Bioedukasi
Jurnal Biologi dan Pembelajarannya
Vol. 23 No 2, June 2025, page 163-176
e-ISSN: 2580-0094; p-ISSN:1693-3931
DOI: 10.19184/bioedu.v23i2.53739
bioedukasi.unej.ac.id/index.php/BIOED

Bioactive Compound Characterization of Medicinal Plants in Meru Betiri National Park (Jember, Indonesia) using SPME-GCMS Analysis

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Article Info
Article history:
Received June 3, 2025
Revised June 22, 2025
Accepted June 25, 2025

Keywords: (A-Z)
Bioactive compound,
Medicinal plants,
Meru Betiri National Park,
Sesquiterpenes

ABSTRACT
This research aimed to identify bioactive compounds in medicinal and aromatic plants in the Meru Betiri National Park area, specifically in the Bandealit area. The sampling of medicinal plants was carried out in June 2023. The samples were analyzed using Solid Phase Microextraction-Gas Chromatography-Mass Spectrometry (SPME-GCMS). The results showed that the most abundant compounds were terpenoid groups, especially sesquiterpene. More than 50% of sesquiterpene compounds were detected in 10 medicinal plants in Meru Betiri National Park. Sesquiterpene compounds identified include Germacrene-D found in seven plants and Caryophyllene found in six plants. Sesquiterpene has been shown to have various pharmacological effects such as anticancer, antibacterial, anti-inflammatory, as well as antioxidant. The results of this research can be a reference for exploring the pharmacological effects of each medicinal plant in Meru Betiri National Park.

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1. INTRODUCTION

Indonesia is a country with a high level of biodiversity in both flora and fauna. About 6000 of Indonesia's flora biodiversity is included in medicinal plants. One of the national parks that has many medicinal plants is Meru Betiri National Park (Nugraha et al. 2020). Meru Betiri National Park (TNMB) is one of the large forest areas in Java. This area is a nature conservation area that has original ecosystems and is managed with a zoning system that can be utilized for research, science, education, supporting cultivation, tourism, and recreation. The TNMB area has an extraordinary diversity of medicinal and aromatic plants, especially as raw materials for medicines and aromatherapy. Meru Betiri National Park has about 518 plant species and of these species, 239 species of medicinal plants have been identified, which can be grouped into the habitus of trees, lianas, herbs, climbing plants, and shrubs (Balai Taman Nasional Meru Betiri 2022).

Medicinal plants are raw materials used to maintain health and treat some diseases for traditional or modern medicine systems. The defition of medicinal and aromatic plants (MAPs) can vary in strictness. Aromatic plants are used not only for medicinal purposes but also in cosmetics, condiments, and food (Novak 2020). Aromatic plants contain aromatic compounds such as volatile oils at room temperature. Volatile oils known as essential oils are produced from flowers, flower buds, seeds, leaves, twigs, barks, wood, fruits, and roots by several methods of extraction (Momin et al. 2021).

Medicinal and aromatic plants produce secondary metabolites as active compounds for pharmacological effects. The broad range of pharmacological and therapeutic potentials of medicinal and aromatic plants such as antioxidants, antidiabetic, hepatoprotective, immunomodulator, antimicrobials, anti-depressant, antiviral, anti-inflammatory, etc. These plants synthesize various bioactive compounds such as alkaloids, flavonoids, terpenes, phenols, saponins, volatile oils, etc (Novak 2020; Weaver 2014). One technique to identify active compounds from plants is using Solid Phase Microextraction-Gas Chromatography-Mass Spectrometry (SPME GC-MS). This is a newer technique that combines sample preparation and preconcentration into a single step. It is particularly useful for the analysis of trace amounts of volatile and semi-volatile compounds in complex matrices. SPME GC-MS can be more sensitive and accurate than traditional GC-MS (Williams and Buica 2020).

The exploration of bioactive compounds in medicinal and aromatic plants is a research priority in Indonesia. This research is not only for health knowledge but also for increasing the economic value of local communities (Cahyaningsih, Magos Brehm and Maxted 2021). This research becomes very important because the medicinal plants that have been explored are still around 40-50% of all the flora on each island of Indonesia (Ministry of National Development Planning, Ministry of Environment, and Indonesian Institute of Sciences 2016). Therefore, this research aimed to identify bioactive compounds in medicinal and aromatic plants in the Meru Betiri National Park area, specifically in the Bandealit area. These bioactive compounds can later be known for their pharmacological potential as medicinal materials and disease therapy.

2. RESEARCH METHOD

Legal administration

The sampling of medicinal plants was in the Bandealit resort area of Meru Betiri National Park, Jember, East Java, Indonesia with an access permit (SIMAKSI Nomor SI.321/T.15/TU/KSA/06/2022) in June 2023.

Medicinal plant collection and identification

Plant materials or samples were obtained from Meru Betiri National Park (TNMB), Jember Regency. The plant parts taken were leaves in the morning at a temperature of about 25-28C. The leaves were cleaned and put into a clean plastic bag then each weighed to 10 grams. There were 10 medicinal plants identified at the Biology Education Botany Laboratory, University of Jember (see Table 1).

