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Ethnopharmacology of medicinal plants used by the Tenggerese community in Bromo Tengger Semeru National Park, Indonesia

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Abstract. *Bhagawan WS, Ekasari W, Agil M. 2023. Ethnopharmacology of medicinal plants used by the Tenggerese community in Bromo Tengger Semeru National Park, Indonesia. Biodiversitas 24: 5464-5477.* Bromo Tengger Semeru National Park is a repository of biodiversity with profound cultural significance. The Tenggerese community residing within the park possesses rich ethnopharmacological knowledge, using medicinal plants for various ailments. This study aims to comprehensively explore the medicinal plant diversity, traditional uses, and potential pharmacological activities among the Tenggerese people. Ethnopharmacological data was gathered through interviews with informants in seven Tenggerese villages. Ethnopharmacological indices like Species Use Value (SUV) and Fidelity Level (FL) were calculated to identify the most important medicinal plants. Phytochemical analysis of selected medicinal plants was conducted using UPLC-QTOF-MS/MS, and its pharmacological potential was assessed through antibacterial tests. A total of 124 medicinal plant species from 54 families were documented. The Tenggerese community utilizes plants to treat diverse diseases, with reproductive healthcare being prominently featured. *Elaeocarpus longifolius* emerged as a key species with high SUV and FL values. Phytochemical analysis identified 25 compounds, including major and minor compounds, already known for their pharmacological activities elsewhere. *Elaeocarpus longifolius* extract showed inhibitor activity against both gram-positive and gram-negative bacteria. The findings contribute to bridging traditional knowledge and modern scientific research, offering potential avenues for the development of drug candidates from indigenous medicinal plants.

Keywords: *Elaeocarpus longifolius*, ethnopharmacology, pharmacology, phytochemical, Tenggerese community

INTRODUCTION

National parks are recognized as crucial repositories of the world's remaining biodiversity, encompassing not only ecologically valuable plants but also those of significant cultural importance to humans (Ong et al. 2018; Wang 2019). Remarkably, approximately 15% of the Earth's land area is presently designated as national parks, while around 18% is officially acknowledged as being under the usage rights of indigenous peoples and local communities (Jufe-Bignoli et al. 2014; Ferretti-Gallon et al. 2021). Indigenous tribes possess profound knowledge regarding the complex relationship between humans and the surrounding nature, including the utilization of plants for traditional medicine (van Wyk and Wink 2017; Jamshidi-Kia et al. 2018). Consequently, national parks serve as invaluable starting points for investigating the harmonious interplay between traditional plant use and medicinal practices (Kim and Song 2014; Song et al. 2014; Tomasini and Theilade 2019; Redouan et al. 2020; Abbas et al. 2021). In this regard, ethnopharmacology plays an important role in connecting plant biodiversity, empirical traditional knowledge, and medicinal practices in an indigenous community. Ethnopharmacological research assumes particular significance, particularly in tropical countries undergoing rapid environmental and cultural transformations (Sujarwo et al. 2014; Heinrich and Jager 2015; Athayde et al. 2017; Aswani et al. 2018).

In Indonesia, numerous ethnopharmacological studies have been conducted within national parks over the past few decades. In Sumatra, Elliott and Brimacombe (1987) initiated such studies in Gunung Leuser, followed by Setyowati and Wardah (2007) documenting medicinal plants in Bukit Tigapuluh while Yudiyanto et al. (2022) conducted ethno-pharmacological studies on the Lampung Tribe residing near Way Kambas National Park. Two ethnopharmacological studies were conducted on Sulawesi Island, specifically in Bantimurung-Bulusaruang (Husaini et al. 2022) and Lore-Lindu (Gailea et al. 2016). In Kalimantan, Susanti and Zuhud (2019) focused on traditional knowledge and the conservation of medicinal plants among the Dayak Krayan people in Kayan Mentarang National Park. In Java, within Meru Betiri National Park, studies have examined the various interests and influences of actors involved in the utilization of medicinal plants (Nurrochmat et al. 2017), as well as revealing the pharmacological potential and phytochemical components of several medicinal plants (Nugraha et al. 2020; Ratnadewi et al. 2020), meanwhile Susiarti et al. (2018) analyzed the diversity of medicinal plants in Mount Gede Pangrango, while Arbiastutie et al. (2017) uncovered the anti-cancer potential of medicinal plants within this national park.

Among the national parks in Indonesia, which are rich in biodiversity of medicinal plants, Bromo Tengger Semeru is inhabited by a traditional tribe known as the Tengger people (Batoro 2017; Huda and Khasanah 2019). The Tengger people have a profound understanding and utilization of various medicinal plants, which play a pivotal role in their primary healthcare (Bhagawan et al. 2023). Their ethnopharmacological knowledge has been passed down through generations, upheld by the priesthood of traditional leaders (*dukun pandhita*), traditional healers (*dukun cilik*), and the Tengger community itself, actively engaging in independent traditional medicine (Nugraha et al. 2022; Putri et al. 2022). However, the relentless cultural influences from external sources have led to rapid environmental and cultural transformations in the region.

Over the past decade, several researchers have conducted ethnopharmacological field studies to document the medicinal plants used by the Tenggerese community residing around Bromo Tengger Semeru National Park (Batoro and Siswanto 2017; Bhagawan et al. 2020, 2021; Jadid et al. 2020; Bhagawan and Kusumawati 2021;). However, it is important to note that these studies have focused primarily on specific villages, leaving gaps in coverage across all areas inhabited by the Tenggerese community. Despite the valuable insights provided by these studies, there remains a surprising lack of research in the field of ethnopharmacology, specifically analyzing the phytochemical content and pharmacological activity of medicinal plants used by the Tenggerese people. Only two ethnopharmacological studies have examined the pharmacological activity of Tengger medicinal plants (Aziz et al. 2019; Shalas et al. 2021).

Therefore, the main objective of this study is to identify and document the important medicinal plants utilized by the Tenggerese people in seven different villages situated in Bromo Tengger Semeru National Park, shedding light on their cultural significance. Additionally, this research represents a pioneering effort to explore the ethnopharmacological relevance of the most frequently cited medicinal plants, analyzing both their pharmacological activities and phytochemical content for the first time. This comprehensive investigation aims to provide a deeper understanding of the potential therapeutic applications of these plants, bridging the gap between traditional knowledge and scientific analysis.

MATERIALS AND METHODS

Study area

The study area for this research was Bromo Tengger Semeru National Park, situated in East Java Province, Indonesia. This national park is located to the east of the provincial capital Surabaya and spans between 7°54’ and 8°55’13’S latitude and 112°5-113°04’E longitude (Figure 1). Encompassing an area of 503 km2, it boasts an altitude range of 750-3676 m above sea level. The landscape mainly consists of hilly and steep mountainous terrain, with Mount Semeru standing as the highest peak on the island of Java. Due to its higher altitude, the region experiences cooler temperatures during summer, ranging from 3° to 20°C. Furthermore, the area receives substantial rainfall, with an average of 6.600 mm per year (https://bromotenggersemeru.org/).

