MOLEKUL
eISSN: 2503-0310

Articles
https://doi.org/10.20884/1.jm.2025.20.3.16009

Solvent-Free Microwave Extraction: Phytochemistry and Bioactivities of Essential Oil from *Stachytarpheta jamaicensis*, L. in Banyuwangi

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Received June 19, 2025; **Accepted** September 11, 2025; **Available online** November 20, 2025

ABSTRACT. *Stachytarpheta jamaicensis*, L. is a member of the Verbenaceae family. It is a medicinal plant easily found on vacant land and in rice fields in Banyuwangi. The present study is the first detail reported to examine the phytochemical compound and bioactivities of essential oil from *S. jamaicensis* L., using solvent-free microwave extraction (SFME). Forty chemical compounds were identified in the inflorescence and thirty in the leaves. β-caryophyllene, fulvoipolamiide, hexahydrofarnesyl acetone, t-phytol, neophytadiene, and squalene were identified in inflorescence oil. In contrast to the inflorescence, where these compounds were present in minor amounts, fulvoipolamiide, t-phytol, and squalene were the predominant components in the leaf oil. The IC_{50} values of leaves and inflorescence essential oils were 30.566 mg/mL and 52.510 mg/mL, respectively. Based on IC_{50} values, leaf essential oils have stronger antioxidant potential than inflorescence. Antibacterial and antifungal tests indicated that the leaf essential oil possesses greater antimicrobial efficacy than that of the inflorescence. These findings suggest that the essential oil of *S. jamaicensis* is a promising source of antioxidant, antibacterial, and antifungal agents, and holds potential for future pharmaceutical applications.

Keywords: antibacterial; antifungal; antioxidant; medicinal plant

INTRODUCTION

The use of local plant-based medicine continues to be developed and researched today to be carried out to determine the phytochemical compounds, potential bioactivity, toxicity, clinical trials, and, ultimately, the production of medicinal compounds from natural products. The advantages of utilizing local plants as medicine include abundant availability, diverse phytochemical compounds, and fewer side effects (Sezer et al., 2024). There is an increasing interest in the use of medicinal plants as an alternative treatment due to the development of adverse effects and resistance of microbes or fungi to synthesized chemical drugs (Ololade et al., 2017). Therefore, the design and discovery of drugs derived from natural plants is challenging due to their largely unexplored structural diversity. Among these natural products, essential oils, which are plants' secondary metabolic products, have been gaining increasing attention due to their medicinal potential.

S. jamaicensis is a member of the Verbenaceae family and is easily found on vacant land and in rice fields in Banyuwangi. *S. jamaicensis* can grow wild along roadsides, fields, shrubs, and river banks (Sivaranjani et al., 2014). *S. jamaicensis* in several other countries has been used as a traditional medicine to treat allergies, respiratory disorders, coughs, colds, fever, constipation, digestive complications, dysentery, and menstruation (Liew & Yong, 2016). Several studies have reported that crude extracts of *S. jamaicensis* can function as anti-inflammatory, antibacterial, antioxidant, antirheumatic, anti-larvicidal, antifungal, and antidiabetic (Bliss et. al., 2022; Idu et al., 2021; Jacela et al., 2021; Miftahussanadi et al., 2021; Pérez et al., 2018; Suneetha et al., 2013; Thomas et al., 2013). The crude extracts of *S. jamaicensis* obtained using conventional extraction methods, including maceration, soxhletation with polar solvents such as ethanol (Darwis et al., 2012; Illing et al., 2021; Jacela et al., 2021), methanol, ethyl acetate, chloroform, and non-polar solvents such as n-hexane (Miftahussanadi et al., 2021; Yuniarni, et al., 2018). The lack of fractionation results in a wide range of active compound components in crude extracts. However, in some of these studies, the detailed components of phytochemical compounds contained in *S. jamaicensis* are still not widely

reported, only phytochemical screening using qualitative tests.

In contrast, essential oils have a higher concentration and purity of compounds than crude extracts. Essential oils are volatile, low-molecular-weight secondary metabolite. They can be found in various plant organs such as flowers, buds, leaves, stems, seeds, fruits, wood, roots, and among others (Jain et al., 2022). Essential oils contain many active compounds, terpenoid groups (monoterpenoids, diterpenoids, triterpenoids, sesquiterpenes), nonterpenoids, and hydrocarbon groups and their derivatives (Asgari et al., 2017). Essential oils are becoming as natural alternatives to synthetic antioxidants, antifungals, and antibacterials, some of which have been linked to adverse effects such as cancer and liver (Khodaei et al., 2021). In recent year, essential oils have application in food flavoring, food preservatives, aromatherapy, cosmetics, agriculture, and microbiology (Pezantes-Orellana et al., 2024).

