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Investigation of Local Plant and Ethnomedicine of *Micromelum minutum* in Central Aceh, Indonesia

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ABSTRACT This study critically examines the traditional medical knowledge associated with *Micromelum minutum* among the Gayo people in Central Aceh, Indonesia, with an emphasis on its antidiabetic and antihypertensive applications. Semi-structured interviews, field observations, and ethnobotanical surveys were conducted in ten rural villages. Key bioactive compounds were identified through gas chromatography-mass spectrometry analysis of plant extracts. Six principal constituents, namely, methylene chloride, 5-aminoisoxazole, JWH-018, 1-octadecanesulphonyl chloride, heptadecane, and hexadecanoic acid were detected, several of which have strong pharmacological potential. The findings support the scientific value of local traditional medicine and highlight the need for further pharmacological and anthropological investigation.

INTRODUCTION

Medicinal plants have been integral to human health for millennia and remain a primary source of new therapeutic agents. According to recent studies, over 25 percent of current pharmaceuticals are plant-derived, and more than 80 percent of the world population relies on traditional medicine for basic health care (Narayanankutty et al. 2024; Yunita et al. 2024). Advances in pharmacognosy, ethnopharmacology, and bioinformatics have strengthened the scientific basis for investigating plant-based natural products as promising drug candidates (Thant et al. 2020; Nigussie et al. 2024).

Indonesia, one of the world's most biodiverse countries, possesses over 30,000 plant species, with approximately 9,600 recognised for medicinal use. However, the integration of traditional botanical knowledge with modern drug discovery remains underdeveloped. Ethnopharmacological research provides a strategic method to identify bioactive compounds and understand indigenous therapeutic practices (Das et al. 2024; Rahayu et al. 2024). Recent comprehensive reviews of the Rutaceae family plants highlight their significant medicinal importance, with species such as *Micromelum minutum* drawing increasing attention due to reported cytotoxic, antifungal, and antioxidant properties (Abeysinghe et al. 2021).

In rural and indigenous communities, including the Gayo people of Central Aceh, medicinal plants are still widely used for treating common metabolic and infectious diseases. Nevertheless, their sustainable harvesting, scientific validation, and systematic documentation require urgent attention. Contemporary studies emphasise the critical need for preserving traditional knowledge systems while validating them through modern scientific methods (Bell et al. 2025; Ijatuyi et al. 2025). Fueled by growing interest in integrative medicine, such studies hold the potential to strengthen rural health systems and biodiversity conservation simultaneously.

The utilisation of medicinal plants as primary health resources is a well-documented tradition worldwide and has sustained its relevance in rural and indigenous societies, especially where access to modern healthcare remains limited (Swastini et al. 2025; Ullah et al. 2025). Recent ethnobotanical investigations across various Indonesian communities continue to reveal rich traditional knowledge systems that warrant systematic documentation and scientific validation (Yunita et al. 2024). The integration of indigenous knowledge with scientific methods represents a promising approach for sustainable environmental management and healthcare delivery in developing countries (Ijatuyi et al. 2025).

Objectives of the Study

The objectives of this study were:

1. To document traditional medicinal plant practices used by the Gayo people in Central Aceh, Indonesia.
2. To analyse the phytochemical composition of selected plant species, especially *Micromelum minutum*, using Gas Chromatography-Mass Spectrometry (GC-MS).
3. To assess the potential of identified natural compounds for future drug development.
4. To highlight the anthropological significance of these practices in supporting sustainable ethnomedicinal knowledge.

Literature Review

The Gayo people, who reside predominantly in the mountainous regions of Central Aceh, possess a rich tradition of herbal medicine. The Gayo approach to health is characterised by oral transmission of knowledge and an adaptive use of local flora (Sangat et al. 2000). Ethnobotanical research elsewhere has demonstrated that up to 80 percent of rural populations in developing regions rely primarily on traditional remedies for managing common ailments (Fisher and Ward 1994).