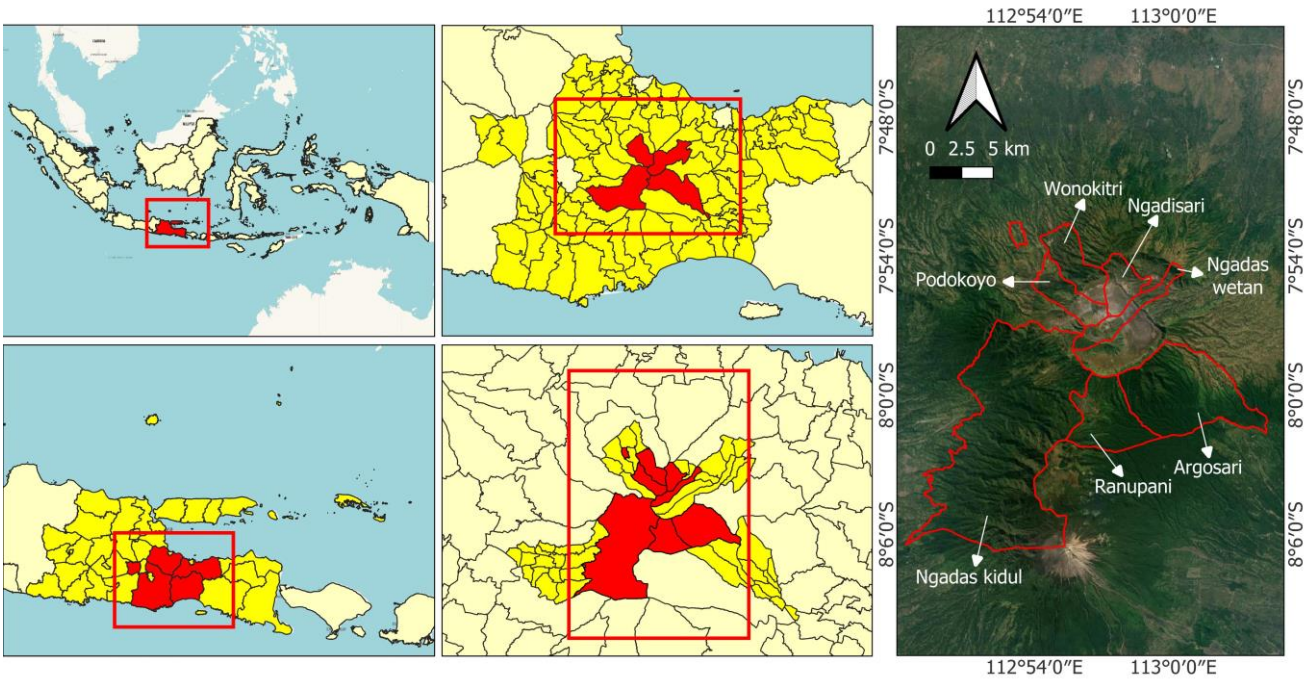

Figure 1. Location of the study area, consisting of seven Tenggerese villages in four different districts around Bromo Tengger Semeru National Park, East Java, Indonesia

Bromo Tengger Semeru National Park is a unique amalgamation of various zones, including nature reserves, tourist parks, production forests, and protected forests. The combined area of the two forests within the park amounts to 432 km^2 (https://bromotenggersemeru.org/). The Tengger tribe, the local inhabitants of this national park, constitute a significant presence in the region. *Tengger Hinduism* is the predominant religion among the tribe. The fertile soil in the area has facilitated traditional farming, which serves as the primary occupation for most of the villagers (Batoro 2017). The research focused on seven principal Tengger villages, namely (Argosari and Ranupani) in Lumajang District, (Ngadas Wetan and Ngadisari) in Probolinggo District, (Ngadas Kidul) in Malang District, and (Podokoyo and Wonokitri) in Pasuruan District. These locations were strategically chosen as the research areas, as they provide a comprehensive representation of the Tenggerese community within the broader context of the national park.

Ethnopharmacological data collection

The research adhered to the ethical guidelines set out by the Code of Ethics of the International Society of Ethnobiology (2006). Ethnopharmacological data were gathered during three distinct periods: 2009-2011, 2017-2019, and 2021-2023. Prior to conducting any interviews, formal permissions were sought from the village heads and tribal chiefs. Additionally, the informed consent of each informant was obtained orally, with a clear explanation of the research objectives. Ethnopharmacological data was collected through interviews and in-depth observations with informants selected through a snowball sampling technique. Interviews were conducted using the local language, namely *Javanese Kromo Inggil*. To ensure a comprehensive ethnopharmacological knowledge, a total of 167 residents from the region were involved in the interviews. Each village was represented by a minimum of 20 informants. The informants, predominantly aged above 40 years, comprised a gender-diverse group consisting of 103 men and 64 women.

During the research, local names of medicinal plants were gathered alongside information about the specific diseases they are used to treat, the parts of the plants that are utilized, the preparation methods, and the routes of drug administration. In order to ensure accuracy, the scientific names of the plants were determined using the website http://www.theplantlist.org/. Photographs were taken of plants that posed identification challenges. These photographs were subsequently submitted to taxonomists at Herbarium Jemberiense (Universitas Jember) and Purwodadi Botanical Garden (BRIN) for precise scientific name identification.

Quantitative ethnopharmacological analysis

The utilization of quantitative information enhances the likelihood of identifying pharmacologically significant plants. The identification of each important plant holds crucial importance for pharmacological screening. In this study, ethnobotanical data was subjected to analysis using ethnopharmacological indices, namely Fidelity Level (FL) and Species Use Value (SUV).

Species Use Value (SUV)

The species use value was employed to determine the significance of medicinal plant species utilized by the Tengger people in Bromo Tengger Semeru National Park. Originally introduced by Phillips and Gentry (1993a, 1993b), the SUV index was adapted for the purpose of this study. To compute plant citations in the national park, we applied the following formula:

$$SUV = \frac{\Sigma Uis}{ns}$$

Where: U denotes the total citation count for a specific plant species, and ns represents the number of informants participating in the study.

Fidelity Level (FL)

The fidelity level originally introduced by Friedman et al. (1986) was employed in this research. FL is calculated as the ratio between the number of informants who independently mentioned the use of a specific plant species for the same primary purpose and the total number of informants who cited the plant. The calculation was performed using the following equation:

$$FL\% = \left(\frac{Np}{N}\right) \times 100$$

Where: Np denotes the number of informants who mentioned or claimed the use of a particular plant species for a specific medicinal treatment, and N represents the total number of informants who cited the plant species for various types of medicinal treatments.

Preparation of selected medicinal plant

Selected medicinal plants were harvested, dried, and ground into powder. The choice of these plants was based on their high Species Use Value (SUV) and Fidelity Level (FL). A remaceration procedure was used to extract the plant using 100 g of their dried powder. Following a 24-hour soak in 5 L of 96% ethanol solvent, the powder was filtered through filter paper to remove only the filtrate. The same 2.5 L of 96% ethanol solvent was used for the second immersion, and the process was repeated for the third immersion and subsequent ones until 10 L of solvent had been used. Until the extract thickened, the filtrate was evaporated in a rotary evaporator at a temperature of 55 °C and 120 rpm. The solvent was then evaporated from the thickened extract in a 50°C oven. The 96% ethanol extract was ready for phytochemical analysis and in vitro pharmacology testing.

Phytochemical analysis

Phytochemical analysis of selected plants was performed to detect the presence of plants' secondary metabolites of pharmacological importance. The samples underwent analysis using Ultra Performance Liquid Chromatography-Quadrupole Time of Flight-Mass Spectrometry (UPLC-QTOF-MS/MS) equipped with electrospray ionization (ESI) sources. To prepare the sample, 100 ppm for 96% ethanol extract was dissolved in methanol. Before injection, a solid-phase filtration process

was utilized. Subsequently, 5 µL of the extract was injected into the tandem detector MS Xevo G2-S QToF of the ACQUITY UPLC® H-Class System (Waters, USA). The samples were separated using an ACQUITY BEH C18 (1.7 µm, 2.1x50 mm) column with a mobile phase of 0.05% acetonitrile and 0.05% formic acid, flowing at a rate of 0.2 mL/min. The UPLC-MS analysis findings were processed using Masslynx version 4.1 to generate the chromatogram and spectra of each observed peak. Additionally, chemical prediction was performed using the ChemSpider website.