Research on essential oils of the genus *Stachytarpheta* remains limited. Among the few available studies, Bliss et al., (2022) successfully isolated the essential oil of *S. jamaicensis*, L. leaf parts using conventional extraction techniques hydrodistillation. The study showed that the essential oil of *S. jamaicensis* has potent anti-inflammatory activity (Bliss et al., 2022). Essential oil from other species, such as *S. gesneiroides*, *S. mutabilis*, and *S. indica*, was successfully extracted using the hydrodistillation technique (Essien et al., 2017; Osorio et al., 2014; Souza Silva et al., 2012).

Conventional extracting methods have various disadvantages such as smaller yield, need for a long time, environmentally unfriendly effects of using organic solvents, and loss of the most volatile compounds (Araujo et al., 2021). Solvent-free microwave extraction (SFME) is a recently developed method of green technology extraction and with many advantages (Susanti & A'yun, 2024; Variyana & Susanti, 2022). This technique offers advantages such as higher yield and extract purity, fast energy transfer, low cost, environmentally friendly, and time saving (Qi et al., 2014). For instance, a study by Mohanty et al. (2023), found that the higher yield was obtained from three species of *Curcuma* using the SFME method rather than the hydrodistillation (Mohanty et al., 2023). Similarly, damask rose and rhizomes of cassumanar ginger essential oil are reported to produce higher yields using the SFME method than hydrodistillation (Manouchehri et al., 2018; Yingngam & Brantner, 2018).

Despite the impressive therapeutic potential of this exceptional plant, scientific research is scarce concerning the therapeutic possibilities of its essential oil components or fractions. Therefore, this study aims to identify and evaluate the essential oil constituents from the inflorescence and leaves of *S. jamaicensis* using solvent-free microwave extraction, a greener and more efficient method.

EXPERIMENTAL SECTION

The fresh inflorescences and leaves of *S. jamaicensis* were used as the plant materials for extraction. The inflorescences and leaves were extracted separately using the solvent-free microwave extraction (SFME) method.

Plant Materials

Fresh leaves and inflorescence of *S. jamaicensis* were collected from Sarimulyo Village in Banyuwangi Regency (8.2192° S, 114.3692° E), Indonesia. The plant was recognized and classified taxonomically by UPT Laboratorium Herbal Materia Medica Batu. Furthermore, the collected plant parts were used immediately for extraction.

Extraction of Essential Oil

The extraction of essential oil from leaves and inflorescence of *S. jamaicensis* using SFME apparatus (Electrolux EMM20M38GW) described in our previous work (**Figure. 1b**) (Susanti & A'yun, 2024). Approximately 300 grams of plant parts ground with a blender are extracted at 700 watts for 3 hours. The layer of essential oils obtained was taken by adding 4 mL n-hexane (MERCK), dried with anhydrous sodium sulfate (MERCK), and stored for further analysis and biological activity test. The extraction yield of *S. jamaicensis* oil was determined using the equation given:

$$\%Yield = \frac{weight\,of\,essential\,oils\,produced(g)}{weight\,of\,the\,plant\,materials\,used(g)x(1-watercontent(\%))} x100 \quad (1)$$

Phytochemistry Analysis

Gas Chromatography-Mass Spectrometry (Shimadzu QP 2020 NX) analysis was conducted to determine the phytochemical content of essential oil. GS analysis using a Rtx-5MS fused silica capillary column with specification thickness 0,25µm., length 30.0 m; and internal diameter 0.25 mm. Helium was used as a carrier gas at a 0.75 mL/min flow rate; pressure 36.2 kPa. The oven started at 60 °C, which was held for 2 minutes. The oven temperature was programed to 200 °C for 2 minutes at the rate of 50 °C for 10 minutes. The samples were introduced in split mode, and the mass-to-charge ratio was scanned from 40 to 400 *m/z*. The compounds' identification was compared to the retention times (RT) and mass fragmentation pattern from the WILEY 7 Library (Mini & Nair, 2021).

Biological Activity Test

Several tests, including antioxidant activity, antibacterial, and antifungal assays, were carried out to determine the potential bioactivity of essential oils of *S. jamaicensis*.

