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Pharmacological Insights and Therapeutic Value of Rudraksha: Scientific Review

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Abstract

Rudraksha (*Elaeocarpus ganitrus*) is a plant that is highly revered and has been found out to be of therapeutic and spiritual value. Traditionally used as the King of Herbal Medicines in use in systems of medicine like Ayurveda, Siddha and Unani systems of medicine, it has been used both prophylactically and as a treatment. As per the mythology of the Hindus, this origin dates back to the Lord Shiva when his tears gave it more spiritual value. Through centuries Rudraksha beads have been attracting the attention of sages, scientists, and medical workers because of the vast quantity of medicinal effectiveness. Conventionally they have been used to treat conditions such as asthma, diabetes, high blood pressure, neurological diseases and sexual disorders. Pharmacological benefits of rudraksha use in form of wearing are reported to minimize anxiety, depression, insomnia, palpitation, rheumatism etc. Studies based on rudraksha reveal that it has antidepressant, antidiabetic, anti-asthmatic, antibacterial, and antiulcerigenic influence. Such advantages are attributed to its diverse phytochemical content, whereby it has been found to contain flavonoids, alkaloids, saponins, cardiac glycosides, steroids, carbohydrates and fixed oils. Quite ethno-medically important in first place and appearing mostly in Himalaya foothills, a large deciduous Rudraksha tree. The present review summarizes the recent scientific evidence on its botanical attributes, biochemical composition and effect on pharmacology and discusses the need of further clinical and pharmacological trials to improve knowledge and corroborate the therapeutic potential.

Keywords: Rudraksha plant, Alkaloids, Herbal medicines, Hindu mythology, Himalayan foothills

Introduction

One of the most significant herbal plants used in indigenous medical systems such as Ayurveda, Siddha, and Unani is *Elaeocarpus ganitrus* **(Figure 1)**, also known as Rudraksha in Sanskrit and rudraki in Hindi. Rudraksha, often known as a bead or nut, is the hard, stony endocarp found in the ripe fruit of the *E. ganitrus* plant (Chopra *et al*., 1956; Maheshwari *et al.,* 2023; Khodape *et al.,* 2024). Rudraksha is regarded as the King of natural remedies and has therapeutic, religious, and spiritual significance.

Figure 1. Shows Rudraksha/ Elaeocarpus sp. Traditional plant with many medicinal applications

Elaeocarpus is one of the major genera in medicine traditional systems of Ayurveda, Siddha, and Unani and includes such species as *E. ganitrus* and *E. sylvestris* (Ogundele & Das, 2019). Olive refers to the name of the genus which is a combination of the Greek words meaning olive and fruit because that is what they give rise to- olive-like drupes (Manu *et al.,* 2013). In this review, focus is made on recorded species of *Elaeocarpus* especially *E. ganitrus* (Rudraksha) and *E. sylvestris.* Rudraksha beads have been observed to have pharmacological activity against many diseases such as stress, anxiety, depression, palpitations, nerve pains, epilepsy, migraine, loss of concentration, asthma, hypertension, diabetes, arthritis and conditions related to the liver (Jain *et al.,* 2014). The therapeutic effects also vary according to the type and pattern of mukhies (Dadhich *et al*., 2014; Sharma *et al*., 2015; Tripathy *et al*., 2016a, 2016b; Tilak *et al*., 2017).

Recent researches confirm these conventional statements and provide additional details. Kaushik *et al.* (2023) demonstrate that *E. ganitrus* can have antioxidant, anti-inflammatory, neuoprotective, anticancer, hepaprotective, and immunomodulatory effects. Maheshwari *et al*. (2023) go further to record its potential phytochemical constituent isoelaeocarpine, elaeocarpine, quercetin, gallic and ellagic acids and rudrakine as well as recording its dielectric and hypoglycemic activities along with analgesic, antimicrobial, and anti-ulcerogenic properties. It

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finds involvement in neurological and cardiovascular disorders as Yadav (2023) incorporates traditional mukhi-based remedies that relate to the equalisation of vata-dosha in the case of anxiety, hypertension, asthma, and depression, as well as insomnia and rheumatism. A comparison list created by Sudrajat (2022) pinpoints the relationship between the interactions of delta-opioid receptors, enzyme inhibition, and the antiviral, anticancer, and CNS-selective effects of alkaloids and phenolics of *Elaeocarpus* **(Table 1)**.