Pharmacological activity test

According to the CLSI (2012) procedure, pharmacological activity tests were conducted using the agar disk-diffusion method against gram-positive (*Staphylococcus aureus*) and gram-negative (*Shigella dysenteriae*) bacteria. *Staphylococcus aureus* and *S. dysenteriae* cultures totaling one mL were placed on a sterile petri dish. A petri dish holding the inoculum was filled with melted Mueller-Hinton Agar (MHA) that had been cooled and swirled thoroughly. After compaction, wells were drilled into the agar plate holding the inoculum using a sterile cork borer (6 mm in diameter). Thereafter, each well received 30 µL of each extract concentration (2.5 mg/mL, 5 mg/mL, 10 mg/mL, 20 mg/mL, and 40 mg/mL). To ensure that the extract mixed thoroughly with the agar, the plates were chilled for 30 minutes. After that, the plate was incubated for 24 hours at 37°C. Before applying chloramphenicol at a concentration of 0.5 mg/mL as positive control and DMSO at a dose of 10% as negative control, the diameter of the inhibitory growth zone was evaluated. The antibacterial tests were conducted in triplicate for each extract and control preparation. The data obtained were subjected to statistical analysis using one-way ANOVA to determine the smallest significant difference at a significance level of $P < 0.05$, employing statistical software (SPSS 22, IBM Corporation, NY, USA). All results are presented as mean values ± standard deviation.

RESULTS AND DISCUSSION

Medicinal plant biodiversity and diseases treated

An ethnopharmacological survey in this study documented 124 medicinal plants belonging to 54 families used by the Tenggerese community living in seven villages in Bromo Tengger Semeru National Park. Detailed information about these medicinal plants can be found in Table 1. The species most used ethnopharmacologically were Zingiberaceae (twelve species), followed by Compositae, Leguminosae, and Solanaceae (seven species each). Other families frequently used include Apiaceae and Apocynaceae (five species each), Cucurbitaceae, Piperaceae, and Poaceae (four species each). The reason why Zingiberaceae plants are used most often is probably due to their habitat and environmental conditions. Zingiberaceae dominance has been found in previous ethnopharmacology studies in other Indonesian national parks, such as in Mount Gede Pangrango (Susiarti et al. 2018), Mount Leuser (Elliott and Brimacombe 1987), and Way Kambas (Yudiyanto et al. 2022).

Medicinal plants play a vital role in providing remedies for a range of health issues within the local community, as outlined in Table 2. These ailments are categorized into six distinct disease groups, with an effort made to align the data with customary classifications established by medical practitioners. These encompass dermatological diseases, gastrointestinal disorders, internal medical diseases, reproductive healthcare, respiratory problems, and skeletal-muscular disorders. Particularly noteworthy is the category of reproductive healthcare, which encompasses the highest number of diseases (nine in total). These include antifertility, erectile dysfunction, female fertility, leucorrhea, low breast milk production, menstrual pain, postpartum, syphilis, and care for pregnant women. The emergence of diseases in the reproductive health category could be intrinsically linked to the Tenggerese people's practice of population control. As elaborated by Laksono (2020), the Tenggerese community's traditions regulate family size due to limited available land. The reproductive health category was also found in ethnopharmacology studies, such as those conducted in Tlemcen National Park, North West Algeria (Zatout et al. 2021) and Queen Elizabeth National Park, South Western Uganda (Gumisiriza et al. 2019).

Plant part used, preparation, and administration route

Parts of plants that are commonly used in medication or health treatment by the Tenggerese tribe are roots, leaves, barks, stems, flowers, tubers, fruits, seeds, rhizomes, and all parts. In this research, among the various parts of the plant used in therapy, leaves were predominately used (41%), followed by fruit (22%) (Figure 2A). This trend aligns with observations in existing literature (Jadid et al. 2020), which notes the accessibility and relatively higher abundance of leaves in the natural environment. This accessibility might contribute to their prevalent usage in medicinal preparation. The prominence of leaf usage is closely associated with the survival strategy of the plants. Removing a reasonable amount of leaf biomass exerts minimal harm to the plant, unlike the collection of stems, roots, or entire plants. Additionally, leaves are renowned for producing diverse secondary metabolites (Zahoor et al. 2017), rendering them particularly valuable for therapeutic purposes.

Among the diverse methods of herbal drug preparation, decoction stands as the most predominant (constituting 43%) in the surveyed area (Figure 2B). The prevalence of using decoction as a method for preparing medicinal plants can be attributed to its simplicity, user-friendliness, and cost-effectiveness (Amri et al. 2014). Moreover, this technique enhances the extraction of a broader spectrum of phytochemical compounds, thus augmenting the plant's pharmacological impact (Barkaoui et al. 2017). The administration route of medicinal plant preparations is primarily oral (81%), although a smaller proportion involves vaginal, topical, optical, and nasal applications as well (Figure 2C). Interestingly, our findings regarding the methods of preparation, routes of administration, and utilized plant parts are in close alignment with the results of prior investigations conducted in other Indonesian national parks (Susiarti et al. 2018; Susanti and Zuhud 2019; Husaini et al. 2022).

Table 1. Medicinal plants used in the Bromo Tengger Semeru National Park, East Java, Indonesia, including family, species name, local name, part used, diseases treated, preparation and administration

