Avens Publishing Group
J Pharmaceu Pharmacol
November 2026 Vol.12, Issue:1

Open Access **Research Article**

Journal of
Pharmaceutics & Pharmacology

GC–MS Phytochemical Profiling and Nutritional Evaluation of Myrica esculenta from Narayan Nagar, Uttarakhand Himalaya, India

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Submission: 26 June 2026
Accepted: 29 July 2026
Published: 31 July 2026

Keywords: GC-MS, Biochemical; phytochemicals and Minerals; Myrica *esculenta*

Abstract

Background: Kafal (*Myrica esculenta*) is an economically valuable wild fruit species native to the Kumaun Himalaya, where it plays a significant role in sustaining the livelihoods of forest-dependent communities. The fruits command a favorable market price, and their seasonal harvesting and marketing constitute an important source of household income for rural populations.

Methods: The aerial parts of *Myrica esculenta* (leaves and stems) were subjected to hydrodistillation for 12 h using a Clevenger-type apparatus for the extraction of essential oil. The mineral content of the plant material was determined after wet acid digestion using standard analytical procedures.

Results: A total of sixty-eight compounds were identified constituting 90.71% of the total oil. The main compounds were Caryophyllene (23.34), Linalool (8.23), Caryophyllene Oxide (6.15), 1-Hexanol (5.54), 3-hexen-1-ol (5.49), Isogermacrene D (3.17), γ-Muurolene (3.11) and δ-Cadinene (2.86). Nutrient contents are was found to Carbohydrate 16.24±0.55mg.100 g-1, Protein 5.28±0.16 and Fat were 7.37±0.14 on a dry weight basis. Overall, the fruit of *M. esculenta* contains high levels of moisture, carbohydrates, protein, fat, and fiber, as well as exceptionally high amounts of vitamin C, phenolic compounds, and potassium.

Conclusion: The findings of the present study indicate that the aerial parts (leaves and stems) of *Myrica esculenta* represent a valuable source of essential oil, whereas the dried fruits possess high levels of minerals and bioactive phytochemicals. Collectively, these results underscore the potential of *M. esculenta* as a multifunctional natural resource for applications in the pharmaceutical, nutraceutical, and food sectors.

Introduction

Medicinal plants have played a pivotal role in the development of human civilization and healthcare systems throughout history. They have served as a primary source of therapeutic agents across diverse cultures and continue to be an integral component of traditional medicine. Owing to their rich diversity of bioactive compounds, medicinal plants have contributed significantly to the discovery and development of numerous modern pharmaceuticals [1]. The Himalayan region in India is particularly known for its diverse range of edible plants, with over 670 different species. *M. esculenta* is valued because it has many health benefits and good nutritional value [2]. This plant is important for its traditional uses and medicinal properties. The plant, locally known as "Kaphal," has considerable cultural and medicinal importance in these regions. It has been traditionally used for centuries to treat various health conditions, including gastrointestinal disorders, respiratory problems, and skin diseases [3].

Myrica esculenta is a naturally occurring forest species whose fruits are harvested directly from wild populations, eliminating the need for cultivation, irrigation, fertilizers, or other agricultural inputs. The low production and harvesting costs associated with its collection enhance its economic value, making it an important source of income for forest-dependent communities. Accordingly, *M. esculenta* is regarded as a high-value Non-Timber Forest Product (NTFP) that plays a significant role in supporting rural livelihoods, enhancing household income, and promoting the socio-economic resilience of communities across the Kumaun Himalayan region.

Myrica esculenta is a nutritionally important wild fruit species indigenous to the Himalayan region, producing highly perishable fruits during the April–June fruiting season. Owing to their rich nutritional profile and diverse bioactive constituents, the fruits have been extensively utilized in traditional Ayurvedic medicine and are incorporated into numerous herbal formulations for the prevention and management of a variety of ailments [4]. *M. esculenta* is a tree that belongs to the family Myricaceae [5]. Studies have demonstrated that methanolic extracts of *M. esculenta* leaves significantly lower blood glucose, blood cholesterol, and body weight in diabetic rats [6].