Table 1. Pharmacological Activities of *Elaeocarpus* Alkaloids and Phenolics

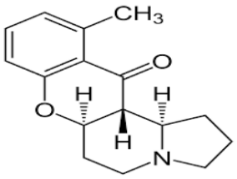
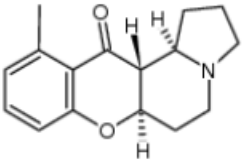
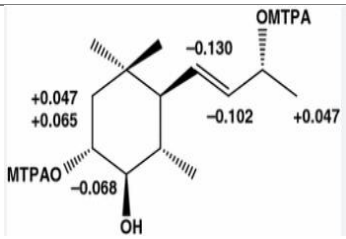
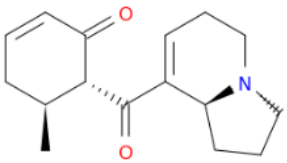
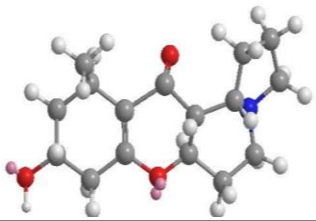
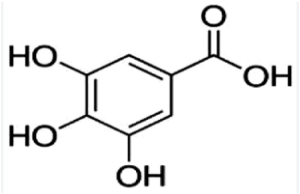
Pharmacological Activity	Phytochemical Class	Target/Mechanism	Primary Species Studied	Reference
Opioid Receptor Modulation	Alkaloids (e.g., Rudrakine)	Delta-opioid receptor binding	E. ganitrus	Sudrajat (2022)
CNS Activity / Neuroprotection	Phenolics, Flavonoids	MAO inhibition, GABA modulation, antioxidant defense	E. ganitrus, E. sylvestris	Sudrajat (2022), Yadav (2023)
Antiviral	Tannins, Ellagic acid	Viral entry inhibition, immune modulation	E. sylvestris	Sudrajat (2022), Park *et al*. (2008)
Anticancer	Ellagic acid, Flavonoids	STAT3 inhibition, apoptosis induction	E. ganitrus	Mehnaj *et al*. (2024)
Enzyme Inhibition	Alkaloids, Flavonoids	Acetylcholinesterase, tyrosinase, α-amylase	E. ganitrus, E. serratus	Sudrajat (2022)
Anti-inflammatory	Saponins, Sterols	COX pathway modulation, cytokine suppression	E. ganitrus	Maheshwari *et al*. (2023)
Antioxidant	Gallic acid, Quercetin	Free radical scavenging (DPPH, ABTS)	E. ganitrus, E. sylvestris	Singh *et al*. (2024)
Radioprotective	Polyphenols	Hematopoietic protection, antioxidant enhancement	E. sylvestris	Park *et al*. (2008)