Family	Species name	Local name	Part used	Diseases or health problems treated	Preparation, administration
Acanthaceae	*Andrographis paniculata* (Burm.f.) Nees	*Sambiloto*	Leaf	Cough, fever, postpartum	Boiled/decoction, oral
	Strobilanthes crispa Blume	*Keji beling*	Leaf	Kidney stones	Decoction, oral
Acoraceae	*Acorus calamus* L.	*Dringu*	Leaf	Fever	Decoction, oral
Aloaceae	*Aloe vera* (L.) Burm. f.	*Lidah buaya*	Leaf	Hair problems	Raw, topical
Amaranthaceae	*Achyranthes aspera* L.	*Aseman*	Leaf, Root	Erectile dysfunction, postpartum	Decoction/raw, oral
	Amaranthus hybridus L.	*Bayam*	Leaf	High cholesterol, postpartum	Boiled, oral
Amarillydaceae	*Allium fistulosum* L.	*Bawang pre*	Leaf	High cholesterol	Decoction, oral
	Allium cepa L.	*Bawang merah*	Tuber	Fever, flatulence	Decoction, oral
	Allium sativum L.	*Bawang putih*	Tuber	Cough, high cholesterol, low breast milk production, postpartum	Raw, oral
Annonaceae	*Annona muricata* L.	*Sirsak*	Fruit	Diabetes	Raw, oral
	Annona squamosa L.	*Srikoyo*	Fruit	Diarrhea	Raw, oral
	Cananga odorata (Lam.) Hook.f. & Thomson	*Kenanga*	Flower	Dry skin, postpartum	Powdered/steam, topical/vaginal
Apiaceae	*Apium graveolens* L.	*Seledri*	Leaf	Hypertension, postpartum	Raw, oral
	Centella asiatica (L.) Urb.	*Calingan*	Leaf	Cough, kidney stones	Decoction, oral
	Coriandrum sativum L.	*Ketumbar*	Fruit	Diarrhea, flatulence	Decoction, oral
	Foeniculum vulgare Mill	*Adas*	Leaf	Cough, fever, leucorrhea, menstrual pain, postpartum	Decoction, oral
	Pimpinella pruatjan Molk.	*Purwoceng*	Root	Erectile dysfunction	Decoction, oral
Apocynaceae	*Alyxia reinwardtii* Blume	*Pulosari*	Bark	Dengue fever, diarrhea, erectile dysfunction, fever, postpartum	Decoction, oral
	Alstonia scholaris (L.) R. Br.	*Pule*	Bark	Fever	Decoction, oral
	Mandevilla sanderi (Hemsl.) Woodson	*Kembang terompet*	Flower	Fever	Decoction, oral
	Plumeria rubra L.	*Kamboja*	Flower	Headache	Decoction, oral
Araceae	*Colocasia esculenta* (L.) Schott	*Talas*	Leaf	Diarrhea	Decoction, oral
Araliaceae	*Polyscias scutellaria* (Burm.f.) Fosberg	*Mangkokan*	Leaf	Wound infection	Decoction, oral
Arecaceae	*Areca catechu* L.	*Jambe*	Seed	Intestinal worms	Decoction, oral
Asteraceae	*Elephantopus scaber* L.	*Tapak liman*	Leaf	Kidney stones, postpartum	Decoction/boiled, oral
	Artemisia vulgaris L.	*Ganjan*	Leaf	Erectile dysfunction	Decoction, oral
	Tithonia diversifolia (Hemsl.) A. Gray	*Insulin*	Leaf	Diabetes	Decoction, oral
Athyriaceae	*Diplazium esculentum* (Retz.) Sw.	*Pakis*	Leaf	Postpartum	Raw, oral
Basellaceae	*Anredera cordifolia* (Ten.) Steenis	*Binahong*	Leaf	Cough, mouth ulcer, postpartum	Boiled, oral
Brassicaceae	*Brassica rapa* L.	*Sawi hijau*	Leaf	Fever, postpartum	Raw, oral
	Nasturtium officinale R.Br.	*Selada*	Leaf	Postpartum	Raw, oral
	Raphanus raphanistrum L.	*Lobak*	Tuber	Erectile dysfunction, syphilis	Decoction, oral
Bromeliaceae	*Ananas comosus* (L.) Merr.	*Nanas*	Fruit	Antifertility, diarrhea	Squeezed, oral
Caricaceae	*Carica papaya* L.	*Pepaya*	Leaf	Low breast milk production, postpartum	Boiled, oral
Caryophyllaceae	*Stellaria saxatilis* Buch.-Ham. ex D. Don	*Tepung otot*	All parts	Osteoporosis	Squeezed, topical
Casuarinaceae	*Casuarina junghuhniana* Miq.	*Cemara*	Bark	Diarrhea	Decoction, oral
Compositae	*Bidens pilosa* L.	*Sempretan*	Leaf	Fever, hypertension	Decoction, oral
	Blumea balsamifera (L.) DC.	*Sembung*	Leaf	Postpartum	Boiled, oral
	Cosmos caudatus Kunth	*Kenikir*	Leaf	Hypertension, insomnia, postpartum, pregnant women	Decoction/raw, oral
	Gynura procumbens (Lour.) Merr.	*Sambung nyawa*	Leaf	Postpartum	Boiled, oral
	Helianthus annuus L.	*Bunga matahari*	Seed	Hypertension	Burn, oral
	Pluchea indica (L.) Less.	*Luntas*	Leaf	Postpartum	Boiled, oral
	Sonchus arvensis L.	*Tempuyung*	Leaf	Hypertension, kidney stones	Decoction, oral
Convolvulaceae	*Ipomoea batatas* (L.) Lam.	*Telo rambat*	Leaf	Postpartum	Boiled, oral
	Jacquemontia paniculata (Burm. f.) Hallier f.	*Tirem*	Leaf	Postpartum	Boiled, oral
Cucurbitaceae	*Citrullus lanatus* (Thunb.) Matsum	*Semangka*	Fruit	Hypertension	Raw, oral

	Cucumis melo L.	*Melon*	Fruit	Hypertension	Raw, oral
	Cucumis sativus L.	*Timun*	Fruit	Hypertension	Raw, oral
	Momordica charantia L.	*Pare*	Fruit	Postpartum	Raw, oral
Cluseaceae	*Garcinia* × *mangostana* L.	*Manggis*	Fruit	Mouth ulcer	Raw, oral
Elaeocarpaceae	*Elaeocarpus longifolius* Blume	*Jambu Wer*	Fruit	Diarrhea	Decoction, oral
Euphorbiaceae	*Jatropha curcas* L.	*Jarak pagar*	Stem	Mouth ulcer, sprue	Decoction, oral
	Manihot utilissima Pohl	*Singkong*	Leaf	Low immune system, postpartum	Boiled, oral
Fabaceae	*Tamarindus indica* L.	*Asem*	Fruit	Cough	Decoction, oral
	Parkia speciosa Hassk.	*Petai*	Seed	Menstrual pain, postpartum	Raw, oral
Lamiaceae	*Mentha* × *piperita* L.	*Min*	Leaf	Asthma, postpartum	Burn/raw/decoction, nasal/oral
	Ocimum citriodorum Vis.	*Kemangi*	Leaf	Diarrhea, postpartum	Decoction/raw, oral
	Orthosiphon aristatus (Blume) Miq.	*Kumis kucing*	Leaf	Kidney stones, postpartum	Decoction/boiled, oral
Lauraceae	*Cinnamomum burmanii* Bl.	*Keningar*	Bark	Diabetes, erectile dysfunction, postpartum	Decoction, oral
	Cinnamomum sintoc Bl.	*Sintok*	Bark	Erectile dysfunction	Decoction, oral
	Persea americana Mill.	*Alpukat*	Fruit	High cholesterol, hypertension	Raw, oral
Leguminosae	*Erythrina variegata* L.	*Dadap srep*	Leaf	Fever	Raw, topical
	Euchresta horsfieldii (Lesch.) Benn.	*Pronojiwo*	Fruit	Erectile dysfunction, leucorrhea	Decoction, oral
	Leucaena leucocephala (Lam.) de Wit	*Lamtoro*	Seed	Postpartum	Raw, oral
	Psophocarpus tetragonolobus (L.) DC.	*Kecipir*	Seed	Postpartum	Boiled, oral
	Sesbania grandiflora (L.) Pers.	*Turi*	Flower	Low breast milk production, postpartum	Boiled, oral
	Trigonella foenum-graecum L.	*Klabet*	Leaf	Low breast milk production, postpartum	Boiled, oral
	Vigna radiata (L.) R.Wilczek	*Kacang hijau*	Seed	Pregnant women	Boiled, oral
Liliaceae	*Aloe vera* Mill.	*Lidah buaya*	Leaf	Hair problems, skin burn	Squeezed, topical
Loranthaceae	*Dendrophthoe pentandra* (L.) Miq.	*Kemladean*	Leaf	Fever	Decoction, oral
Lycoperdaceae	*Bovista gigantea* (Batsch) Gray	*Jamur impes*	All parts	External wound	Squeezed, topical
Magnoliaceae	*Magnolia* × *alba* (DC.) Figlar	*Kanthil*	Flower	Postpartum	Steam, vaginal
Marceliaceae	*Marsilea crenata* C. Presl	*Semanggi*	Leaf	Postpartum	Raw, oral
Meliaceae	*Swietenia mahagoni* (L.) Jacq.	*Mahoni*	Seed	Diabetes	Decoction, oral
Menispermaceae	*Tinospora crispa* (L.) Hook. f. & Thomson	*Brotowali*	Leaf	Postpartum, hypertension	Decoction, oral
Moraceae	*Morus alba* L.	*Krokot*	Leaf	Hypertension	Decoction, oral
	Ficus carica L.	*Buah Lo*	Fruit	Female fertility	Raw, oral
Moringaceae	*Moringa oleifera* Lam.	*Kelor*	Leaf	Low breast milk production, postpartum	Boiled, oral
Muntingiaceae	*Muntingia calabura* L.	*Kersen*	Fruit	Hypertension	Raw, oral
Musaceae	*Musa* × *paradisiaca* L.	*Pisang*	Flower	Postpartum	Boiled, oral
Myrtaceae	*Psidium guajava* L.	*Jambu biji*	Leaf	Diarrhea, hemorrhoid	Raw, oral
	Syzygium polyanthum (Wight) Walp.	*Salam*	Leaf	Diabetes	Decoction, oral
Oleaceae	*Jasminum sambac* (L.) Aiton	*Melati*	Flower	Postpartum	Steam, vaginal
Oxalidaceae	*Averrhoa bilimbi* L.	*Blimbing wuluh*	Fruit	Mouth ulcer	Raw, oral
Phyllanthaceae	*Phyllanthus niruri* L.	*Meniran*	Leaf	Low immune system	Decoction, oral
Plantaginaceae	*Digitalis purpurea* L.	*Digitalis*	Leaf	External wound	Squeezed, topical
	Plantago major L.	*Suri pandak*	Leaf	Erectile dysfunction, menstrual pain, postpartum	Decoction, oral
Piperaceae	*Peperomia pellucida* (L.) Kunth	*Suruhan*	Leaf	Menstrual pain, postpartum	Decoction/raw, oral
	Piper betle L.	*Sirih*	Leaf	Erectile dysfunction, flatulence, menstrual pain, postpartum, wound infection	Decoction/steam, oral/vaginal
	Piper ornatum N.E.Br.	*Sirih merah*	Leaf	Low immune system, postpartum	Decoction/steam, oral/vaginal
	Piper retrofractum Vahl	*Cabe jawa*	Fruit	Erectile dysfunction	Decoction, oral
Poaceae	*Cymbopogon citratus* (DC.) Stapf	*Sereh*	Leaf	Diarrhea, postpartum	Decoction/steam, oral/vaginal
	Cynodon dactylon (L.) Pers.	*Grinting*	Stem	External wound	Squeezed, topical
	Saccharum officinarum L.	*Tebu merah*	Stem	Cough	Squeezed, oral
	Imperata cylindrica (L.) Raeusch.	*Alang-alang*	Root	Erectile dysfunction	Decoction, oral
Polypodiaceae	*Leptochilus buergerianus* (Miq.) Bosman	*Pangotan*	Fruit	Diabetes	Raw, oral
Rosaceae	*Rosa chinensis* Jacq.	*Mawar*	Flower	Postpartum	Steam, vaginal
	Rubus rosaefolius Sm.	*Grunggung*	Fruit	Diarrhea, mouth ulcer	

