, which are associated with antioxidant, antihypertensive, antimicrobial, and antiproliferative effects.

Among the species, C. *album* shows strong antioxidant activity due to its high phenolic content. *C. odontophyllum* demonstrates broader cardiometabolic benefits linked to its diverse lipid and secondary metabolite profile, while *C. ovatum* exhibits potential antihypertensive effects through ACE inhibitory peptides. These findings highlight their potential use as functional foods and adjunct therapeutic agents.

However, most available data are based on in vitro and animal studies, limiting direct clinical application. In addition, variability in extraction methods and lack of standardized protocols contribute to inconsistent findings. Pharmacokinetics and bioavailability are also poorly understood, particularly for polyphenols, which may have limited systemic effects. Safety and toxicity data at therapeutic doses remain insufficient.

Overall, Canarium species show promise for clinical and nutritional applications. Further well-designed clinical trials and standardized studies are needed to confirm their safety and efficacy.

6. Conclusion

In summary, *Canarium ovatum*, *Canarium album*, and *Canarium odontophyllum* are promising sources of bioactive compounds with significant pharmacological potential, particularly in the management of oxidative stress and metabolic disorders. While current evidence supports their functional and therapeutic value, it remains largely preclinical.

To advance their application, future research should prioritize clinical validation, standardization of extraction and analytical methods, and comprehensive evaluation of pharmacokinetics and safety profiles. Addressing these gaps is essential for the successful translation of Canarium species into evidence-based functional foods and phytopharmaceuticals, thereby contributing to the development of sustainable plant-derived therapeutic resources.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors confirm that there is no conflict of interest

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