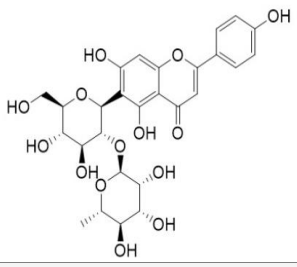
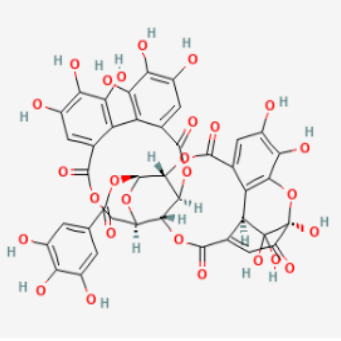
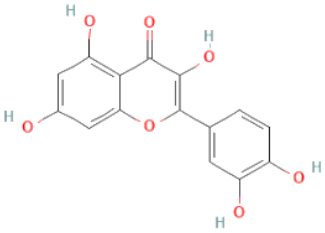
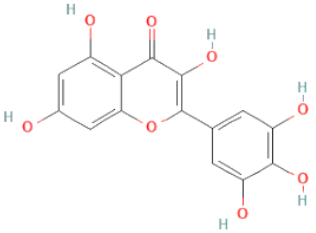
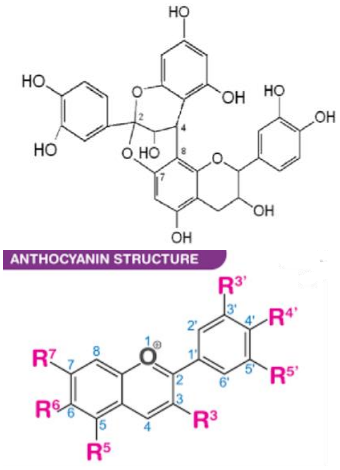
Rudraksha is a dried herbal fruit that originates in the Himalayan foothills. It is regarded as the most sacred and spiritual plant in the Indian medicinal system, with significant medicinal value as a curative and preventive agent (Asolkar, 1992). E. ganitrus has a special place in Hinduism, as documented in ancient literature such as the Shiv Puran, Devi Bhagwat Puran, Padmapurna, and Ayurveda (Rashmi & Kaur, 2014; Zeenath Banu *et al*., 2024). The name *Elaeocarpus* combines the Greek words Elai and Carpus, where Elai means 'wild olive' and Carpus means 'fruit. Elaeocarpus refers to the seeds of wild olive-like trees (Pant *et al.,* 2013; Khodape *et al.,* 2024). This plant's fruits or beads are used in daily worship to count prayers and have a variety of magical abilities. In Hindu culture, it is also used to make necklaces and bracelets (Botelho *et al*., 2023; Bulusu *et al*., 2023; Hussien *et al*., 2023). The Rudraksha plant has traditionally been used to treat ailments such as stress, anxiety, palpitation, depression, nerve pain, migraine, insomnia, acne, ringworm, epilepsy, asthma, loss of concentration, arthritis, hypertension, and liver disease (Swami, 2010; Awan, 2012; Joshi & Jain, 2014). According to Ayurvedic medicine, Rudraksha can treat ailments such as hypertension, asthma, anxiety, diabetes, and gynecological and neurological issues (Lal, 2013). *Elaeocarpus ganitrus,* a traditional medicinal herb, has a long history of use in therapeutic science. Rudraksha is a conjugation word associated with Lord Shiva from Hindu mythology. Rudraksha holds great significance in ancient Indian literature. "Rudra" translates to "Shiva", and "Aksh" means "Eyes". Rudraksha, which translates to "Lord Rudra's eyes," is formed by combining these two terms.

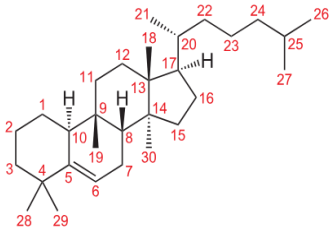
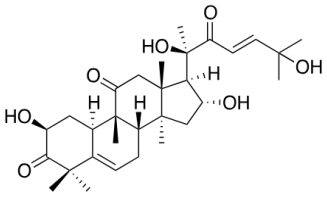
Rudraksha comes from the fruit stone of the *Elaeocarpus ganitrus* plant (Rudraksha tree). When the plant's blue-colored fruit pulp is removed, the Rudraksha bead emerges. The Rudraksha bead has a rough, bumpy feel and is separated from the segment by a ridge that runs from top to bottom. The ridges are known as Rudraksha faces (Singh *et al*., 2010; Singh & Singh, 2020; Aryal, 2021). The Rudraksha seed is thought to have electromagnetic capabilities that help drive away negative energy. *Elaeocarpus* plants can be found in about 300 different species around the world. Rudraksha plants are found in roughly 35 different kinds in India. A prior study found quantifiable results for phytochemicals such as flavonoids, tannins, phenolics, anthocyanins, ascorbic acid, saponins, alkaloids, and terpenoids (Doe *et al.,* 2020) Among the several phytoconstituents, alkaloids' biological activities and medicinal applications have sparked extensive research. Alkaloids are classified into several classes. The classification is based on the biosynthetic precursor and heterocyclic ring system. Imidazoles, quinolizidines, indoles, piperidines, pyrrolidines, tropanes, isoquinoline purines, and pyrrolizidines are some examples. Rudraksha is claimed to contain the indolizidine type of alkaloids with a typical five-membered ring connected to a six-membered ring sharing a nitrogen atom.

Elaeocarpus' key bioactive components include alkaloids, phenolics, flavonoids, and cucurbitacins. **Table 2** provides lists of bioactive chemicals. *Elaeocarpus* contains intriguing bioactive chemicals with potential for chemotherapy (Cambie & Ferguson, 2003).