Rubiaceae	*Coffea arabica* L.	*Kopi*	Seed	Erectile dysfunction, headache	Decoction, oral
	Morinda citrifolia L.	*Bentis*	Fruit	Diabetes, high cholesterol	Decoction, oral
	Paederia foetida L.	*Sembukan*	Leaf	Leucorrhea, menstrual pain, postpartum	Decoction/boiled, oral
Rutaceae	*Citrus aurantiifolia* (Christm.) Swingle	*Jeruk nipis*	Fruit	Cough	Raw, oral
	Citrus hystrix DC.	*Jeruk purut*	Fruit	Cough, postpartum	Raw/steam, oral/ vaginal
Solanaceae	*Datura metel* L.	*Kecubung*	Flower	Eye irritation	Raw, optical
	Physalis angulata L.	*Ceplukan*	Fruit	Diarrhea	Raw, oral
	Solanum betaceum Cav.	*Terong belanda*	Fruit	Pneumonia, sprue	Raw, oral
	Solanum melongena L.	*Terong*	Fruit	High cholesterol, postpartum	Raw, oral
	Solanum muricatum Aiton	*Buah melodi*	Fruit	Hypertension	Raw, oral
	Solanum nigrum L.	*Ranti*	Fruit, Leaf	Postpartum	Raw, oral
	Solanum tuberosum L.	*Kentang*	Tuber	Dry skin	Powdered, topical
Usneaceae	*Usnea barbata* Fries	*Jenggot wesi*	All parts	Erectile dysfunction	Decoction, oral
Zingiberaceae	*Alpinia galanga* (L.) SW.	*Laos*	Rhizome	Erectile dysfunction, low immune system, menstrual pain, postpartum	Decoction, oral
	Amomum cardamomum L.	*Kapulaga*	Fruit	Erectile dysfunction	Decoction, oral
	Boesenbergia rotunda (L.) Mansf.	*Temu ireng*	Rhizome	Postpartum	Steam, vaginal
	Curcuma alba L.	*Kunir putih*	Rhizome	Dry skin	Powdered, topical
	Curcuma heyneana Valeton & Zijp	*Temu giring*	Rhizome	Rheumatoid arthritis	Decoction, oral
	Curcuma longa L.	*Kunir*	Rhizome	Fever, headache, menstrual pain, postpartum	Decoction, oral
	Curcuma xanthorrhiza Roxb.	*Temulawak*	Rhizome	Erectile dysfunction, hepatitis, low immune system, menstrual pain, postpartum	Decoction, oral
	Kaempferia galanga L.	*Kencur*	Rhizome	Cough, postpartum	Decoction/steam, oral/vaginal
	Kaempferia rotunda L.	*Kunci*	Rhizome	Erectile dysfunction, postpartum	Decoction/steam, oral/vaginal
	Zingiber cassumunar Roxb.	*Bangle*	Rhizome	Fever, headache, menstrual pain, postpartum	Decoction, oral
	Zingiber officinale Roscoe	*Jahe*	Rhizome	Cough, leucorrhea, menstrual pain, postpartum	Decoction, oral
	Zingiber zerumbet (L.) Roscoe ex Sm.	*Lempuyang*	Rhizome	Leucorrhea, hypertension, menstrual pain, postpartum	Decoction/steam, oral/vaginal

Table 2. Group of diseases and health-related problems treated by medicinal plants in Bromo Tengger Semeru National Park

Disease categories	**Specified disease name**
Dermatological diseases	Dry skin, external wound, eye irritation, hair problems, nose bleeding, skin burn, wound infection
Gastro-intestinal disorders	Diarrhea, flatulence, hemorrhoid, intestinal worms, sprue
Internal medical diseases	Dengue fever, diabetes, fever, high cholesterol, hypertension, insomnia, kidney stones, low immune system
Reproductive healthcare	Antifertility, erectile dysfunction, female fertility, leucorrhea, low breast milk production, menstrual pain, postpartum, syphilis, pregnant women
Respiratory problems	Asthma, cough, mouth ulcer, pneumonia
Skeleto-muscular disorders	Headache, osteoporosis, rheumatoid arthritis

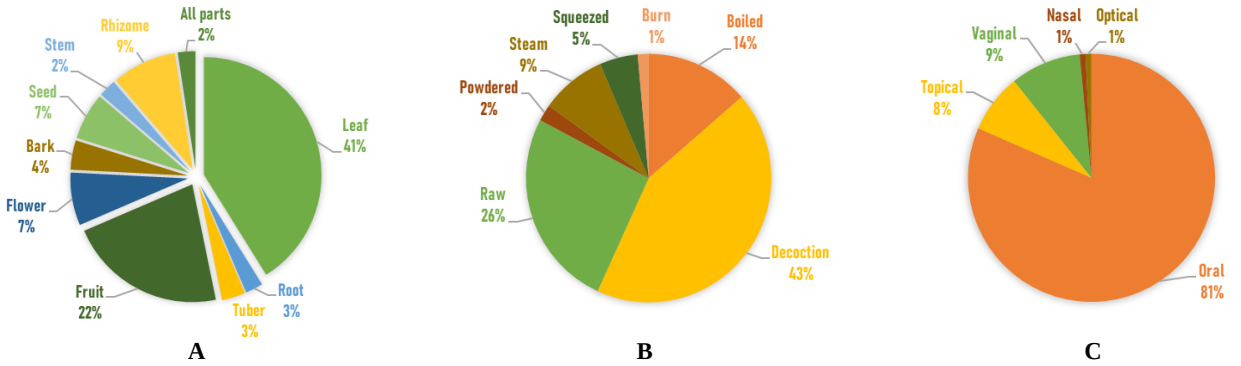

Figure 2. A) Plant part used, B) preparation, and C) administration route of medicinal plants in Bromo Tengger Semeru National Park

