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Phytochemical Profile and Therapeutic Potential of Elaeocarpus Species: A Comprehensive Review

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ABSTRACT

Generically *Elaeocarpus* belongs to Elaeocarpaceae while spanning from 350-400 rainforest trees that grow in palaeo-tropical areas yet do not exist in mainland Africa. The genus fulfills essential functions for scientists who analyze rainforest ecology while studying evolution and perform geographic analysis using ecological methods. Researchers currently provide information about the taxonomic placements along with geographic distributions and phylogenetic relationships of *Elaeocarpus* species and their morphology adaptations and human traditional treatments. Tropical and subtropical rainforests heavily depend on *Elaeocarpus* as it forms a significant link with its related genus Aceratium for maintaining ecological framework operations. Numerous organisms such as fungi and epiphytes use *Elaeocarpus* species as their ecological habitats while they draw resources from the species. Indian culture venerates *Elaeocarpus ganitrus* (Rudraksha) because it has become integral to religious worship and healthcare approaches. However, many *Elaeocarpus* species face severe threats from human activities such as deforestation, habitat fragmentation, and land-use changes. The systematic evolutionary family relationships throughout the entire genus depend heavily on analysis of genetic tree data. *Elaeocarpus* originated in Australia before its spread across neighboring areas because of regional geological events as well as climate changes and dispersal patterns throughout its history. Traditional medical

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practices in Ayurveda and Unani systems document the broad application of *Elaeocarpus* species for medicinal purposes. Plant research has identified four major phytochemical groups found in *Elaeocarpus* species which contain alkaloids, flavonoids, tannins and saponins and display proved antimicrobial, anticancer and antioxidant pharmacological actions. Additional research must happen to understand the medical capability of these plants while ensuring their secure usage for medical purposes. The successful management of *Elaeocarpus* species requires immediate attention because they hold critical value to nature as well as traditional human practices and medicinal applications.

Keywords: *Elaeocarpus*, Biogeography, Molecular systematics, Morphology, Phylogenetics

1. Introduction

This paper gives a comprehensive introduction to the genus *Elaeocarpus*, a component of the family Elaeocarpaceae which is of great importance. The genus includes a large number of species estimated to be between 350 and 400 rainforest trees dispersed in palaeo-tropical areas with an absence from mainland Africa [1]. *Elaeocarpus* has a particularly wide distribution and species richness, and so is an important subject for studying evolutionary processes, biogeographic patterns and ecological interactions in a variety of rainforest ecosystems. We will discuss on the taxonomic position, biogeography, phylogenetic affiliations, morphology and ecology and traditional use in a synoptic review of most recent works [1–3]. Importance of this genus in various ecosystems and in the cultural significance to India in its name of Rudraksha will be presented [3,4]. In addition to the challenges still in place with respect to ongoing taxonomic work and research gaps of this diverse genus, we will also take into consideration the limitations of previous studies as well as recent knowledge from molecular methods. Indicatively, the genus *Elaeocarpus* has to be understood using a combination of traditional taxonomic approaches relying on primarily on primary and secondary structural data as well as up-to-date molecular phylogenetics and ecological studies. The *Elaeocarpus* genus belongs to the Elaeocarpaceae family as an Oxalidales order member. Evolutionary research using molecular technologies has strengthened our knowledge about flowering plant relationships thus placing *Elaeocarpus* in this position [5]. Elaeocarpaceae family centers around *Elaeocarpus* as this genus maintains a solid relationship to Aceratium. Throughout history the classification of *Elaeocarpus* rest upon morphological characteristics related to seed morphology including seed embryo shape and endosperm ornamentation. DNA sequence data within molecular systematics has succeeded in transforming our knowledge about *Elaeocarpus* taxonomic classification [5]. Extensive molecular marker studies of expanded *Elaeocarpus* species populations led to necessary phylogenetic relationship discovery that brought about taxonomic changes. Morphometric investigations on the species within the polystachyus complex enable better understanding of taxonomic definitions and alpha taxonomy connections. The continual taxonomic improvement in the genus becomes