Solid Phase Microextraction Gas Chromatography-Mass Spectrometry (SPME-GCMS)

Before GC-MS analysis, plant samples were extracted using the Solid Phase Microextraction technique. 10 leaves of medicinal plants that have been collected, each leaf of 10 grams is heated in a water handler at 75ºC and incubated for 1 hour. Volatile compounds from each sample were extracted with an SPME absorber, Polydimethylsyloxane-divinylbenzene (PDMS-DVB) polymer (Supelco, USA). The absorber was injected into the GCMS device. The GC-MS instrument used was a Shimadzu GCMS-QP2010 Plus equipped with a split injector set at 260ºC. The sample in the SPME holder was injected by the split method. MS detector temperature 200ºC. The column used the Restek Rtx®-50 column (Crossbond® 5% phenyl-50% methyl polysiloxane) with an inner diameter of 0.25 mm, length of 30 m, and thickness of 0.25 μm. The carrier gas used was helium with a pressure of 38.8 kPa, oven temperature of 60ºC, holding time of 3.00 minutes and final temperature of 220ºC holding time of 13.00 minutes. Total flow 4.6 mL/min, column flow 0.78 ml/min, linear velocity 32.2 cm/sec, purge flow 3.0 ml/min. The mass spectra of each compound peak detected in the chromatogram were compared with known compounds in the Wiley7.LIB data bank. The quantity of the chemical compound was indicated as a percentage of the peak area shown on the chromatogram. SPME GC-MS analysis was carried out at the Biosciences laboratory of Politeknik Negeri Jember.

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Table 1. Medicinal Plants in Bandealit Resort of Meru Betiri National Park

Botanical name	Part used	Family	Local Name
Murraya paniculate	Leaves	Rutaceae	Kemuning
Piper baccatum	Leaves	Piperaceae	Sirih tempel
Piper nigrum	Leaves	Piperaceae	Lada
Peperomia pellucida	Leaves	Piperaceae	Sirih Cina
Lunasia amara	Leaves	Rutaceae	Kayu sanrego
Knema cinerea	Leaves	Myristicaceae	Widara putih
Cinnamomum zeylanicum	Leaves	Lauraceae	Kayu manis
Actinodaphne macrophylla	Leaves	Lauraceae	Kayu bakang
Synedrella nodiflora	Leaves	Asteraceae	Jotang
Hiptis capitata	Leaves	Lamiaceae	Rumput knop

Solid Phase Microextraction Gas Chromatography-Mass Spectrometry (SPME-GCMS)

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3. RESULT AND DISCUSSION

Bioactive compounds of Murraya paniculate

Based on the results of SPME-GCMS analysis, it shows that the most active compound in Kemuning leaves was Germacrene-D (63.45%) in peak 11 and peak 12. In addition, there was trans-caryophyllene (20.32%) in peak 12. The number of identified compounds was 17 compounds (see Table 2 and Figure 1). Germacrene-D and trans-caryophyllene belong to the terpenoid, especially the sesquiterpene compound.

Table 2. SPME-GCMS results of *Murraya paniculate*

Peak#	Area%	Name
1	0.03	4H-Pyran-4-one, 2,6-dimethyl-
2	0.17	Carbamic acid, monoammonium salt
3	0.03	2-Heptanamine, 5-methyl-
4	0.23	Cyclohexene, 1-methyl-4-(1-methylethenyl)-
5	0.17	.beta.-Myrcene
6	0.61	1,7-OCTADIENE, 3-METHYLENE-
7	0.33	Pentanamide
8	0.18	CYCLOOCTENE, 3-METHYL-
9	0.41	1-OCTENE, 6-METHYL-
10	0.72	1,4,6-HEPTATRIENE, 2,3,6-TRIMETHYL
11	**12.42**	**GERMACRENE-D**
12	**20.32**	**trans-Caryophyllene**
13	3.97	.alpha.-Humulene
14	**51.03**	**GERMACRENE-D**
15	2.82	.delta.-Cadinene
16	3.19	SILANE, TRIMETHYL-2-PROPYNE-
17	3.36	2,4,4-Trimethyl-1-pentanol

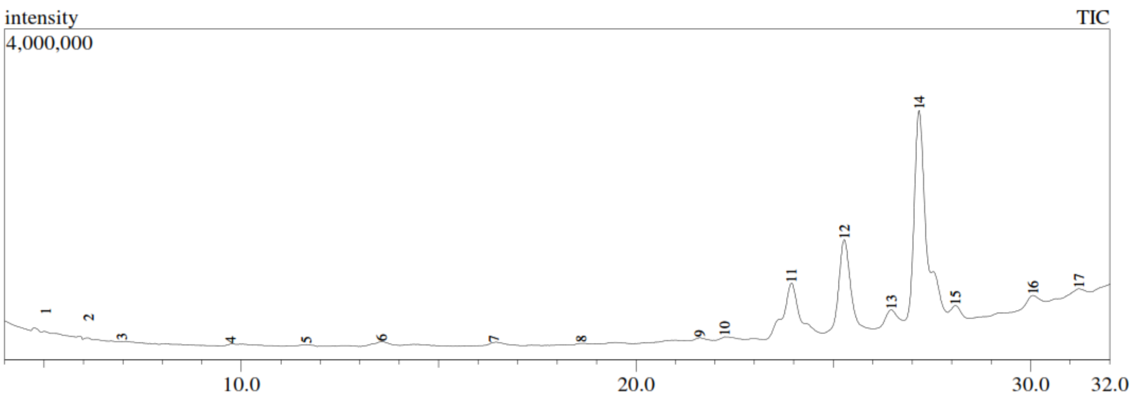

Figure 1. Chromatogram SPME-GCMS of *Murraya paniculate*

Bioactive compounds of Piper baccatum

Based on the SPME-GCMS results, the most bioactive compounds of Piper baccatum were Linalool L (21.64%) at peak 9 and Isopropyl myristate (19.6%) at peak 27. The number of bioactive compounds identified was 27 compounds (see Table 3 and Figure 2). Linalool is one of the essential oils which is a terpenoid compound and Isopropyl myristate is an ester.