Table 2. Shows bioactive compounds of Elaeocarpus with their pharmacological actions

Elaeocarpus Alkaloid List	Species	Part	Chemical structure	Bioactivity	References
Elaeocarpine Isoelaeocarpine	*E. fucoides*	Leaf		Affinity for DOR (Delta-Opioid Receptor)	(Katavic *et al*., 2007a, 2007b)
Tectoramidines A, B Tectoricine Tectoraline	*E. tectorius*	Leaf	 Tectoramidine A	Antioxidant and antibacterial properties of E. tectorius.	(Ezeoke *et al*., 2018)
(±)--8,9-Dehydroelaeocarpine (±)-Elaeocarpine trifluoroacetate (±)--9-Epielaeocarpine cis-N-oxide trifluoroacetate	*E. angustifolius*	Branch, Leaf		Cholinesterase inhibitory properties	(Hong *et al*., 2019)
Elaeocarpionoside	*E. japonicus*	Leaf		moderate anti-proliferative, apoptotic, anti-inflammatory properties, and antioxidant activities	(Rasha & Thukaa, 2023)
Grandisine C, D, E, G	*E. grandis*	Leaf		Affinity for DOR (Delta-Opioid Receptor)	(Katavic *et al*., 2006)
Rudrakine	*E. ganitrus*	Leaf		Ameliorative activity, Antidepressant activity, and Anti-hypersensitive effect	(Sakat *et al*., 2009; Dadhich *et al*., 2014; Kakalij *et al*., 2014)
Phenolic compounds Gallic acid	*E. floribundus*	Seed		Antioxidant and antimicrobial properties	(Ogundele *et al*., 2021)

4′ -O-Methylellagic acid 3-(2″,3″-di-Oacetyl)-α-L-rhamnoside 4,4′ -O-Dimethylellagic acid 3-(2″,3″-di-O-acetyl)-α-L-rhamnoside	*E. mastersii*	Bark		Antiviral property	(Ito *et al*., 2002)
Geraniin 1, 2, 3, 4, 6-penta-O-galloyl-β-D-glucose (PGG)	*E. sylvestris*	50% aqueous ethanolic EtOAc fraction		Viral Protein Production, Anticancer and Immunomodulatory Activity	(Chan *et al*., 2019; Kim *et al*., 2021; Joo *et al*., 2022)
Quercetin Isoquercitrin Umbelliferone Scopoletin	*E. sylvestris*	EtOAc		**Antivirus, Antimutagenic, Rheumatoid arthritis**	(Ohta *et al*., 1983; Kim *et al*., 2020)
Myricetin 4′ -Methylmyricetin	*E. lanceofolius*	Leaf		Antibacterial, Antifungal, Anti-inflammatory, antiarthritic, antidiabetic, and anticancer activities	(Ray *et al*., 1976)
Proanthocyanidins anthocyanins	*E. reticulatus*	Fruit, water, ethanol, acetonitrile, and acetone		Antioxidant, Apoptotic activity	(Turner *et al*., 2020)

Cucurbitacin F	*E. dolichostylus* *E. mastersii*	bark		Anticancer activity and Antiviral activity	(Ito *et al*., 2002)
Cucurbitacins D	*E. hainanensis* *E. mastersii*	Crude Bark		Anticancer activity Block the cell cycle in G1/S phase and promote the expression of tumor suppressor microRNAs.	(Meng *et al*., 2008)

Modern scientific research now studies Rudraksha benefits through pharmacological investigation of its antioxidant properties and anti-inflammatory effects and antimicrobial characteristics, and neuroprotective mechanisms. Scientists want to merge traditional knowledge with modern empirical data through the examination of Rudraksha phytochemicals and testing of their therapeutic abilities through present-day pharmacological techniques (Costa *et al*., 2022; Sugimori *et al*., 2022). The properties discovered in this study create opportunities to establish authentic ancient natural medicines while developing innovative pharmaceutical products using plant-based components (Shaheen *et al*., 2023; Yurievna *et al*., 2023).