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evident through the recent discovery of new species identified as *E. mahamayensis* [6] and *E. sedentarius* [7].*Elaeocarpus* exists in the palaeo-tropical ecological zones which extend across Asia and Australasia together with the Pacific Islands. *Elaeocarpus* completely lacks its presence in mainland Africa making it a major biogeographic characteristic because historic events influenced its present-day distribution range. Genus historical biogeographic evolution needs detailed research to explain its present-day distribution through analysis of geological events as well as climatic changes and dispersal patterns. Analysis through Fitch parsimony and Dispersal-Extinction-Cladogenesis methods together with molecular dating methods have enabled researchers to study how *Elaeocarpus* evolved [1]. Research investigations demonstrate that *Elaeocarpus* stems from Australia and then spread throughout neighboring areas. Experts believe that the Eocene split of *Elaeocarpus* from Aceratium in Australian territory triggered several dispersal events that led to migration across New Guinea and Central and West Malesia as well as New Zealand and Pacific islands and continental Asia before reaching Madagascar. Molecular docking analysis was performed to explore the interaction between key phytoconstituents of *Elaeocarpus serratus* and selected hub proteins implicated in Parkinson's disease. Quercetin demonstrated strong and stable binding within the active sites of critical targets, particularly BCL2, TP53, and MMP9, indicating favorable molecular recognition. These interactions suggest a potential role of quercetin in modulating apoptotic and inflammatory signaling relevant to neuroprotection.[8] *Elaeocarpus* radiation throughout the New Guinean region alongside Borneo underwent changes because the Miocene geological phase formed novel habitats through mountain formation and thereby triggered species diversification. Seeds of *Elaeocarpus* benefit from zoochory dispersal techniques which enable their movement across geographic barriers as described in Sook-Ngoh Phoon (2015) [1]. The distribution together with conservation status of many *Elaeocarpus* species faces severe threats from human activities through deforestation and habitat fragmentation and land-use changes [9,10]. *E. venustus*, endemic and threatened species in the Agasthiyamalai Biosphere Reserve of India demonstrates the plight of *Elaeocarpus* to anthropogenic threats [9].

1.1 Ethnobotanical Uses

The ethnobotanical value of *Elaeocarpus ganitrus* (Rudraksha) species reaches its peak within Indian culture because people use them extensively in religious ceremonies and practices. People use the seeds of *E. ganitrus* because of their acknowledged spiritual capabilities for religious practice [11]. Multiple *Elaeocarpus* plant species have traditionally been employed for medical purposes in both Ayurveda and Unani medicine practices since ancient times [12]. Traditional plant usage occurs through evaluation of phytochemical assets that contain alkaloids and flavonoids and tannins and saponins based on numerous documented research findings. Scientific reports show This wide range of bioactive compounds including antioxidants to antiviral compounds show various pharmacological properties such as

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antimicrobial activities and anticancer activity. Scientists extensively examine the medicinal properties of *E. ganitrus* species alongside *E. variabilis* according to reports [13–16]. The traditional medicinal use of *E. ganitrus* extends to treating mental ailments along with epilepsy and liver discomfort and stomach pain [4]. The native Western Ghats species *E. variabilis* displays four therapeutic effects including antioxidant action along with anti-inflammatory ability and antimicrobial properties and anticancer activity [14,16]. The medicinal potential demonstrated by *E. tonkinensis* regarding anti-influenza methods and *E. grandis* in ulcer prevention shows the strong therapeutic qualities within this plant genus. New therapeutic drugs have a promising future following researchers synthesizing alkaloid elaokanines A, B and C from *Elaeocarpus* species. The recent years have seen a rise in in silico research applications that support experimental work to reveal vital information about how *Elaeocarpus* compounds operate [13,17]. Computational methods analyze bioactive molecule structural relationships to pharmaceutical activities and this reduces research time for developing new pharmaceutical treatments. Most of the present information regarding *Elaeocarpus* medicinal properties originates from traditional applications coupled with preclinical research findings. Laboratory trials and medical studies will be necessary to prove the therapeutic advantages of these medicinal plants while also confirming their secure application habits.