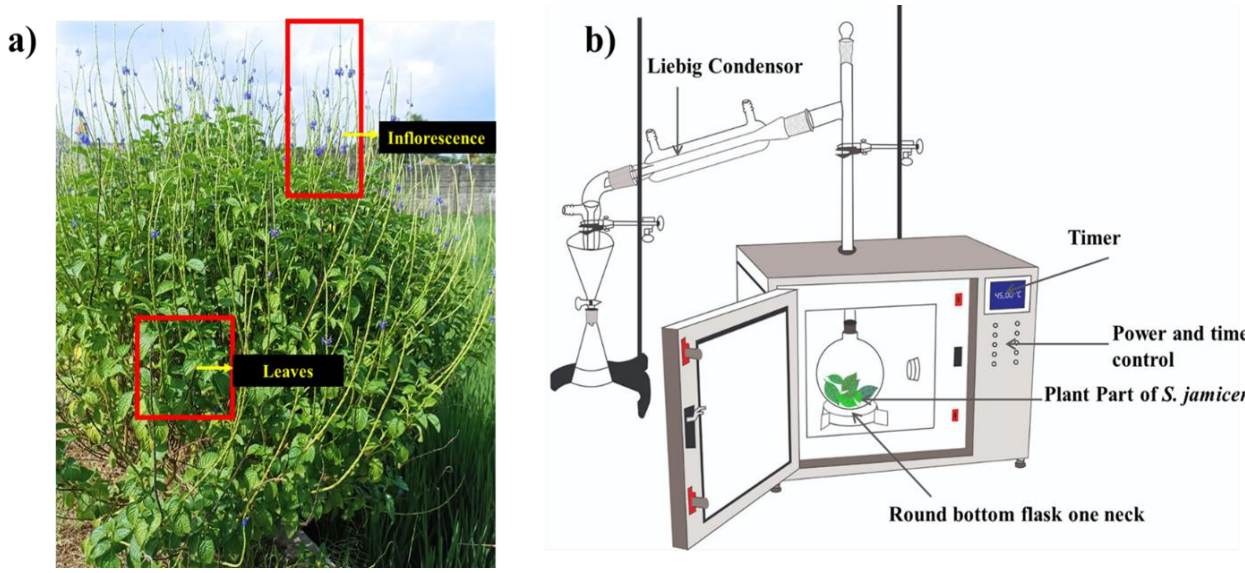


Figure 1. a) Plant part of *S. jamaicensis*, L. **b**) SFME Apparatus

Antioxidant Activity

The antioxidant activity of the essential oils from inflorescences and leaves of *S. jamaicensis* is determined by measuring the mechanism of free radical scavenging activity by the DPPH assay using a Shimadzu UV-VIS 1240 spectrophotometer (Marxen et al., 2007). The extract of essential oils with various concentrations (mg/mL) was each added with 1.0 ml of 0.4 mM DPPH and ethanol until the total volume was 5 mL in a cuvette. The solution was incubated for 30 minutes in a dark room. The sample solution is then measured for absorbance at the maximum wavelength to determine the absorbance of the sample. A total of 1 mL of 0.4 mM DPPH solution was added, with 4 mL of Ethanol used as a control. Ascorbic acid as a standard and the test was run in triplicate. The percentage of inhibition of DPPH was determined using the following equation (2) (Kusuma et al., 2020).

$$\%inhibition = \frac{(controlabsorbance - sampleabsorbance)}{controlabsorbance} x100$$

Antibacterial and Antifungal Activity Assay

Antibacterial and Antifungal activity was determined by agar well disk diffusion method (Hossain et al., 2022) against bacteria Gram-positive (*Staphylococcus aureus*) and *Candida albicans* fungus (Firdani et al., 2021). Nutrient Agar (NA) or Sabouraud Dextrose Agar (SDA) was used as media to pour into petri dishes in antibacterial and antifungal activity, respectively. A cotton swab was plunged into a microbial suspension and connected to the surface of the NA media or SDA media. Twenty microliters of essential oils were dropped into 6-8 mm was made on the media using a sterile cork borer. Chloramphenicol and ketoconazole were applied as positive controls in antibacterial and antifungal activity, respectively. The agar plates were incubated at 37 °C for 24 h. The effectiveness of the antibacterial and antifungal activity of *S.jamaicensis* essential oil was determined based on the clear zone around the wells that measured in mm. This assay was conducted three times.

RESULTS AND DISCUSSION

Phytochemistry Analysis

Essential oil from *S. jamaicensis* was extracted using the solvent-free microwave extraction (SFME) method. The resulting oil was yellowish, with a thin, visible layer on the surface. The essential oil yields from the inflorescences and leaves were 0.021% and 0.012%, respectively. Similarly low yields were observed in the essential oils of *Stachytarpheta gesnerioides* (0.01%) and *Stachytarpheta mutabilis* (0.025%) leaves (Bliss et al., 2022; Osorio et al., 2014; Souza Silva et al., 2012). GC-MS analysis of the inflorescence oil from *S. jamaicensis* revealed 40 peaks, indicating the presence of multiple phytochemical compounds (**Figure 1**). Compound identification based on retention time and peak area is summarized in **Table 1.**

Based on **Table 1**, the phytochemical compounds contained in the essential oil of *S. jamaicensis* inflorescence include monoterpene compounds (0.68%), diterpene (11.1%), triterpene (1.8%), sesquiterpene (0.43%), aldehyde (7.63%), ester (3.25%), alcohol (12.43%), and carboxylate (10.76%) and aliphatic hydrocarbons (51.92%). This study is the first to report on the phytochemical content of *S. jamiacensis* inflorescence. Terpene group compounds successfully identified in inflorescence include β-caryophyllene, fulvoipolamiide, hexahydrofarnesyl acetone, t-phytol, neophytadiene, and squalene.