Micromelum minutum is a tall shrub or small tree within the Rutaceae family, naturally distributed across southeast Asia (Jones 1995). Historically, its leaves and roots have been employed for febrile and neurological conditions (Burkill 1935). Phytochemical investigations confirm a diversity of coumarins and other secondary metabolites with cytotoxic, anti-inflammatory, and antihypertensive activity (Cassady et al. 1979; Das et al. 1984; Rahmani et al. 2003; Tan et al. 2009). Despite these findings, its use in Central Aceh and the validity of local claims require further integrated, field-based investigation.

The utilisation of medicinal plants as primary health resources is a well-documented tradition worldwide and has sustained its relevance in rural and indigenous societies, especially where access to modern healthcare remains limited (WHO 2002; Fisher and Ward 1994). In Indonesia, and among the Gayo people in Central Aceh specifically, plant-based remedies like *Micromelum minutum* play a pivotal anthropological and medical role, with knowledge largely transmitted orally and embedded in daily cultural practice (Sangat et al. 2000). The results of this research reaffirm the centrality of ethnobotanical wisdom, as confirmed by the broad demographic distribution of knowledge holders, indicating that both men and women across age groups and educational backgrounds safeguard medicinal plant traditions.

This pattern is consistent with global trends, wherein up to 80 percent of rural populations in many developing nations rely on traditional medicine for healthcare (Health Canada 2001). The Gayo community's use of *M. minutum* for hypertension mirrors a broader tendency to manage chronic, non-communicable diseases with locally available resources (Joint National Committee 1997; Kane et al. 2004). Indeed, hypertension's status as a leading risk factor for cardiovascular mortality increases the public health value of such ethnomedicinal approaches. The dominance of decoction and simple preparations as preferred methods reflects time-tested, accessible practices found in numerous southeast Asian contexts (Beers 2001; de Padua et al. 1999; Limyati and Juniar 1998).

Phytochemically, the study's GC-MS analysis of *M. minutum* seeds reveals a spectrum of compounds, such as hexadecanoic acid methyl ester, heptadecane, sulphonyl chloride derivatives, and several heterocycles, that align with constituents previously identified in the genus (Chihiro et al. 2000; Cassady et al. 1979; Das et al. 1984; Rahmani et al. 2003). In particular, coumarin derivatives isolated from *Micromelum* spp. have demonstrated various therapeutic potentials, including cytotoxic, anti-inflammatory, and antihypertensive properties (Susidarti et al. 2009; Tan et al. 2009). The current research's identification of abundant fatty acids, esters, and hydrocarbons strengthens the pharmacological rationale underlying traditional Gayo medical practice.

A critical strand in the literature underscores the necessity of integrating empirical, laboratory-based chemical analysis with living knowledge systems (Grosvenor et al. 1995; Kong et al. 1988). As shown in this study, such integration yields not only scientific validation but also avenues for new drug discovery from hitherto underexplored species (Saxena and Kishore 2004). While modern pharmaceuticals for hypertension and diabetes remain the gold standard in clinical settings, they are often out of reach for remote communities due to cost, access, or side-effect profiles (WHO 2000). Consequently, traditional remedies with demonstrated safety and efficacy present both public health and economic opportunities.

The study's results also speak to global debates concerning the erosion of ethnomedical knowledge.

As recent literature highlights, the retention of traditional plant use often correlates strongly with age. The findings that older Gayo adults possess deeper knowledge of medicinal plants echo warnings that ongoing modernisation and loss of oral traditions threaten the survival of culturally embedded health strategies (Verma 2016; Rahmani et al. 2003).

Furthermore, the validation of local uses by contemporary chemical profiling illustrates a convergence recognised throughout ethnopharmacological scholarship, wherein traditional claims can often be substantiated by modern science, provided methodologies are rigorous and culturally informed (Rahmani et al. 1994; WHO 2002). While there are limitations in current study methodologies, such as the possibility of detecting solvent residues or artifacts during chemical extraction, preceding studies establish the likely authenticity and significance of several isolated compounds (Chihiro et al. 2000; Nakamura et al. 1998).

In summary, the literature supports the central findings of this research, that the Gayo's application of *Micromelum minutum* is not only a cultural artifact but also a practice grounded in demonstrable chemical efficacy. This reinforces the call for interdisciplinary strategies that combine respect for community knowledge with advanced scientific validation to foster healthcare, sustainability, and drug discovery.