2. Bioactive compounds from *Elaeocarpus*

2.1 Alkaloids: An Important Source of Novel Compounds and Wide Range of Bioactivities *Elaeocarpus* species have earned recognition for their habit of producing indolizidine alkaloids according to research [18]. Scientists have studied *Elaeocarpus tectorius* and *Elaeocarpus angustifolius* specifically to isolate novel alkaloids and phenethylamine-containing compounds which collectively amount to a significant number. Scientists recorded the first phenethylamine-containing alkaloids from the Elaeocarpaceae family during this investigation. The work presented by Ezeoke [18] provides exhaustive information about the extraction process which resulted in identification of tectoricine along with tectoraline and tectoramidines A and B. Various spectroscopic approaches helped understand the chemical structures while their biological properties received evaluation. The tested alkaloids demonstrated no harmful effects onto cancer cell lines during biochemical assays which indicates their potential usage as starting materials for new anticancer formulations. The discovery of non-toxic properties in these compounds stands out because numerous alkaloids typically demonstrate destructive effects. Researchers need to carry out more investigations to determine the physical mechanism behind this observed non-cytotoxic effect. Extensive studies have conducted alkaloid analysis on the seeds of *Elaeocarpus sphaericus* [19]. The mix of alkaloids in the extract was confirmed through LC-MS analysis which detected elaeokanine C and (+)-elaeocarpine

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together with elaeocarpenine and isoelaeocarpine while grandisine B and isoelaeocarpiline were also present. The research work conducted by Primiani et al. [19] identified the exact amounts of alkaloids contained in seed extracts. The presence of these alkaloids and their bioactivities should consequently encourage additional research for their therapeutic potential. A thorough evaluation of *Elaeocarpus* species needs to happen to reveal which factors affect alkaloid production while explaining their natural diversity. As show in **Table 1**.

Table 1- Alkaloids

Alkaloid	Species	Part	Bioactivity	Reference
Elaeocarpine	*E. fucoides*	Leaves	Binds to δ-opioid receptors	[20]
Isoelaeocarpine	*E. fucoides*	Leaves	Binds to δ-opioid receptors	[20]
Elaeocarpenine	*E. fucoides*	Leaves	Binds to δ-opioid receptors	[20]
(±)−8,9-Dehydroelaeocarpine	*E. angustifolius*	Branch, Leaves	Inhibits cholinesterase enzyme activity	[21]
(±)-Elaeocarpine trifluoroacetate	*E. angustifolius*	Branch, Leaves	Inhibits cholinesterase enzyme activity	[21]
(±)−9-Epielaeocarpine cis-N-oxide trifluoroacetate	*E. angustifolius*	Branch, Leaves	Inhibits cholinesterase enzyme activity	[21]
Isoelaeocarpicine	*E. fucoides*	Leaves	Binds to δ-opioid receptors	[20]
Elaeocarpionoside	*E. japonicus*	Leaves	-	[22]
Grandisine C, D, E, G	*E. grandis*	Leaves	Binds to δ-opioid receptors	[23]
Habbemines A, B	*E. habbemensis*	Leaves	Binds to δ-opioid receptors	[20]
Rudrakine	*E. ganitrus*	Leaves	-	[24]
Tectoricine	*E. tectorius*	Leaves	Inhibits cholinesterase enzyme activity	[25]
Tectoraline	*E. tectorius*	Leaves	Binds to δ-opioid receptors	[25]

Tectoramidines A, B	*E. tectorius*	Leaves	neuroprotective & antioxidant properties	[25]

2.2 Polyphenols and Flavonoids: Rich Antioxidant Property, Widely Distributed across the Biological Roles

The polyphenols and flavonoid levels in numerous *Elaeocarpus* species are observed to be exceptionally high [13,26,27]. These compounds have established potential antioxidant functions that explain many health benefits associated with extracting *Elaeocarpus*. Different *Elaeocarpus* species have had their total phenolic content (TPC) and total flavonoid content (TFC) measured using standard methods including Folin-Ciocalteu assay and aluminum chloride colorimetric method in scientific studies. Scientific research has extensively studied *Elaeocarpus serratus* to investigate its polyphenol and flavonoid concentrations in multiple investigations including [27–29]. Research conducted by Chen and Yang [27] demonstrated the effectiveness of using ultrasound-assisted extraction (UAE) to obtain high recovery rates of TPC and TFC from *E. serratus* leaves. The FRAP method assessed antioxidant properties in the extracts of these plants. Several studies with varied extraction methods have confirmed the significance of optimizing extraction parameters to obtain maximum yields of valuable compounds from *E. serratus*. [28,29]The main identified flavonoids in *E. serratus* include myricitrin quercetin and kaempferol which demonstrate strong antioxidant properties. Scientists have studied *Elaeocarpus floribundus* along with its contents of both polyphenols and flavonoids [30]. The level of TPC in *Elaeocarpus serratus* leaf extract reached higher levels when compared to the TPC measured in stem bark extract as reported by Utami et al. [30]. The research employed the DPPH free radical scavenging method that indicated strong antioxidant activity levels. Researchers isolated triterpenoids friedelin and epifriedelanol through their investigation which consequently increased the number of identified bioactive compounds from this plant species. Comparative studies between TPC and TFC contents in different *Elaeocarpus* species would reveal important elements that determine their synthesis and occurrence patterns. As show in **Table 2**.