GC-MS analysis of essential oils from leaf of *S. jamaicensis* identified 40 peaks, which are shown in **Figure 3**. The phytochemical compounds identified in essential oil are presented in **Table 2**.

Table 1. Phytochemicals of essential oil from inflorescence of *S. jamaicensis*

No.	Retention Time	Name of the Compounds	Molecular Formula	Similarity Index (SI)	Nature of the Compound	% Peak Area
1	12.196	β-caryophyllene	$C_{15}H_{24}$	83	Bicyclic sesquiterpene	0.32
2	12.296	Myristic aldehyde	$C_{14}H_{28}O$	83	Fatty aldehyde	2.09
3	12.335	Fulvoipolamiide	$C_{11}H_{10}O_3$	89	Monoterpene	0.68
4	13.568	Palmitic aldehyde	$C_{16}H_{32}O$	96	Aldehyde	7.43
5	14.385	3-Heptadecen-5-yne	$C_{17}H_{30}$	86	Alkene	0.21
6	14.599	Tridecanal	$C_{13}H_{26}$	94	Aldehyde	0.24
7	14.904	Hexahydrofarnesyl acetone	$C_{18}H_{36}O$	95	Sesquiterpene	0.43
8	15.529	2-Pentadecyn-1-ol	$C_{15}H_{28}O$	90	Alcohol aromatis	5.36
9	15.75	Methyl eicosanoate	$C_{21}H_{42}O_2$	93	Ester	0.62
10	16.447	2,2-dimethyl-decan-1-ol	$C_{12}H_{26}O$	83	Alcohol	0.29
11	16.909	Heptadecanoic acid	$C_{17}H_{34}O_2$	94	Carboxylat	10.76
12	17.5	Nonadecane	$C_{19}H_{40}$	92	Alkane	5.73
13	17.86	t-phytol	$C_{20}H_{40}O$	95	Hydrogenated diterpene alcohol	6.95
14	18.222	Methyl linolenate	$C_{19}H_{32}O$	85	Fatty acids, ester	2.63
15	18.42	Pentacosane	$C_{25}H_{52}$	92	Alkane	3.13
16	18.666	Neophytadiene	$C_{20}H_{38}$	91	Diterpene	4.15
17	19.109	Muscalure	$C_{23}H_{46}$	92	Alkene	1.14
18	19.439	Eicosane	$C_{20}H_{42}$	96	Alkane	13.58
19	19.677	Heneicosane	$C_{21}H_{44}$	92	Alkane	0.21
20	19.894	Tetracosane	$C_{34}H_{70}$	91	Alkane	0.12
21	20.239	Nonacosane	$C_{29}H_{60}$	96	Alkane	3.73
22	20.52	Octacosane	$C_{28}H_{58}$	93	Alkane	0.94
23	20.87	1-heptacosanol	$C_{27}H_{56}O$	94	Alcohol	2.13
24	21.113	Hexacosane	$C_{26}H_{54}$	96	Alkane	4.87
25	21.37	Pentatriacontane	$C_{35}H_{72}$	94	Alkane	1.16
26	21.585	1-pentacontanol	$C_{50}H_{102}O$	88	Alcohol	1.9
27	21.936	Pentatriacontane	$C_{35}H_{72}$	95	Alkane	2.7
28	22.177	Hexatriacontane	$C_{36}H_{74}$	94	Alkane	1.91
29	22.583	1-hentetracontanol	$C_{41}H_{84}O$	95	Alcohol	1.86
30	22.832	Tetratecontane	$C_{44}H_{90}$	96	Alkane	2.75
31	23.067	Tritetracontane	$C_{43}H_{88}$	96	Alkane	1.08
32	23.331	11,20-Didecyltriacontane	$C_{50}H_{102}O$	94	Alkane	0.97
33	23.816	Tetratecontane	$C_{44}H_{90}$	95	Alkane	1.9
34	24.145	Squalene	$C_{30}H_{50}$	89	Triterpen	1.8
35	24.564	n-dotriacontanol	$C_{32}H_{66}O$	93	Alcohol	0.85
36	25.044	11-n-Decyldocosane	$C_{32}H_{66}$	94	Alkane	1.65
37	26.438	Triacontane	$C_{50}H_{102}$	92	Alkane	0.45
38	25.87	2-Butyloctyl alcohol	$C_{12}H_{26}O$	89	Alcohol	0.33
39	26.438	Triacontane	$C_{50}H_{102}$	94	Alkane	0.58
40	28.253	Hexatriacontane	$C_{36}H_{74}$	95	Alkane	0.36
			Class of Compositions			
		Monoterpene			0.68	
		Diterpene			11.1	
		Triterpene			1.8	
		Sesquiterpene			0.43	
		Aldehyde			7.63	
		Ester			3.25	
		Alcohol			12.43	
		Carboxylate			10.76	
		Aliphatic hydrocarbons			51.92	