Table 3. SPME-GCMS of *Piper baccatum*

Peak#	Area%	Name
1	7.58	Acetic acid (CAS) Ethylic acid
2	6.37	.ALPHA.-PINENE, (-)-
3	2.5	Camphene
4	0.38	Sabinene
5	0.21	.beta.-Myrcene
6	1.14	l-Limonene
7	0.31	1-Hexanol, 2-ethyl- (CAS) 2-Ethylhexanol
8	0.47	Nonanal
9	**21.64**	**LINALOOL L**
10	2.53	Camphor
11	6.53	Decanal
12	0.18	3-Cyclohexene-1-methanol, .alpha.,.alpha.,4-
13	0.82	2-Decenal, (E)-
14	1.25	.alpha.-Copaene
15	1.18	Alloaromadendrene
16	2.79	trans-Caryophyllene
17	0.41	.alpha.-Humulene
18	2.48	Naphthalene, 1,2,3,4,4a,5,6,8a-octahydro-7-
19	1.28	Germacrene D
20	0.65	Camphene
21	0.43	Hexadecane, 1-chloro- (CAS) 1-Chlorohexa
22	0.36	MYRISTCIN
23	1.22	9-Octadecene, (E)- (CAS)
24	1.49	2-Hexene, 2,5,5-trimethyl- (CAS) 2,5,5-Tri
25	7.71	Dodecanamide, N,N-bis(2-hydroxyethyl)-
26	8.49	2H-1-Benzopyran, 6,7-dimethoxy-2,2-dimet
27	**19.6**	**Isopropyl myristate**

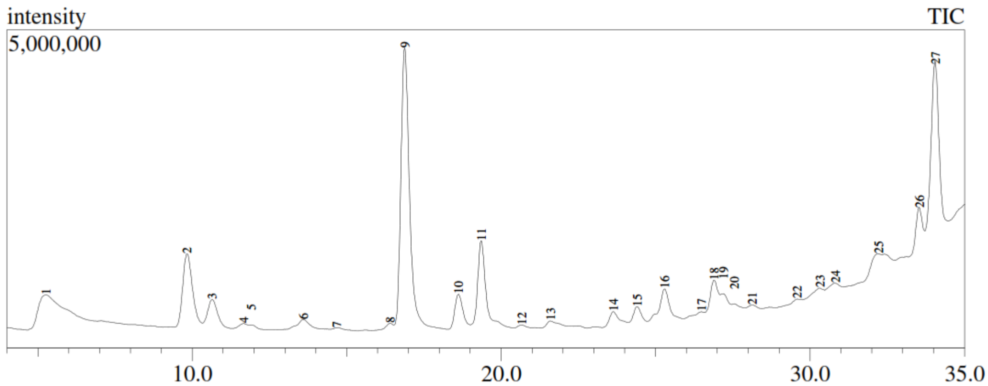

Figure 2. Chromatogram of *Piper baccatum*

Bioactive compounds of Piper nigrum

Based on Table 4 and Figure 3 of SPME-GCMS results, Piper nigrum leaves were found 25 bioactive compounds. The most bioactive compounds were (-)-β-Elemene (21,14%) at peak 19 and δ- (20,23%) at peak 13. The (-)-β-Elemene dan δ-Elemene are sesquiterpenes compounds.

Table 4. SPME-GCMS of *Piper nigrum*

Peak#	Area%	Name
1	0.19	7-Oxabicyclo[4.1.0]heptane
2	0.49	Heptanal (CAS) n-Heptanal
3	0.03	1,3,5,7-Cyclooctatetraene
4	0.02	1-Methyl-[3-(15)N]-urea

Peak#	Area%	Name
5	0.25	(1S,2S)-2-hydroxymethyl-2-methylcyclopent
6	0.08	.ALPHA.-PINENE, (-)-
7	0.26	Nonanal (CAS) n-Nonanal
8	1.63	LINALOOL L
9	0.19	3-Nonen-1-ol, (Z)-
10	0.11	Dodecanal
11	0.02	Benzene, [3-(2-cyclohexylethyl)-6-cyclopent
12	0.2	2-DOCECEN-1-AL
13	**20.23**	**.delta.-Elemene**
14	0.08	(-)-ISOLEDENE
15	4.56	.alpha.-Copaene
16	6.83	(-)-.beta.-Elemene
17	4.99	trans-Caryophyllene
18	2.8	.alpha.-Humulene
19	**21.14**	**(-)-.beta.-Elemene**
20	2.35	Kauran-18-al, 17-(acetyloxy)-, (4.beta.)-
21	2.74	2-Propenamide, 2-methyl-N-phenyl-
22	2.12	Octadecane, 1-chloro-
23	12.61	Torreyol
24	9.2	2H-1-Benzopyran, 6,7-dimethoxy-2,2-dimet
25	6.9	Isopropyl myristate