The fruits and roots of *Myrica esculenta* are widely used in traditional Ayurvedic medicine and constitute important ingredients in several herbal formulations, including *Chyawanprash* and *Brahma Rasayan*. These formulations are prescribed to promote digestion, enhance memory and concentration, improve cognitive function, and increase physical vitality [2]. According to traditional literature, the oil extracted from the flowers of *Myrica esculenta* has been used as a tonic and is employed in the management of conditions such as paralysis, headache, earache, and diarrhea [7].

Previous studies have demonstrated that the antioxidant activity

ISSN: 2327-204X

Figure 1: Myrica esculenta plants.

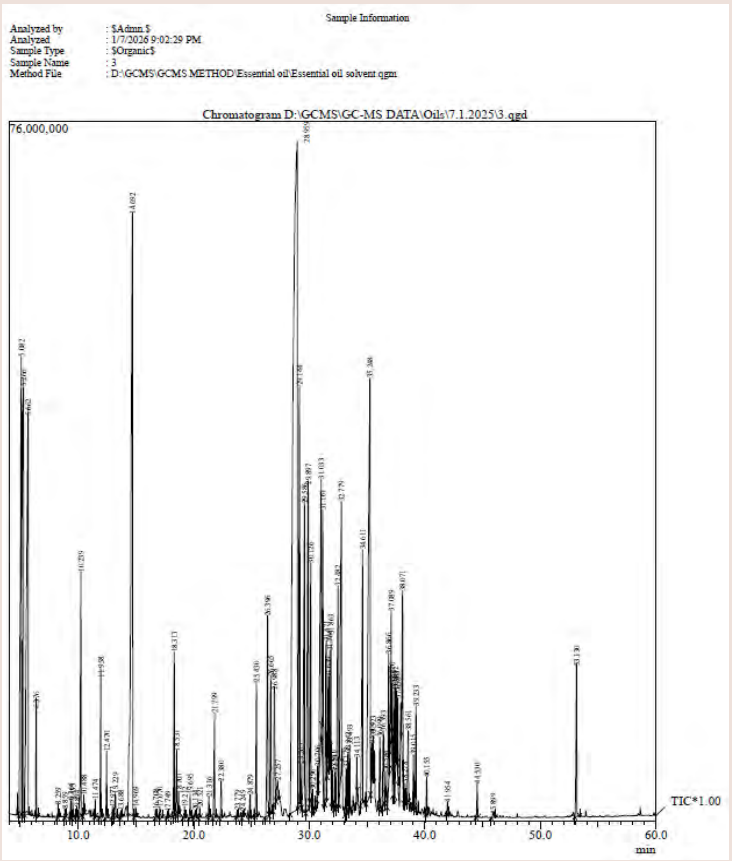

Figure 2: GC Chromatogarm of M. esculenta.

of *Myrica esculenta* extracts is primarily attributed to their high concentrations of flavonoids and phenolic acids, which constitute the major bioactive compounds responsible for their free radical scavenging properties [8-10]. In addition to their antioxidant potential, experimental and preclinical studies have reported a broad spectrum of pharmacological activities associated with *M.*

ISSN: 2327-204X

esculenta extracts, including analgesic and anti-asthmatic [11], anticancer [12], antidepressant [13], antidiabetic [6], antidiarrheal [14], antihypertensive, anti-inflammatory, and antimicrobial [4], antipyretic [10, 15], as well as chemopreventive and hepatoprotective activities [15, 16].

The fruits of *Myrica esculenta* have been reported to exhibit hepatoprotective [17] and antihypertensive activities [18]. In addition, preclinical studies have suggested that fruit extracts possess promising anticancer potential, highlighting their prospective therapeutic applications in cancer management [12]. Furthermore, the ethanolic bark extract has demonstrated wound-healing activity in experimental studies, supporting its traditional use in wound management [19].