Table 2. Phytochemicals of essential oil from leaf of *S. jamaicensis*

No.	Retention Time	Name of the Compounds	Molecular Formula	Similarity Index (SI)	Nature of the Compound	% Peak Area
1	12.125	Cinnamyl aldehyde	C_9H_8O	86	Polyphenol	0.42
2	12.457	Fulvoipolamiide	$C_{11}H_{10}O_3$	89	Monoterpene	56.83
3	13.448	Palmitic Aldehyde	$C_{16}H_{32}O$	97	Aldehyde	0.59
4	13.525	2-penten-1-ol	$C_{15}H_{24}O$	82	Allyl alcohol	0.15
5	14.784	Cyclopentene	$C_{12}H_{22}$	88	Alkene	0.27
6	14.881	2-Pentadecanone	$C_{18}H_{36}O$	90	Ketone	0.14
7	15.048	Limonene dioxide	$C_{10}H_{16}O_2$	86	Cyclic monoterpene	0.2
8	15.248	Cyclododecanol	$C_{12}H_{24}O$	88	Alcohol	0.17
9	15.445	13-Oxabicyclo[10,1,0]tridecane	$C_{12}H_{22}O$	91	Cycloalkane	0.33
10	15.723	methylpalmitate	$C_{17}H_{34}O_2$	95	Ester	0.41
11	15.977	2,5-dimethylcyclohexanol	$C_8H_{16}O$	88	Alcohol	0.16
12	17.431	Pentacosane	$C_{25}H_{52}$	92	Alkane	0.76
13	17.556	Methyl linolenate	$C_{19}H_{32}O_2$	95	Fatty acid	4.12
14	17.771	t-phytol	$C_{20}H_{40}O$	95	Hydrogenated di terpene alcohol	17.76
15	18.007	Myristic aldehyde	$C_{14}H_{28}O$	88	Fatty Aldehyde	0.27
16	18.169	8,11,14-Eicosatrienoic acid	$C_{20}H_{34}O_2$	86	Fatty acid	0.15
17	18.365	Docosane	$C_{22}H_{46}$	89	Alkane	0.34
18	18.608	Neophytadiene	$C_{20}H_{38}$	89	Diterpene	1.04
19	19.307	Tetracosane	$C_{24}H_{50}$	95	Alkane	4.28
20	20.036	Laurinsaeure, 2-Hexen-1-Ylester	$C_{18}H_{34}O_2$	92	Ester	0.61
21	20.151	Eicosane	$C_{20}H_{42}$	93	Alkane	0.42
22	21.003	Tricosane	$C_{23}H_{48}$	95	Alkane	0.85
23	21.523	10-undecenyl aldehyde	$C_{11}H_{20}O$	89	Aldehyde	0.41
24	21.6	2-pentadecyn-1-ol	$C_{15}H_{28}O$	85	Aromatic Alcohol	0.94
25	21.828	Heptacosane	$C_{27}H_{56}$	94	Alkane	0.41
26	22.473	Lignocerol	$C_{24}H_{50}O$	92	Fatty Alcohol	0.16
27	22.676	Octacosane	$C_{28}H_{58}$	96	Alkane	0.52
28	23.637	Hexatriacontane	$C_{36}H_{74}$	94	Alkane	0.32
29	24.097	Squalene	$C_{30}H_{50}$	93	Triterpene	5.59
30	24.809	Tetratetracontane	$C_{44}H_{90}$	97	Alkane	1.39

Class of Compositions	
Monoterpene	57.03
Diterpene	18.8
Triterpene	5.59
Ketone	0.14
Ester	1.17
Alcohol	1.58
Aliphatic hydrocarbons	15.69

