REVIEW ARTICLE

Exploring The Phytochemistry, Ethnobotany, Traditional Uses, Pharmacology, Nutraceutical Benefits, and Clinical Potential of *Myrica esculenta*

Krishna Raninga*, Vaibhavi Savalia, Ruchi Dobariya[2], Pravin Tirgar, Jital Desai[2]

DOI: 10.18811/ijpen.v11i03.05

Abstract

The increasing use of spices and medicinal plants in pharmaceuticals and daily life has significantly boosted agronomy, pharmacy, and export sectors. Within this context, *Myrica esculenta* (Boxberry/Kaiphal), the only Indian species of the genus *Myrica* (family Myricaceae), has gained prominence due to its ethnobotanical and pharmacological importance, particularly in the Himalayan regions. This study explores the phytochemical composition, traditional uses, and pharmacological potential of *M. esculenta*. Preliminary screening of methanolic and aqueous extracts from bark and leaves revealed bioactive compounds like tannins, flavonoids, phenols, and saponins known for antioxidant, antimicrobial, and cardioprotective activities. Characterization through HPLC, GC-MS, and FTIR confirmed their presence. *In-vitro* assays demonstrated significant antioxidant activity in the methanolic extract and effective antimicrobial action against common pathogens. Ethnobotanical surveys highlighted its traditional use in treating cough, fever, digestive issues, and skin diseases. The findings validate the plant's therapeutic potential and support its development into herbal remedies and nutraceuticals. Further *in-vivo* studies and clinical trials are recommended to substantiate these results. Integrating traditional knowledge with modern science could promote sustainable use of this valuable Himalayan species and contribute to the advancement of plant-based healthcare solutions.

Keywords: Kaiphala, M. esculenta, Myricaceae, Pharmacology, Phytochemicals, Nutritional profile.

Highlights:

- *Myrica esculenta* holds important ethnobotanical and cultural value in the Himalayan region.
- Phytochemical screening reveals bioactive compounds such as tannins, phenols, flavonoids, and saponins in its extracts.
- The plant demonstrates significant pharmacological and nutraceutical potential for use in pharmaceuticals and dietary supplements.
- Further research is needed to fully explore its therapeutic properties and integrate traditional knowledge with modern science.

International Journal of Plant and Environment (2025); **ISSN:** 2454-1117 (Print), 2455-202X (Online)

Introduction

Medicinal agents have been indigenous to nature for millennia. An extraordinary quantity of modern medications are derived from natural sources and are indispensable for the treatment of numerous diseases. The search for novel treatments has always been explored by medicinal plants containing traditional knowledge. In their raw or in simpler medicinal preparations, traditional medicinal herbs are frequently more affordable, readily accessible, and easily ingested. Because of their active chemical ingredients, these straightforward medical formulations frequently elicit positive effects. *M. esculenta*, popularly called bayberry or '*Kaafal*' in Hindi, is an important traditional food in many cultures, particularly in India's hilly regions. This evergreen shrub is indigenous to the Himalayan region and is highly valued not just for its ecological significance but also for its profound cultural and traditional significance among the nearby people. *M. esculenta Buch. -Ham. ex. D. Don, Ex. D. Don, Buch. -Ham. Morella esculenta* is now officially called I.M. Turner; the latter name is considered a basionym of *Morella esculenta* (Kabra, A. *et al*., 2017; Mallya, S. V. *et al.,* 2016). Furthermore, the fruits and roots of *M. esculenta* are employed in many ayurvedic compositions as an active botanical element. This study is novel in its comprehensive integration of traditional knowledge with modern analytical and pharmacological evaluations of *M. esculenta*, offering new insights into its bioactive potential and clinical applications

The current review delves into traditional, ethnobotanical, phytochemical, pharmacological, and nutraceutical knowledge. Modern pharmacological research and the presence of several important phytochemicals back up ethnobotanical and traditional assertions. The presence of essential proteins, vitamins, amino acids, and minerals demonstrates *M. esculenta's* importance as a nutraceutical (Figs 1, and 2).

[1]School of Pharmacy RK University, Rajkot, Dhananjay, Gokul Nagar, Talala, Gir Somnath, 362150 India.

[2]Parul institute of pharmacy, Limda Waghodia, India.

***Corresponding author:** Krishna Raninga,School of Pharmacy RK University, Rajkot, Dhananjay, Gokul Nagar, Talala, Gir Somnath, 362150 India., Email: krishnaraninga3@gmail.com

How to cite this article: Raninga, K., Savalia, V., Dobariya, R., Tirgar, P., Desai, J. (2025). Exploring The Phytochemistry, Ethnobotany, Traditional Uses, Pharmacology, Nutraceutical Benefits, and Clinical Potential of *Myrica esculenta*. International Journal of Plant and Environment. 11(3), 472-483.

Submitted: 24/09/2024 **Accepted:** 16/06/2025 **Published:** 30/09/2025

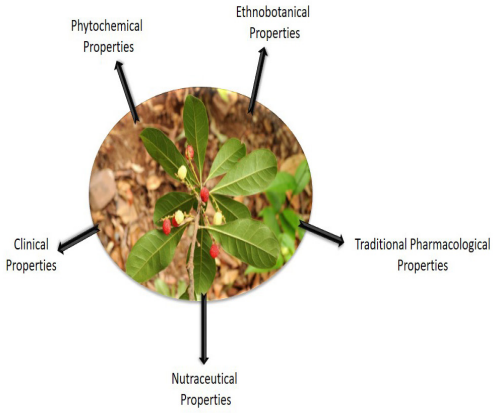

Figure 1: Multifunctional attributes of M. esculenta highlighting its phytochemical, ethnobotanical, pharmacological, nutraceutical, and clinical properties.

Materials and Methods

Comprehensive information on *M. esculenta* was gathered using keywords, *M. esculenta's* botanical name, and *M. esculenta's* common name, *Kaafal,* in several electronic databases such as PubMed, Google Scholar, and Science Direct. In addition, some novels were mentioned.

Distribution

Originating in Himachal Pradesh, it inhabits the northern Indian highlands (Kumari, A. *et al.*, 2012; Shri, K. S. *et al.*, 2018) as well as southern Bhutan and Nepal, as well as the eastern regions of the Himalayan nations, including Arunachal Pradesh and Meghalaya. Southeast China, Vietnam, Thailand, Assam, Borneo, Sumatra, and the Lesser Sunda Islands, Malaya, Myanmar, and the Philippines are additional locations where it can be discovered. An important native crop in the Himalayas is kaafal. It's a well-known wild edible tree species that could be profitable. Nearly every part of the tree has some purpose. The fruit can be used to create a range of commodities with additional value and is consumed raw. Conventional medicine employs it frequently to treat a vast array of ailments. (Mishra, R. N. *et al.,* 2011, Pandey, M. M. *et al.,* 2013) *Myrica* plants thrive in nitrogen-depleted soils, agricultural fields, mixed forests, and peripheries (Yanthan, M. *et al.*, 2013).

Taxonomy

The Nyshi language of Arunachal Pradesh designates this region as "maching," while northern India designates it as "kaphal" or "kaafal" and Meghalaya as "sohphie.

Four known diversities exist. (Shen, S. *et al.,* 2019, Shen, S. *et al.,* 2019, Shen, S. *et al.,* 2019)

- *Myrica esculenta var. balansae Dode*
- *Myrica esculenta var. tonkinensis A. Chev.*
- *Myrica esculenta var. chevalieri H.H. Pham*
- *Myrica esculenta var. esculenta*

Shweta (white) and Rakta (red) are the two varieties distinguished by the colour of their flowers, as per Ayurveda.

M. esculenta is a species of *Myricaceae*, which is a member of the order Fagales, division magnoliophyta of the kingdom plantae, class Magnoliopsida of the order Myrica (Ginwal, H.S. *et al.,* 2024). *Ajooree, Nagatenga*, and *Vdulbark* are three in Assam. *Karachi, Kaiphal* are Bengali words. Bayberry in English, *kariphal* (Gujarati), *capha* and *kaiphal* in Hindi, *irishvani, kirishivane, kandujai kai*, are all Kannada terms. "*Maruta*," in Malayalam, *Kayaphala*, Marathi words *khaculi* and *katphala* are Nepalese terms. *Caiphal, kahela*, and *kahi* are Punjabi words. *Krishnagarba, kathphala, aranya*, and *mahavalkala* are Sanskrit terms. *Marudam/marudampatai* in Tamil the *kainaryamu* in Telugu (Panwar, S. *et al.*, 2024, Zhang, B. *et al.,* 2017).