In the villages of Ogla, Charma, and Narayan Nagar, local communities harvest substantial quantities of *Myrica esculenta* fruits from nearby forests, and their sale constitutes an important source of household income and livelihood. Given its considerable medicinal, nutritional, and economic significance, the present study investigates the antioxidant potential, aromatic oil composition, and nutraceutical constituents of the aerial parts and fruits of *M. esculenta*. The findings are expected to provide valuable insights into the phytochemical profile of this underutilized species and support its sustainable utilization as a potential source of bioactive compounds for pharmaceutical, nutraceutical, and functional food applications.

Materials and Methods

Plant Material

The aerial parts of *Myrica esculenta* were collected in September 2025 from the campus of Narayan Nagar Government Degree College, Pithoragarh, Uttarakhand, India, located in the Indian Himalayan region. The plant material was taxonomically identified and authenticated by the Department of Botany, Soban Singh Jeena University, Government Post Graduate College (SNS GPGC), Narayan Nagar, Pithoragarh. Following collection, the samples were thoroughly washed with cold water to remove adhering soil and other extraneous matter, and subsequently shade-dried at ambient temperature until a constant weight was achieved. The dried material was then pulverized into a fine powder using a laboratory grinder and accurately weighed using an electronic analytical balance prior to further analysis.

Chemicals

All chemicals, reference standards, and reagents used in this study were of analytical grade and were purchased from Merck Life Science Pvt. Ltd., India, through the Government e-Marketplace (GeM) portal.

Isolation of essential oil

The aerial parts of *Myrica esculenta* (leaves and small stems) were subjected to hydrodistillation for 8 hours using a Clevenger-type apparatus to extract the essential oil. The obtained oil was dried over anhydrous sodium sulfate to remove residual moisture and stored in sealed amber glass vials at room temperature until further analysis. The essential oil yield (%) was calculated on a dry weight basis and expressed as the percentage (v/w) of oil obtained relative to the dry weight of the plant material.

GC and GC/MS analyses and identification

The chemical composition of the essential oil was analysed using gas chromatography coupled with flame ionization detection (GC–FID) and gas chromatography–mass spectrometry (GC–MS) on a Shimadzu QP-2010 Plus system equipped with a flame ionization detector (FID). Chromatographic separation was achieved on an Rtx-5MS fused-silica capillary column (30 m × 0.25 mm i.d., 0.25 µm film thickness). Helium (99.999% purity) was employed as the carrier gas at a constant flow rate of 1.21 mL min^{-1} (69.0 kPa). 1 µL aliquot of the essential oil diluted in *n*-hexane was injected in spitless mode. The injector and interface temperatures were maintained at 270 °C. The oven temperature was programmed from 50 to 280 °C at a heating rate of 3 °C min^{-1}. Mass spectra were acquired under electron ionization (EI) at 70 eV, with the ion source temperature maintained at 230 °C. GC–FID analyses were performed under identical chromatographic conditions, and the relative percentage composition of individual constituents was calculated from the GC peak areas without applying response-factor corrections.

The volatile constituents were identified by comparing their mass spectra and calculated retention indices (RIs) with those reported in the literature and available spectral libraries [20]. Retention indices were calculated relative to a homologous series of *n*-alkanes according to the method of Kovats [21].

$$\log t^{1}_{R}(\text{unknown}) - \log t^{1}_{R}(C_n)$$

$$KI = 100\,[n + (N-n)\ X \quad \frac{\log t^{1}_{R}(\text{unknown}) - \log t^{1}_{R}(C_n)}{\log t^{1}_{R}(C_N) - \log t^{1}_{R}(C_n)}$$

t^{1}_{R} – the net retention time ($t_R - t_0$)

t_0 – the retention time of solvent (dead time)

t_R – the retention time of the compound.

C_N – number of carbons in longer chain of alkane

C_n – number of carbons in shorter chain of alkane

n - is the number of carbon atoms in the smaller alkane

N - is the number of carbon atoms in the larger alkane

Total phenolic

The whole plant was dried in shade and powdered using electrical grinder. The amount of total phenolic content was estimated following [22] with modification. The reaction mixture contained 100 Dl of sample extract, 500 Dl Folins-Ciocalteu's reagent (freshly prepared), 2 ml of 20% Sodium Carbonate and 5 ml of distilled water. After 15min reaction at 45^{0}C the absorbance at 650 nm was measured using spectrophotometer. The result was expressed as mg of Catechol equivalent per 100 g of dry weight.