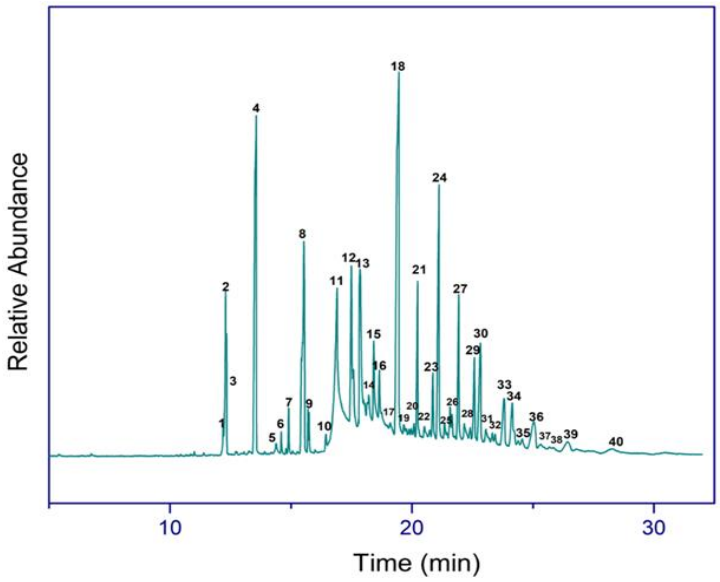


Figure 2. GC-MS Chromatogram of essential oil from inflorescence of *S. jamaicensis*

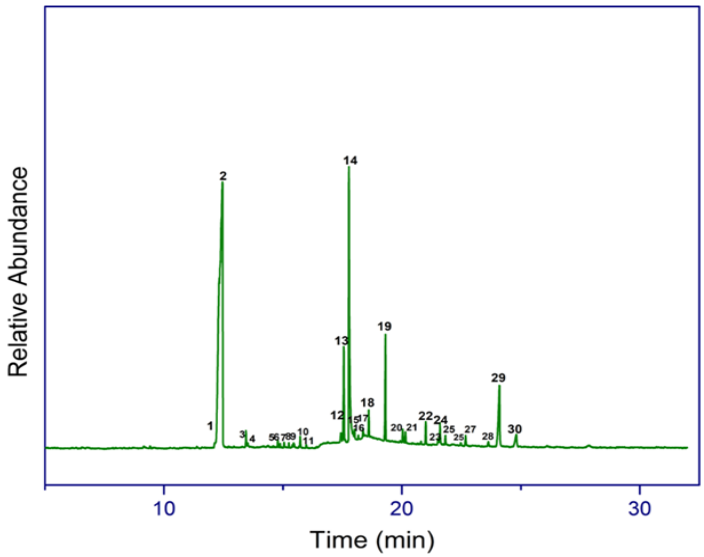


Figure 3. GC-MS chromatogram of essential oil from leaf of *S. jamaicensis*

Based on **Table 2**, the identified components were majorly monoterpene (57.03%), diterpene (18.8%), triterpene (5.59%), ketone (0.14%), ester (1.17%), and aliphatic hydrocarbons (15.69%). The most bioactive compound identified in leaf oil were Fulvoipolamiide, t-phytol, and squalene. Fulvoipolamiide belongs to the class of iridoid compounds with similar characteristics to flavonoids (Hussain, Nazir, Green, Saleem, & Raza, 2019; Viccini et al., 2008). In the leaves, fulvoipolamiide, t-phytol, and squalene compounds are more significant than in the inflorescence. At the same time, neophytadiene compounds are found more in the inflorescence than leaves. Interestingly, the phytochemical composition of essential oils extracted from the inflorescence and leaves of *S.jamaicensis* exhibits a distinct phytochemical profile, containing several bioactive compounds that differ significantly from earlier findings. Based on research conducted by Bliss *et al.*, (2022) the essential oil content in the leaves of *S. jamaicensis* includes limonene (13.85%), β-phellandrene (5.59%), eucalyptol (10.73%), and linalool (5.36%). In this study, no iridoid previously identified (Bliss et al., 2022). In the research of Fatmawati *et al.*, 6β-hydroxyipolamiide compounds were found in the content of crude extract of *S.jamaicensis* leaves (Fatmawati et al., 2023). Different results were also obtained from research by Ololade *et al.*, who identified the phytochemical content of crude extracts of *S.jamaicensis* leaves (Liew & Yong, 2016; Ololade et al., 2017). Crude extracts and essential oils differ significantly in purity, contributing to the variation observed in their phytochemical contents. Essential oil production is closely related to environmental conditions, habitat, and climate (Fan et al., 2016). In addition, extraction techniques can affect both essential oils' yield and phytochemical content (Mohammadhosseini, 2015; Mohammadhosseini & Nekoei, 2014; Mohanty

et al., 2023). The structure of the terpene compounds of inflorescence and leaves of essential oil is shown in **Figure 4**.