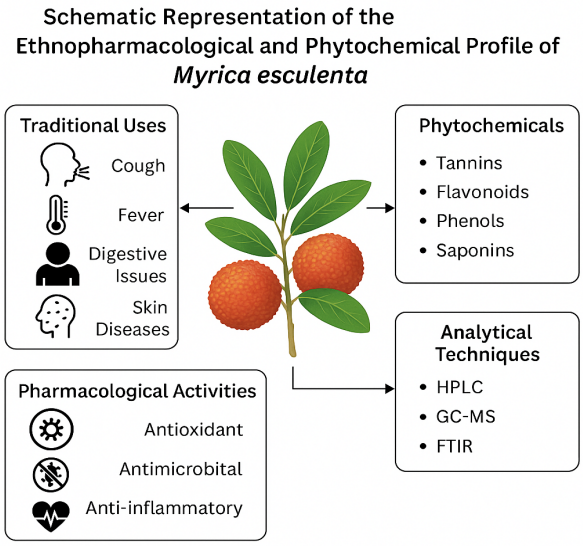

Figure 2: Schematic overview of Myrica esculenta highlighting its traditional uses, key phytoconstituents, and pharmacological relevance.

Botanical Description

The height of the medium-sized evergreen *M. esculenta* tree ranges from 6 to 8 metres (equivalent to 26 feet). The yellow foliage is delicate and vulnerable. The leaflets of its 30–60 cm (1–2 ft) conjoint leaves are arranged in pairs of 6–9 and measure 19 mm (0.75 in) in width. Collecting in clusters, the blossoms have a white hue. Containing a rigid endocarp, the fruit is a succulent, globose drupe, 1.1–1.3 cm (0.43–0.51 in) in diameter, and an average mass of 670 mg (10.3 g). Comparable in appearance to a mulberry. The triangular seeds possess an astringent taste (Jeeva, S. *et al.*, 2011).

From February until the second week of April, the flowering season is in full swing. Nevertheless, its height occurs during the initial week of March, and it continues until the fruiting season concludes in late May, commencing in the first week of May (Dhani, A., 2013). The fruit of the tree is a drupe, which is ellipsoidal or elliptical, possesses a reddish-brown hue, and has a diameter of approximately 2 to 7 mm. It is sweet and acidic in flavour and contains an oily-tasting, ovoid-shaped, smooth-surfaced, light brown seed measuring between 1 and 6 millimetres in diameter (Chauhan, N. S, 1999).

The mucilaginous cuticle, which comprises the upper and lower epidermis of the leaf, is enveloped by single-layered polygonal cells. The vein islet was found to be 9 to 11 in number, while the vein termination was measured to be 13 to 15. A manifold cork composed of rectangular, thin-walled

Table 1: Biological effects of *M. esculenta*

Extract	*Animals/cell lines*	*Experimental model*	*Results*	*References*
Anti-inflammatory				
Methanolic extract of the leaves	Rat	Carrageenan-induced rat paw edema	Remarkable analgesic and anti-inflammatory activity	Shrivastava, A. K. *et al*., 2023
Stem bark essential oil	Swiss albino mice	In-vitro	Remarkable anti-inflammatory activity	Suryawanshi, J. S. *et al*., 2009
Ethyl acetate and aqueous extract of the bark	Wistar albino rats	Egg albumin-induced allergy test Carrageenan and histamine induced rat paw edema	Mast cell stabilization activity. Remarkable anti-inflammatory potential (EAE> AE)	Bhat, R. A. H. *et al*., 2021
Antimicrobial				
Stem bark volatile oil	Gas Chromatography–Mass Spectrometry.	Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Candida albicans, Saccharomyces cerevisiae Bacillus pumilus, Staphylococcus and epidermidis, Aspergillus niger,	Remarkable antimicrobial potential	Bhat, R. A. H. *et al*., 2021
Bark and fruit, methanolic and chloroform extract	---	Agar Well diffusion method	Remarkable antimicrobial potential (Bark > Fruits)	Chandra, S. *et al*., 2012
Fruit pulp Ethanolic extract	In-vitro	Disc diffusion assay	Dose-dependent antimicrobial potential	Jain, V. K. *et al*., 2010
Antifungal				
Fruit Methanolic, ethanolic and aqueous extract	Candida albicans, Aspergillus flavus and Aspergillus parasiticus	Disc diffusion assay	Remarkable antifungal activity	Seal, T. *et al*., 2011
Anthelmintic				
Bark 50% Aqueous Ethanolic extract	Earthworms (Pheretima posthuma)	---	Paralysis and death at 12.5 mg/mL	Rawat, S. *et al*., 2013
Anticancer				
Fruit Methanol, acid methanol, acetone, and acidic acetone	C33A, SiHa and HeLa cell lines	---	Acetone and acidic acetone extracts showed anticancer potential	Syed, S. *et al*., 2013
Fruit Methanolic extract	HepG2, Hela and MDA-MB-231 cells	MTT assay	Moderate anticancer activity	Mishra, R. N. *et al*., 2011
Antioxidant				
Fruit Methanolic extract	In-vitro	DPPH, ABTS, and FRAP assay	Remarkable antioxidant activity	Nainwal, P. *et al*., 2009
Fruit pulp Methanolic extract	In-vitro	DPPH, ABTS, and FRAP assay	Good scavenging potential	Pant, G. *et al*., 2014
Fruit aqueous methanol and acetone extract	In-vitro	DPPH assay	Acetone extract showed a higher scavenging potential	Dhani, A., 2013
Fruit Methanol, acidic methanol, acetone, and acidic-acetone extract	In-vitro	DPPH, ABTS, FRAP, and Superoxide anion radicals scavenging assay	MeAA showed higher antimicrobial potential, and MeAM and MeA were intermediate	Sharma, R. *et al*., 2018
Antidiabetic				
Leaves methanolic extract	Albino Wistar rats	STZ-induced diabetes	Significant anti-dyslipidemic effect at 150 mg/kg and maintain blood glucose level	Nayak, B. K. *et al*., 2017

Antidepressant				
Bark Methanolic	Albino mice	Open field test, head-dip test, cage-crossing test, rearing test, forced swimming test, and traction test.	Remarkable antidepressant activity	Patel, K. G. *et al*., 2008
Anxiolytic				
Bark Ethanolic	Rats	Forced swimming test, Tail suspension test	Remarkable and dose-dependent anxiolytic activity	Suresh, P. *et al*., 2007
Antihypertensive				
Leaves Methanolic	In-vitro	ACE inhibitory activity	Potent ACE inhibition	Pandey, M. M. *et al*., 2013
Antiasthmatic				
Bark Ethanolic	Guinea pig	Acetylcholine induced bronchospasm	Protection against bronchospasm and anaphylaxis	Srivastava, B. *et al*., 2016
Stem bark Ethanolic	Guinea pig	Histamine-induced bronchospasm	↓TLC and DLC	Srivastava, B. *et al*., 2016
Bark Polar, non-polar and methanolic	Rat and In-vitro	Acetylcholine induced bronchospasm in conscious guinea pigs; acetylcholine induced contraction on isolated guinea pig tracheal chain preparation; compound 48/80 induced mast cell degranulation using rat; and trypsin and egg albumin induced bronchospasm	PE showed higher potential than NPE and ME	Mallya, S. V. *et al*., 2016
Antiulcer				
Bark Ethanolic	Albino rat	Pyloric ligation induced ulcer	↓level of GV, FA, LPO and GSH and ↑ CAT, nitrate and MPO ↓ level of GV, FA, LPO and GSH and ↑ CAT, nitrate and MPO	Laloo, D. *et al*., 2011
Antidiarrheal				
Leaves Ethanolic	Mice	Castor oil-induced diarrhoea	Remarkable antidiarrheal activity	Shrestha, P. M. *et al*., 2003
Antipruritic				
Stem bark Aqueous	Male mice	Compound 48/80-induced pruritis	Remarkable decrease in the scratching effect	Bich, D. H. *et al*., 2004
Analgesic				
Fruit Methanolic	Mice	Eddy's hot plate method	Remarkable analgesic activity	Shen, S. *et al*., 2019
Leaves ME-EtAC	Mice	Acetic acid induced writhing and tail immersion assay	Remarkable analgesic response at 200 mg/kg	Mann, S. *et al*., 2015
Leaves Methanolic	Mice	Acetic acid induced writhing	54.56% inhibition of writhing	Shen, S. *et al*., 2019
Antipyretic				
Fruit Methanolic	Mice	Yeast-induced pyrexia in mice	Remarkable antipyretic effect at 100 mg/kg	Kabra, A. *et al*., 2017
Wound healing				
Bark Aqueous Ointment	Albino rats	Wound excision and incision	Remarkable wound-healing potential	Swathi, D. *et al*., 2015

cells that were tangentially elongated was identified through cross-sectional analyses of the developed stem bark. On the other hand, oval-shaped starch granules were contained within parenchymatous cells that were rectangular-polygonal in shape and constituted the secondary cortex (Gangwar, K. K. *et al.*, 2010).

Ethnobotany

The culinary applications of *M. esculenta* are among its most prized traditional values. In the areas where it grows in abundance, the small, spherical, reddish-purple berries of this plant are considered a delicacy. In addition to being eaten raw, the berries are also used to produce drinks, jams, and jellies. The intake of kaafal is frequently linked to celebratory occasions and festivals because of its peculiar sweet and tangy flavour, which gives traditional meals a unique taste. During the fruiting season, families get together to gather the berries, transforming the gathering process into a socially cohesive pastime.