Taxonomical Hierarchy and Botanical Traits of Rudraksha

Elaeocarpus ganitrus Roxb. ex G. Don functions as a broad-leaved evergreen tree of the Elaeocarpaceae family under the common name Rudraksha. The plant grows within tropical and subtropical areas throughout the Himalayan foothills, as well as Southeast Asia and Indonesia, and parts of Australia. The species exists in importance for its special seeds that bear historic religious significance for Hindu and Buddhist devotees. The plant reaches heights of 60–80 feet and develops a straight cylindrical trunk with grayish bark that reveals itself through irregular pieces. The loosely arranged leaves have a lengthened shape that appears lanceolate as well as serrated edges. The plant produces raceme-borne greenish-white flowers followed by a bluish drupe that protects the well-known grooved Rudraksha seed (Parmar & Kaushal, 1982)

Plants of *Elaeocarpus ganitrus* require warm, humid regions with loamy soils that drain well, and this species has its roots in Nepal, while also growing in India, Sri Lanka, and several parts of Indonesia. The tree grows naturally between 500 meters and 2,000 meters above sea level. The plant began its natural existence in India and Nepal, but spread to other tropical areas as people became interested in its bead production for religious and commercial purposes. Knowledge of environmental conditions remains vital because ecological distribution regulates phytochemical patterns and plant structure (Bhargava & Vasudeva, 2011) **(Table 3)**.

Table 3. Taxonomic Classification of *Elaeocarpus ganitrus* (Rudraksha)

Rank	Classification
Kingdom	Plantae
Clade	Angiosperms
Clade	Eudicots
Clade	Rosids
Order	Oxalidales
Family	Elaeocarpaceae
Genus	*Elaeocarpus*
Species	*Elaeocarpus ganitrus* Roxb. ex G. Don

Analysis of Phytochemicals and Bioactive Compounds

Plants of *Elaeocarpus ganitrus* (Rudraksha) contain many bioactive compounds, which lead to its therapeutic effects along with its multiple phytochemical components. Rudraksha contains multiple phytoconstituents comprising alkaloids, flavonoids, tannins, steroids, triterpenes, carbohydrates, and fatty acids. The central nervous system shows pharmacological effects from the principal compound of Rudraksha seeds named rudrakine, which falls under the indole alkaloid classification (Chopra *et al*., 1956). Bhargava and Vasudeva (2011), reported that Elaeocarpine and gallic acid, and betulinic acid compounds exist within the plant substance and demonstrate anti-inflammatory and antioxidant, and antimicrobial properties.

The extraction procedure of phytochemicals from *E. ganitrus* begins with drying, then commences with powdering before performing solvent extraction through various methods, including Soxhlet extraction, maceration, or cold percolation. Scientists use methanol and ethanol and chloroform, and water solvents to extract phytochemical substances based on their polarity requirements. The identification and quantification process uses Thin Layer Chromatography (TLC), High-Performance Liquid Chromatography (HPLC), and Gas Chromatography–Mass Spectrometry (GC-MS) as well as Fourier Transform Infrared Spectroscopy (FTIR) (Mishra & Singh, 2013). These methods

create a profile of bioactive elements while maintaining standard quality control across herbal formulation batches produced from Rudraksha **(Figure 2)**.

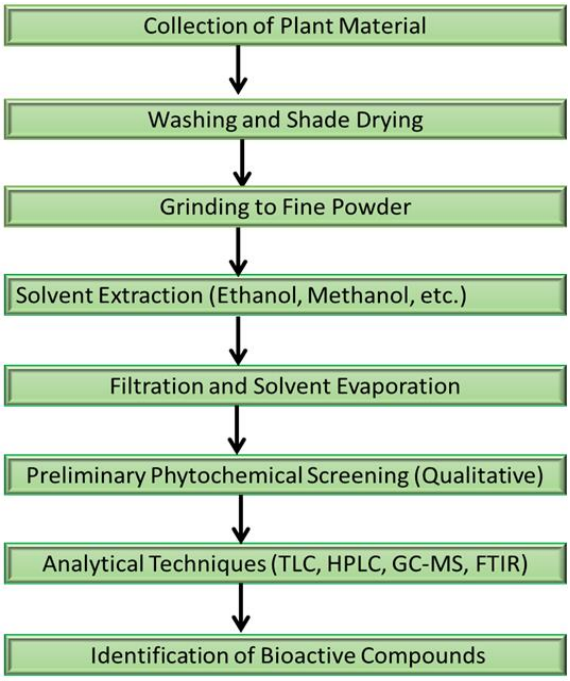


Figure 2. The flowchart delineates the conventional procedure for phytochemical analysis, commencing with the collection of plant materials, followed by drying and grinding. This is succeeded by solvent extraction, filtration, and qualitative assessment of phytochemicals. Subsequently, sophisticated methods such as TLC, HPLC, GC-MS, and FTIR are employed to identify bioactive compounds.