Antioxidant Activity

The results of the antioxidant activity test of *S. jamaicensis* essential oil are shown in **Figure 5**. The results indicated a positive correlation between sample concentration and %DPPH inhibition. Based on the regression curve of concentration vs % inhibition, a regression equation was obtained to determine the IC_{50} value. Based on the results of the IC_{50} calculation (**Table 3**), the most significant antioxidant activity was observed in the leaves' oil. The leaf oil has a lower IC_{50} (below 50 mg/mL) value, classified as an extreme antioxidant activity. The inflorescence has an IC_{50} value above 50, which is classified as a strong antioxidant. As a comparison, the antioxidant activity of ascorbic acid was tested. Ascorbic acid is a powerful antioxidant with an IC_{50} value of 3.638 µg/mL. Chemical compounds that might play an important role in leaf antioxidant activity include Fulvoipolamiide, t-phytol, and squalene, in greater quantities than in inflorescence.

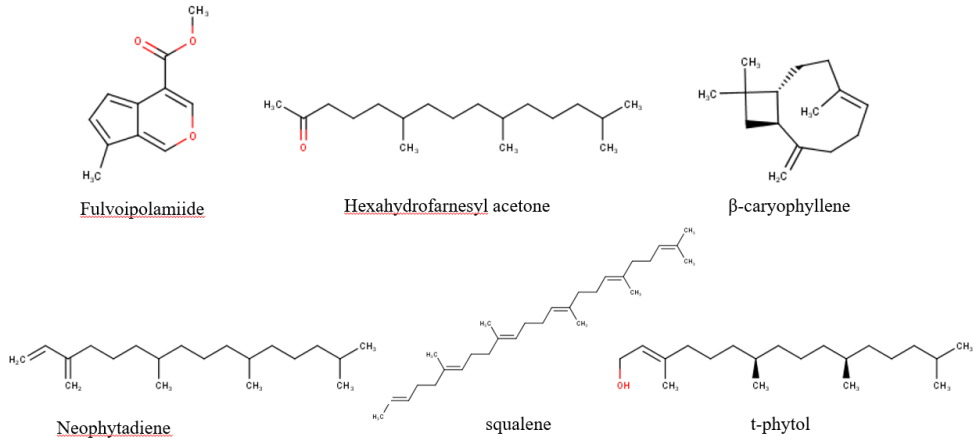


Figure 4. Structure of major compounds present in the essential oil of *S. jamaicensis*

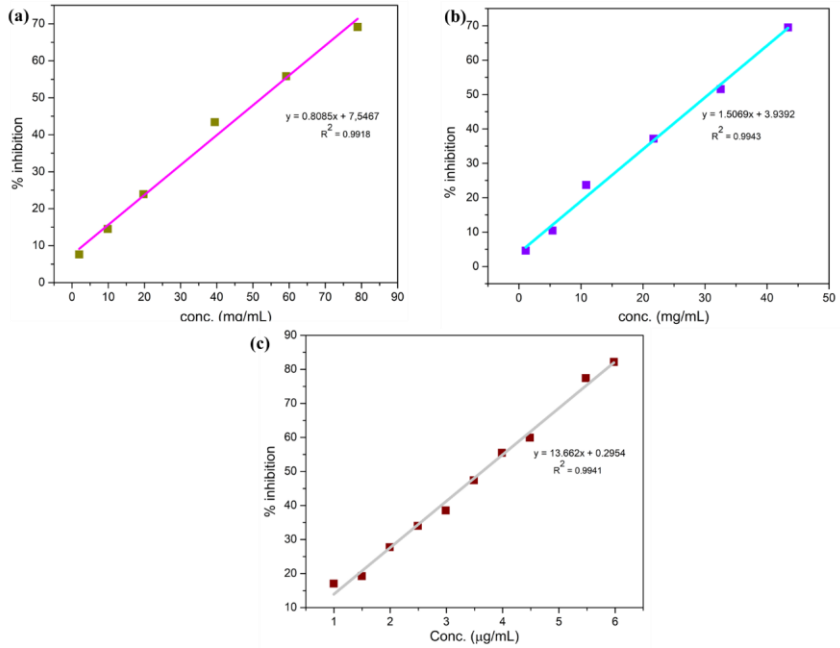


Figure 5. Regression curve of concentration vs % inhibition (**a**) leaves, (**b**) inflorescence, (**c**) ascorbic acid

Table 3. IC_{50} value from Essential oils of *S. jamaicensis*

Plan Part	IC_{50}
Leaves	30.566 mg/mL
Inflorescence	52.510 mg/mL
Ascorbic acid	3.638 µg/mL