M. esculenta is valued for its therapeutic properties in traditional medicine, in addition to its culinary importance. Traditional medicine has made use of various components of the plant, such as its foliage and bark, on account of the potential health benefits it may provide. Traditional remedies for ailments such as coughs, colds, and gastrointestinal problems incorporate the plant due to its purported anti-inflammatory and antioxidant properties. Traditional physicians in the region have perpetuated the wisdom of incorporating kaafal into medicinal formulations, thereby contributing to the cultural heritage of the surrounding communities.

The bayberry, *M. esculenta*, has complex traditional values in the cultures in which it is found. The herb is woven into everyday life and cultural customs, serving as a beloved culinary element as well as a part of traditional medicine, religious rites, and economic sustenance. As we begin to understand the many advantages of *M. esculenta*, it becomes clear that maintaining this plant is crucial for maintaining both the ecological balance and the rich cultural traditions and values.

Additionally, *M. esculenta* is essential to spiritual and religious activities. The plant is revered and connected to regional deities in various cultures. The leaves and berries of *M. esculenta* are frequently offered to the gods at religious rites and festivals, signifying abundance and purity. This plant's inclusion in religious rites is a reflection of how deeply spirituality and nature are woven into the community's cultural fabric.

Additionally, *M. esculenta* is important to the local population's economy. In addition to being consumed locally, the berries are also sold in marketplaces, giving the communities in the hilly areas-where there may not be many possibilities for alternative livelihood, a source of revenue. *M. esculenta* is valuable to the local population's livelihoods, and the sustainable collection of the plant and its products enhances the economic well-being of the populace.

Apart from its intended applications, *M. esculenta* holds environmental importance. Because of its excellent adaptation to the challenging environment of the Himalayas, the plant is essential for preserving soil and halting erosion. Its presence in the ecosystem promotes biodiversity and helps different wildlife species survive. The customary wisdom is connected to *M. esculenta*. Additionally, *M. esculenta* is important to the local population's economy. In addition to being consumed locally, the berries are also sold in marketplaces, giving the communities in the hilly areas, where there may not be many possibilities for alternative livelihood, a source of revenue. *M. esculenta* is valuable to the local population's livelihoods, and the sustainable collection of the plant and its products enhances the economic well-being of the populace.

Apart from its intended applications, *M. esculenta* holds environmental importance. Because of its excellent adaptation to the challenging environment of the Himalayas, the plant is essential for preserving soil and halting erosion. Its presence in the ecosystem promotes biodiversity and helps different wildlife species survive. The customary wisdom connected to Myrica

A significant portion of the community in Uttarakhand's rural districts uses stem bark to treat ulcers, asthma, and chronic cough (Kumari, P. *et al.*, 2011). Bark powder is inhaled to manage headache (Arya, D. *et al.*, 2014). Bark paste is used to treat headaches and colds, as well as wounds, joint troubles, and paralysis (Maikhuri, R.K. and Gangwar, A.K., 1993). Fruit is either ingested uncooked or incorporated into refreshing beverages. Meghalayan tribal communities employ its juice as a remedy for bacterial diarrhoea (Kayang, H., 2007; Laloo, D. *et al.*, 2011; Khan, M. Y. *et al.*, 2008). Bark is utilized by several ethnic communities residing in the rural Orissa region as a remedy for mental disorders (Singh, N., 2009).

Phytochemical description

Tannins and Phenolic Acids

The presence of *M. esculenta* bark in the mobile phases during chromatography resulted in the detection of constraints denoting stigmasterol, lupeol, oleanolic acid, and gallic acid

Table 2. Ayurvedic formulations of the plant with their uses

Formulation	*Uses*
Chwayanprash	Increased stamina and ingestion, as well as vitality
Katphaladi Churna	Fever, pharynx infection, abdominal pain, and respiratory disorders are managed with medication.
Pushyanuga Churna	Candidiasis and bleeding disorders are treated.
Katphala Taila	Medications for joint discomfort
Arimedadi Taila	Relieves dental caries and hygiene issues.
Mahavisagarbha Taila	Employed to treat vata imbalance and neuromuscular disorders.
Bala Taila	Vata disorders, respiratory infections, and frailty are treated.
Khadiradi Gutika	Oral, dental, tonsillar, and pharyngeal infections are treated.
Maha Vatagajankusa Rasa	Muscular paralysis, rheumatoid arthritis, asthma, cough, and cold
Brihat Phala Ghrta	Interventions for infertility

Table 3. Mineral contents of *M. esculenta* fruits and stem bark

Minerals (mg/g)	*Fruit*	*Stem bark*
Sodium	0.81 ± 0.013	0.060 ± 0.03
Calcium	4.63 ± 0.06	3.155 ± 0.18
Crude fibre%	5.22±0.08	
Zinc	0.216 ± 0.0016	0.006 ± 0.001
Crude fat%	4.93 ±0.06	
Energy (kcal/g)	395.04±0.54	
Magnesium	8.4 ± 0.20	1.061 ± 0.4
Copper	0.004 ± 0.0002	NR
Iron	0.404 ± 0.0021	0.123 ± 0.16
Manganese	0.032 ± 0.0001	NR
Carbohydrates%	78.03 ±0.14	
Potassium	7.75 ± 0.11	2.939 ± 0.23
Phosphorous	0.24 ± 0.25	0.030 ± 0.01
Sulphur	NR	0.277 ± 0.34
Crude protein%	9.62 ± 0.03	

Table 4. Physicochemical parameters of different parts of *M. esculenta*

Parameters	*Results*			
	Leaves	*Bark*	*Stem bark*	*Small branches*
Extractive value (%w/w)				
Methanolic extract	28.32	38.52	23.57	5.03
Ethyl acetate extract	25.46	21.20	NR	NR
Aqueous extract	21.28	15.7	18.36	3.52
Ash Values (%w/w)				
Total ash	2.83	3.3312	1.010	1.856
Acid insoluble ash	0.52	1.2300	0.187	0.320
Foreign matter (% w/w)	<1%	NR	Nil	Nil
Loss on drying (%w/w)		5	6.47	6.81
Total phenolics mg of GAE/g d.w.	NR	NR	276.78 ± 5.36	31.24 ± 2.57
Total flavonoids mg of QE/g d.w.	NR	NR	121.68 ± 6.81	12.94 ± 1.12

at RF 0.38, 0.62, 0.49, and 0.56, respectively. The fruit extract was inspected employing reverse-phase high-performance liquid chromatography to identify catechin, coumaric acids, chlorogenic acid, and gallic acid. The application of LC-MS analysis enabled the identification of bioactive compounds, including ferulic acids and gallic acid in the fruit extract. Isomerillin, 4-methoxybenzoic acid, ethyl-β-D-glucopyranoside, 4-hydroxymethylphenol, and 3-hydroxybenzaldehyde are among the compounds present in the leaves (Rawat, S. *et al.*, 2011; Mann, S. *et al.*, 2015; Wei, Y. *et al.*, 2011; Srivastava, B. *et al.*, 2016).

Flavonoids

Observations of myricetin in fruits, foliage, and stem bark (Nguyen, X. N. *et al.*, 2010; Panthari, P. *et al.*, 2012; Dawang, S. *et al.*, 1991), nevertheless, the detection occurred solely in leaf quercetin. Two flavonoid glycosides make up the substance. -D-glucopyranosyl (4′-hydroxy-3′,5,5′-trimethoxy-7-O-β) functional group Fatty acids3–6–methoxy-7–O–α-L-rhamnopyranoside and –α-L-rhamnopyranoside were identified in the foliage. Two derivatives of myricetin were identified in the bark: myricetin-3-O-(2-Ogalloyl)-α-L-rhamnopyranoside and myricetin-3-O-(2‴-Ogalloyl). Ribopyranoside omega-L (Mann, S. *et al.*, 2015; Singh, N., 2009).

Triterpenoids

Lupeol, oleanolic acid, dihydroxytaraxerane, tetrahydroxytaraxenoic acid, 3-epi-ursonic acid, trihydroxytaraxaranoic acid and arjunolic acid were among the numerous triterpenoids identified in the leaf and bark of *M. esculenta* (Agnihotri, S. *et al.*, 2016; Hui-fen, M. A. *et al.*, 2011; Wei, Y. *et al.*, 2011).

Terpenes

Monoterpenic acid is the compound that Prior investigations have successfully identified myresculoside in the foliage of *M. esculenta* (Bambola, A. *et al.*, 2009).

Volatile Compounds

The foliage was found to contain volatile compounds including linalool, nerolidol, -pinene, -selinene, -caryophyllene, and -cadinol. The bark contained volatile compounds including n-octadecanol, n-hexadecanol and eudesmol acetate (Patel, V. G. *et al.*, 2017).