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Table 2- Polyphenols and Flavonoids

Active Compound	**Plant Species**	**Type of Extract (Plant Part)**	**Biological Action**	**Reference**
Gallic Acid	*Elaeocarpus flooribundus*	Ethanolic, EtOAc Seed Extract	Exhibits strong antioxidant and antimicrobial effects	[31]
Gallic Acid	*Elaeocarpus serratus*	Ethanolic Leaf Extract	Suppresses tyrosinase activity and promotes skin lightening	[32]
Methylellagic Acid Derivative with Acetylation	*Elaeocarpus mastersii*	Bark Extract	Potential antiviral properties	[33]
Dimethylated Ellagic Acid with Acetylation	*Elaeocarpus mastersii*	Bark Extract	Antiviral effects observed	[33]
Geraniin	*Elaeocarpus sylvestris*	Aqueous Ethanol & EtOAc Fraction (50%)	Modulates immune system, alleviates diarrhea, supports anticancer properties, and inhibits tumor necrosis factor	[34–36]
Galloylated Glucose Derivative (PGG)	*Elaeocarpus sylvestris*	Aqueous Ethanol & EtOAc Fraction (50%)	Antiviral, antioxidant, supports immune function, provides radioprotection, anti-tumor and inhibits angiogenesis	[34,37,38]
Quercetin	*Elaeocarpus sylvestris*	Ethyl Acetate Extract	Inhibits viral growth	[38]

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Isoquercitrin	*Elaeocarpus sylvestris*	Ethyl Acetate Extract	Displays antiviral activity	[38]
Myricetin	*Elaeocarpus lanceofolius*	Leaf Extract	Bioactivity not yet specified	[39]
Myricetin	*Elaeocarpus serratus*	Ethanolic Leaf Extract	Acts as a skin-whitening agent and inhibits tyrosinase	[32]
4'-Methylmyricetin	*Elaeocarpus lanceofolius*	Leaf Extract	Bioactivity not yet specified	[39]
Myricetin 3-O-rhamnoside	*Elaeocarpus serratus*	Unknown Extract Type	Demonstrates antioxidant potential	[40]
Mearnsetin	*Elaeocarpus serratus*	Ethanolic Leaf Extract	Provides antioxidant benefits, reduces skin pigmentation, and inhibits tyrosinase	[32]
Polyphenolic Pigments	*Elaeocarpus reticulatus*	Fruit Extract (Water, Ethanol, Acetonitrile, Acetone)	Antioxidant and inhibits α-amylase and α-glucosidase	[41]
Tamarixetin Rhamnoside	*Elaeocarpus serratus*	Leaf Extract	Bioactivity not yet specified	[40]
Umbelliferone	*Elaeocarpus sylvestris*	Unknown Extract Type	Provides antimutagenic activity, UV protection, antioxidant benefits, and inhibits type 3 17β-hydroxysteroid dehydrogenase	[42]
Scopoletin	*Elaeocarpus sylvestris*	Unknown Extract Type	Exhibits anti-rheumatic properties	[43]

2.3 Cucurbitacins of *Elaeocarpus*

Therapeutic compounds of the cucurbitacin group belong to tetracyclic triterpenoid compounds with high levels of oxidative degradation. Cucurbitacins initially work as heterologous pheromones which help plants defend themselves from external biological threats [44,45]. Table 3 shows that *Elaeocarpus* contains cucurbitacins D, E, F and I together with its multiple species. The derivatives of these compounds show comparable functions to cucurbitacins. Scientists obtained petiolaticins A-D and petiolaticin A-D through bark and leaf extraction from *Elaeocarpus petiolatus*. Multiple research revealed that Cucurbitacins possess promising pharmacological effects of anticancer, anti-inflammatory properties and hepatoprotective effects [44,45]. Scientists view anti-cancer potential as one of the main reasons that drives their interest in new anticancer drug development. The anticancer effects of cucurbitacins become stronger when combined with other anticancer medicines [46]. The petiolaticins A, B and D from the curcubitacins have anticancer activities because they belong to the curcubitacins group. Research reveals that these compounds show anti-cancer effects against human cells which originate from breast cancer, pancreatic cancer, and colorectal cancer. Experimental research shows that cucurbitacins trigger apoptotic responses in multiple cell lines which have been diagnosed with cancer. Research shows that apoptotic effects stem from how cucurbitacins affect genetic material expression [47]. Cucurbitacins inhibit the enzyme Signal Transducers and Activators of Transcription-3 as well as both JAK-STAT pathway and MAPK pathway. The cell survival mechanisms along with proliferation processes depend on these factors. In addition, petiolaticin D displays antiviral activities [48]. As show in **Table 3**.