Table 4. Antibacterial activity of essential oil *S. jamaicensis*

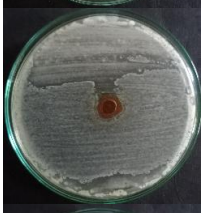
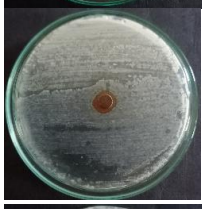
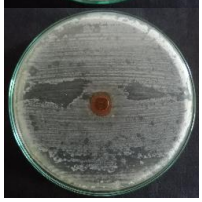
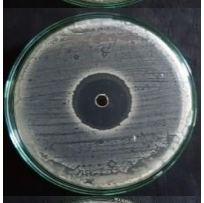
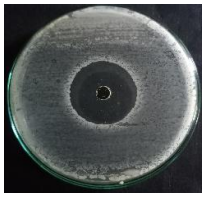
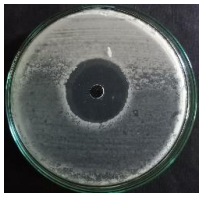
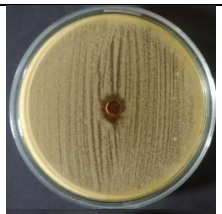
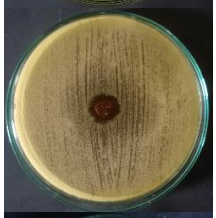
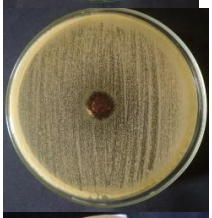
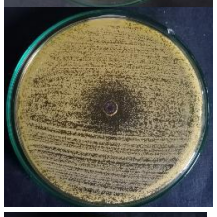
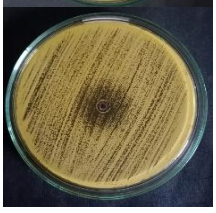
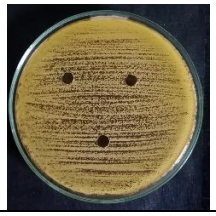
Sample	1st	2nd	3rd	Average Zone of Inhibition (mm)
Inflorescence				2.98
Leaves				4.95
Positive Control (Cloramphenicol)				24.52
Negative Control (Aquades)				0

Table 5. Antifungal activity of essential oil *S. jamaicensis*

Sample	1st	2nd	3rd	Average Zone of Inhibition (mm)
Inflorescence				5.033
Leaves				7.30
Positive control (Ketoconazole)				10.35
Negative control (Aquades)				0

Antibacterial and Antifungal Activity

The antibacterial and antifungal activity results of *S. jamaicensis* essential oil against *Staphylococcus aureus* and *Candida albicans* showed various zones of inhibition (**Tables 4** and **5**). This study showed that inflorescence oil could inhibit *Staphylococcus* lower than the inhibition of leaf oil. Similarly, the activity test results against *Candida albicans* showed that leaf oil has higher potential in inhibiting the growth of *Candida albicans* than inflorescence oil. The zone of inhibition of *S. jamaicensis* essential oil against fungi demonstrated greater inhibitory activity than against bacteria. Inhibition zones of less than 5 mm indicate that *S. jamaicensis* oil possesses weak antibacterial activity, while 6–10 mm zones suggest moderate antifungal activity (Fachriyah, Wibawa, & Awaliyah, 2020). This shows that *S. jamaicensis* essential oil has good antifungal potential for development. The primary mechanism of antimicrobial activity of essential oils is damage to cell membranes and the cytoplasm of microorganisms. The presence of bioactive compounds such as t-phytol and Neophytadiene might be attributed to the antimicrobial activities of *S. jamaicaensis*. Further research is being conducted to evaluate the antimicrobial activity of *S. jamaicensis* oil against various strains of pathogenic microbes at different concentrations.

CONCLUSIONS

GC-MS analysis confirmed that the phytochemical composition of *Stachytarpheta jamaicensis* essential oil is influenced by the Solvent-Free Microwave Extraction (SFME) method. The antioxidant assays demonstrated that both leaf and inflorescence essential oils exhibit significant antioxidant activity, with the leaf oil showing stronger potential. Similarly, antibacterial and antifungal tests indicated that the leaf essential oil possesses greater antimicrobial efficacy than that of the inflorescence. These findings highlight the potential of *S. jamaicensis* essential oil—particularly from the leaves—as a promising natural source for the development of pharmaceutical products derived from local plant resources.

ACKNOWLEDGMENTS

We thank the Indonesian Ministry of Research, Technology, and Higher Education for financially supporting this research through the Competitive-Based Research Grant.

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