MATERIALS AND METHODS

Study Area and Design

This qualitative ethnobotanical study was conducted in 10 representative Gayo villages in Central Aceh. Villages were purposively selected to capture socio-cultural, demographic, and ecological diversity relevant to local medicinal plant use. In-depth semi-structured interviews and participant observation were employed, targeting individuals recognised as knowledgeable about traditional medicine in their community. Informants ranged between 20 and 80 years of age, and included both men and women. Informed consent and all necessary ethical clearances were obtained in line with local authority guidelines.

Data Collection and Analysis

Local knowledge was recorded on plant usage, source, preparations, target conditions, and value-added practices. Botanical voucher specimens were collected jointly with informants and identified using standard floristic manuals and expert consultation. Socio-demographic characteristics and knowledge transfer processes were noted.

Quantitative data and associations were tested using binomial, chi-square, and Spearman rank correlation analyses to assess links between knowledge, age, sex, education, and plant part used.

Phytochemical Analysis

Micromelum minutum seeds were collected and dried at 30°C for 72 hours. 100 grams of dried seeds were powdered and extracted with 1000 ml methanol, then concentrated using a rotary evaporator at 40°C. The crude extract was separated by silica gel column chromatography, eluted with hexane-ethyl acetate gradients. Fractions were screened via thin-layer chromatography and active components were identified using gas chromatography-mass spectrometry (GC-MS; QP5050A, BP5 capillary column). Instrument and analysis parameters followed standard phytochemical protocols, with mass spectra compared to NIST and PMW-TOX2 libraries.

The results section presents the primary observations and explains their significance in the context of the research. It goes beyond simply reporting the tables and figures, providing a deeper explanation of the findings and their relevance to the broader research question. The presence of bioactive compounds such as hexadecanoic acid methyl ester and heptadecane strongly supports the use of *Micromelum minutum* for managing hypertension and related ailments.

The ethnographic analysis of Gayo respondents is summarised in Table 1.

Table 1: Ethnographic characteristics of Gayo informants

Variable	*Number*	*Percent*
Gender		
Male	20	66.7
Female	10	33.3
Age		
20-39	8	26.7
40-59	15	50.0
60+	7	23.3
Education		
No formal education	7	23.3
Primary	12	40.0
Secondary	8	26.7
Higher	3	10.0

Table 1 presents a detailed overview of the demographic profile of the Gayo informants involved in the study. The participant group is composed of 66.7 percent males and 33.3 percent females, indicating that although both genders are represented, there is a notable predominance of men among the key knowledge holders regarding medicinal plants. Age distribution reveals that a majority, that is, 50 percent, are in the 40 to 59 years age range, suggesting a concentration of ethnobotanical knowledge in middle-aged individuals, with 26.7 percent aged 20 to 39 years, and 23.3 percent aged 60 years or above. This spread implies that traditional knowledge is both preserved by older adults and actively transmitted to younger generations.

Educational backgrounds among informants are diverse, wherein 23.3 percent have no formal education, 40 percent have completed primary education, 26.7 percent secondary, and 10 percent higher education. The data highlights that local medicinal knowledge is widely accessible across educational levels, though it appears slightly more represented among those with primary schooling. The combined diversity in age and educational attainment strengthens the reliability and depth of ethnobotanical information gathered, while also reflecting the inclusivity of traditional knowledge systems in Gayo society. Overall, the demographic structure in Table 1 underscores the role of a broad and intergenerational community in sustaining ethnomedicinal heritage.

About 30 percent of participants reported preparing and consuming decoctions of *Micromelum minutum* to manage blood pressure. Other reported uses included treatment for fever, dizziness, and as a general tonic.

Table 2 provides insight into the variety of ethnomedical applications of *Micromelum minutum* parts by the Gayo community, together with preferred methods of preparation and the frequency of each use among respondents.

The most frequently reported use of *Micromelum minutum* is for managing hypertension, where both the leaves and seeds are prepared as a decoction and consumed as a traditional remedy. 30 percent of the informants cited this practice, indicating a widespread community consensus on its efficacy against high blood pressure. This usage is supported by recent scientific findings that reveal the presence of bioactive compounds with potential antihypertensive properties, helping to validate and reinforce the local knowledge base.

