



Chemical and Functional Group Profiling of *Eucalyptus globulus* Essential Oil from Zaria, Nigeria

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Abstract

The chemical composition and functional group profiling of essential oil of *Eucalyptus globulus*, which was obtained in Zaria, Kaduna State, Nigeria, were studied by gas chromatography-mass spectrometry (GC-MS) and Fourier transform infrared (FTIR). As far as we are aware, *E. globulus* oils have been reported in more extensive areas of Nigeria, but this is the first study to report a concerted GC-MS and FTIR dataset of Zaria in particular, thus providing a constituted baseline phytochemical information to the area. The GC-MS analysis with the peak areas normalized to 100% revealed that the domineating constituent was the eucalyptol (1, 8 -cineole) (49.27), followed by 2-terpineol (14.35), 3-terpinene (9.91), endo-borneol (4.96), fenchol (3.84) camphene (2.36), 2 -pinene (2.03), myrcene (1.74), 2 - The existence of oxygenated monoterpenes was supported by FTIR spectroscopy with the characteristic OH, C O and C H absorption bands. The relatively lower composition of 1,8-cineole in comparison to reports in certain foreign countries supports the fact that local edaphic, climatic and agronomic factors may indeed impact essential oil composition. This work, with rigorously normalized quantitative profiling and FTIR functional-group validation, provides validated chemoprofiling data, which can be used to inform chemotaxonomic comparisons and aid initial assessment of Zaria-derived *E. globulus* oil in pharmaceutical, cosmetic and industrial applications. These background data will inform future studies in the region, sustainable valourization and conservation of the same at the local level.

Keywords: *Eucalyptus globulus*, Essential oil, GC-MS, FTIR spectroscopy, Monoterpenes, Eucalyptol.

Introduction

Essential oils are complicated blends of volatile secondary metabolites, mostly mono- and sesquiterpenes, and their oxidised analogues that play a role in the biological functions and commercial worth of aromatic plants. Recent

efforts have highlighted the therapeutic and preservative abilities of essential oils, and this has prompted a new interest in effective chemical characterization to enhance safe and effective usage [1]. The genus *Eucalyptus* (Myrtaceae) is a widely grown source of industrially useful oils;

Eucalyptus globulus is a particularly popular cultivated source of volatile fraction, which is often dominated by the oxygenated monoterpene 1,8-cineole (eucalyptol). Antimicrobial, anti-inflammatory and mucolytic applications in pharmaceutical preparations and food preservations have been associated with high 1,8-cineole chemotypes of *E. globulus* [2].

Nevertheless, the genotype, geographic origin, edaphic factors, phenological stage and harvest season highly affect the composition of essential oils, e.g., the same species can produce different chemotypes in various sites. A number of recent GCMS studies and metabolomic analyses have shown that the chemical profiles of *E. globulus* vary significantly between regions and seasons within and among species, with significant implications on bioactivity and utilization [3 and 5]

In Nigeria, GC-MS analysis of *E. globulus* in selected areas of the North-Central region have recorded inconsistent profiles - at times with high proportions of terpinen-4-ol or γ -terpinene - indicating the importance of location-specific baseline data to inform consumption and comparison with other chemotypes across nations [4]. However, as at the time of this research, no published research has used normalized quantitative GC-MS profiled paired with a complementary FTIR functional-group

verification of *E. globulus* that is sourced specifically at Zaria, Kaduna State. The significance of creating such a combination of such data is as follows: (i) such data sets can be used to set reproducible local chemoprofiles of chemotaxonomic and application-level analysis (ii) such data can be compared directly with oils in other regions and seasons, (iii) such data serve to inform initial appraisals of local agronomic feasibility of pharmaceutical, cosmetic, or industrial applications.

Based on this, the current study presents the first GC-MS and FTIR analysis of *Eucalyptus globulus* essential oil grown in Zaria. Data on major constituents, normalized at 100% of its rigorous peak areas, to confirm these results with FTIR functional-group assignments were also determined. By connecting quantitative composition with functional-group signature data, the work presents validated baseline phytochemical data of Zaria-sourced *E. globulus* and comments on the potential environmental and agronomic forces behind the observed chemotype.