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Table 3- Bioactive Compounds and Their Properties-Cucurbitacins and Related Compounds

Active Compound	Source Species	Extraction Method (Plant Parts)	Biological Activity	References
Cucurbitacin D	*Elaeocarpus hainanensis*	Unrefined Extract	Anti-neoplastic potential	[49]
Cucurbitacin D	*E. mastersii*	Bark-derived extract	Tumor suppression, apoptosis induction, cell cycle arrest (G1/S), upregulation of tumor suppressor miRNAs	[50,51]
Cucurbitacin D	*E. chinensis*	Chloroform-methanol (fruit & bark)	Cytotoxic properties against cancer cells	[52]
Cucurbitacin F	*E. dolichostylus*	Solvent not specified	Tumor-inhibiting effects	[53]
Cucurbitacin F	*E. mastersii*	Bark extract	Anti-cancer, antiviral potential	[33]
Cucurbitacin I	*E. reticulatus*	Acetone (fruit extract)	Antioxidant, inflammatory suppression, apoptosis promotion	[54]
Cucurbitacin I	*E. hainanensis*	Unrefined Extract	Growth inhibition, apoptosis induction, PI3K/AKT/p70S6K pathway suppression	[49,55]
Elaeocarpins A-H	*E. chinensis*	Chloroform-methanol (fruit & bark)	Oncoprotective properties	[52]
Petiolins A-D	*E. petiolatus*	Bark & foliage-derived extract	Antiviral, cytotoxic potential	[48]

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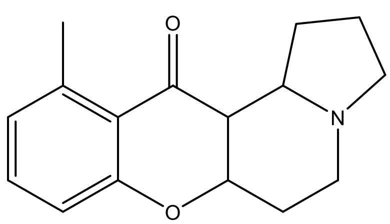
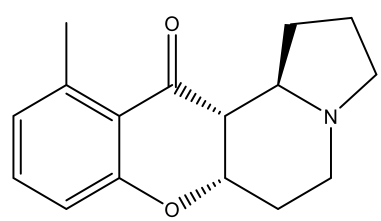
Friedelin	*E. floribundus*	Chloroform-methanol (leaf & bark)	Free radical scavenger, tumor inhibition	[30]
Epifriedelanol	*E. floribundus*	Methanol-based extract (leaf & bark)	Antioxidant, cytotoxic effects	[30,48]
Tanacetene	*E. floribundus*	Hexane (leaf extract)	Delta-opioid receptor affinity, antimicrobial, anti-cancer	[56]
α-Tocopherolquinone	*E. floribundus*	Hexane (leaf extract)	Neuroprotective, antioxidant, cytotoxic properties	[56]
Phytol	*E. floribundus*	Hexane (leaf extract)	Antioxidant, tumor-suppressing, microbial defense	[56]
Euphorbol	*E. floribundus*	Hexane (leaf extract)	Immune modulation, cancer-fighting capabilities	[56]
Phaeophytins	*E. floribundus*	Hexane (leaf extract)	Radical scavenger, antimicrobial, potential anti-tumor activity	[56]

