Indonesian Journal of Chemical Science and Technology (IJCST)

State University of Medan, https://jurnal.unimed.ac.id/2012/index.php/aromatika

IJCST-UNIMED 2026, Vol. 09, No. 1, Page; 150 – 157

Received : Nov 28nd, 2025 Accepted : Jan 24th, 2026 Web Published : Jan 31st, 2026

Chemical Composition and Quality Parameters of Citronella (*Cymbopogon nardus*) Essential Oil Based on GC–MS and Physicochemical Analysis

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ABSTRACT

Citronella (Cymbopogon nardus (L.) Rendle) essential oil is widely utilized in the perfume, cosmetic, and pharmaceutical industries, primarily due to its high content of citronellal, geraniol, and citronellol. This study aimed to evaluate the chemical composition and quality parameters of citronella essential oil using gas chromatography–mass spectrometry (GC–MS) and physicochemical analysis. The oil sample was obtained by steam distillation of fresh leaves and subsequently characterized in terms of specific gravity, refractive index, optical rotation, and flash point, while the chemical composition was determined based on GC–MS chromatogram peak areas. The physicochemical analysis showed a specific gravity of 0.894, refractive index of 1.477, optical rotation of −6.59°, and a flash point above 80 °C, indicating compliance with quality standards for citronella essential oil. GC–MS analysis identified 21 compounds, with trans-geraniol (70.65%), geranyl acetate (7.70%), β-citronellol (3.17%), and citronellal (1.78%) as the major constituents. These findings confirm that steam-distilled citronella essential oil exhibits good quality and a chemical profile that supports its potential for essential oil-based industrial applications.

Keywords: citronella essential oil; GC–MS; chemical composition; physicochemical properties; quality parameters

1. INTRODUCTION

Citronella (*Cymbopogon nardus*) essential oil is one of the major essential oils widely used in the perfume, cosmetic, and pharmaceutical industries due to its aromatic constituents, such as citronellal, geraniol, and citronellol.[1, 2] Commercially, citronella oil derived from *Cymbopogon* species is classified into two main chemotypes, namely the Ceylon type and the Java type, each of which exhibits a distinct compositional profile.

e-ISSN : 2622-4968, p-ISSN : 2622-1349

The Ceylon type (*C. nardus*) generally contains approximately 18–20 % geraniol, 5–15 % citronellal, 6–8 % citronellol, and 9–11 % limonene.[3, 4] In contrast, the Java type (*C. winterianus*) is characterized by a higher citronellal content of 32–45 %, accompanied by 21–24 % geraniol, 3–8 % geranyl acetate, and 11–15 % citronellol.[5, 6] These differences are practically significant, for instance, the Indonesian National Standard (SNI) for Java-type citronella oil requires a minimum citronellal content of 35 %, as this component plays a crucial role in determining aroma quality and market value in the perfume and aromatherapy industries.

Indonesia is one of the major global producers of citronella oil, along with Sri Lanka, India, and China. National production centers are distributed across North Sumatra, West Java, Central Java, and Aceh [7, 8], supported by relatively simple cultivation systems, as *Cymbopogon* species grow optimally in tropical climates and have a short harvesting cycle of 2–3 months. Data from the Central Bureau of Statistics indicate that the cultivated area of citronella continues to increase in line with the growth of the essential oil industry and the high demand in the global market.[9] The year-round availability of raw materials positions citronella oil as a strategic commodity for both domestic and export markets, while also supporting the development of value-added products through downstream essential oil industries.

GC–MS analysis has been widely employed to identify the chemical composition of citronella oil. Previous studies have reported compositional variations, such as geraniol (35.7 %), trans-citral (22.7 %), cis-citral (14.2 %), geranyl acetate (9.7 %), citronellal (5.8 %), and citronellol (4.6 %).[10] Other studies have reported citronellal (24.57 %), citronellol (11.69 %), and geraniol (15.59 %) in samples obtained from West Sumatra.[11] Alternative approaches involving oil fractionation have also demonstrated high concentrations of citronellal, citronellol, and geraniol in specific fractions. In addition to chemical composition, physicochemical parameters such as specific gravity and refractive index serve as important indicators of oil quality. Several studies have reported typical values of approximately 0.89–0.90 for specific gravity and 1.47 for refractive index at 20 °C, which are considered to comply with industrial standards.[12, 13]

Although numerous studies have independently examined GC–MS composition and physicochemical properties, only limited research has systematically integrated both approaches by combining physicochemical and GC–MS data within a single comprehensive investigation. Therefore, this study offers a distinct contribution by aiming to: (1) evaluate the chemical composition of citronella oil using GC–MS, (2) measure physicochemical quality parameters including specific gravity, refractive index, optical rotation, and flash point, and (3) compare the results with the Indonesian national quality standards.