Elaeocarpus ganitrus Roxb. ex G. Don operates as Rudraksha among the sacred traditions of Hinduism and Buddhism, as well as South Asian cultural practices. Historical records show that people wore Rudraksha beads because they promoted spiritual defense and mental acuity, while scripture sources link these beads to Shiva during his most mystical state. This sacred beaded form of *Elaeocarpus ganitrus Roxb*. ex G. Don has acquired a reputation as a healing remedy that fights off negative energies and enhances mental focus, together with physiological balance. Traditional healers throughout Nepal and India's Himalayan and tribal lands use Rudraksha beads and extracts from its seeds and bark to treat neurological problems as well as hypertension, although stress-related disorders (Singh & Kumar, 2021).

In Ayurvedic and Siddha medical traditions, Rudraksha receives Medhya Rasayana classification as a substance that supports mental health. Ayurvedic texts document its capability to control vata dosha because vata dosha relates to nervous system disorders. People use the powdered or decocted form of Rudraksha seeds to treat epilepsy as well as anxiety and insomnia, and palpitations (Patil, 2022). The traditional Siddha practitioners recommend Rudraksha as a powder preparation mixed with herbal extracts to support neurological functions and cardiovascular health, according to Radhakrishnan and Sheeja (2020). Current evidence supporting the scientific validity of ethnomedicinal uses is insufficient, while additional pharmacological and clinical studies must confirm traditional healthcare practices (Zuev, 2022).

Pharmacological Properties of Elaeocarpus ganitrus

Antioxidant Activity

Scientific studies show Elaeocarpus ganitrus exhibits strong antioxidant actions because its chemical structure includes significant levels of phenolic compounds together with flavonoids and alkaloids. Free radical neutralization functions as a key antioxidant role to prevent diseases such as neurodegeneration, cancer, and cardiovascular disorders from developing through oxidative stress damage. The research conducted by Sinha *et al*. (2020) showed that methanolic extracts of Rudraksha demonstrated equal DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging power equivalent to ascorbic acid. The radical scavenging effects of gallic acid and ellagic acid, along with quercetin components, provided substantial contributions to this chemical activity (Malinga & Laing, 2024; Watanabe *et al*., 2024).

Anti-inflammatory Effects

Numerous research studies, both investigational and observational, have confirmed the notable anti-inflammatory effects of Rudraksha seed extracts. The inflammatory defense mechanism can become detrimental when it progresses to conditions such as arthritis and metabolic syndrome. According to Gupta *et al*. (2021), the ethanolic extracts of *E. ganitrus* were shown to significantly reduce paw edema in rats following carrageenan administration, as reported in the Indian Journal of Natural Products and Resources. Scientific findings indicate that the presence of triterpenoids and flavonoids in the plant contributes to these beneficial effects.

Antimicrobial Activity

Researchers have proven that Rudraksha demonstrates antimicrobial properties against both bacterial and fungal pathogens. Both aqueous and ethanol extract solutions show effectiveness against bacterial strains Escherichia coli, Staphylococcus aureus, and Pseudomonas aeruginosa, as well as fungal pathogen Candida albicans. The seed extract established a zone of inhibition between 12–18mm according to Meena *et al*. (2019) against gram-positive bacteria. Antimicrobial effects from Elaeocarpine and rudrakine compounds cause membrane disruption in microorganisms.

Cardioprotective and Neuroprotective Effects

Traditional medical practices have documented heart-related benefits in Rudraksha, while new scientific research confirms the traditional findings about this plant. The cardioprotective properties of Rudraksha prevent high blood pressure by affecting vascular nitric oxide and calcium channels. The protection of brain cells stems from the antioxidant activities, together with the blocking effect on glutamate neurotransmitters (Domatskiy & Sivkova, 2023; Dongmo & Tamesse, 2023). Hydroalcoholic extracts of this plant type provided both pressure reduction and

cognitive improvement to rats who received memory loss induction (Sharma & Bhatia, 2022).

Immunomodulatory and Antidiabetic Potential

Research studies have discovered that Rudraksha enhances immune cell proliferation while simultaneously controlling the release of cytokines to create immunomodulatory effects. The seed extract successfully decreased blood glucose levels while at the same time boosting insulin sensitivity among diabetic animal subjects. When diabetic rats were given *E. ganitrus* extract orally, the researchers from Rajan *et al*. (2020) demonstrated that their blood insulin levels increased and their fasting blood glucose levels decreased. Scientific evidence indicates that alkaloids, together with polyphenolic compounds, produce these measurable effects.