3. Chemical structure of bioactive compounds



Elaeocarpine



Isoelaeocarpine

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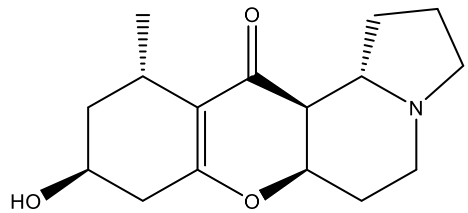
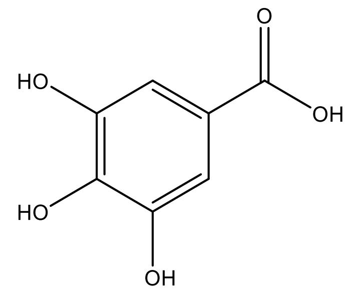
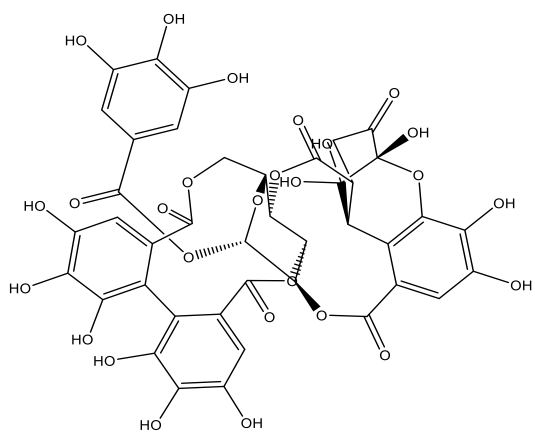


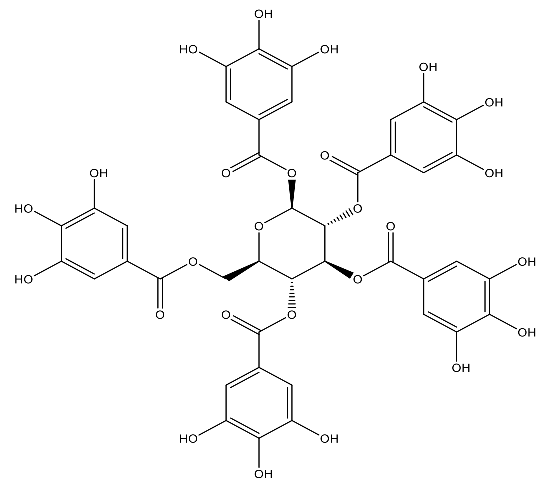
Grandisine C



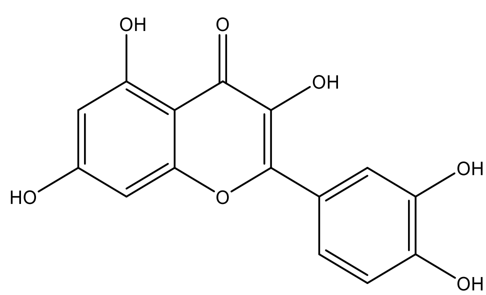
Gallic Acid



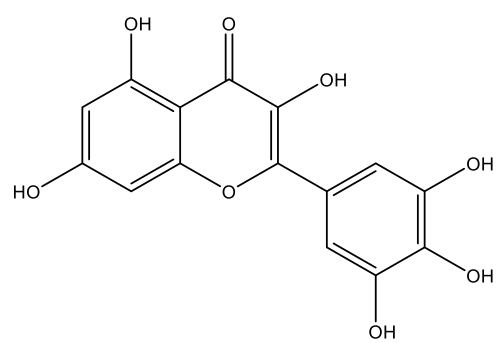
Geraniin



PGG (1,2,3,4,6-penta-O-galloyl-β-D-glucose)



Quercetin



Myricetin

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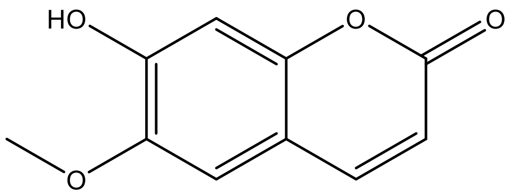
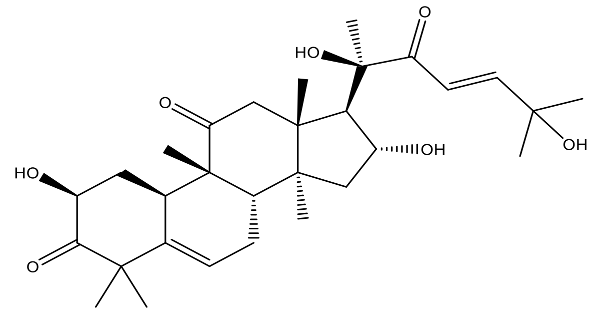
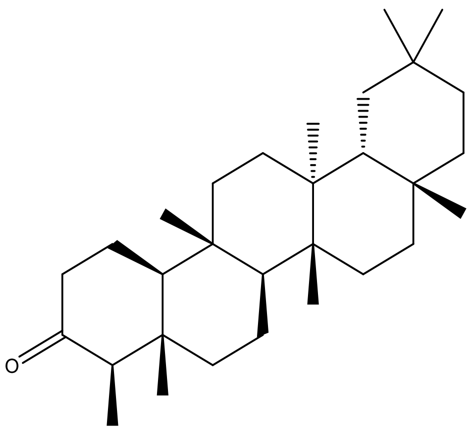