2. EXPERIMENTAL

2.1. Chemicals, Equipment and Instrumentation

Citronella (*C. nardus*) essential oil of the Aster variety was obtained through steam distillation of fresh leaves collected in West Java, Indonesia. The chemicals used included 80% v/v ethanol (analytical grade, Merck) for solubility testing, as well as reagents and helium carrier gas (99.99%, UHP grade) for GC–MS analysis. The main equipment comprised a pycnometer (Pyrex, 10 mL capacity) for specific gravity measurement, an Abbe refractometer (ATAGO DR-A1) for refractive index determination, a digital polarimeter (Atago POLAX-2L) for optical rotation measurement, and a Cleveland Open Cup flash point tester (Seta Series 3). GC–MS analysis was performed using a Shimadzu GC-2010 Plus gas chromatograph coupled

e-ISSN : 2622-4968, p-ISSN : 2622-1349

with a Shimadzu QP2010 Ultra mass detector and equipped with a DB-5MS capillary column (30 m × 0.25 mm × 0.25 µm).

2.2. Research Procedure

2.2.1. Physicochemical Analysis

Physicochemical properties were evaluated according to the methods specified in SNI 3953:2019 for Java-type citronella essential oil. Specific gravity was measured at 20 °C using a pycnometer, while the refractive index was determined at 20 °C with a calibrated refractometer. Optical rotation was measured at 20 °C using a digital polarimeter. The flash point was determined using the Cleveland Open Cup method in accordance with SNI 3953:2019. Solubility in 80% v/v ethanol was assessed by mixing one volume of oil with ethanol at graded ratios ranging from 1:1 to 1:3, followed by visual observation of solution clarity.

2.2.2. GC–MS Analysis

The oil sample was filtered and injected into a Shimadzu GC-2010 gas chromatograph coupled with a GCMS-QP2010 Ultra mass spectrometer. The injection mode was split with a ratio of 1:40, injector temperature of 250 °C, and pressure-controlled flow mode at 24.9 kPa, with a total flow of 31.7 mL/min, column flow of 0.70 mL/min, purge flow of 3.0 mL/min, linear velocity of 30.2 cm/s, and the carrier gas saver set to off. Separation was achieved using an apolar 5% phenyl–methylpolysiloxane capillary column equivalent to DB-5MS. The oven temperature program was set at 40.0 °C with a hold time of 3.00 min, increased at a rate of 5.00 °C/min to 250.0 °C with a final hold of 5.00 min, and an equilibrium time of 3.0 min. The mass spectrometer was operated with an ion source temperature of 200 °C, interface temperature of 250 °C, solvent cut time of 0.50 min, scan acquisition mode over an m/z range of 30–800, scan speed of 3333, event time of 0.30 s, start time of 4.00 min and end time of 50.00 min, and detector gain mode relative to tuning at 0.99 kV. Compound identification was performed by matching mass spectra with the Wiley.7 MS library and considering retention times, while component composition was reported as percentage peak area. In accordance with SNI 3953:2019 referring to ISO 11024, chromatographic profiles were used to evaluate quality marker components.

2.2.3. Data Analysis

Physicochemical data were compared with the value ranges specified in SNI 3953:2019. The percentages of the major chemical components were determined based on the peak area percentages of the GC–MS chromatogram, and the results were compared with SNI quality standards and relevant literature.