Steroids

The leaves contained dacosterol, rosasterol, and sitosterol; -D-glucopyranoside was identified (Das, L. *et al.*, 2024; Chandra, S. *et al.*, 2012). Taraxerol and stigmasterol, conversely, were identified in bark (Sinha, A. K. *et al.*, 2024; Middha, S. K. *et al.*, 2016). *M. esculenta* leaves and bark (Agnihotri, S. *et al.*, 2012) each included β-sitosterol. Other compounds identified in the fruits of *M. esculenta* (Patel, T. *et al.*, 2011, Shrivastava, A. K. *et al.*, 2023) Aniso-inositol, methyl-d-lyxofuranoside, 1-ethyl-4-methylcyclohexane, 2-furancarboxyaldehyde, oxirane, furfural, amino acids, and 2,5-furandionedihydro-3-methylene were all components of the composition.

Diarylheptanoids

Tree roots, bark, and foliage of *M. esculenta* contained diaylheptanoids. Identified in the foliage and bark were *myricanol* and *myricnone* (Shukla, M. K. *et al.*, 2024). Anomalous compounds were identified in the leaves and bark, except for the root, wh

ich contained 13-oxomyricanol, which was detected in the bark, and 5-O-β-D-glucopyranosylmyricanol.

Pharmacological Profile

M. esculenta, sometimes known as the velvet bean or wild yam bean, is a tropical leguminous plant native to Asia and Africa. *M. esculenta* is well known for its nutritional content and

position as a traditional food source, but it has recently gained interest for its possible medicinal effects. Recent studies have concentrated on identifying the particular bioactive compounds found in *M. esculenta* and investigating their potential health benefits, despite the fact that the plant has been used in alternative/traditional medicine for a considerable duration. Because of its complex chemical content, this leguminous plant has inspired study, with a focus on substances such as L-3,4-dihydroxyphenylalanine, a precursor to the neurotransmitter dopamine. *M. esculenta* extracts have been linked to antioxidant, neuro-protective, anti-inflammatory, and maybe antidiabetic properties in preliminary research. However, because the area of *M. esculenta* pharmacology is dynamic, and continuing research strives to clarify its mechanisms of action and therapeutic potential, it is critical to approach these findings with care (Table 1).

Anti-inflammatory

The methanolic extract of the leaves contains natural antioxidants. Rat model results provide additional scientific support for the traditional utilise of this herb as an anti-inflammatory agent and analgesic (Bhat, R. A. H. *et al.*, 2021).

Comparable in potency to a conventional medication, the essential oil demonstrated a notably potent topical anti-inflammatory impact in the ear of Swiss albino rodents (Agnihotri, S. *et al.*, 2016). Experimental animals subjected to an egg albumin-induced allergy test exhibited mast cell stabilisation activity in response to ethyl acetate along with aqueous extract of the bark (Bhat, R. A. H. *et al.*, 2021).

To identify the bioactive phytoconstituent found in *M. esculenta,* the gas chromatography–mass spectrometry. A spectroscopic technique was utilised. In the subsequent analysis, the bark and root extracts were analysed for their total flavonoid and phenolic contents. The anti-inflammatory properties of both extracts were also determined through *in-vitro* analysis.

The deposition of bioactive substances onto inflammation-causing proteins, including IL-10, COX-2, and TNF-α, COX-1 was accomplished via molecular docking research. While the root extract contained fewer total phenolic compounds with flavonoid compounds, drawn out of the bark of *M. esculenta*, the latter demonstrated the highest concentrations in the current study (336.02 ± 8.04 mg quercetin/g/g equivalent, 553.44 ± 18.38 mg GAE/g equivalent, respectively).

In contrast, the root extract exhibited the most pronounced inhibitory effect on 15-LOX (IC_{50} = 16.95 ± 5.92 µg/mL), whereas bark extract effectively inhibited the assays for HYA and 5-LOX (IC_{50} = 11.26 ± 3.93 ± and 21.61 ± 8.27 µg/mL, respectively). Arjunolic acid, myricetin, and myricitrin had the potential of more affinity for binding with all inflammation-causing proteins, according to the docking results. Myricitrin exhibits the highest affinity relative to myricanone, followed by celecoxib, myricitrin, and arjunolic acid, and ultimately 3-uronic acid. Concerning the molecular dynamics simulations of TNF-α and myricanone (1.377 to 3.457) and COX-1 and myricitrin (0.193-1.885 Å), the myricetin and molecular dynamics simulation of COX-1 at 310 K exhibited the least amount of deviation and the highest degree of stability (the values of root mean square deviation range from 1.07 to 2.3). The active constituents of the extracts significantly demonstrated anti-inflammatory efficacy. To precisely delineate their mechanism of action, critical additional research is necessary (Chandra, S. *et al.*, 2012).

Antimicrobial

Capillary gas chromatography and gas chromatography mass spectrometry were utilized to determine the concentration of 0.3% in the hydrodistilled oil of *M. esculenta* stem bark. Palmitic acid (11.6%), cis-caryophyllene (8.7%), n-pentadecanol (7.7%), n-hexadecanol (25.2%), and eudesmol acetate (21.9%) constituted the primary constituents of the volatile oil. *Staphylococcus aureus, Candida albicans, Bacillus pumilus, Staphylococcus epidermidis, Aspergillus niger* and *Pseudomonas aeruginosa* have all been identified as susceptible microorganisms to the oil (Jain, V. K. and Jain, B., 2010).

The phenolic and chloroform extracts of the fruit and foliage presented significant antimicrobial activities as determined by agar well diffusion. In comparison to fruit extract, bark demonstrated more potential (Patel, T. *et al.*, 2011).

Ten bacterial strains and three fungal strains were subjected to *in-vitro* evaluation of the antibacterial properties of wild edible fruit of *Myrica nagi* using the disc diffusion method. Significant inhibitory effects were observed on food poisoning bacteria (MTCC 729) and *Escherichia coli* (MTCC 443) and *Streptococcus pyogenes* (MTCC 1925), employing ethanolic fruit extracts derived from *M. nagi* (Mann S. *et al.*, 2015).

Minimum inhibitory concentration (MIC)

The MIC of MeLAE for *A. hydrophila* is 2 mg/mL, as determined by colorimetric analysis (Rawat, S. *et al.*, 2011). The outcome indicated that the lowest inhibiting concentrations of Propionibacterium acne were found in the essential oil and crude extract of *M. esculenta*, at 1.7 and 2.1 mg/mL, respectively (Seal, T., 2011).

Minimum bactericidal concentration (MBC)

MeLAE exhibited an MBC of 25 mg/mL odds to *A. hydrophila* (Rawat, S. *et al.*, 2013). The outcome aligns with the hypothesis that the extract derived from the *M. esculenta* plant exhibits potent antibacterial characteristics.

Antifungal

Antifungal activity hostile to *Candida albicans, Aspergillus flavus,* and *Aspergillus parasiticus* was observed in fruit extracts in methanolic, ethanolic, and aqueous solutions via disc diffusion (Syed, S. *et al.*, 2013).

Anthelmintic

On Indian Pheritima posthuma earthworms, the antihelmintic activity of a liquid form of ethanolic extract derived from the bark of *M. esculenta* was assessed. These earthworms are physiologically and morphologically similar to the intestinal roundworm parasites that affect humans. Piperazine citrate was used as the standard of comparison. The extraction process was carried out and concentrated using a soxhlet apparatus. At the tested dosage level, this extract was evaluated for its antihelmintic activity and worm-killing potency was observed to be greater than that of the reference control, piperazine citrate. A 12.5 mg/mL aqueous ethanolic extract incited fatality after 41.25

minutes and paralysis in 20.11 minutes, respectively. The time required for paralysis and concentration both contribute to the increasing impact, while mortality is observed to be inversely proportional to the dosage (Nainwal, P. and Kalra, K., 2009).

Anticancer

Fruit extracts containing acetone and acidic acetone demonstrated anticancer activity against C33A, SiHa, and HeLa cell lines (Pant, G. *et al.*, 2014).

Antioxidant

Methanolic extract of fruits showed significant antioxidant properties in *in-vitro* study (Dhani, A, 2013). Fruit pulp methanolic extract demonstrated significant scavenging capacity in an *in-vitro* experiment (Sharma, R. *et al.*, 2018). A separate *in-vitro* investigation observed that acetone extract exhibited the highest scavenging potential compared to aqueous, methanolic, and aqueous extracts (Nayak, B. K. *et al.*, 2017). Naturally occurring antioxidants found in copious quantities in the fruit of *M. esculenta* mitigate oxidative stress and prevent specific degenerative diseases. The chemical activity of the extract may be enhanced through purification (Patel, K. G. *et al.*, 2008).

Antidiabetic

Albino Wistar rats administered 150 mg/kg of a notable anti-dyslipidemic effect had been examined in the methanolic extract of leaves and maintained normal blood glucose levels (Patil, S. P. *et al.*, 2016).

Antidepressant

An open-field test, rearing test, traction test, head-dip test, forced-swimming test and cage crossing test are all indicators that Albino rodents treated with methanolic extract of bark exhibited significant antidepressant activity (Nainwal, P. and Kalra, K., 2009).

Wound healing

The aqueous extract exhibited a notable capacity for wound healing in Albino rodents of bark during wound excision and incision (Mann S. *et al.*, 2015).