Biochemical analysis

The moisture content was estimated by drying in electrical oven at 80 ^{0}C for 24 hours and expressed on a percentage basis. The dried leaves were powdered separately in electric mill to 60 mesh size. The fine fruits powders so obtained was used for further biochemical and mineral analysis (three replication of each parameter). Total

ISSN: 2327-204X

Table1: Essential oil composition of *M. esculenta* in plants leaves.

SN	Compoud Name	Area %	Mol. Formula	Mol. Weight	Retention Indices	Mode of Identification
1.	3-hexen-1-ol	5.49	$C_6H_{12}O$	100	840	a, b
2.	1-Hexanol	5.54	$C_6H_{14}O$	102	861	a, b
3.	n- Heptanal	0.37	$C_7H_{14}O$	114	904	a, b
4.	Hept-(2E)-enal	0.05	$C_7H_{12}O$	112	956	a, b
5.	2-pentylfuran	0.08	$C_9H_{14}O$	138	960	a, b
6.	(E)-3-Hexen-1-ol acetate	1.48	$C_8H_{14}O_2$	142	970	a, b
7.	Hexyl acetate	0.08	$C_8H_{16}O_2$	144	1000	a, b
8.	beta-Ocimene	0.66	$C_{10}H_{16}$	136	1010	a, b
9.	Oct-(2E)-enal	0.32	$C_8H_{14}O$	126	1020	a, b
10.	cis-Linalool oxide	0.05	$C_{10}H_{18}O_2$	170	1040	a, b
11.	1-Octanol	0.20	$C_8H_{18}O$	130	1050	a, b
12.	Linalool	8.23	$C_{10}H_{18}O$	154	1070	a, b
13.	4,8-dimethyl- (E)- Nona-1,3,7-triene	0.05	$C_{11}H_{18}$	150	1102	a, b
14.	p-Vinylanisole	0.05	$C_9H_{10}O$	134	1110	a, b
15.	2-nonenal	0.09	$C_9H_{16}O$	140	1130	a, b
16.	3Z- Hexenyl butyrate	0.86	$C_{10}H_{18}O_2$	170	1162	a, b
17.	Methyl-Salicylate	0.43	$C_8H_8O_3$	152	1175	a, b
18.	α-Terpineol	0.08	$C_{10}H_{18}O$	154	1182	a, b
19.	Decanal	0.05	$C_{10}H_{20}O$	156	1202	a, b
20.	β-Cyclocitral	0.14	$C_{10}H_{16}O$	152	1220	a, b
21.	(Z)-3-Hexenyl crotonate	0.05	$C_{10}H_{16}O_2$	168	1230	a, b
22.	2E-Decenal	0.61	$C_{10}H_{18}O$	154	1260	a, b
23.	Edulan III	0.04	$C_{13}H_{20}O$	192	1320	a, b
24.	2,4-Decadienal	0.03	$C_{10}H_{16}O$	152	1325	a, b
25.	δ-Elemene	0.14	$C_{15}H_{24}$	204	1335	a, b
26.	α-Cubebene	0.81	$C_{15}H_{24}$	204	1345	a, b
27.	α-Copaene	2.54	$C_{15}H_{24}$	204	1370	a, b
28.	β-Bourbonene	0.95	$C_{15}H_{24}$	204	1380	a, b
29.	1,5,9,13-Tetradecatetraene	0.22	$C_{14}H_{24}$	190	1392	a, b
30.	Caryophyllene	23.34	$C_{15}H_{24}$	204	1414	a, b
31.	cis-Muuroladiene	0.10	$C_{15}H_{24}$	204	1468	a, b
32.	Vitispirane	0.20	$C_{13}H_{20}O$	192	1470	a, b
33.	γ-Muurolene	3.11	$C_{15}H_{24}$	204	1470	a, b
34.	α-Guaiene	0.15	$C_{15}H_{24}$	204	1472	a, b
35.	γ-Gurjunene	0.14	$C_{15}H_{24}$	204	1476	a, b
36.	Guaia-6,9-diene	2.58	$C_{15}H_{24}$	204	1480	a, b
37.	α-Humulene	1.48	$C_{15}H_{24}$	204	1485	a, b
38.	β-Selinene	1.28	$C_{15}H_{24}$	204	1486	a, b
39.	Isogermacrene D	3.17	$C_{15}H_{24}$	204	1490	a, b
40.	α-Selinene	0.54	$C_{15}H_{24}$	204	1504	a, b
41.	γ-Cadinene	2.71	$C_{15}H_{24}$	204	1512	a, b
42.	ε-Amorphene	1.89	$C_{15}H_{24}$	204	1514	a, b
43.	α-Muurolene	0.66	$C_{15}H_{24}$	204	1515	a, b
44.	δ-Cadinene	2.86	$C_{15}H_{24}$	204	1520	a, b
45.	trans-Cadina-1,4-diene	0.22	$C_{15}H_{24}$	204	1528	a, b
46.	α-Cadinene	0.40	$C_{15}H_{24}$	204	1536	a, b
47.	β-Calacorene	0.31	$C_{15}H_{20}$	200	1546	a, b
48.	Germacrene B	0.15	$C_{15}H_{24}$	204	1556	a, b
49.	trans-Nerolidol	1.88	$C_{15}H_{26}O$	222	1560	a, b
50.	Caryophyllene Oxide	6.15	$C_{15}H_{24}O$	220	1580	a, b
51.	Diethyl Phthalate	0.23	$C_{12}H_{14}O_4$	222	1592	a, b
52.	Salvial-4(14)-en-1-one	0.19	$C_{15}H_{24}O$	220	1596	a, b
53.	1,10-di-epi-Cubenol	0.75	$C_{15}H_{26}O$	222	1614	a, b
54.	Junenol	0.12	$C_{15}H_{26}O$	222	1628	a, b