3. RESULTS AND DISCUSSION

3.1. Physicochemical Parameters of Citronella Essential Oil

The evaluation of physicochemical parameters of citronella essential oil was conducted to assess its quality based on standardized quality criteria. According to SNI 3953:2019 for Java-type citronella essential oil, physicochemical parameters such as specific gravity, refractive index, optical rotation, solubility in ethanol, and flash point are important indicators reflecting oil purity, chemical composition, and stability. These parameters are influenced by several factors, including plant genetic characteristics, raw material maturity, distillation methods, and storage conditions. The assessment of physicochemical parameters is not only

e-ISSN : 2622-4968, p-ISSN : 2622-1349

essential for ensuring compliance with national quality standards but also for identifying characteristic differences among chemotypes and detecting potential adulteration or oil degradation during production and distribution.

Physicochemical testing was performed to evaluate the conformity of citronella essential oil quality with the requirements of SNI 3953:2019. The results of the physicochemical analysis are presented in Table 1.

Table 1. Physicochemical parameters of Aster variety citronella essential oil compared with SNI 3953:2019.

Parameter	Test Result	SNI 3953:2019 Requirement (Java Type)	Remark
Specific gravity (20 °C)	0.894	0.880 – 0.900	Complies
Refractive index (20 °C)	1.477	1.466 – 1.476	Slightly above the limit
Optical rotation (20 °C)	–6.59°	–5° to –15°	Complies
Flash point (°C)	>80	≥70	Complies
Solubility in 80% ethanol	1:3 clear	1:1 – 1:3 clear	Complies

The results indicate that almost all physicochemical parameters fall within the ranges specified by SNI, except for the refractive index, which is slightly higher (1.477) than the upper limit (1.476). The increase in refractive index may be attributed to the high content of unsaturated alcohol compounds such as geraniol and the relatively significant ester content, particularly geranyl acetate, which can influence the optical properties of the oil. Furthermore, the refractive index value at 20 °C of 1.477, which is marginally above the SNI limit for the Java type (1.466–1.476), represents a deviation of +0.001 that may be caused by several factors, including the high concentration of oxygenated compounds or terpenols such as geraniol and citronellol, the possible contribution of sesquiterpenes that tend to increase refractive index values, measurements conducted at temperatures slightly above 20 °C or less precise refractometer calibration, as well as mild oxidation processes producing peroxides or allylic alcohols, or the presence of residual solvents.

3.2. Chemical Composition of Citronella Essential Oil Based on GC–MS

Analysis of the chemical composition of citronella essential oil using gas chromatography–mass spectrometry (GC–MS) is a standard technique for the identification and quantification of volatile compounds in essential oils. According to the literature, citronella oil derived from *Cymbopogon nardus* (Ceylon chemotype) generally exhibits a high geraniol content (approximately 18–20 %), accompanied by lower citronellal levels (5–15 %), geranyl acetate (approximately 2 %), citronellol (6–8 %), and limonene (9–11 %).[14] In contrast, the Java variety (*Cymbopogon winterianus*) shows a distinct profile characterized by a much higher citronellal content (32–45 %), geraniol at 21–24 %, and geranyl acetate at 3–8 %.[15]

Based on the GC–MS analysis, the chromatographic profile of the Aster variety citronella essential oil revealed the presence of 26 volatile compound peaks with varying intensities (Figure 1). The dominant peak appeared at a retention time of 21.242 min and was identified as trans-geraniol, accompanied by other notable peaks such as geranyl acetate at 24.811 min and β-citronellol at 20.201 min.