Therapeutic Applications

Laboratory research of *Elaeocarpus ganitrus* indicates positive results for different disease conditions, yet human clinical evidence remains scarce. Rudraksha seed hydroalcoholic extracts proved beneficial for both anxiety symptoms reduction and brain protection through animal-model laboratory testing of stress-related and scopolamine-outcome neurodegeneration defects. Research by Pandey *et al*. (2021) reported substantial improvements in brain memory function and reduced oxidative damage markers, which indicates *Elaeocarpus ganitrus'* potential for treating Alzheimer's disease. Rajan *et al*. (2020) confirmed antidiabetic effects through their research, which demonstrated that aqueous extract of Rudraksha reduced fasting blood glucose levels and enhanced insulin sensitivity in streptozotocin-induced diabetic rats. The promising results from current studies have been limited by an inadequate number of human trial studies, which creates challenges for clinical adoption.

The traditional medical practice develops different dosage forms of Rudraksha, which include powders (churna), decoctions (kwatha), capsules, and tinctures. The Ayurvedic practice mixes Rudraksha seed powder with nervine tonics, including Brahmi and Ashwagandha, to enhance cognitive ability and decrease mental stress. The physician-prescribed polyherbal commercial capsule, which contains *E. ganitrus* and multiple adaptogens, has demonstrated effectiveness in controlling hypertension according to an unreviewed pilot study by Joshi and Mehra (2019). For daily treatment, a single dose of powdered evening primrose seed extract contains 250 mg to 1 gramme of the material, which should be taken with water or honey. The current medical regulations limit its therapeutic potential because the therapeutic profile, along with standard dosage requirements and pharmacokinetic information for Withania somnifera, remains incomplete.

Molecular Mechanism of Action of Elaeocarpus ganitrus

Elaeocarpus ganitrus works through various molecular pathways to affect its pharmacological results by controlling oxidative stress pathways and inflammatory mediator activities (Lassmann *et al*., 2022; Patatou *et al*., 2022; Wilhelmy *et al*., 2022). Elaeocarpus ganitrus exhibits antioxidant properties through the stimulatory effect on superoxide dismutase (SOD) and catalase, and glutathione peroxidase (GPx) endogenous defense enzymes, which detoxify reactive oxygen species (ROS) within cells. Scientific studies reveal that extract from Rudraksha seeds stimulates Nrf2 (nuclear factor erythroid 2 related factor 2) activity to activate protective genes under oxidative stress situations (Pandey *et al*., 2021). The activation of Nrf2 protein leads to greater gene expression of antioxidant response element (ARE)-linked genes, which sustains redox homeostasis and guards against cell damage (Furukawa *et al*., 2024; Seoane-Viaño *et al*., 2024).

The NF-κB signaling cascade serves as a major pathway affected by *E. ganitrus* while it maintains functionality in immune response and inflammation processes (Chen *et al*., 2023; Weerasinghe *et al*., 2023). Studies have proved that Rudraksha extract blocks activation and transport of the NF-κB protein to the nucleus to lower the levels of pro-inflammatory substances TNF-α, IL-6, and COX-2 (Gupta *et al*., 2021). Scientific studies indicate why this substance shows anti-inflammatory properties in neuroinflammation and arthritis. Lab studies show that Rudraksha alkaloids inhibit the activity of iNOS, which reflects their regulatory function on cellular inflammatory processes (Figueroa-Valverde *et al*., 2024; Suchy & Jurkowski, 2024).

Research conducted through receptor binding experiments together with enzyme interaction tests revealed how Rudraksha influences nerve cells while modifying metabolic functions (Aleidi *et al*., 2022; AlHussain *et al*., 2022; Daivasigamani *et al*., 2022; Burgt *et al*., 2024; Petronis *et al.*, 2024). The essential alkaloid in Rudrakshina seed, known as Rudrakine, has been found to bind with GABA-A receptors, which increases inhibitory neurotransmission before leading to anxiolytic and sedative effects according to Sharma and Bhatia (2022). Rudraksha polyphenols show the ability to block α-glucosidase and dipeptidyl peptidase-4 enzymes, making them important factors for diabetic glucose control (Rajan *et al*., 2020). The combination of neurological and metabolic interaction pathways that Rudraksha produces shows strong potential for managing diseases with multiple components **(Table 4)**.