ISSN: 2327-204X

55.	Isospathulenol	0.66	$C_{15}H_{24}O$	**220**	1630	a, b
56.	Copaborneol	0.23	$C_{15}H_{26}O$	222	1636	a, b
57.	Caryophylladienol II	0.66	$C_{15}H_{24}O$	220	1645	a, b
58.	t-Cadinol	0.44	$C_{15}H_{26}O$	222	1650	a, b
59.	τ-Muurolol	0.16	$C_{15}H_{26}O$	222	1655	a, b
60.	Himachalol	1.39	$C_{15}H_{26}O$	222	1660	a, b
61.	Antar	0.06	$C_{16}H_{34}O$	242	1688	a, b
62.	4(15),5,10(14)-Germacratrien-1-ol	0.49	$C_{15}H_{24}O$	220	1690	a, b
63.	Eudesma-4(15),7-dien-1.beta. -ol	0.26	$C_{15}H_{24}O$	220	1694	a, b
64.	7R,8R-8-Hydroxy-4-isopropylidene-7-methylbicycloundec-1-ene	0.63	$C_{15}H_{24}O$	220	1754	a, b
65.	(2E,6Z)-Farnesol	0.20	$C_{15}H_{24}O$	220	1760	a, b
66.	Phytone	0.18	$C_{18}H_{36}O$	268	1841	a, b
67.	n-Hexadecanol	0.06	$C_{16}H_{34}O$	242	1884	a, b
68.	Phytol	0.99	$C_{20}H_{40}O$	296	2106	a, b
		90.71				
a=Retention Index (RI), b=MS (GC-MS)						