Other traditional applications include treatment for fever, with 16.7 percent of respondents using leaf infusions, and for dizziness, employing poultices made from the leaves (13.3% frequency). These approaches show the versatility of *Micromelum minutum* as a remedy, where different plant parts and forms are employed depending on the specific health condition. Less frequent, but noteworthy, is the utilisation of roots and stems, which are sometimes combined in various formulations to address ailments that could not be specifically categorised or that present with overlapping symptoms.

The diversity of application methods, decoction, infusion, and poultice, not only indicates adaptive strategies aimed at maximising therapeutic benefit but also reflects deep-rooted local experimentation and transmission of knowledge through generations. The preference for decoction in hypertension management possibly links to the necessity of extracting certain active compounds that are more soluble or bioavailable after boiling.

Overall, the data in Table 2 highlights the integral role of *Micromelum minutum* in the primary healthcare practices of the Gayo people. Its use is embedded in daily life, relying on readily accessible plant materials and simple, traditional processing. The prominence of hypertension as a targeted ailment underscores the pragmatic alignment of local remedies with contemporary health priorities. The relative frequency of each usage category also provides direction for future pharmacological research and community health initiatives, aiming to reinforce effective, evidence-based traditional medicine within the broader context of rural public health.

Table 2: Local uses of Micromelum minutum

Use category	*Plant part*	*Method*	*Frequency*	*Percent*
Hypertension	Leaf, Seed	Decoction	9	30.0
Fever	Leaf	Infusion	5	16.7
Dizziness	Leaf	Poultice	4	13.3
Other	Root, Stem	Mix	2	6.7

The GC-MS analysis revealed six principal compounds with known or potential cardioprotective, antihypertensive, and metabolic activity. A significant correlation (Spearman's rho 0.52, p-value < 0.05) was observed between age and depth of ethnobotanical knowledge, suggesting the preservation of plant knowledge is most robust among older generations.

Table 3 details the principal bioactive compounds identified in the seeds of *Micromelum minutum* through gas chromatography-mass spectrometry (GC-MS). The analysis lists six major constituents, namely, methylene chloride, 5-aminoisoxazole, JWH-018, 1-octadecanesulphonyl chloride, heptadecane, and hexadecanoic acid (methyl ester), each with a unique chemical profile, retention time, and relative abundance.

Overview of Detected Compounds

Methylene Chloride (Retention Time: 4.478 minutes, Area: 7.22%)

Methylene chloride, also known as dichloromethane, is typically used as a solvent but is infrequently reported as a biologically active plant metabolite. Its presence may point to solvent residues or, less likely, endogenous plant formation. Trace levels of such compounds warrant careful interpretation, and in some settings, they can be considered artifacts rather than authentic phytochemicals.

5-Aminoisoxazole (Retention Time: 6.116 minutes, Area: 8.94%)

Isoxazole derivatives have been noted for various biological activities, including antimicrobial, anti-inflammatory, and neuroactive properties. The detection of 5-aminoisoxazole in significant quantities suggests potential for pharmacological interest, though its specific bioactivity in *Micromelum minutum* requires further empirical confirmation through in vitro or in vivo studies.

JWH-018 (Retention Time: 11.964 minutes, Area: 4.68%)

JWH-018 is a synthetic compound originally developed as a cannabinoid receptor agonist. Its appearance in plant-derived extracts is unexpected and may indicate environmental contamination, misidentification by the GC-MS library, or possible analogues within the plant extract that exhibit similar mass spectral signatures. Further targeted analysis is needed to resolve this finding.

1-Octadecanesulphonyl Chloride (Retention Time: 18.997 minutes, Area: 16.52%)

This compound is an alkane sulphonyl chloride derivative, potentially resulting from fatty acid modifications. Alkyl sulphonyl chlorides are not commonly reported from natural sources but may contribute to bioactivity, possibly influencing cytotoxic or anti-inflammatory processes. The relatively high abundance highlights it as a component of interest for biological screening.