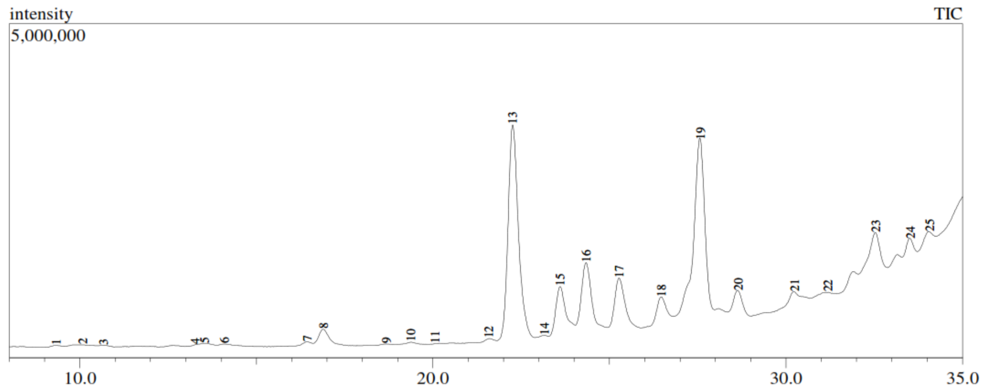

Figure 3. Chromatogram of *Piper nigrum*

Bioactive compounds of Peperomia pellucida

The most bioactive compounds of Peperomia pellucida were 3a(1H)-Azulenol, 2,3,4,5,8,8a-hexahydro-6 (24,81%) at peak 21 and (-)-Caryophyllene oxide (17,86%) at peak 20. In addition, Peperomia pellucida leaves contained Bicycloelemene, (-)-β-Elemene, Cis-Caryophyllene, and Germacrene D (see Table 5 and Figure 4). 3a(1H)-Azulenol, 2,3,4,5,8,8a-hexahydro-6, also known as 3-Isopropyl-6,8a-dimethyl-1,2,4,5,8,8a-hexahydroazulene, is a compound that belongs to terpenoid compounds.

Table 5. SPME-GCMS results of *Peperomia pellucida*

Peak#	Area%	Name
1	0.18	Carbamic acid, monoammonium salt
2	0.49	Hexanal
3	0.24	Propane, 2-isocyanato-
4	1	N HEPTANAL
5	3.87	l-Limonene
6	0.21	2,6-Dideutero-pyridine
7	3.81	Nonanal
8	1.19	Acetic acid, 2-ethylhexyl ester
9	1.3	.delta.-(2)-dodecanol
10	2.01	2-DOCECEN-1-AL
11	0.89	BICYCLO[4.1.0]HEPTAN-3-OL, 4,7,7-TRI
12	0.99	.alpha.-Ylangene

Peak#	Area%	Name
13	**8.37**	**(-)-.beta.-Elemene**
14	**8.78**	**CIS-CARYOPHYLLENE**
15	2.27	Cyclohexene, 1-methyl-4-(1-methylethenyl)-
16	**8.12**	**Germacrene D**
17	**10.16**	**Bicycloelemene**
18	0.34	Methyl 3-oxo-5-(1-nitro-2-oxocyclododecyl)
19	3.12	d-Nerolidol
20	**17.86**	**(-)-Caryophyllene oxide**
21	**24.81**	**3a(1H)-Azulenol, 2,3,4,5,8,8a-hexahydro-6,**

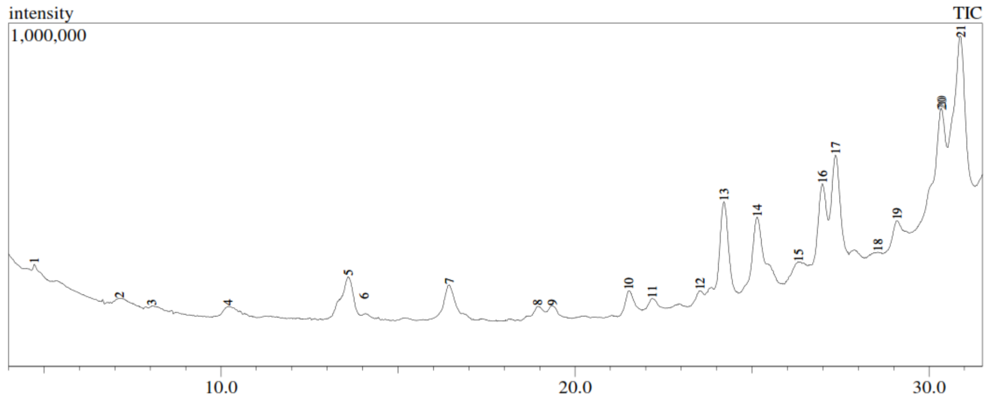

Figure 4. Chromatogram of *Peperomia pellucida*

Bioactive compounds of Lunasia amara

Lunasia amara leaves contained Tricyclo[2.2.1.0(2,6)]heptane, 1,7-dimethyl-7 (25,58%) at peak 12, and Alloaromadendrene (24,12%) at peak 18. Both compounds belong to the group of terpenoid compounds. Alloaromadendrene is precisely a sesquiterpene compound. Other sesquiterpene compounds in the leaves of this plant are Farnesene, γ-Gurjunene, α-Muurolene, (-)-β-Elemene, and Germacrene-D (see Table 6 and Figure 5).

Table 6. SPME-GCMS results of *Lunasia amara*

Peak#	Area%	Name
1	0.1	2-Pyridinepropanoic acid, .alpha.-methyl-.bet
2	0.7	Hexanal
3	0.66	Heptanal
4	0.93	Octanal
5	0.01	Ethene, tetrafluoro-
6	0.62	Nonanal
7	0.45	Cyclodecanol
8	0.69	2-Decenal, (Z)-
9	0.09	Neodihydrocarveol
10	0.93	.alpha.-Copaene
11	0.81	Germacrene D
12	**25.58**	**Tricyclo[2.2.1.0(2,6)]heptane, 1,7-dimethyl-7**
13	2.38	.BETA. ELEMENE
14	3.05	.beta.-Sesquiphellandrene
15	10.56	Farnesene
16	5.62	.gamma.-Gurjunene
17	10.76	.alpha.-Muurolene
18	**24.12**	**Alloaromadendrene**
19	4.63	Bicylo[4.1.0]Heptan, 7-Bicyclo[4.1.0
20	4.94	Kauran-18-Al, 17-(Acetyloxy)-, (4.Beta.)- (CA
21	2.37	8-Methoxy-8,9,9-Trimethyl-6-Decy