Most important medicinal plants

The utilization of ranking and scoring methodologies is instrumental in evaluating the extensive therapeutic potential of medicinal plants, which is substantiated by their frequent references. The ranking outcomes are derived from quantitative ethnopharmacological analysis (SUV and FL) for the five most extensively cited medicinal plants. We found five plant species have demonstrated notable high SUV values, specifically *F. vulgare* (1.29), *E. longifolius* (0.92), *P. bettle* (0.78), *B. pilosa* (0.75), and *A. calamus* (0.59) (Figure 3). Concurrently, we have recorded five plant species with high FL values that exhibit distinct efficacy against particular diseases. Notably, *E. longifolius* emerges as a prominent candidate for addressing diarrhea (92%), while *A. calamus* is a potent contender against fever (59%). Additional noteworthy species encompass *Psidium guajava* for diarrhea (47%), *Pimpinella pruatjan* for erectile dysfunction (35%), and *A. fistulosum* for high cholesterol (32%) (Figure 4).

Plant species exhibiting high SUV values inherently signify their pivotal pharmacological relevance within local communities, as underscored by Kayani et al. (2015). Moreover, the research by Utaminingrum et al. (2022) emphatically underscores the utility of relative frequency of citation, as gauged through FL, in determining species' pivotal roles in specific medicinal contexts. Previous investigations have consistently highlighted that plant species commanding dominant SUV and FL are notably recognized as substantial biopharmacological assets (Saudah et al. 2022), often prompting further exploration into their pharmacological properties and phytochemical composition (Bhagawan et al. 2022). Hence, based on the discernment gleaned from SUV and FL analyses, the current study has identified *E. longifolius* as a prime candidate warranting thorough investigation into its pharmacological attributes and phytochemical constituents. This strategic selection aligns with the broader trends observed in ethnopharmacological research, ensuring that efforts are concentrated on the most promising avenues of medicinal exploration.

Phytochemical compounds of *E. longifolius*

Our investigation centered on the ethanol extract of immature *E. longifolius* fruit. A comprehensive analysis unveiled the presence of twenty-five distinct compounds encompassing diverse chemical classes. Among these, twenty-two compounds have been confidently identified and their chemical names elucidated. However, a subset of three compounds remains unidentified. The fundamental peak chromatograms generated through UPLC-QTOF-MS/MS analysis are visually represented in Figure 5, providing a snapshot of the detected constituents. Table 3 shows the details of all the compounds identified based on their high-resolution mass spectrometry values and their pharmacological activities.

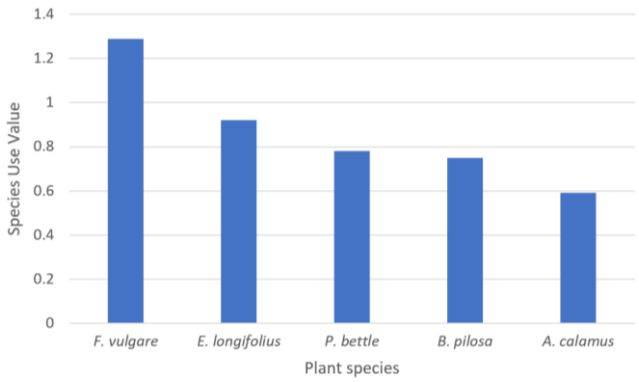

Figure 3. Five plant species with high SUV values by the Tenggerese tribe in Bromo Tengger Semeru National Park

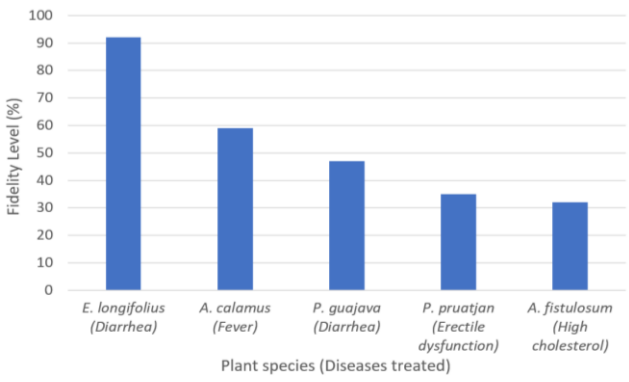

Figure 4. Five plant species with high FL values by the Tenggerese tribe in Bromo Tengger Semeru National Park

Table 3. Phytochemical profile of *E. longifolius* fruit extract using the UPLC-QToF-MS/MS

RT (min)	% Area	Measured m/z	Compound formula	Compound name	Pharmacological activity
1.055	6.93%	150.0279	$C_3H_6N_2O_5$	L-serine	Neurological dysfunction (De Koning et al. 2003; Maugard et al. 2021), antibacterial (Duan et al. 2016), antioxidant, cytoprotective (Maralani et al. 2012), antifungi (Hua et al. 2021), antiproliferative (Rathgeb et al. 2014)
1.971	2.67%	293.1487	$C_{13}H_{19}N_5O_3$	N-diethyl-acetamide	Antioxidant (Sribalan et al. 2015).
3.278	2.12%	143.0580	$C_6H_9NO_3$	Methyl pyroglutamate	Epithelial cancer (Stefanucci et al. 2014).
3,837	0.69%	354.0948	$C_{16}H_{18}O_9$	Scopolin	Antioxidant (Lee et al. 2013), antiosteoporotic (Park et al. 2020), antihepatocellular carcinoma (Wang et al. 2022)
4.258	0.71%	354.0936	$C_{13}H_{10}N_{10}O_3$	1,2,4-triazine-6-carboxamide	-
4.595	2,32%	419.1807	$C_{19}H_{25}N_5O_6$	1H-purine-2,6-dione	Analgesic (Zygmunt et al. 2015), anti-inflammatory (Abou-ghadir et al. 2014)
5.069	2.98%	312.1336	$C_{15}H_{16}N_6O_2$	1,3,5-triazine	Antibacterial, fungicidal, antimalarial, anticancer, antiviral, antimicrobial, anti-inflammatory, antiamoebic, antitubercular activities (Singh et al. 2021).
6.090	0.26%	539.2339	$C_{22}H_{33}N_7O_9$	L-Histidine	Coagulation (He et al. 2018), anticancer (Mahmoud et al. 2018), antitumor (Abolmaali et al. 2016), antioxidant (Ruszkiewicz and Albrecht 2015)
6.502	0.53%	308.0881	$C_{12}H_8N_{10}O$	N-9H-Purin-3-pyridazinecarboxamide	-
6.860	0.26%	350.1005	$C_{17}H_{18}O_8$	3-propanoic acid	
7.281	0.05%	502.3279	$C_{27}H_{38}N_{10}$	1,1'-bis-1,3,5-triazine-2,4-diamine	-
8.040	0.26%	673.2167	$C_{29}H_{35}N_7O_{10}S$	Unknown	-
8.493	0.99%	501.3431	$C_{34}H_{47}NS$	1-cyclohexyl ethyl benzene	-
8.893	0.60%	715.2321	$C_{44}H_{33}N_3O_7$	2,2,4-trimethylquinolin-2-phenylacetate	-
9.251	0.08%	501.3457	$C_{30}H_{47}NO_5$	3-Hydroxy-2-nitrolup-2-en-28-oic acid	-
9.472	0.11%	307.2054	$C_{20}H_{25}N_3$	4-piperidinyl-1,2,3,4-tetrahydroisoquinoline	-
10.031	0.70%	484.3186	$C_{30}H_{44}O_5$	Fupenzic acid	Lipid-lowering activity (Zhu et al. 2022), antifungal (Xing et al. 2019), cytotoxic activity (Zhang et al. 2022)
10.347	0.01%	502.3294	$C_{30}H_{46}O_6$	Medicagenic acid	Cytotoxic, antioxidant, antimicrobial activities (Wang et al. 2021)
10.642	14.52%	276.1725	$C_{17}H_{24}O_3$	6-Shogaol	Anticancer, antimicrobials, antioxidants, cardiovascular, anti-ulcer, antiemetic, anti-inflamatory antiviral, neuroprotective (Kou et al. 2018; Roli et al. 2020; Bischoff-Kont and Fürst 2021; Rahaman et al. 2023), myelodysplastic syndrome (Ooi et al. 2021)
11.105	11.65%	285.1367	$C_{17}H_{19}NO_3$	Piperine	Antiproliferative, antitumor, antiangiogenesis, antioxidant, antidiabetic, anti-obesity, anti-ashmatic, cardioprotective, antimicrobial, antiaging, and immunomodulatory activities (Meghwal and Goswami 2013; Derosa et al. 2016; Haq et al. 2020; Tiwari et al. 2020)
11.938	7.15%	517.3162	$C_{29}H_{39}N_7O_2$	Piperidine	Analgesic, antipsychotic, antihistamine, local anastetic, anticholinergic, CNS stimulant, antiemetic, immunosuppresant (Vardanyan 2017).
12.433	1.97%	519.3334	$C_7H_{37}N_{25}OS$	Unknown	-
12.675	21.91%	519.3347	$C_{28}H_{33}O_{16}$	Peonidin	Antioxidant and prebiotic activity (Sun et al. 2018), anticancer (Laksmiani et al. 2017), anti-inflammatory (Sari et al. 2019)
13.192	15.89%	495.3352	$C_{31}H_{45}NO_4$	D-phenylalanine-benzoxazole	Antitubercular activity (Pepi et al. 2022, 2023)
13.908	4.11%	618.3916	$C_{31}H_{58}N_2O_8S$	Unknown	-