Table 4. Molecular Mechanisms of Action of *Elaeocarpus ganitrus*

Mechanism	Target Pathway	Effect	Phytochemical Component
Antioxidant Activity	Nrf2 / ARE Pathway	Upregulation of SOD, CAT, GPx; scavenging of ROS	Polyphenols, flavonoids
Anti-inflammatory Activity	NF-κB Pathway	Downregulation of TNF-α, IL-6, and COX-2	Alkaloids, flavonoids
Anti-inflammatory Activity	iNOS Suppression	Decreased nitric oxide synthesis, reduced inflammation	Alkaloids
Neuromodulatory & Anxiolytic Activity	GABA-A Receptor Modulation	Enhances inhibitory neurotransmission; anxiolytic effects	Rudrakine (alkaloid)

Antidiabetic Activity	α-Glucosidase and DPP-4 Enzyme Inhibition	Reduces postprandial glucose and improves insulin sensitivity	Polyphenols, tannins

Rudraksha Research: Current Constraints and Prospective Pathways

The rising interest in the pharmacological and therapeutic properties of Rudraksha (Elaeocarpus ganitrus) creates new scientific challenges from the insufficient research available today. Few investigations about Rudraksha (*Elaeocarpus ganitrus*) exist, as experimental validations are weak, along with evidence from traditional practices. Some studies report evidence of antioxidants and antimicrobial effects from laboratory assays yet provide little experimental validation in living beings or human patients (Purohit & Sharma, 2016; Khan *et al*., 2018). Scientific understanding regarding bioactive compound bioavailability, along with pharmacokinetics in Rudraksha, remains inadequate because it reduces its prospects for standardized therapeutic applications. Current findings fail to achieve clinical practice implementation because there is no evidence from large-scale randomized controlled trials (İlhan *et al*., 2022; Uzun & Karataş, 2022; Yoong *et al*., 2022; Zhang *et al*., 2022; Bratt & Fagerström, 2023; Ghati *et al*., 2023; Savva *et al*., 2023).

Different studies face an important gap due to insufficient standardization and quality control measures for phytochemicals. Most research neglects important factors that affect Rudraksha phytoconstituents, including geographic origin and methods of processing and species cross-variance (Das *et al*., 2015). Research needs to investigate molecular and cellular actions involving Rudraksha more thoroughly at the detailed level. The traditional sources indicate neuroprotective and cardiotonic properties of Rudraksha, but modern scientific investigations lack studies on receptor binding pathways or gene expression regulation mechanisms (Mubayrik *et al*., 2022). Rudraksha's complete therapeutic potential requires standardized investigation using an integrative framework based on ethnopharmacology combined with modern pharmacology and molecular biology (Ingle *et al*., 2023; Shaheen *et al*., 2023; AlShammasi *et al*., 2024; Ludovichetti *et al*., 2024; Menhadji *et al*., 2024).

Conclusion

The expanding scientific evidence about *Elaeocarpus ganitrus* strength confirms both conventional practices and contemporary pharmacological measurements due to its extensive therapeutic power. Phytochemical evaluations demonstrate that *Elaeocarpus ganitrus* contains multiple bioactive compounds, including alkaloids, flavonoids, triterpenoids, and polyphenols that produce antioxidant, anti-inflammatory, antimicrobial, neuroprotective, cardioprotective, and antidiabetic effects and immunomodulation abilities. Preliminary studies from laboratories have shown how Rudraksha produces its multiple benefits by activating Nrf2, blocking NF-kB, and controlling enzymes, thus demonstrating its molecular effects. Rudraksha has been incorporated into various Ayurveda and Siddha medicinal preparations since antiquity for mental health management and cardiovascular maintenance, and metabolic disorder management, yet recent scientific research confirms their usefulness through experimental evidence.

The therapeutic capabilities of Rudraksha have strong potential to generate organic plant-derived pharmacological treatments that support holistic and integrative healthcare methods. The current research demand requires well-designed human trials for confirming safety and determining effectiveness at optimal doses, together with understanding how it functions in human pharmacokinetics. Modern medicine would gain from standardized extract preparation combined with improved drug delivery methods and proper regulatory systems that link traditional healthcare wisdom to scientific research. The medicinal potential of *Elaeocarpus ganitrus* indicates promising prospects for modern therapeutic applications that use this plant as an alternative healthcare resource.

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