e-ISSN : 2622-4968, p-ISSN : 2622-1349

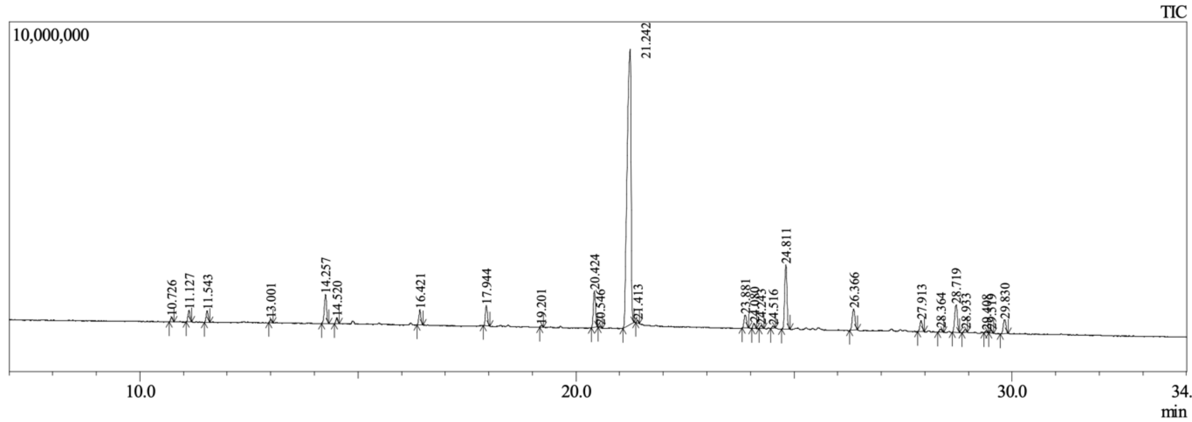

Figure 1. GC–MS chromatogram of Aster variety citronella essential oil (*C. nardus* var. Aster).

GC–MS analysis identified 26 compounds constituting the Aster variety citronella essential oil. The dominant components included trans-geraniol (70.65%), geranyl acetate (7.70%), β-citronellol (3.17%), and citronellal (1.78%), as presented in Table 2. The GC–MS results in this study demonstrate a compositional profile that closely corresponds to the Ceylon chemotype, characterized by a dominant geraniol content (70.65%) accompanied by geranyl acetate (7.70%) and a low citronellal level (1.78%), thereby reinforcing the classification of the Aster variety as a Ceylon chemotype. These findings are consistent with general reports indicating that compositional conformity between samples and chemotypes supports varietal classification and potential market applications.

The remarkably high dominance of geraniol in the Aster variety citronella essential oil (70.65%) provides broad opportunities for applications in the pharmaceutical, cosmetic, and personal care industries. Geraniol is known to exhibit antibacterial, antifungal, antioxidant, and moisturizing properties, making it suitable as an active ingredient in skincare products such as creams, lotions, and masks.[16, 17] In addition, other studies have reported that geraniol is widely used in industry due to its high safety profile, environmentally friendly nature, and low toxicity characteristics.[17] Therefore, the Ceylon chemotype characteristics of the Aster variety, with its high geraniol content, may be exploited as a natural preservative and antibacterial agent in the formulation of safer and more functional personal care products.

Table 2. Major chemical composition of Aster variety citronella essential oil

No.	Compound Name	Molecular Formula	% Area	Compound Group
1	trans-Geraniol	C10H18O	70.65	Monoterpene alcohol
2	Geranyl acetate	C12H20O2	7.70	Monoterpene ester
3	β-Sitronellol	C10H20O	3.17	Monoterpene alcohol
4	Citronellal	C10H18O	1.78	Monoterpene aldehyde
5	Linalool	C10H18O	1.55	Monoterpene alcohol
6	Limonene	C10H16	1.43	Monoterpene hydrocarbon
7	Neral	C10H16O	1.21	Monoterpene aldehyde
8	Geranial	C10H16O	1.10	Monoterpene aldehyde
9	Myrcene	C10H16	0.98	Monoterpene hydrocarbon
10	α-Pinene	C10H16	0.87	Monoterpene hydrocarbon

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11	β-Pinene	C10H16	0.76	Monoterpene hydrocarbon
12	Camphene	C10H16	0.69	Monoterpene hydrocarbon
13	Terpinolene	C10H16	0.65	Monoterpene hydrocarbon
14	α-Terpineol	C10H18O	0.60	Monoterpene alcohol
15	Isopulegol	C10H18O	0.55	Monoterpene alcohol
16	Citronellyl acetate	C12H22O2	0.50	Monoterpene ester
17	β-Caryophyllene	C15H24	0.45	Sesquiterpene hydrocarbon
18	α-Humulene	C15H24	0.42	Sesquiterpene hydrocarbon
19	Germacrene D	C15H24	0.38	Sesquiterpene hydrocarbon
20	Bicyclogermacrene	C15H24	0.35	Sesquiterpene hydrocarbon
21	δ-Cadinene	C15H24	0.33	Sesquiterpene hydrocarbon
22	Caryophyllene oxide	C15H24O	0.30	Sesquiterpene oxide
23	Humulene epoxide II	C15H26O2	0.28	Sesquiterpene oxide
24	Globulol	C15H26O	0.25	Sesquiterpene oxide
25	Viridiflorol	C15H26O	0.20	Sesquiterpene oxide
26	Others	-	1.49	Compound mixture