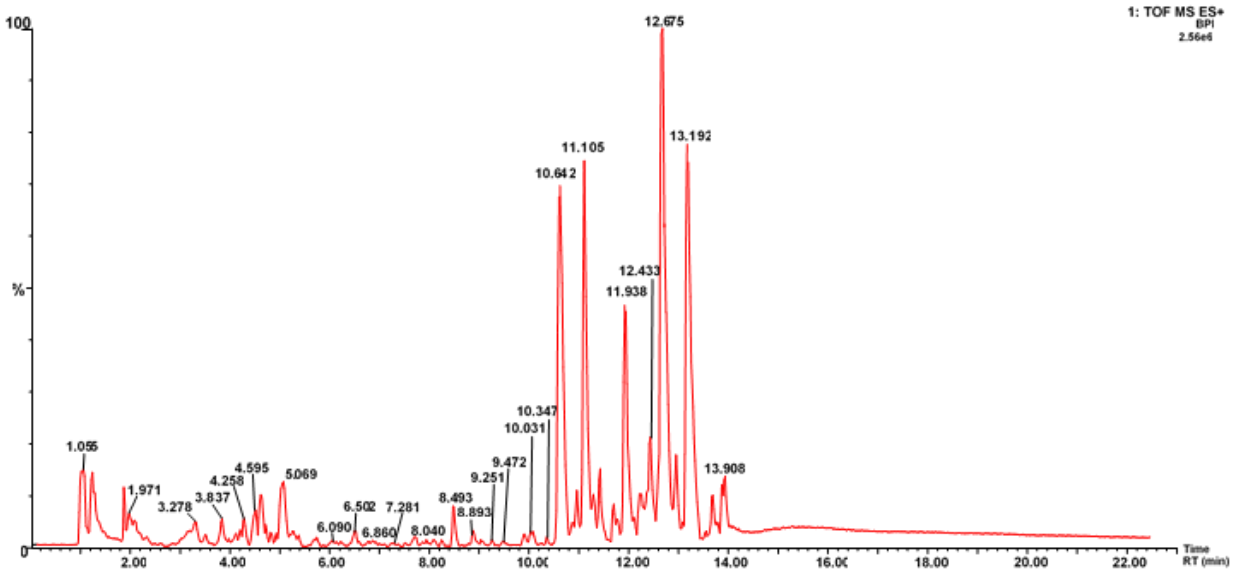

Figure 5. Chromatogram profile of *E. longifolius* extract using the UPLC-QToF-MS/MS

An in-depth analysis of the *E. longifolius* extract revealed several major phytochemical compounds, each contributing significantly to the overall composition. Notably, Peonidin (21.91%), D-phenylalanine-benzoxazole (15.89%), 6-Shogaol (14.52%), and Piperine (11.65%) emerged as dominant constituents, constituting more than 10% of the extract. The pivotal role of these compounds in the overall phytochemical profile is further magnified by their pharmacological activities, as gleaned from contemporary literature. Peonidin, D-phenylalanine-benzoxazole, 6-Shogaol, and Piperine each exhibit diverse pharmacological potential, positioning them as promising candidates for therapeutic applications. Of noteworthy mention, D-phenylalanine-benzoxazole, as underscored by recent studies by Pepi et al. (2022, 2023), has garnered attention for its robust antitubercular properties.

While major phytochemical constituents often take the limelight, the significance of minor compounds in driving pharmacological activity should not be underestimated. Among these, Piperidine and L-Serine stand out as compelling examples, demonstrating a wide range of pharmacological activities. Piperidine has demonstrated its utility as an analgesic, antipsychotic, antihistamine, local anesthetic, anticholinergic, CNS stimulant, antiemetic, and immunosuppressant, as reported by Vardanyan (2017). L-Serine influence spans across multiple domains of pharmacology, rendering it a versatile agent for various health concerns. Notably, it exhibits profound potential in obstructing neurological dysfunction, as highlighted in studies by De Koning et al. (2003) and Maugard et al. (2021). Furthermore, L-Serine has shown efficacy as an antibacterial agent (Duan et al. 2016), and it holds promise as an antioxidant and cytoprotective entity (Maralani et al. 2012). Its multifaceted nature extends to antifungal activities (Hua et al. 2021) and antiproliferative effects (Rathgeb et al. 2014).

Antibacterial activity of *E. longifolius*

The study examined the antibacterial potential of the 96% ethanol extract of *Elaeocarpus longifolius* against *Staphylococcus aureus* and *Shigella dysenteriae* (Figure 6 and Table 4). The results revealed a significant suppression of bacterial growth, indicating the extract's potent antibacterial attributes against both gram-positive and gram-negative bacteria. The inhibition zones against *S. aureus* ranged from 11.48±0.26 mm to an impressive 19.17±0.31 mm across concentrations of 2.5 mg/mL to 40 mg/mL, surpassing the positive control (9.91±0.43 mm). Similarly, against *S. dysenteriae*, the extract exhibited inhibition zones ranging from 14.67±0.53 mm to an impressive 23.78±0.57 mm, outperforming the chloramphenicol as positive control (10.27±0.75 mm). In general, it is noteworthy that the antibacterial activity of the extracts against gram-negative bacteria exhibited higher potency compared to their effect on gram-positive bacteria. Based on the statistical analysis conducted on the antibacterial activity of *E. longifolius* extract against *S. aureus* at concentrations ranging from 2.5 mg/mL to 40 mg/mL, as well as the positive control group, no significant differences were observed among these groups. Likewise, the statistical analysis for *S. dysenteriae* yielded similar results, indicating the absence of significant differences among the groups tested.