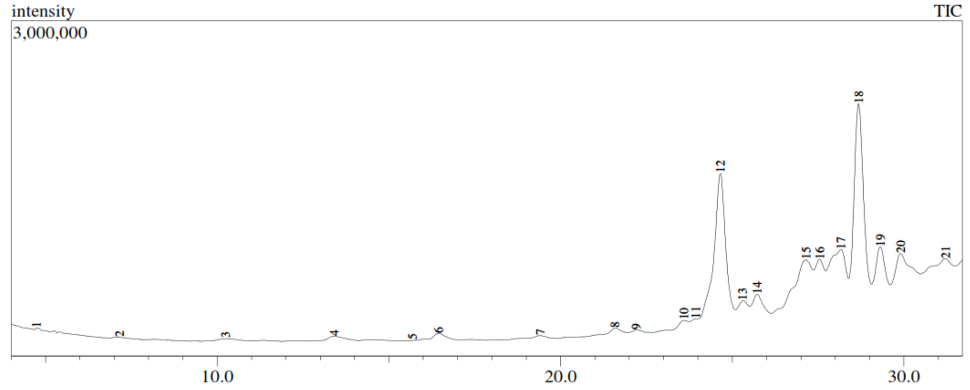

Figure 5. Chromatogram of *Lunasia amara*

Bioactive compounds of Knema cinerea

Leaves of Knemara cinerea also known as Widara putih contained β-Myrcene (25,15%), α-pinene,(-)-(20,88%), and α- copaene (16,9%). β-Myrcene and α-pinene are monoterpenes, while α-copaene is a sesquiterpene. All of them are terpenoid compounds. Additionally, Widara putih had Cis-Caryophyllene, Germacrene-D, and Bicycloelemene which belong to the group of sesquiterpene compounds (see Table 7 and Figure 6).

Table 7. SPME-GCMS results of *Knema cinerea*

Peak#	Area%	Name
1	0.01	Carbamic acid, monoammonium salt
2	0.16	1-Butanol, 2-methyl-
3	**20.88**	**.ALPHA.-PINENE, (-)-**
4	**25.15**	**.beta.-Myrcene**
5	1.14	.beta.-Phellandrene
6	0.01	2,6-Octadiene, 4,5-dimethyl-
7	1.48	.alpha.-Cubebene
8	**16.9**	**.alpha.-Copaene**
9	1.69	.alpha.-Guaiene
10	5.56	CIS-CARYOPHYLLENE
11	2.19	TRANS-.ALPHA.-BISABOLENE
12	6.72	Germacrene D
13	7.62	Bicycloelemene
14	6.62	.delta.-Cadinene
15	0.26	NERYL LINALOOL ISOMER
16	1.49	EPIGLOBULOL
17	0.79	.alpha.-Cadinol
18	1.34	2H-1-Benzopyran, 6,7-dimethoxy-2,2-dimet

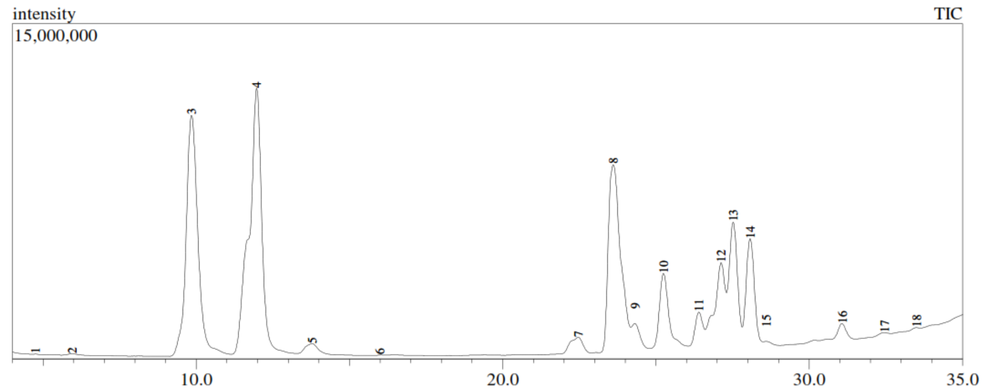

Figure 6. Chromatogram of *Knema cinerea*

Bioactive compounds of Cinnamomum zeylanicum

Cinnamon leaves had the most compounds that are different from other medicinal plants, Nerol compound (14.99%). Nerol is a monoterpene compounds. The octadecanal compound was the second largest compound (11.51%). Sesquiterpene compounds found in cinnamon leaves are (-)-β-Elemene and trans-Caryophyllene. Nonanal compounds were identified around 9.36% (see Table 8 and Figure 7). Nonanal and Octadecanal compounds belong to the aldehyde group.

Table 8. SPME-GCMS results of *Cinnamomum zeylanicum*

Peak#	Area%	Name
1	1.09	1,2-Propanediamine
2	2.46	Hexanal
3	7.14	2-Hexenal, (E)-
4	5.2	2-Hepten-1-ol, (E)-
5	0.21	n-Butyl o-[3-(dimethylamino)propyl]salicyla
6	5.8	Octanal
7	0.86	1-methyl-cis-octahydroindole
8	1.74	1-Hexanol, 2-ethyl-
9	7.31	Nonanal
10	2.05	Nonanal
11	0.45	Piperidine, 2,6-dimethyl-
12	**14.99**	**Nerol**
13	6.6	Citral
14	1.4	Tridecane, 6-methyl-
15	2.12	.alpha.-Copaene
16	3.17	11-DODECEN-1-AL
17	5.95	trans-Caryophyllene
18	1.54	4H-FURO(3,2-B)PYRROLE
19	0.9	2-(3-METHYL-UNDEC-3-ENYL)-[1,3]DI
20	9.97	(-)-.beta.-Elemene
21	1.15	6-(3-HYDROXY-BUT-1-ENYL)-1,5,5-TRI
22	1.8	(+)-Aromadendrene
23	**11.51**	**Octadecanal**
24	4.59	1-Hexanol, 2-ethyl-