Antipyretic

An antipyretic effect of fruit methanolic extract was observed in the mice with yeast-induced pyrexia at an amount of 100 mg/kg (Bich, D. H. *et al.*, 2004).

Analgesic

A notable response was observed in mice subjected to ME-EtAC at a dosage of 200 mg/kg in the acetic acid-induced writhing and tail immersion assay (Das, P. *et al.*, 2024).

Antipruritic

Stem bark's aqueous extract in male mice was tested in pruritis induced by compound 48/80, which showed a notable decrease in scratching effect (Patel, K. G. *et al.*, 2008).

Antidiarrheal

Ethanolic extract of leaves was used in castor oil-induced diarrhoea in mice, showing significant antidiarrheal activity (Rana, R.K. *et al.*, 2016; Kumar, A. *et al.,* 2024).

Antiasthmatic

Acetylcholine-induced bronchospasm in Guinea pig was treated with ethanolic extract of bark protected against bronchospasm and anaphylaxis (Swathi, D. *et al.*, 2015). In contrast, another study utilised ethanolic extract of stem bark to induce histamine-induced bronchospasm in guinea pigs and observed thin-layer chromatography results (Pant, G. *et al.*, 2014).

Wound healing

Albino rodents were administered bark's aqueous ointment for wound excision and incision, and the ointment was discovered to have significant wound healing potential (Middha, S.K. *et al.*, 2016).

Ayurvedic formulations

Ayurvedic preparations, including Chwayanprash and Brahmarasayan, are formulated from fruits and roots. These substances have been found to improve cognitive functions, memory, concentration, digestion, and physical endurance (Dai, G. *et al.*, 2015). A crucial constituent of the Ayurvedic remedy Visweshwara rasa, which is employed to treat fevers induced by pitta and kapha, is the bark of *M. esculenta* (Qin, M. *et al.*, 2015). Furthermore, the fruits or bark of M. *esculenta* are integral components in Ayurvedic formulations that address menstrual disorders such as dysentery, neuralgia, rheumatoid arthritis, and menorrhagia. Mahavisagarbha taila, Katiedi churna, Katphala taila, Khadiradi gutika, Pusyanuga churna, Arimedadi taila, Bala taila, Kaas-har churna, Katphala kvatha, and Brihatphala ghrita are among the formulations mentioned (Table **2**) (Domitrović, R. *et al.*, 2015).

Nutritional value

Numerous nutrients found in the fruits of *M. esculenta* were observed for proximate analysis as part of the evaluation. In addition to minerals such as Cu, Na, Ca, Fe, Zn, Mn, K, and Mg, these nutrients comprised crude fibre, crude carbohydrates, crude fat, and crude protein. The results presented in Table 3 indicate that malnutrition-related diseases can be adequately protected against through the consumption of fruit in adequate quantities.

Physiochemical profile

Table 4 presents the physicochemical parameters of various parts of *M. esculenta,* including leaves, bark, stem bark, and small branches. Methanolic extractive values range from 5.03% (small branches) to 38.52% (bark), while ethyl acetate extracts are reported for leaves (25.46%) and bark (21.20%) but not recorded (NR) for stem bark and small branches. Aqueous extracts show values between 3.52% (small branches) and 21.28% (leaves). Total ash content varies from 1.010% (stem bark) to 3.3312% (bark), and acid-insoluble ash is highest in bark (1.2300%). Foreign matter is less than 1% in leaves and not detected in other parts. Loss on drying ranges from 5% (leaves) to 6.81% (stem bark). Total phenolic content is reported for stem bark (276.78 mg GAE/g) and small branches (31.24 mg GAE/g), with total flavonoids

also higher in stem bark (121.68 mg QE/g) compared to small branches (12.94 mg QE/g).

Clinical studies done on *M. esculenta* Muscle atrophy

Muscle atrophy was prevented with 5 mg/kg of myricanol. Muscle mass loss in the quadriceps was reduced from 1.18 ± 0.06% b/w in the non-treated group to 1.36 ± 0.02% b/w in the group which is treated. The untreated group experienced a muscle mass loss of 0.78 ± 0.05% b/w, whereas the treated group lost 0.87 ± 0.08% b/w. The treatment group exhibited an increase in grasp strength from 70.90 ± 04.59 to 120.58 ± 7.93 g. In the treated group, the forced swim time was 48.80 ± 11.43 seconds, whereas it increased to 83.75 ± 15.19 seconds. Inhibition of muscle atrophy was indicated by a 25% increase in muscle fibre diameter compared to the untreated group (Yang, Y. L. *et al.*, 2019).

Antiobesity

Diabetes and insulin resistance were induced in rodents fed a high-fat diet; administration of *myricanol* at a rate of 25 mg/kg prevented both conditions. A greater accumulation of adipose tissue and a decrease in body mass were observed in the treated group as a result of the high-fat diet. Triglycerides, LDL-cholesterol, serum total cholesterol, and the LDL/HDL ratio all decreased by 33%. In contrast, the treated group exhibited a 5% reduction in basal insulin levels. Compared to the untreated group, insulin sensitivity increased by approximately a factor of two. The treated group exhibited a 1.5-fold decrease in GSK-3β phosphorylation, a 0-5% decrease in IRS-1 phosphorylation, and a 3-fold decrease in AKT reduction. When comparing adipocytes treated and untreated, a 35% reduction in diameter was observed. The untreated group exhibited a 33% increase in serum concentrations of irisin (Kabra, A. *et al.*, 2020).

Zebrafish exhibited antiobesity activity in response to administration of myricanol at a concentration of 1 M. Lipid accumulation in the high-fat diet group decreased by 66% relative to the untreated group (positive control AICAR (5 μM): 75% decrease). The expression levels of PPARγ, C/EBPα, SREB-1, and aP2 (which correspond to the positive control values) decreased by 70 to 80% when compared to the untreated group.

Antitumor

An amount of 40 mg/kg of myricanol exhibited antitumor activity in nude rodents when administered. After 14 days, the A549 xenograft tumor volume was reduced by 39.4% compared to the untreated group. Bax expression levels increased by approximately 33% to the untreated group. When compared to the untreated group, expression levels of Bcl-2 (25%), vascular endothelial growth factor (VEGF) (20%), and Survivin (33%) were lower. There was a 20% increase in the number of apoptotic tumor cells as compared to the untreated group (Nhiem, N. X. *et al.*, 2010).

Atherosclerosis

Mice received 50 mg/kg of myricitrin. Intercepted atherosclerosis. Ox-LDL serum levels were reduced by approximately 25% (comparable to the positive control group treated with 2 g/kg probucol). The aortic wall thickness was reduced by 22% as compared to the untreated group. Complete suppression of calcification in the aortic arch. (Calcification was seen in the untreated group). In comparison to the untreated group, there was a 26% reduction in atherosclerotic plaque area. Approximately 20% reduction in caspase-3 expression in the aortic arch (Dua, T. K. *et al.*, 2021).

Hepatoprotective

Myricitrin at a quantity of 100 mg/kg in mice demonstrated hepatoprotective action. Protection from CCl4 intoxication. Body weight decreased (–12.9 ± 0.8 vs. 19.6 ± 2.3% in the untreated group). Reduced ALT serum levels (481 ± 53 vs. 2126 ± 268 U/L in the untreated group). Reduced AST serum levels (592 ± 74 vs. 2538 ± 322 U/L in the untreated group). Reduction of hepatic lipid peroxidation. Glutathione concentrations increased by 46.1 ± 3.4 μmol/g protein compared to 28.6 ± 2.8 μmol/g protein in the untreated group. Necrotic regions on the liver decreased by approximately 25% compared to the untreated group. 5-fold increase in CYP2E1 expression when compared to the untreated group (Lohani, N. *et al.*, 2013).

Diabetic cardiomyopathy

At a quantity of 300 mg/kg, myricitrin protected mice from diabetic cardiomyopathy. Diabetic mice's heart function improved by approximately 20 to 25% compared to the untreated group. When compared to the untreated group, there was a decrease in anomalies in cardiac fiber organization and cardiomyocyte morphology. Inhibition of collagen network degradation and decrease of cardiac fibrosis. TGF-β1 expression decreased 2-fold compared to the untreated group. Collagen-1 expression levels were reduced eightfold. Reduction in serum IL-6 levels (35.72 vs. 112.41 pg/mL in the untreated group). TNF-α serum levels were reduced to 24.83 pg/mL, compared to 56.21 pg/mL in the untreated group. Expression levels of Bax/Bcl-2 ratio (35-fold), caspase-3 (5-fold), and caspase-9 (4-fold) were reduced when compared to the untreated group (Gusain, Y. S. *et al.*, 2016).

Neuroprotective effects

Neuroprotective effects were observed in rodents when administered a dose of 50 mg/kg of myricitrin. PSD-95 and TH expression levels were approximately twofold greater in rodents that were stimulated with LPS compared to the untreated group. Expression levels of MCP-1, IL-1β, IL-6 and TNF-α were all decreased by a factor of two compared to the untreated group. In contrast, comparison to the untreated group, the units of COX-2 and iNOS expression were reduced by a factor of two and three, respectively. P38, ERK, and JNK activation, each of which was increased by a factor of four, were inhibited in response to LPS.