These outcomes underscore the potent antibacterial attributes of *E. longifolius* extract against both gram-positive and gram-negative bacteria. As elucidated by Balouiri et al. (2016), the *in vitro* antibacterial method serves as a practical and cost-effective tool for the preliminary assessment of plant extract pharmacology. Notably, this research validates the substantial pharmacological promise harbored by *E. longifolius*, thereby establishing a strong foundation for its potential utilization in antimicrobial applications. It is important to

note that these results represent the initial pharmacological confirmation conducted on *E. longifolius*. Two major constituents, specifically 6-Shogaol and Piperine, have exhibited antibacterial efficacy. To date, no existing publication has presented evidence of its pharmacological activity or the analysis of its phytochemical compounds. However, it is noteworthy that other species within the Elaeocarpaceae family showcase diverse pharmacological activities, often corroborated by their phytochemical compositions. These findings, coupled with the validation of the traditional use of *E. longifolius* as an anti-diarrheal agent, can serve as a broader platform for the potential development of this plant as a promising plant-based medicinal resource.

Table 4. Antimicrobial screening test of *E. longifolius* ethanolic extract against *S. aureus* and *S. dysenteriae*

Samples	Concentration (mg/mL)	Inhibition zones (mm)	
		Gram positive bacteria *S. aureus*	Gram negative bacteria *S. dysenteriae*
E. longifolius extract	2.5	11.48 ± 0.26	14.67 ± 0.53
	5	12.31 ± 0.42	16.18 ± 0.22
	10	13.42 ± 0.76	17.25 ± 0.89
	20	16.46 ± 0.10	18.11 ± 0.72
	40	19.17 ± 0.31	23.78 ± 0.57
Positive control (chloramphenicol)	0.5	9.91 ± 0.43	10.27 ± 0.75
Negative control (DMSO)	10	0 ± 0.00	0 ± 0.00

Note: Data are means of three replicates (n=3) ± standard deviation

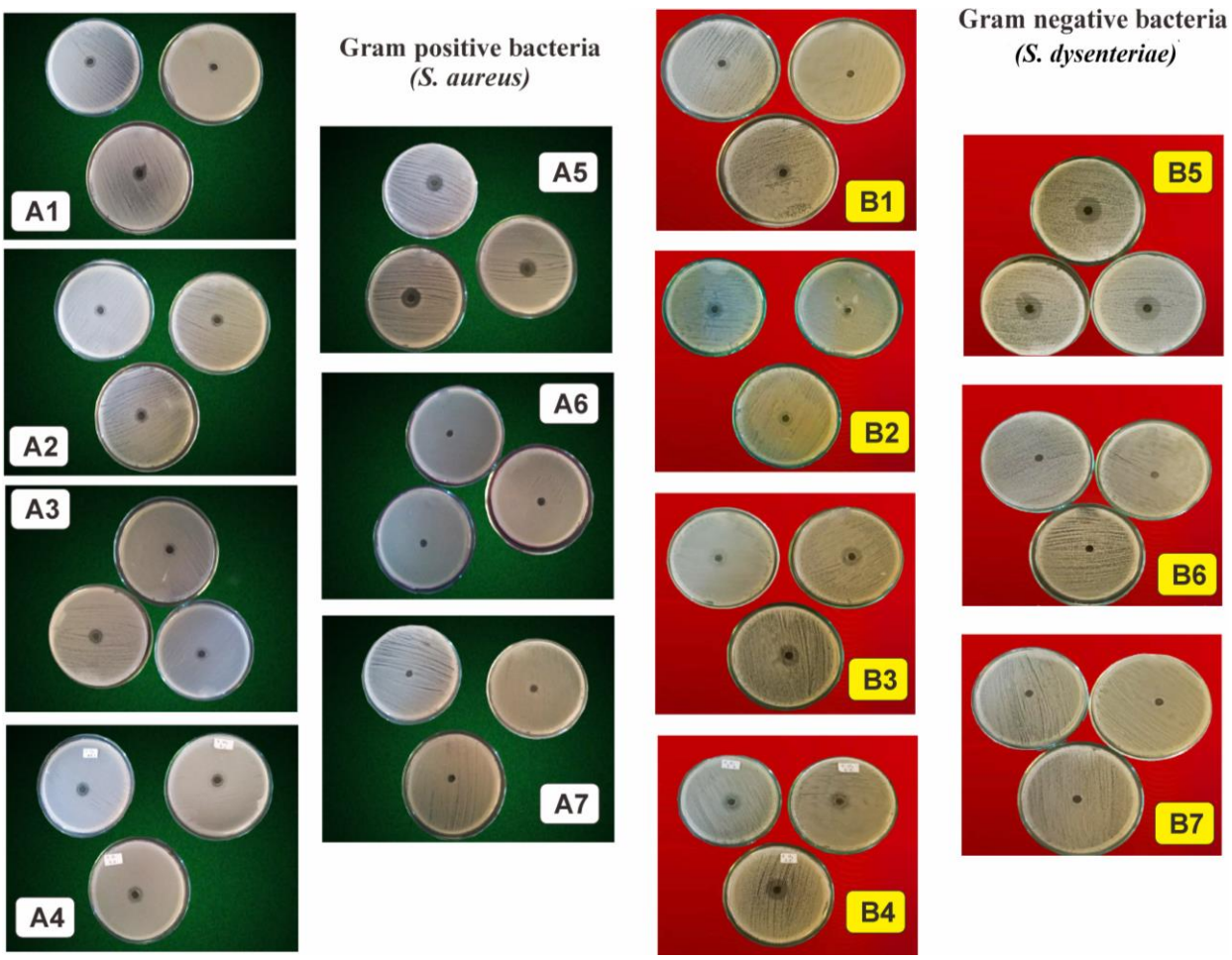

Figure 6. Antibacterial activity assessment using *E. longifolius* extract against *S. aureus* at concentrations of 2.5 mg/mL (A1), 5 mg/mL (A2), 10 mg/mL (A3), 20 mg/mL (A4), 40 mg/mL (A5), with corresponding negative control (A6) and positive control (A7). It also illustrates the results of the antibacterial activity test against *S. dysenteriae* at concentrations of 2.5 mg/mL (B1), 5 mg/mL (B2), 10 mg/mL (B3), 20 mg/mL (B4), 40 mg/mL (B5), alongside the negative control (B6) and positive control (B7)

In conclusion, the area of Bromo Tengger Semeru National Park inhabited by the Tenggerese people, is rich in medicinal plants and requires further exploration. Medicinal plants still play an important role in this region, but traditional medicine used in this national park lacks ethnopharmacological evidence. Our ethnopharmacological exploration led us to document a remarkable array of 124 medicinal plant species spanning 54 families. Notably, Zingiberaceae emerged as the most prominent family in this regard. The prevalence of the reproductive healthcare category, followed by internal medical diseases, underlines the specific health concerns that traditional medicine seeks to address in this community. The part of the plant that is commonly used is the leaf, followed by the fruit. The most frequent form of preparation is the decoction, followed by the raw material. We found a species *Elaeocarpus longifolius*, that has a combination of high SUV and FL values. Thus, these plant species should be further considered for phytochemical and pharmacological studies. We found 25 phytochemical compounds and obtained information about their high pharmacological activity. Ultimately, these findings hold promise for the development of novel plant-derived therapeutic solutions that could benefit both the Tengger community and broader healthcare perspectives.

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