Materials and Methods

Sample Collection

Fresh *Eucalyptus globulus* were obtained on August 15, 2025 from the National Research Institute of chemistry Technology, Zaria, Kaduna State in Nigeria (11°10' N, 7°38' E). 2000 g of

fresh *Eucalyptus globulus* leaves were hydro-distilled using a Clevenger-type apparatus equipped with 100 mg of 1.5 L of distilled water to yield the distilled product at room temperature (100 °C) for 3 hrs. The extract product (yield: 1.5% v/w, 30 mL) stored in amber glass bottles at -4 °C [6].

Extraction and Yield Calculation

The percentage yield of the essential oil was calculated relative to the fresh weight of the leaves using the formula:

$$\text{Yield (\% v/w)} = (\text{Volume of oil obtained} / \text{Weight of fresh leaves}) \times 100.$$

A total of 30 mL of pale-yellow essential oil was obtained from 2000 g of fresh leaves, giving a yield of 1.5% (v/w).

GC-MS Analysis

The oil was analyzed using a Shimadzu GC-MS QP2010 Ultra with an Rtx-5MS column (30 m × 0.25 mm, 0.25 µm). 1 mL oil sample was diluted

to 100 mL with n-hexane, and 1 µL of the resulting solution (1:100 dilution) was injected in split mode with a 5:1 split ratio. Helium served as the carrier gas at a flow rate of 2.5 mL/min, with an injector temperature of 250 °C. The oven temperature was programmed starting at 60°C, held for 3 minutes, then ramped gradually to 240°C (rate unspecified, assumed 10°C/min unless otherwise indicated), and held for a duration sufficient for analysis (typically until all peaks elute, e.g., 10–20 minutes depending on the sample [7].

FTIR

Fourier Transform Infrared (FTIR) spectroscopy was carried out on a PerkinElmer Spectrum Two spectrometer using an attenuated total reflectance (ATR) accessory using a diamond crystal. A protein oil sample was pipetted directly onto the ATR crystal and spectra were taken in the 4000-400 cm⁻¹ range with a resolution of 4 cm⁻¹ across 16 scans. Available literature data served to make the functional group assignments [8].

Result and Discussion

Table 1: Major compounds identified in the essential oil of *Eucalyptus globulus* by GC-MS analysis.

Retention Time (RT, min)	Compound Name	CAS No.	Raw Area %	Normalized % (100)
7.800	Camphene	79-92-5	1.44	2.36
8.239	β -Pinene	127-91-3	1.24	2.03
8.380	Myrcene	123-35-3	1.06	1.74
8.439–9.057	Eucalyptol (1,8-Cineole)	470-82-6	30.00	49.27
9.431	α -Phellandrene	99-83-2	1.15	1.89
9.808	γ -Terpinene	99-85-4	6.03	9.91
11.917	Fenchol	1632-73-1	2.34	3.84
14.365	endo-Borneol	507-70-0	3.02	4.96
15.755–15.826	α -Terpineol	98-55-5	8.73	14.35
24.866	Caryophyllene	87-44-5	1.57	2.58

The GC-MS analysis of essential oil of *Eucalyptus globulus* in Zaria showed that there were ten major compounds with retention times between 7.8 and 24.9 minutes (Table 1). Eucalyptol (1,8-cineole) was the major constituent, which constituted 49.27% of normalized composition. Other prominent ones were α -terpineol (14.35%), γ -terpinene (9.91%), endo-borneol (4.96%), and fenchol (3.84%). Camphene (2.36%), β -pinene (2.03%), myrcene

(1.74%), α -phellandrene (1.89%), and caryophyllene (2.58%), were minor constituents. The profile was generally characterized by oxygenated monoterpenes, especially versions of eucalyptol, and had strong but less representation as monoterpene hydrocarbons, including γ -terpinene and β -pinene. Sesquiterpene hydrocarbons were also found in limited levels, and included caryophyllene.

The chemical composition of *E. globulus* essential oil extracted in Zaria aligns with other researchers in other part of the world with the essential oil containing eucalyptol (1,8-cineole), which typically occurs between 40 and 70 percent [9 and 10]. Eucalyptol content of 49.27 percent in this research is within this chemotype range indicating that Zaria populations of *E. globulus* are cineole-rich. It is remarkable that α -terpineol (14.35) is highly concentrated, because this substance has been reported to have a potent antimicrobial and antioxidant effect [11]. In a similar manner, the antioxidant potential of g-terpinene (9.91%) is also added, and borneol and fenchol are also oxygenated monomeric terpenes that have a fragrance and pharmacological activity [12]. These secondary components most probably increase the functional versatility of the oil beyond those of eucalyptol by itself.