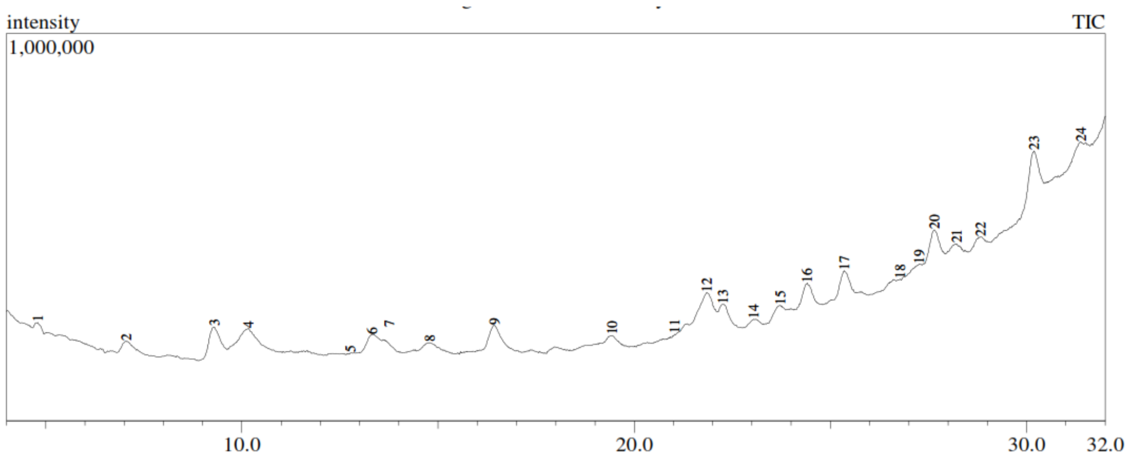

Figure 7. Chromatogram of *Cinnamomum zeylanicum*

Bioactive compounds of Actinodaphne macrophylla

Kayu bakang (Actinodaphne macrophylla) leaves have the most compounds similar to Widara putih leaves, β-Myrcene (36,76%), α-pinene, (-)- (22.25%), and α-copaene (13.26%) (see Table 9 and Figure 8). The three compounds are terpenoid compounds. In addition, Nonanal compound was also detected in peak 9 at 6.93%.

Table 9. SPME-GCMS results of *Actinodaphne macrophylla*

Peak#	Area%	Name
1	0.65	Carbamic acid, monoammonium salt
2	0.7	Ethyne, fluoro-
3	0.58	Methanamine, N-methyl-, compd. with bora
4	**22.25**	**.ALPHA.-PINENE, (-)-**
5	7.5	Sabinene
6	**36.76**	**.beta.-Myrcene**
7	1.2	Pentanal, 2,3-dimethyl-
8	1.3	cis-(1S,3R)-Deltamethrinic acid
9	6.93	Nonanal
10	1.02	Bis(cyclopent-2-enyl) ether
11	0.58	2-Furanmethanol, tetrahydro-
12	0.57	Silane, tetrafluoro-
13	2.31	Hexadecanal
14	0.31	2-Piperidinecarboxamide, N-(2,6-dimethylp
15	0.36	2-Methylthiazole
16	0.26	Cyclohexane, 1,1'-[1-(2,2-dimethylbutyl)-1,3
17	0.13	Methanediamine, N,N,N',N'-tetramethyl- (C
18	2.46	1-Dodecanol
19	0.86	Octadecane, 6-methyl-
20	**13.26**	**.alpha.-CopaeneGer**

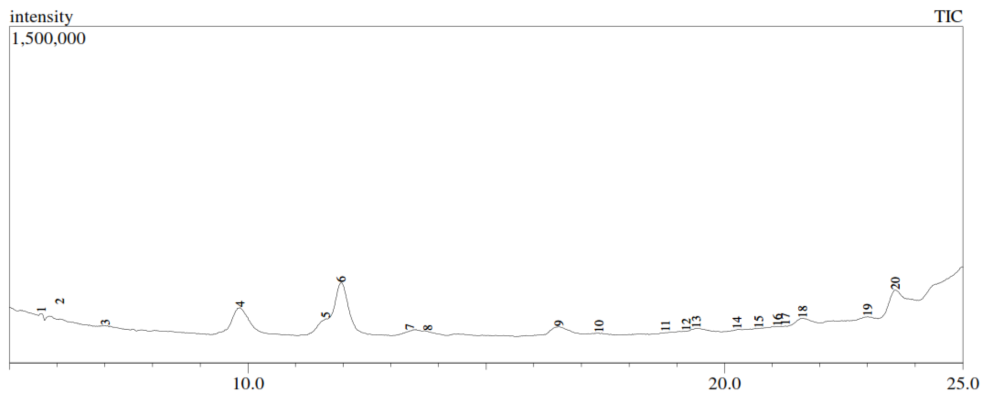

Figure 8. Chromatogram of *Actinodaphne macrophylla*

Bioactive compounds of Synedrella nodiflora

Synedrella nodiflora or Jotang leaves had bioactive compounds that are almost the same as kemuning leaves. There were Germacrene-D (23,96%), (-)-Caryophyllene oxide (23,35%), and trans- Caryophyllene (12,26%) which were identified as the most compounds (see Table 10 and Figure 9). All of them are terpenoids.