According to SNI 3953:2019 for Java-type citronella essential oil, the minimum citronellal content for the Java chemotype is specified as ≥ 35%, whereas the Ceylon chemotype does not require a high citronellal content because its aromatic characteristics are primarily determined by the dominance of geraniol. Therefore, the compositional profile observed in this study confirms that the sample belongs to the Ceylon chemotype, which is recognized for its sweet floral aroma and better oxidative stability.

In addition, the presence of minor compounds such as linalool, limonene, myrcene, and sesquiterpenes (β-caryophyllene, germacrene D, and δ-cadinene) contributes to the aromatic complexity and potential biological activity of the oil. The content of monoterpene esters such as geranyl acetate further enhances the floral aroma and provides favorable solubility characteristics in perfume formulations. This profile differs significantly from that of Java-type citronella oil produced in Indonesia, which generally exhibits dominant citronellal peaks and lower geraniol content. A comparison among the three types is presented in Table 3.

Table 3. Comparison of major compound contents of Aster variety citronella essential oil with SNI 3953:2019 (Java type) and Ceylon-type literature data

Major Compound	**Sample Content (%)**	**SNI 3953:2019 Java Type (%)**	**Ceylon Type (%)** [14, 18]
Citronellal	1.78	>= 35.00	5.00 - 15.00
Geraniol	70.65	21.00 - 24.00	18.00 - 20.00
Geranyl acetate	7.7	3.00 - 8.00	~2.00
β-Citronellol	3.17	11.00 - 15.00	6.00 - 8.00

3.3. Comparison with Quality Standards

The chemical composition analysis of the Aster variety citronella essential oil indicates that the citronellal content is only 1.78%, which is far below the minimum requirement of ≥ 35% specified by SNI 3953:2019 for the Java chemotype. In contrast, the geraniol content reaches 70.65%, greatly exceeding the range of 21.00–

e-ISSN : 2622-4968, p-ISSN : 2622-1349

24.00% established for the Java type, while remaining consistent with the Ceylon chemotype profile reported to contain high geraniol levels (18–20%) and low citronellal content (5–15%). This very high dominance of geraniol confirms that the sample exhibits characteristics of the Ceylon chemotype, which is commonly utilized in the perfume industry due to its sweet floral aroma and better oxidative stability compared to the Java chemotype.[18–20]

From a physicochemical perspective, the values of specific gravity (0.894 g/mL), refractive index (1.471 at 20 °C), and optical rotation (+4.2°) fall within the SNI standard ranges for citronella essential oil, which specify 0.885–0.905 g/mL, 1.466–1.473, and +1° to +10° for the Java type, respectively. This indicates that although the chemical profile does not meet the criteria for the Java type, the physicochemical quality still satisfies the general requirements for high-quality citronella essential oil. The pronounced differences in the chemical composition of the Aster variety citronella oil, particularly the dominance of geraniol and the low citronellal content, can be explained by genetic factors, agroclimatic conditions, as well as harvesting and distillation techniques.[5] The composition of essential oils among different *Cymbopogon* species is strongly influenced by genetic and environmental factors.[21, 22]

4. CONCLUSION

This study demonstrates that the Aster variety citronella essential oil exhibits a chemical profile characteristic of the Ceylon chemotype, with dominant geraniol content (70.65%), followed by geranyl acetate (7.70%) and β-citronellol (3.17%), along with a very low citronellal content (1.78%). The physicochemical parameters, including specific gravity (0.894 g/mL), refractive index (1.471 at 20 °C), and optical rotation (+4.2°), fall within the ranges specified by SNI 3953:2019 for Java-type citronella essential oil. However, in terms of chemical composition, the sample does not meet the criteria for the Java chemotype due to its citronellal content being below the established minimum. These differences highlight the importance of applying quality standards that consider chemotype variation, allowing Ceylon-type citronella oil to be evaluated and marketed based on relevant quality parameters, particularly for perfume, cosmetic, and aromatherapy industries requiring a sweet floral aroma and high oxidative stability.

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