Table 2: Nutrients composition investigated in fruits of *M. Esculenta.*

S.no.	Biochemical Parameter	Composition (mg.100g^{-1})	Range
1.	Moisture	65.49±0.29	65.23-65.89
2.	Tot. Mineral	9.92±0.07	9.83-9.99
3.	Silica	1.60±0.17	1.37-1.77
4.	Acid soluble	8.33±0.12	8.16-8.46
5.	Carbohydrate	16.24±0.55	16.47-16.77
6.	Protein	5.28±0.16	5.13-5.50
7.	Fat	7.37±0.14	7.17-7.49
8.	Fiber	4.65±0.34	4.18-4.95
9.	Vit-c	310.82±0.42	310.27-311.29
10.	Phenolics	494.82±0.60	494.03-495.49
11.	Ca (mg/100g)	114.85±0.50	114.18-115.38
12.	Na (mg/100g)	16.36±1.03	15.19-17.69
13.	K (mg/100g)	1353.67±1.27	1351.93-1354.94
14.	Li (mg/100g)	4.46±0.32	4.19-4.91
15.	N (mg/100g)	880.86±0.16	880.70-88107
16.	P(mg/100g)	215.16±1.17	214.33-216.82

NOTE: Results expressed as mean ± standard deviation.

carbohydrate content in plant fruits was estimated by the [23]. Total nitrogen was estimated by Micro-Kjeldahl method, according to AOAC method [24]. Crude protein was calculated as Kjeldahl N x 6.25 (based on assumption that nitrogen constitutes 16.0% of a protein). The content of crude fat was estimated by AOAC method [25].

Mineral analysis

Ash content was estimated by AOAC method, [24] and ash insoluble content was estimated by method [26, 27]. Mineral content in plant was estimated by wet digestion method. 1.0 g plant material was first digested with conc. HNO_3 (5 ml each), followed by application of 15 ml of tri-acid mixture (HNO_3, $HClO_4$ and H_2SO_4, 10:4:1, v/v) heated at 200 ^{0}C and reduce to 1 ml. The residue after digestion was dissolved in double distilled water, filtered and diluted to 100 ml. This solution was used for the estimation of minerals. Macro minerals viz., Na, K, Ca and Li was estimated by AIMIL, Flame Photometer.

Ascorbic acid

Ascorbic acid content was estimated by method [28] with modification. Dry leaves powder (2.0 g) was extracted with 4% oxalic acid and made up to 100 ml and centrifuged at 10,000 rpm for a 10 minute. 5 ml supernatant liquid was transferred in a conical flask, followed by addition of 10 ml 4% oxalic acid and titrated against standard dye solution (2, 6-dichlorophenol indophenol) to a pink end point. The procedure was repeated with a blank solution omitting the sample.

Statistical analysis of data

The results were statistically analyzed and expressed as mean (n = 3) ± standard deviation. All experiments were performed in triplicates and the data expressed as mean ± SD using the Microsoft Excel 2016 spreadsheet.

Results and Discussion

Hydrodistillation of the aerial parts of *Myrica esculenta* afforded an essential oil yield of 0.15% (w/w), based on the fresh weight of the plant material. Comprehensive GC–FID and GC–MS analyses identified 68 volatile constituents, accounting for 90.71% of the total essential oil composition (Table 1). The oil was characterized

ISSN: 2327-204X

predominantly by sesquiterpene hydrocarbons and oxygenated sesquiterpenes, whereas monoterpenes, oxygenated monoterpenes, aliphatic alcohols, aldehydes, and their corresponding esters were detected in comparatively lower abundances.

The essential oil was characterized by a predominance of sesquiterpene hydrocarbons. the major constituent was identified as, Caryophyllene (23.34%), linalool (8.23%) and caryophyllene oxide (6.15%). Other relatively abundant compounds included 1-hexanol (5.54%), 3-hexen-1-ol (5.49%), isogermacrene D (3.17%), γ-muurolene (3.11%), δ-cadinene (2.86%), γ-cadinene (2.71%), guaia-6,9-diene (2.58%), and α-copaene (2.54%). These compounds collectively contribute to the characteristic aroma and biological properties of the oil.

caryophyllene was found to be effective against gastrointestinal disease caused due to *Helicobacter pylori* infection. A randomized double-blind placebo-controlled study has reported that administration of 126 mg β-caryophyllene daily for 8 weeks showed significant anti-inflammatory properties by downregulating the level of IL-1β. It further improved conditions of nausea, epigastric pain and dyspepsia associated with the disease thereby proving that it can stand as a potential therapy against inflammation and gastrointestinal ailments [29, 30].