Table 10. SPME-GCMS results of *Synedrella nodiflora*

Peak#	Area%	Name
1	0.14	Carbamic acid, monoammonium salt
2	0.14	Butane, 1-chloro-3-methyl-
3	0.13	Pentanal
4	0.25	alpha.-Thujene
5	0.3	2-.BETA.-PINENE
6	0.89	l-Limonene
7	0.27	Nonanal
8	0.22	1-Decene
9	0.95	alpha.-Copaene
10	6.5	Germacrene D
11	**12.26**	**trans-Caryophyllene**
12	2.55	alpha.-Humulene
13	**23.96**	**GERMACRENE-D**

14	1.62	9-Eicosene, (E)-
15	2.8	Hexadecane, 1-chloro-
16	8.23	Dillapiole
17	6.72	GLOBULOL
18	8.73	1,3-Benzodioxole, 4,7-dimethoxy-5-(2-propenyl)-
19	**23.35**	**(-)-Caryophyllene oxide**

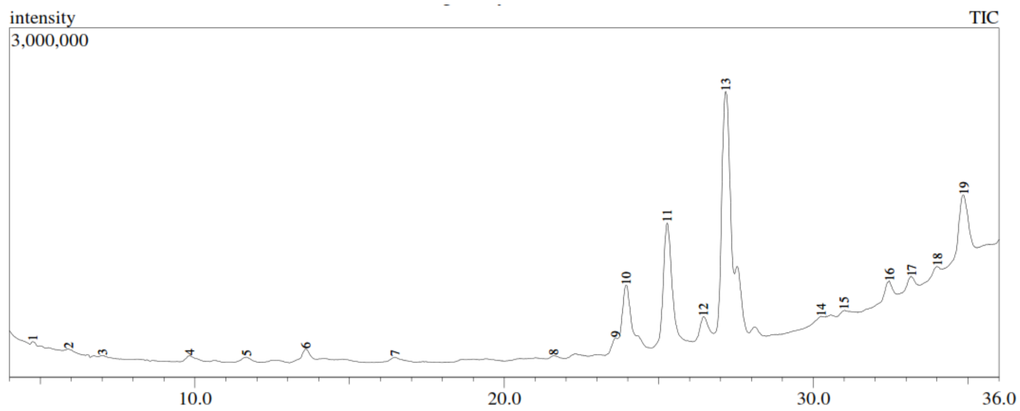

Figure 9. Chromatogram of *Synedrella nodiflora*

Bioactive compounds of Hiptis capitata

Leaves of rumput knop (Hiptis capitata) had more trans-Caryophyllene than jotang and kemuning leaves (31,13%). Germacrene-D were identified in these leaves (22,56%). There were 22 compounds were identified by SPME-GCMS (see Table 11 and Figure 10). *Most abundant compounds from ten medicinal plants in Meru Betiri National Park*. The most compounds identified from the SPME-GCMS results of 10 medicinal plants in Meru Betiri National Park were sesquiterpenes. The compounds were Germacrene-D found in 7 plants, Caryophyllene found in 7 plants, The (-)-β-Elemene and δ-Elemene found in 4 plants. In addition, Linalool L which is essential oil was found in 3 plants. Isopropyl myristate, ester compound, was found in two plants. The results could be seen in Table 12.

Table 11. SPME-GCMS results of *Hiptis capitata*

Peak#	Area%	Name
1	0.58	Carbamic acid, monoammonium salt
2	0.79	1-Butanol, 3-methyl- (impure)
3	0.5	Butanal, 3-methyl-
4	0.1	2-Butanol, 1-(dimethylamino)-
5	1.25	3-Heptanone, 5-methyl-
6	2.46	2-Octen-1-ol (CAS) 2-Octenol
7	0.04	2-(3,3-dimethyl-bicyclo[2.2.1.]hept-2-yl)-pro
8	2.15	Nonanal
9	0.19	10-Undecenoic acid, methyl ester
10	0.09	2,5-Furandione
11	0.25	Decane, 2,3,7-trimethyl- (CAS)
12	0.33	3,4-DIHYDRO-5,5-DIMETHYL-4-ETHOX
13	0.73	Cyclopentane, (1-methylbutyl)-
14	3.39	.alpha.-Copaene
15	5.26	.beta.-Bourbonene
16	**31.13**	**trans-Caryophyllene**
17	12.12	TRANS(.BETA.)-CARYOPHYLLENE
18	3.28	L-LINALOOL
19	2.24	(1R,2'S)-[1,1'-[BICYCLOPENTYL]-2,2'-DI
20	**22.56**	**GERMACRENE-D**
21	4.39	CYCLOHEPTAN, 4-METHYLEN-1-MET
22	6.17	.delta.-Cadinene

Table 12. The most abundant bioactive compounds

Name of compounds	Group of Compounds	Found at…	Pharmacological effect
Germacrene-D	Sesquiterpenes	*Murraya paniculate* *Piper baccatum* *Peperomia pellucida* *Lunasia amara* *Knema cinerea* *Synedrella nodiflora* *Hiptis capitata*	Antibacterial (Thakur et al. 2023) Anticancer (Essien et al. 2016)
Caryophyllene and its derivatives	Sesquiterpenes	*Murraya paniculate* *Piper baccatum* *Peperomia pellucida* *Knema cinerea* *Synedrella nodiflora* *Hiptis capitata* *Cinnamomum zeylanicum*	Anticancer (Pinho-Da-Silva et al. 2012) Antimicrobial and antioxidant (Dahham et al. 2015) Antitumor (Ahmed et al. 2022)
Linalool L	Essential oil	*Piper baccatum* *Piper nigrum* *Knema cinerea*	Anticancer, Anti-inflammatory, Antimicrobial, Neuroprotective, Antihyperlipidemic (Pereira et al. 2018)
(-)-β-Elemene dan δ-Elemene	Sesquiterpenes	*Lunasia amara* *Peperomia pellucida* *Piper nigrum*	Anticancer (Wang et al. 2006) Antioxidant (Wang and Zhang 2020) Antitumor (Chen et al. 2023b)
Isopropyl myristate	Ester	*Piper nigrum* *Piper baccatum*	Antioxidant and anti-inflammatory (Józsa et al. 2022)