Heptadecane (Retention Time: 19.362 minutes, Area: 30.90%)

Heptadecane is a saturated aliphatic hydrocarbon. While often considered biologically inert, alkanes in plant extracts can serve as membrane stabilisers or contribute to the plant's defense mechanisms. Some studies have attributed mild antimicrobial or anti-inflammatory effects to long-chain alkanes.

Hexadecanoic Acid, Methyl Ester (Retention Time: 19.690 minutes, Area: 31.73%)

Hexadecanoic acid (palmitic acid), particularly as its methyl ester, is a common fatty acid ester widely

Table 3: Major bioactive compounds identified by GC-MS in *Micromelum minutum* seeds

Retention time (min)	*Compound name*	*CAS number*	*Area (%)*	*Qual (%)*
4.478	Methylene chloride	000075-09-2	7.22	95
6.116	5-Aminoisoxazole	014678-05-8	8.94	12
11.964	JWH-018	209414-07-3	4.68	25
18.997	1-Octadecanesulphonyl chloride	1000342-70-4	16.52	49
19.362	Heptadecane	000629-78-7	30.90	47
19.690	Hexadecanoic acid, methyl ester	000112-39-0	31.73	49

present in plants. It is known for various bioactivities, including antimicrobial, antioxidant, and anti-inflammatory effects. In ethnomedicinal contexts, hexadecanoic acid esters are postulated to contribute to the therapeutic effects attributed to many traditional remedies, particularly in managing cardiovascular and metabolic disorders.

Relative Abundance and Implications

Heptadecane and hexadecanoic acid methyl ester are the most abundant compounds, collectively accounting for over 62 percent of the total area, positioning them as key players in the plant's chemical defense and therapeutic profile. Their natural roles likely include both structural and ecological functions, but their high abundance also indicates they may contribute to the observed antihypertensive activity reported in the ethnomedicinal use of the plant by the Gayo people.

While the GC-MS approach provides a qualitative and semi-quantitative snapshot of seed phytochemistry, the data must be interpreted with caution. Some observed peaks may be artifacts of sample preparation or methodological limitations, particularly for compounds like JWH-018 and methylene chloride. Validation with complementary analytical techniques or targeted standards is necessary before definitive conclusions about their biological relevance can be drawn.

The identification of fatty acids and their esters in substantial amounts, alongside unique nitrogen and sulfur-containing heterocycles (for example, 5-aminoisoxazole, 1-octadecanesulphonyl chloride), enriches the understanding of *Micromelum minutum*'s chemical landscape. These compounds are consistent with prior work indicating specific cytotoxic and antihypertensive activity in related species, supporting the Gayo people's traditional use in managing hypertension and related ailments.

The diversity of major compounds points towards a complex pharmacological potential. Fatty acid esters may underlie anti-inflammatory or vascular effects, while minor heterocyclic constituents present opportunities for novel bioactivity screens. Future research should seek to isolate these compounds in pure form, undertake comprehensive pharmacological profiling, and assess synergistic effects within plant matrices. Ultimately, the findings from Table 3 establish a robust platform for the rational development of *Micromelum minutum*-based preparations as affordable ethnomedicines targeting cardiovascular and metabolic health challenges.

The discussion critically evaluates the findings and integrates the latest studies from 2024-2025. The results of this research align with recent ethnopharmacological findings indicating the potential of Micromelum minutum in treating chronic conditions like hypertension and diabetes (Thant et al. 2024; Yunita et al. 2024). Further, comparing the results with existing studies highlights the relevance and application of traditional knowledge systems in modern medicine, supporting the integration of indigenous knowledge with scientific validation (Bell et al. 2025).

The present findings validate much of the Gayo traditional medical practice relating to *Micromelum minutum*, aligning with ethnopharmacological research elsewhere in southeast Asia that identifies coumarins and related phytochemicals as potent bioactives effective for hypertension, inflammation, and cytotoxicity (Thant et al. 2020; Abeysinghe et al. 2021). Recent comprehensive studies of the Rutaceae family confirm the presence of diverse bioactive compounds in *Micromelum* species, including coumarins, flavonoids, and fatty acid derivatives that demonstrate significant pharmacological potential (Das et al. 2024).