The dominance of caryophyllene and its oxygenated derivative, caryophyllene oxide, is noteworthy because both compounds have been widely reported to possess anti-inflammatory, antimicrobial, antioxidant, and insecticidal activities. Caryophyllene is a common sesquiterpene found in numerous aromatic and medicinal plants and is often associated with therapeutic applications. Similarly, caryophyllene oxide has been recognized as an important bioactive constituent with significant pharmacological potential [31].

Among the oxygenated monoterpenes, linalool was the most abundant component (8.23%). Linalool is known for its pleasant floral aroma and has been reported to exhibit antimicrobial, antioxidant, anxiolytic, and anti-inflammatory activities [32].

Several sesquiterpene hydrocarbons were identified in significant quantities, including α-copaene, β-bourbonene, α-humulene, β-selinene, γ-muurolene, γ-cadinene, and δ-cadinene. These compounds are commonly found in the essential oils of medicinal plants and are linked to a variety of ecological and biological functions, such as plant defence mechanisms against pathogens and herbivores.

The presence of oxygenated sesquiterpenes, such as trans-nerolidol, himachalol, t-cadinol, cubenol derivatives, and farnesol, significantly enhances the biological importance of the oil. Oxygenated terpenoids are generally recognized for their substantial contribution to the antimicrobial and antioxidant properties of essential oils. This is mainly due to their greater chemical reactivity compared to their hydrocarbon counterparts [33, 34].

The essential oil of *M. esculenta* has a chemically diverse composition, with a notable dominance of sesquiterpenes, particularly caryophyllene and caryophyllene oxide. Additionally, it contains significant amounts of linalool and green leaf volatiles. The presence of these bioactive compounds suggests that the oil may have substantial pharmacological and industrial potential, supporting the traditional medicinal uses of the plant. Further research focused on the biological activities and therapeutic applications of the essential oil is necessary to confirm its medicinal value.

Both, the major as well as minor constituents were identified by their retention indices and comparison of their mass spectra.

The fruit of *M. esculenta* has a nutrient-dense biochemical profile, highlighted by significant levels of moisture, macronutrients, minerals, vitamin C, and phenolic compounds (Table 2). The moisture content was found 65.49 ± 0.29 % in fresh fruits, indicating that the fruit tissue is well-hydrated and physiologically active. The shelf-life and stability of food components are primarily determined by their moisture content. A low moisture content suggests that food products have a longer shelf life and are less susceptible to microbial contamination [35]. The elemental evaluation of the wild-harvested sub-Himalayan bio-resource *Myrica esculenta* (Kafal) demonstrated a distinct, high-density mineral. On a dry weight basis, the total mineral ash was quantified at 9.92 ± 0.07 g/100g, which accurately mirrors structural parameters noted across underutilized wild mountain fruits [36]. The fruit also silica at (1.80±0.12 mg/100 g) and acid-soluble fraction at (8.33±0.12 mg/100 g) respectively, on a dry weight basis. The ash content in these fruits was notably high, indicating a significant concentration of essential mineral nutrients. These minerals act as inorganic cofactors in various metabolic processes [37].

In terms of proximate constituents, the carbohydrate content was measured (16.24 0.55 g / 100 g), while fat recorded (7.37±0.14 g /100 g) and protein was recorded (5.28±0.16 g/ 100g). The energy content of fruits was determined by multiplying the crude protein, crude lipid and total carbohydrate content by the factor 4, 9 and 4 respectively [38]. The calorific values of the plant leaves were found 152.38 K.Cal/100 g. The relatively high protein level of *M. esculenta* fruits could make it a useful supplement to diets. Dietary proteins play an important role in the manufacturing and safeguarding of certain organic materials necessary for the smooth functioning of the human body. Proteins also serve the purpose of enzymatic catalyst and mediate metabolic and energy regulation [39]. Carbohydrate content was the highest nutritional composition. The high carbohydrate content makes it rich source of energy, and this could be used to enhance the energy content of diets [40]. The overall energy derived from *M. esculenta* fruits sample calculated was 152.38 kcal/100g which is below the recommended daily energy value. Therefore *M. esculenta* as a low energy food source maybe very helpful in weight management programmes as used by traditional practitioners. Fiber at (4.65±0.34 g/100 g) all based on a dry weight basis. The relatively high fibre content prevents constipation by facilitates peristaltic movement and aids the absorption of certain minerals in the gut and reduces cholesterol absorption [41].