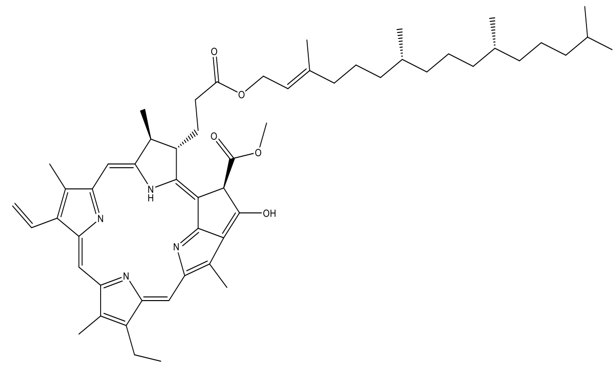
Scopoletin



Cucurbitacin D



Friedelin



Phaeophytin

4. Pharmacological benefits of Elaeocarpus

4.1 Antibacterial Activity

Some *Elaeocarpus* species show valuable antibacterial capability which function as substitute antibiotics to treat multiple-drug resistant bacterial strains. The antimicrobial behavior of *Elaeocarpus ganitrus* (Rudraksh) against human pathogenic bacteria was examined in detail by Sakha et al. (2018) [57]. The antibacterial examination by Sakha et al. (2018) [57] established that the test substance effectively inhibited S. aureus growth by creating a 16 mm area of no bacterial growth through disc diffusion tests. The laboratory tests confirmed that *E. ganitrus* extract has the ability to effectively fight S. aureus bacteria between concentrations of 12.5-25 mg/ml [57]. The antibacterial effect demonstrated by *E. ganitrus* indicates strong potential to develop new antimicrobial products from this source.

The antibacterial capabilities of *Elaeocarpus* were validated by Panda et al. (2019) [58]. The research evaluated the in vitro antibacterial properties of selected Indian medicinal plants used against MDR and biofilm-forming Staphylococcus aureus. Laboratory tests revealed *Elaeocarpus serratus* showed strong anti-staphylococcal properties [58]. The research shows that *Elaeocarpus* species represent promising options to discover new antibacterial compounds for combating antibiotic resistance faced today. The ability to combat biofilms stands out as exceptional because these bacterial

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communities embedded in self-made matrices create especially difficult to treat persistent infections. The analysis requires recognition of its boundaries. *In vivo* research about the efficacy and safety of antibacterial agents from *Elaeocarpus* demands further investigation since the initial studies only conducted laboratory tests. The identification and detailed characterization of the antibacterial bioactive compounds from *Elaeocarpus* represents the next crucial step of research. Future research needs to identify antibacterial compounds in *Elaeocarpus* while determining their basic properties that will establish their suitability for medical development. The study requires determination of both the best delivery method along with the safe dosage amounts and Toxicity risks.

4.2 Antioxidant Activity

Multiple phytochemicals present in *Elaeocarpus* species establish their antioxidant properties which scientists have studied due to their documented antioxidant capabilities. Scientists investigated antioxidant compounds produced by Pseudocercospora sp. ESL 02 endophytic fungus originating from *Elaeocarpus sylvestris* according to Prihantini and Tachibana (2016) [59]. Research by Prihantini and Tachibana [59] demonstrated that when grown on an endophytic Pseudocercospora sp. ESL 02 fungus isolated from *Elaeocarpus sylvestris* there was a production of terreic acid and 6-methylsalicylic acid which displayed strong DPPH radical scavenging effects. The antioxidant performance was demonstrated by IC50 values (concentration required to inhibit 50% of DPPH radical) which measured 0.22 ± 0.02 mmol/L for terreic acid and 3.87 ± 0.27 mmol/L for 6-methylsalicylic acid according to scientific data presented in Prihantini (2017) [59]. Laboratory evaluations indicated that these compounds displayed high reducing capability along with β-carotene bleaching activities thus suggesting their potential value as new antioxidant agents.