When exposed to the methanolic extract of *M. esculenta*, subjects demonstrated enhanced muscular coordination and notably dosage-dependent rises in behavioural activity. The stages of malonaldehyde and antioxidant enzymes, like glutathione, catalase, and superoxide dismutase, were significantly higher in the extract-treated group when compared to the control group. Histopathological commutes indicate that MEME minimised neuronal atrophy while substantially reducing haloperidol-induced damaging to the substantia nigra.

Antihypertensive

Myresculoside, an unidentified monoterpenoid glycoside, was produced through the application of repetitive column chromatography and methanol extraction from the foliage of *M. esculenta*. Eleven known compounds were also extracted. The compounds' capacity to inhibit the actions of the angiotensin I-converting enzyme (ACE) was assessed. The compounds with the highest observed inhibitory rates of ACE were Compounds 3 and 4, both at 100 mM: 29.997 and 25.63%, respectively. The inhibitory activity of compounds 5, 6, and 11 was moderate, along with rate ranges from 0.07 to 1.41% at 100 mm.

Diabetic Nephropathy

Concerning diabetic nephropathy, an investigation was conducted of myricitrin in therapeutic potential, a glycosidic flavone derived from the bark of *M. esculenta*. When type 2 diabetic (T2D) rodents fed a high-fat diet were administered a smaller amount of streptozotocin, blood glucose levels decreased significantly. By stimulating the IRS-1/PI3K/Akt/GLUT4 signalling pathway, *M. esculenta* has been shown to improvements in glucose uptake by the skeletal muscles in pair *in-vitro, in-vivo* experiments. *M. esculenta* effectively reduced the toxicity that was caused by heightened hyperglycemia (HG) the kidneys of T2D rodents and in NRK cells. The promotion of inflammation and oxidative stress by hyperglycemia in this study led to nephrotoxicity, which manifested as fibrosis, apoptosis, and inflammation, causing injury. *In-vivo* and *in-vitro* studies have demonstrated that *M. esculenta* reduces oxidative stress via activating Nrf-2 and scavenging/neutralizing oxidative radicals, thereby enhancing endogenous redox defence. By inhibiting NF-κB activation, Myr has the potential to alleviate diabetes-induced inflammation of the kidneys. As indicated by alterations in the expression of fibrotic and apoptotic factors, *M. esculenta* inhibited apoptosis and apoptosis induced by hyperglycemia in renal cells. *M. esculenta* interactions with a diverse array of signal proteins were predicted via molecular docking.

Conservation

Destruction of plant life is an everyday occurrence. The present pace of eradication, which is man-made, is roughly several hundred times faster than the rate of natural extinction. Several botanical species that provide therapeutic benefits, such as *M. esculenta*, are approaching extinction due to training activities conducted in the Himalayan region. *M. esculenta* is frequently substituted and applied as a traditional remedy. The proliferation of untamed populations is a consequence of the rising demand for this substance, which is fueled by national and international trade and its wide range of applications. As a result, there have been notable declines in population.[93] Alternative methods for conservation and propagation are urgently required for averting the possible extinction of this indispensable species, which is characterized by restricted geographic distribution, extreme overexploitation in natural habitats, and unalterable uncertainties regarding seed viability and germination. Biotechnology offers innovative strategies for enhancing biodiversity and developing biotechnological processes. Micropropagation techniques, for instance, have garnered increased interest and may play a notable role in the establishment of botanical varieties that are resistant to genetic variation for the enterprise. With any luck, the development of consistent micropropagation standards could guarantee adequate availability of the *M. esculenta* plant (without imposing unwarranted ecological pressures), thereby reducing the uncontrolled growth pressure on natural populations.

Conclusion

This review underscores the substantial ethnobotanical, phytochemical, and pharmacological value of *M. esculenta*, validating its traditional use in Ayurvedic and Unani systems. Its rich content of flavonoids, phenolics, vitamins, and minerals supports its classification as a potent nutraceutical, with demonstrated efficacy against ailments such as diabetes, asthma, cancer, ulcers, and inflammation. However, further in-depth studies are required to elucidate its immunomodulatory, cardioprotective, neuroprotective, and nephroprotective mechanisms.

Future research should focus on clinical trials to validate its therapeutic effects, standardization of extracts, and identification of active constituents responsible for specific pharmacological actions. Advanced molecular docking and *in-vivo* studies can help uncover its mode of action at the cellular level. Additionally, sustainable harvesting practices and conservation strategies are critical to protect this valuable Himalayan species from overexploitation. Integrating traditional knowledge with modern scientific approaches can pave the way for novel drug development and contribute meaningfully to global healthcare and biodiversity preservation.

Acknowledgment

The authors are thankful to the School of Pharmacy, RK University, Rajkot, and Parul Institute of Pharmacy for their encouragement and for providing facilities.

Author Contribution

Krishna Raninga is involved in the complete writing of the article. Vaibhavi Savalia and Ruchi Dobariya are involved in the overall formatting and editing. Pravin Tirgar and Jital Desai were involved in the critical revision of tables and graphs and the improvement of the article.

Conflict of interest

None

References

Agnihotri, S.; Wakode, S. R.; Agnihotri, A. Formulation and Evaluation of Herbal Anti-acne Gel of Myrica esculenta. *Asian J. Pharm. Clin. Res.* 2016, *9*, 358–361.

Agnihotri, S.; Wakode, S.; Ali, M. Essential Oil of Myrica esculenta Buch. Ham: Composition, Antimicrobial and Topical Anti-inflammatory Activities. *Nat. Prod. Res.* 2012, 26, 2266–2269. DOI: (https://Doi.org/10.1080/14786419.2011.652959).

Agnihotri, S.; Wakode, S.; Ali, M. Triterpenoids from the Stem Bark of Myrica esculenta Buch. Ham. *World J. Pharm. Pharm. Sci.* 2016, *5*, 1319–1327.

Arya, D.; Khan, A. H.; Adhikari, M. Plant Species Used by Locals as Ethno-Medicine in Kumaun Region of Western Himalaya (India). *Int. J. Pharm. Sci. Res.* 2014, 5, 3128–3132. DOI: (https://Doi.org/10.13040/

IJPSR.0975-8232.5(8).3128-32).

Bambola, A.; Semwal, D. K.; Semwal, S.; Rawat, U. Flavonoid Glycosides from Myrica esculenta Leaves. *J. Indian Chem. Soc.* 2009, *86*, 535–536.

Bhat, R. A. H.; Rehman, S.; Tandel, R. S. Immunomodulatory and Antimicrobial Potential of Ethanolic Extract of Himalayan Myrica esculenta in Oncorhynchus mykiss: Molecular Modelling with Aeromonas hydrophila Functional Proteins. *Aquaculture*, 2021, 533, 736213. DOI: (https://Doi.org/10.1016/j.aquaculture.2020.736213).

Bich, D. H.; Chung, D. Q.; Chuong, B. X.; Dong, N. T.; Dam, D. T.; Hien, P. V. The Medicinal Plants and Animals in Vietnam. *Hanoi Sci Tech,* 2004; Vol. 1, pp 612-613.

Chandra, S.; Saklani, S.; Mishra, A. P.; Badoni, P. P. Nutritional Evaluation, Antimicrobial Activity and Phytochemical Screening of Wild Edible Fruit of Myrica nagi Pulp. *Int. J. Pharm. Pharm. Sci.* 2012, *4*, 407–411.

Chauhan, N. S. Medicinal and Aromatic Plants of Himachal Pradesh; Indus Publishing Company: New Delhi, India, 1999; p 226.

Dai, G.; Tong, Y.; Chen, X.; Ren, Z.; Ying, X.; Yang, F. Myricanol Induces Apoptotic Cell Death and Antitumor Activity in Non-Small Cell Lung Carcinoma *In-vivo*. *Int. J. Mol. Sci.* 2015, *16*, 2717–2731. Doi: 10.3390/ijms16022717.

Das, L.; Das, M.; Barkalita, L.M.; Borah, P. Comprehensive Analysis of Antioxidant Properties, GC-MS, and FTIR Profiles of *Myrica esculenta* Fruit Extracts from Western East Khasi Hills of Meghalaya. *Chem. Biodivers.* 2024, *21*(12), e202401006. Doi: https://Doi.org/10.1002/cbdv.202401006

Das, P.; Nayak, P.K.; Kesavan, R.K. Computational Modeling for the Enhancement of Thermosonicated Sohphie (Myrica esculenta) Fruit Juice Quality Using Artificial Neural Networks (ANN) Coupled with a Genetic Algorithm. *Sustain. Food Technol.* 2024, *2,* 790–805. Doi: https://Doi.org/10.1039/D4FB00004H.