The *M. esculenta* fruits collected from Charma showed a better nutritional composition and bioactive profile. The vitamin C concentration was found (310.82±0.42 mg/100g). Total phenolic content (TPC) was found 494.82 ± 0.60 mg/100 g. Ascorbic acid, commonly known as vitamin C, is a biologically active compound primarily found in plant-based products, particularly in leafy vegetables and citrus fruits [42]. This vitamin is regarded as the most abundant water-soluble antioxidant in plants (Rufino et al., 2010). The levels of ascorbic acid can vary based on factors such as the plant species, the stage of maturity, environmental conditions, and storage practices, as this vitamin is highly unstable [42, 43]. The dry fruits are show *M. esculenta* are good source of Vitamin-C. Phenolic compounds can be classified into two main categories: water-soluble compounds, such as phenolic acids and flavonoids, and water-insoluble compounds, including tannins and lignins. Both groups

ISSN: 2327-204X

have significant bioactive potential and are found in all wild fruits [44-46]. This study indicates that M. esculenta dry fruits contain measurable (494.82 ± 0.60 mg/100 g) amounts of phenolics.

Minerals are essential in human nutrition for the overall physical and mental health, as well as important constituents of nerve cells, bones, teeth, tissues, muscles, and blood. The mineral analysis potassium (K) was founds (1353.67 ± 1.27 mg/100g), sodium (Na) was measured at (16.36±1.03 mg/per 100g). The micromineral spectrum was heavily dominated by Potassium (1353.67 ± 1.27 mg/100g), whereas Sodium was trace (16.36 ± 1.03 mg/100g), culminating in an exceptional therapeutic K/Na ratio of 82.74. This remarkably high index positions *M. esculenta* as an optimal functional food ingredient for managing hypertension and fluid homeostasis. Sodium is very important mineral element involved in the transmission of nerve impulse as well as maintenance of osmotic pressure of body fluids. Deficiency of sodium cause dehydration and muscle cramps [47]. Potassium plays an important role in water as well as acid-base balance in the body. It is also responsible for maintaining cardiac rhythm, nerve action and functioning of muscles. Deficiency of potassium cause muscle paralysis [48]. In the present investigation of Myrica esculenta, we found a nitrogen (N) concentration of 880.86 ± 0.16 mg per 100 grams and a phosphorus (P) concentration of 215.16 ± 1.17 mg per 100 grams, based on dry weight. The relatively low standard deviations indicate high analytical precision and limited variability among the replicate measurements, which supports the reliability of these mineral estimates.

The mineral analysis revealed the presence of calcium (Ca) and lithium (Li) in the dried fruits of *Myrica esculenta*, with calcium and lithium contents of 114.85 ± 0.50 mg/100 g and 4.46 ± 0.32 mg/100 g, respectively. Calcium is an essential mineral involved in various physiological functions, including muscle contraction, nerve transmission, blood coagulation, cellular permeability regulation, and maintenance of skeletal structure [49, 50].

Conclusion

The present study demonstrates that *Myrica esculenta* is a valuable bioresource with significant essential oil, nutritional, and functional properties. The aerial parts of the plant represent a promising source of chemically diverse essential oil enriched with bioactive terpenoid constituents, which may contribute to its reported pharmacological potential, including antioxidant, antimicrobial, and anti-inflammatory activities. The fruits exhibited a rich biochemical and mineral profile, highlighting their nutritional importance and potential role as a functional food ingredient.

Acknowledgement

The authors are grateful to Dr Ajay Kumar, AIRF, Jawaharlal Nehru University, New Delhi for the Gas Chromatography coupled with Mass Spectrometry (GC-MS).

Abbreviations

The following abbreviations are used in this manuscript.

GC-MS gas chromatography/mass spectrometry

GC-FID gas chromatography/flame ionization detector

RI: retention index

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