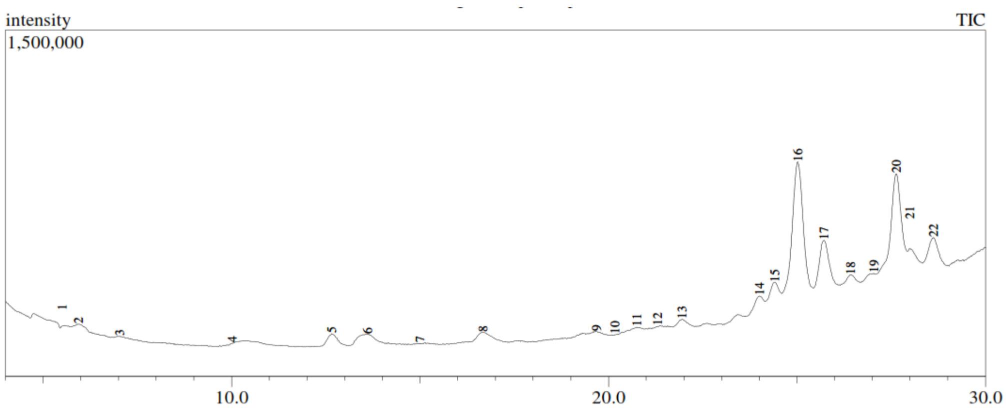

Figure 10. Chromatogram of *Hiptis capitata*

Results and Discussion should be written separately. Results should be clear and concise. State the obtained results based on the methods. Do not present the same data in both table and graph format. Means should be accompanied by standard deviation.

1. Discussion

Based on the SPME-GCMS results of the ten medicinal plants in the Meru Betiri National Park, the most common compound group is terpenoids, especially sesquiterpene. These compounds exist in hydrocarbon form or in oxygenated forms including lactones, alcohols, acids, aldehydes, and ketones. The molecular formula of sesquiterpenes is $C_{15}H_{24}$ which can be cyclic form. Sesquiterpenes are constituent components of essential oils and aromatic elements that have pharmacological activity (Breitmaier 2006). Sesquiterpene compounds are the most abundant among other terpene compounds that have therapeutic and pharmacological effects (Sülsen 2021).

Sesquiterpene compounds shown to have anti-inflammatory activity and immunoregulatory response through in vivo studies (Paço et al. 2022). They can inhibit the production of cytokines and pro-inflammatory enzymes, which are involved in the inflammatory response. This makes sesquiterpenes potential candidates for the treatment of inflammatory diseases such as rheumatoid arthritis and inflammatory bowel disease (Sülsen 2021). Sesquiterpenes have been shown to inhibit cancer cell growth and induce apoptosis and tumor regression in cancer cells (Dhyani et al. 2022). Some sesquiterpenes have also been found to have antiangiogenic properties, which prevent the formation of new blood vessels that supply nutrients to tumor cells (Breitmaier 2006). Sesquiterpenes have been found to have neuroprotective properties (15), which can protect neurons from damage caused by oxidative stress and inflammation. This makes sesquiterpenes potential candidates for the treatment of neurodegenerative diseases such as Alzheimer's and Parkinson's disease (Chen et al. 2021).

Besides sesquiterpenes, there are two other most common compounds found in ten plants in Meru Betiri National Park, ester compounds and essential oils. Based on the results (Table 12), the five compounds have pharmacological effects that have been studied both in vivo and in vitro. According to (Essien et al. 2016), germacrene-D has antibacterial activity and anticancer activity. Caryophyllene has been shown to enhance antitumor activity in lung cancer cells through cell cycle regulation and apoptosis signaling molecules (Ahmed et al. 2022). Linalool is a bioactive compound that has many potentials as an anti-inflammatory, anticancer, antihyperlipidemic, antimicrobial, analgesic, and neuroprotective drug (Pereira et al. 2018). (-)-β-Elemene and δ-Elemene have antioxidant activity as well as antitumor activity through enhanced radiosensitization and chemical sensitization of cancer cells (Chen et al. 2023a; Wang and Zhang 2020). Isopropyl myristate enhanced the antioxidant and inflammatory effects of drug delivery systems (Józsa et al. 2022).

Based on the above explanation, the ten medicinal plants in Meru Betiri National Park have abundant bioactive compounds, especially in the sesquiterpene group. The results of this research can be a reference for exploring the pharmacological effects of each medicinal plant in Meru Betiri National Park.

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4. CONCLUSION

According to results and discussion, ten medicinal plants in The Meru Betiri National Park have abundant bioactive compounds. The most abundant bioactive compound was the sesquiterpenes group. Sesquiterpene has been shown to have various pharmacological effects such as anticancer, antibacterial, anti-inflammatory, as well as antioxidant. The results of this research can be a reference for exploring the pharmacological effects of each medicinal plant in Meru Betiri National Park.

5. ACKNOWLEDGEMENT

The researcher would like to thank the Institute of Research and Community Service of the University of Jember for providing the Keris-Dimas 2023 Research Grant from the DIPA UNEJ 2023.

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