Dawang, S.; Zuchun, Z.; Foo, L. Y.; Wong, H. Flavonols from Myrica esculenta Bark. *Chem. Indus. Forest Prod.* 1991, *4*, 251–257.

Dhani, A. Major Wild Edible Fruits Used by Locals of Garhwal Himalaya. *Int. J. Adv. Life Sci.* 2013, *6*, 145-149.

Domitrović, R.; Rashed, K.; Cvijanović, O.; Vladimir-Knežević, S.; Škoda, M.; Višnić, A. Myricitrin Exhibits Antioxidant, Anti-inflammatory, and Antifibrotic Activity in Carbon Tetrachloride-Intoxicated Mice. *Chem. Biol. Interact.* 2015, *230*, 21–29. Doi: 10.1016/j.cbi.2015.01.030.

Dua, T. K.; Joardar, S.; Chakraborty, P.; Bhowmick, S.; Saha, A.; De Feo, V.; Dewanjee, S. Myricitrin, a Glycosyloxyflavone in Myrica esculenta Bark, Ameliorates Diabetic Nephropathy via Improving Glycemic Status, Reducing Oxidative Stress, and Suppressing inflammation. *Molecules,* 2021, *26*, 258. Doi: 10.3390/molecules26020258.

Gangwar, K. K.; Deepali; Gangwar, R. S. Ethnomedicinal Plant Diversity in Kumaun Himalaya of Uttarakhand, India. *Nat. Sci.* 2010, *8*, 66–78.

Ginwal, H. S.; Meena, R.K.; Bhandari, M.S. SSR-Based Genetic Analysis Depicted High Gene Diversity with Subtle Population Genetic Structure in Myrica esculenta, a High-Valued Edible Fruit Tree of the Western Himalayas. *Trees* 2024, *38*, 1189–1203. Doi: https://Doi.org/10.1007/s00468-024-02545-2.

Gusain, Y. S.; Khanduri, V. P. Myrica esculenta Wild Edible Fruit of Indian Himalaya: Need a Sustainable Approach for Indigenous Utilization. *Ecol. Environ. Conserv.* 2016, *22*, S267–S270.

Hui-fen, M. A.; Zheng-liang, Y.; Sang-zi, Z. E.; Yong-jie, L.; De-lu, N.; Zhen, Y. U. GC/MS Analysis of Volatile Components from Leaf of Myrica esculenta Buch. Ham. *Guangdong Agric. Sci.* 2011, *16*, 18.

Jain, V. K.; Jain, B. Anthelmintic Activity of Ethanolic Extract of Bark of Myrica esculenta. *Int. J. Pharm. Sci. Res.* 2010, *1*, 129-131.

Jeeva, S.; Lyndem, F. B.; Sawian, J. T.; Laloo, R. C.; Mishra, B. P. Myrica esculenta Buch. -Ham. ex D. Don. A Potential Ethnomedicinal Species in a Subtropical Forest of Meghalaya, Northeast India. *Asian Pac. J. Trop. Biomed*. 2011, 1, S174–S177. DOI: (https://Doi.org/10.1016/S2221-1691(11)60149-6).

Kabra, A.; Baghel, U. S.; Hano, C.; Martins, N.; Khalid, M.; Sharma, R. Neuroprotective Potential of Myrica esulenta in Haloperidol Induced Parkinson's Disease. *J. Ayurveda Integr. Med.* 2020, *11*, 448–454. Doi: 10.1016/j.jaim.2020.06.007.

Kabra, A.; Sharma, R.; Singla, S.; Kabra, R.; Baghel, U. S. Pharmacognostic Characterization of Myrica esculenta Leaves. *J. Ayurveda Integr. Med.* 2017, *10*, 18–24. Doi: 10.1016/j.jaim.2017.07.012.

Kayang, H. Tribal Knowledge on Wild Edible Plants of Meghalaya, Northeast India. *Indian J. Tradit. Know.* 2007, *6*, 177–181.

Khan, M. Y.; Sagrawat, H.; Upmanyu, N.; Siddique, S. Anxiolytic Properties of Myrica nagi Bark Extract. *Pharm. Biol.* 2008, 46, 757–761. DOI: https://Doi.org/10.1080/13880200802180350.

Kumar, A.; Singh, H.; Kumar, D.; Kapoor, V. Ethnopharmacology of *Myrica esculenta*: A Systemic Review. *J. Res. Appl. Sci. Biotechnol.* 2024, *3*(3), 113–119. Doi: https://Doi.org/10.55544/jrasb.3.3.19.

Kumari, A. Nutritional Quality, Functional Properties, and Value Addition of Underutilized Fruits of Himachal Pradesh, 2012.

Kumari, P.; Joshi, G. C.; Tewari, L. M. Diversity and Status of Ethnomedicinal Trees of Almora District in Uttarakhand, India. *Int. J. Biodivers. Conserv.* 2011, 3, 298–326. DOI: (https://Doi.org/10.5897/IJBC.9000118).

Laloo, D.; Hemalatha, S. Ethnomedicinal Plants Used for Diarrhea by Tribals of Meghalaya, Northeast India. *Pharmacogn. Rev.* 2011, 5, 147–154. DOI: (https://Doi.org/10.4103/0973-7847.79103).

Lohani, N.; Tewari, L. M.; Joshi, G. C.; Kumar, R.; Kishor, K.; Upreti, M. R. Population Assessment and Threat Categorization of Endangered Medicinal Orchid Malaxis acuminata D. Don from North-West Himalaya. *Int. J. Conserv. Sci.* 2013, *4*, 483–940.

Maikhuri, R. K.; Gangwar, A. K. Ethnobiological Notes on the Khasi and Garo Tribes of Meghalaya, *Northeast India. Econ. Bot.* 1993, 47, 345–357. DOI: https://Doi.org/10.1007/BF02862295.

Mallya, S. V.; Nesari, T.; Kumar, K. N. Pharmacognostic Standards of Katphala (Myrica nagi Hook. f. non-Thumb); A Potent Bark Drug Used in Indian Systems of Medicine. *J. Sci. Innov. Res.* 2016, *5*, 135–137.

Mann, S.; Satpathy, G.; Gupta, R. K. In-vitro Evaluation of Bioprotective Properties of Underutilized Myrica esculenta Buch. -Ham. ex D. Don Fruit of Meghalaya. *Indian J. Nat. Prod. Resour.* 2015, *6*, 183-188.

Middha, S. K.; Kumar, G. A.; Talambedu, U.; Babu, D.; Misra, A. K.; Prakash, L. Evaluation of Antioxidative, Analgesic and Anti-inflammatory Activities of Methanolic Extract of Myrica nagi Leaves—An Animal Model Approach. *Symbiosis*, 2016, 213, 179–184. DOI: (https://Doi.org/10.1007/s13199-016-0422-y).

Mishra, R. N. Rasayan–The Ayurvedic Perspective. *Res. J. Pharm. Biol. Chem. Sci.* 2011, *2*, 269–282.

Nainwal, P.; Kalra, K. Study on the Wound Activity Potential on the Aqueous Extract of the Bark of Myrica esculenta Buch. & Ham. *Int. J. Pharm. Clin. Res.* 2009, *1*, 85-87.

Nayak, B. K.; Deka, P.; Eloziia, N. Assessment of Phytochemical & Pharmacological Activities of the Ethanol Leaves Extracts of Myrica esculenta Buch. Ham. *J. Pharm. Res.* 2017, *11*, 444-449.

Nguyen, X. N.; Phan, V. K.; Chau, V. M.; Bui, H. T.; Nguyen, X. C.; Vu, K. T. A New Monoterpenoid Glycoside from Myrica esculenta and the Inhibition of Angiotensin I-Converting Enzyme. Chem. Pharm. Bull. 2010, 58, 1408–1410. DOI: (https://Doi.org/10.1248/cpb.58.1408).

Nhiem, N. X.; Kiem, P. V.; Minh, C. V.; Tai, B. H.; Cuong, N. X.; Thu, V. K. A New Monoterpenoid Glycoside from Myrica esculenta and the Inhibition of Angiotensin I-Converting Enzyme. *Chem. Pharm. Bull.* 2010, *58*, 1408–1411.

Pandey, M. M.; Rastogi, S.; Khatoon, S.; Mehrotra, S.; Rawat, A. K. S. Evaluation of Ayurvedic Compound Formulation 5-Katphaladi Churna. *Indian J. Tradit. Know.* 2013, *12*, 295–299.

Pant, G.; Prakash, O.; Chandra, M.; Sethi, S.; Punetha, H.; Dixit, S. Biochemical Analysis, Pharmacological Activity, Antifungal Activity and Mineral Analysis in Methanol Extracts of Myrica esculenta and Syzygium cumini: The Indian Traditional Fruits Growing in Uttarakhand Himalaya. *Indian J. Pharm. Biol. Res.* 2014, *2*, 26-34.

Panthari, P.; Kharkwal, H.; Kharwal, H.; Joshi, D. D. Myrica nagi: A Review on Active Constituents, Biological and Therapeutic Effects. *Int. J. Pharm. Pharm. Sci.* 2012, *4*, 38–42.