The antioxidant features of *Elaeocarpus* become more pronounced through the multiple phytochemicals including alkaloids, flavonoids, glycosides, tannins and triterpenes, fatty acids and ellagic acid derivatives [60]. Several antioxidant compounds in *Elaeocarpus* extracts demonstrate their antioxidant effects that support the complete antioxidant strength of the extracts. Research should investigate how individual phytochemicals merge to form the complete antioxidant capacity of the plant extracts. Scientists need to use relevant test animals to conduct extensive studies on *Elaeocarpus* extract properties regarding their potential to protect against and reduce diseases associated with oxidative stress conditions. The investigation of these compounds in human bioavailability and metabolism also requires additional specific research studies.

4.3 Anti-inflammatory Activity

The absence of specific studies regarding *Elaeocarpus'* anti-inflammatory properties in available literature does not diminish the likelihood of such potential because multiple inflammatory-fighting compounds have been identified. Flavonoids occur naturally in *Elaeocarpus* while also being known widely for their ability to reduce inflammation [61]. The anti-inflammatory compounds achieve their action points by blocking inflammatory mediator production and regulating signaling networks and eliminating free radicals. Besides flavonoids *Elaeocarpus* contains tannins and triterpenes which strengthen its anti-inflammatory properties [60,61].

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Phytochemicals play a crucial role in managing inflammation-associated diseases according to Nisar et al. (2023) [61]. A review report underscores that more scientific investigations should proceed relating to plant-based anti-inflammatory compounds while stressing the significance of *Elaeocarpus* investigation in this field. Research needs to concentrate on evaluating *Elaeocarpus* extracts and isolated compounds through testing their anti-inflammatory properties within *in vitro* and *in vivo* experimental environments. Research needs to examine both the biological processes involved together with an evaluation of treatment possibilities for inflammatory problems such as arthritis, diabetes and cardiovascular diseases.

4.4 Anticancer Activity

Elaeocarpus demonstrates potential anticancer effects since triterpenoids exist within this species and these compounds are known to exhibit diverse biological properties as well as anticancer effects [62]. The biological compound triterpenoids exists in *Elaeocarpus* species according to Ren and Kinghorn (2019) [62] who published an extensive report about naturally occurring and semi-synthetic anticancer triterpenoids. The research review establishes that different plant-sourced triterpenoids display proven antitumor effects.

The anticancer potential of *Elaeocarpus* triterpenoids remains uncertain because current research lacks studies focusing specifically on cancer-fighting properties of its medicinal compounds or plant extract. The investigation of *Elaeocarpus*-derived triterpenoids for anticancer functions with their action mechanisms remains a point that needs additional research. The research agenda should include both *in vitro* cancer cell line tests and *in vivo* animal experimentation while identifying the particular bioactive compounds leading to these observed anticancer properties.

5. Ethnobotany: Uses in the Traditional Medicine

Tribal cultures have documented their traditional applications of *Elaeocarpus* species in the ethnobotanical literature base. Several studies [57,58] establish the traditional medical applications of *Elaeocarpus ganitrus*. According to several research works *Elaeocarpus* species receive traditional medical applications across different geographical areas [63–67]. Various traditional practices incorporate *Elaeocarpus* species for medicinal ends toward healing different conditions as well as religious and spiritual ceremonies. Multiple societies stretching across numerous regions have historically used this plant for medicine which offers scientific researchers important leads for further investigation.

Ethnobotanical data cannot independently validate either complete efficacy or safety effectiveness. The traditional uses of plants serve as important indicators for possible therapeutic functions but need scientific validation for confirmation. Scientists should conduct examinations through experimental protocols and clinical studies to validate traditional documentation about *Elaeocarpus* species applications. Future research needs to perform structured investigations on traditional usage reports while identifying which bioactive substances create observable effects and conducting safety and effectiveness assessments through well-planned studies.

6. Conclusion:

Elaeocarpus species contain diverse bioactive compounds, including flavonoids and triterpenoids, that exhibit promising antibacterial, antioxidant, anti-inflammatory, and anticancer activities. However, most existing evidence is limited to in vitro studies and ethnobotanical reports, highlighting the need for systematic research. Future work should focus on isolating active constituents, clarifying mechanisms of action, conducting robust *in vivo* and clinical studies, and standardizing extraction and cultivation practices. Advancements in modern extraction and drug delivery technologies, supported by interdisciplinary collaboration, will be essential to translate *Elaeocarpus*-derived compounds into effective and sustainable therapeutic agents.

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