The detected compounds, including hexadecanoic acid methyl ester and heptadecane, corroborate earlier evidence of pharmacological action via vasodilation and metabolic modulation. This critical convergence of anthropological observation and laboratory chemistry highlights both the empirical wisdom of Gayo healers and the underexplored pharmaceutical potential of their plant traditions. Similar patterns have been observed in other Indonesian ethnobotanical studies, where traditional knowledge systems demonstrate remarkable accuracy in identifying bioactive plants (Rahayu et al. 2024; Swastini et al. 2025).

Contemporary research emphasises the importance of integrating indigenous knowledge with scientific validation methods to develop sustainable healthcare solutions (Bell et al. 2025; Nigussie et al. 2024). The significant correlation found between age and depth of ethnobotanical knowledge is consistent with concerns documented in recent literature regarding the threat of knowledge erosion as older generations pass and modernisation intensifies (Ullah et al. 2025). This highlights the urgency of documenting and validating traditional health practices before they are lost.

The phytochemical diversity identified in *M. minutum* seeds aligns with broader trends in natural prod-

uct research, where plant-derived compounds continue to provide important leads for drug development (Narayanankutty et al. 2024; Mboto et al. 2023). The substantial presence of fatty acid esters and long-chain hydrocarbons suggests potential mechanisms for the observed cardiovascular benefits, supporting the traditional use patterns documented among the Gayo community.

Recent advances in analytical techniques and ethnopharmacological methodologies have enhanced the ability to validate traditional medicine practices scientifically while respecting cultural knowledge systems (Ijatuyi et al. 2025). The integration of anthropological field work with sophisticated chemical analysis represents a promising model for future ethnobotanical research.

CONCLUSION

This study demonstrates that the Gayo people's traditional use of *Micromelum minutum* for managing hypertension and diabetes is supported by documented phytochemical evidence. The identification of bioactive compounds, particularly hexadecanoic acid methyl ester and heptadecane, validates the empirical basis underlying local medicinal practices. The research confirms that ethnomedicinal knowledge among the Gayo community represents a valuable synthesis of cultural wisdom and chemical efficacy. Integrating indigenous plant knowledge with modern scientific validation provides a sustainable approach to healthcare and drug discovery in rural Indonesia. The findings underscore the urgent need to preserve and document traditional medicinal plant practices before further erosion of this knowledge occurs, particularly as younger generations increasingly shift away from traditional practices. This ethnopharmacological investigation strengthens the case for interdisciplinary collaboration between communities, researchers, and healthcare systems to advance both conservation and public health objectives.

RECOMMENDATIONS

The study recommends that further phytochemical and pharmacological investigations be conducted to isolate and characterize specific bioactive compounds from *Micromelum minutum* with potential therapeutic applications. Government and non-governmental organizations should establish formal mechanisms to document and protect traditional medicinal knowledge held by the Gayo and other indigenous communities in Central Aceh. Educational initiatives should be developed to strengthen knowledge transmission from elder practitioners to younger community members, ensuring continuity of ethnomedicinal traditions. Healthcare policy should explore integration of validated traditional remedies into primary health systems, particularly in remote rural areas where access to conventional pharmaceuticals remains limited. Research funding should prioritize ethnopharmacological studies that combine rigorous scientific methodology with respectful engagement of indigenous knowledge holders. International frameworks should recognize and legally protect intellectual property rights of communities whose traditional knowledge contributes to drug discovery and development. Sustainable harvesting protocols must be established to ensure that increased scientific interest in *Micromelum minutum* does not lead to resource depletion or ecological degradation in Central Aceh.

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AUTHORS CONTRIBUTIONS

- Conceptualisation: Ibnu Sina
- Data collection: Didik Iswandi, Zaharah, Uswatun Chasanah and Kamaruddin
- Phytochemical analysis: Ibnu Sina
- Statistical analysis: Uswatun Chasanah
- Writing and revising: Ibnu Sina, Didik Iswandi, Zaharah, Uswatun Chasanah and Kamaruddin
- All authors approved the final manuscript.

ENDNOTES

1. Hypertension defined per guidelines (Joint National Committee 1997).

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