Panwar, S.; Chandra, G.; Ginwal, H.S. Contouring of an Indistinct Sex Ratio and COVID-19 Threat to the Sustainability of *Myrica esculenta* in the Northwestern Himalayas. *Vegetos* 2024, 1, 1-12. Doi: https://Doi.org/10.1007/s42535-024-00984-3

Patel, K. G.; Bhalodia, P. N.; Patel, A. D.; Patel, K. V.; Gandhi, T. R. Evaluation of Bronchodilator and Antianaphylactic Activity of Myrica sapida.

Iran. Biomed. J. 2008, *12*, 191-196.

Patel, T.; Dudhpejiya, A.; Sheath, N. Anti-Inflammatory Activity of Myrica nagi Linn. Bark. *Anc. Sci. Life,* 2011, *30*, 100-103.

Patel, T.; Rajshekar, C.; Parmar, R. Mast Cell Stabilizing Activity of Myrica nagi Bark. *J. Pharmacogn. Phytother.* 2011, *3*, 114–117.

Patel, V. G.; Patel, K. G.; Patel, K. V.; Gandhi, T. R. Development of Standardisation Parameters and Isolation of Phytomarker Myricetin from Stem Bark of Myrica esculenta Buch. Ham. Ex D. Don. J. *Pharmacogn. Phytochem.* 2017, *6*, 29–34.

Patil, S. P.; Pardeshi, M. L.; Ghongane, B. B. Screening for Anti-Allergic and Anti-Histaminic Activity of Extract of Momordica dioica, Myrica esculenta and Euphorbia hirta in Animal Models. *Res. J. Pharm. Biol. Chem. Sci.* 2016, *7*, 21-28.

Qin, M.; Luo, Y.; Meng, X.-B.; Wang, M.; Wang, H.-W.; Song, S.-Y. Myricitrin Attenuates Endothelial Cell Apoptosis to Prevent Atherosclerosis: An Insight into PI3K/Akt Activation and STAT3 Signalling Pathways. *Vasc. Pharmacol.* 2015, *70*, 23–34. Doi: 10.1016/j.vph.2015.03.002.

Rana, R. K.; Patel, R. K. Pharmacological Evaluation of Antiasthmatic Activity of Myrica nagi Bark Extracts. Antiinflamm. Antiallergy Agents Med. Chem. 2016, 15, 145-152. Doi: (https://Doi.org/10.2174/1871523015666160923154547).

Rawat, S.; Jugran, A.; Giri, L.; Bhatt, I. D.; Rawal, R. S. Assessment of Antioxidant Properties in Fruits of Myrica esculenta: A Popular Wild Edible Species in Indian Himalayan Region. Evid. Based Complement. Alternat. Med. 2011, 2011, 1-8. Doi: (https://Doi.org/10.1093/ecam/neq055).

Rawat, S.; Jugran, A.; Giri, L.; Bhatt, I. D.; Rawal, R. S. Assessment of Antioxidant Properties in Fruits of Myrica esculenta: A Popular Wild Edible Species in Indian Himalayan Region. Evid. Based Complement. Alternat. Med. 2011, 2011, 1–8. DOI: (https://Doi.org/10.1093/ecam/neq055).

Rawat, S.; Kumar, N.; Kothiyal, P. Evaluate the Antidiabetic Activity of Myrica esculenta Leaves in Streptozotocin Induced Diabetes in Rat. *Int. J. Univ. Pharm. Bio. Sci.* 2013, *2*, 510-525.

Seal, T. Antioxidant Activity of Some Wild Edible Fruits of Meghalaya State in India. *Adv. Biol. Res.* 2011, *5*, 155-160.

Sharma, R.; Kabra, A.; Rao, M. M.; Prajapati, P. K. Herbal and Holistic Solutions for Neurodegenerative and Depressive Disorders Leads from Ayurveda. *Curr. Pharm. Des.* 2018, 24, 2597-2608. Doi: (https://Doi.org/10.2174/1381612824666180821165741).

Shen, S.; Liao, Q.; Feng, Y.; Liu, J.; Pan, R.; Lee, S. M.-Y. Myricanol Mitigates Lipid Accumulation in 3T3-L1 Adipocytes and High Fat Diet-Fed Zebrafish via Activating AMP-Activated Protein Kinase. *Food Chem.* 2019, *270*, 305–314. Doi: 10.1016/j.foodchem.2018.07.117.

Shen, S.; Liao, Q.; Liu, J.; Pan, R.; Lee, S. M.; Lin, L. Myricanol Rescues Dexamethasone-Induced Muscle Dysfunction via a Sirtuin 1-Dependent Mechanism. *J. Cachexia Sarcopenia Muscle,* 2019, *10*, 429–444. Doi: 10.1002/jcsm.12393.

Shen, S.; Liao, Q.; Zhang, T.; Pan, R.; Lin, L. Myricanol Modulates Skeletal Muscle–Adipose Tissue Crosstalk to Alleviate High-Fat Diet-Induced Obesity and Insulin Resistance. *Br. J. Pharmacol.* 2019, *176*, 3983–4001. Doi: 10.1111/bph.14802.

Shri, K. S.; Sharma, Y. P.; Pankaj, S.; Pratima, V.; Randhawa, S. S. Wild Edible Fruits of Himachal Pradesh State Centre on Climate Change & UNEP-GEF-MoEFCC Project Report, 2018.

Shrivastava, A. K.; Chaudhary, D.; Shrestha, L.; Awadalla, M. E.; Al-Shouli, S. T.; Palikhey, A. GC-MS Based Metabolite Profiling, and Anti-Inflammatory Activity of Aqueous Extract of Myrica esculenta through *In-vitro* and In Silico Approach. Med. Sci. Forum, 2023, 21, 52. DOI: https://Doi.org/10.3390/ECB2023-14079.

Shukla, M. K.; Sharma, A.; Kumar, R.; Pandey, S.; Kumar, D. Anticancer Potential of Myrica esculenta Plant: A Comprehensive Review. In: Sobti, R.C.; Ganguly, N.K.; Kumar, R. (Eds) Handbook of Oncobiology: From Basic to Clinical Sciences. Springer, Singapore 2024. Doi: https://Doi.org/10.1007/978-981-99-6263-1_65.

Singh, N.; Khatoon, S.; Srivastava, N.; Rawat, A.; Mehrotra, S. Qualitative and Quantitative Standardization of Myrica esculenta Buch.-Ham. Stem Bark by Use of HPTLC. J. Planar Chromatogr. 2009, 22, 287–291. DOI: https://Doi.org/10.1556/JPC.22.2009.4.9

Sinha, A. K.; Choudhary, D. GC-MS Based Metabolite Profiling, and Anti-Inflammatory Activity of Aqueous Extract of Myrica esculenta through *In-vitro* and In Silico Approach. *Eur. Chem. Bull.* 2024, *21*(1), 52. https://www.mdpi.com/2673-9992/21/1/52.

Srivastava, B.; Sharma, V. C.; Pant, P.; Pandey, N. K.; Jadhav, A. D. Evaluation for Substitution of Stem Bark with Small Branches of Myrica esculenta for Medicinal Use—A Comparative Phytochemical Study. J. Ayurveda Integr. Med. 2016, 7, 1–6. DOI: (https://Doi.org/10.1016/j.jaim.2016.08.004).

Swathi, D.; Prasad, K. V. S. R. G. Antioxidant and Antiulcer Potential of Ethanolic Extract of Bark of Myrica esculenta in Pyloric Ligation Ulcer Model. *Int. J. Pharm. Pharm. Sci.* 2015, *7*, 195–198.

Syed, S.; Ahmad, M.; Fatima, N.; Mahjabeen; Jahan, N. Neuropharmacological Studies of Myrica nagi Bark. *Int. J. Biol. Biotechnol.* 2013, *10*, 553-558.

Wei, Y.; Chang-ming, T.; Xian, L.; Ya, Z.; Li, W.; Liang, L. Study on the Chemical Constituents of Myrica esculenta. *J. Yunnan Univ.* 2011, *33*, 453–457.

Yang, Y.-L.; Liu, M.; Cheng, X.; Li, W.-H.; Zhang, S.-S.; Wang, Y.-H. Myricitrin Blocks Activation of NF-κB and MAPK Signalling Pathways to Protect Nigrostriatum Neuron in LPS-Stimulated Mice. *J. Neuroimmunol.* 2019, *337*, 577049. Doi: 10.1016/j.jneuroim.2019.577049.

Yanthan, M.; Misra, A. K. Molecular Approach to the Classification of Medicinally Important Actinorhizal Genus Myrica. *Indian J. Biotechnol.* 2013, *12*, 133–136.

Zhang, B.; Shen, Q.; Chen, Y.; Pan, R.; Kuang, S.; Liu, G. Myricitrin Alleviates Oxidative Stress-Induced Inflammation and Apoptosis and Protects Mice Against Diabetic Cardiomyopathy. *Sci. Rep.* 2017, *7*, 44239. Doi: 10.1038/srep44239.