The Zaria chemotype has a larger percentage of α -terpineol and borneol than the North-Central

region of Nigeria, where g-terpinene and terpinen-4-ol are sometimes dominant [13]. The difference supports the geographic and edaphic impact on the essential oil composition as [14]. indicated a significant intra-species chemical diversity of *E. globuli* with respect to geographic factors and harvesting time of the year.

The presence of relatively few sesquiterpenes (2.58% caryophyllene) indicates that the Zaria chemotype is closer to Mediterranean and Asian *E. globuli* that also exhibit dominance by oxygenated monoterpene [15]. Practically, the composition is more inclined to use in the sphere of pharmaceuticals, perfume and food preservation when the use of oils containing cineole is to be preferred. Therefore, the results, in addition to validating the worldwide cineole-rich chemotype pattern, provide a baseline profile characteristic of Zaria, Nigeria, which adds new chemotaxonomic and functional data.

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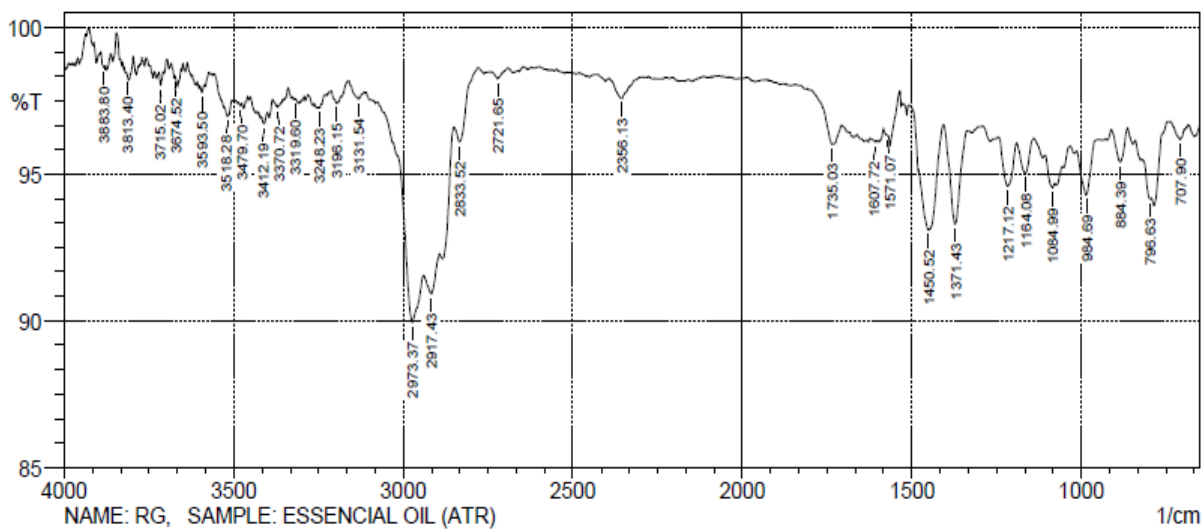


Figure 1: FTIR Spectrum of *E. globulus*' essential oil

Table 2: Major absorption bands in the FTIR spectrum of *Eucalyptus globulus*' essential oil.

No.	Peak (cm ⁻¹)	%T	Corr. Intensity	Functional Group Assignment
1	707.90	96.18	0.436	C-H out-of-plane bending (aromatic/alkene)
2	796.63	94.17	0.055	C-H out-of-plane bending (alkene)
3	884.39	95.41	1.145	C-H bending (vinylidene)
4	984.69	94.29	1.678	C=C stretching (conjugated alkene)
5	1084.99	94.54	0.401	C-O stretching (ether/alcohol)
6	1164.08	95.03	1.123	C-O stretching (tertiary alcohol/ether)
7	1217.12	94.60	1.577	C-O stretching (phenolic ether)
8	1371.43	93.31	3.279	C-H bending (methyl/methylene)
9	1450.52	93.10	2.676	C-H bending (asymmetric methyl)

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No.	Peak (cm ⁻¹)	%T	Corr. Intensity	Functional Group Assignment
10	1571.07	96.31	0.060	C=C stretching (aromatic/alkene)
11	1607.72	96.10	0.061	C=C stretching (conjugated alkene)
12	1735.03	96.02	0.155	C=O stretching (ester/carbonyl trace)
13	2356.13	97.58	0.525	CO ₂ artifact (atmospheric interference)
14	2721.65	98.25	0.064	C-H stretching (aldehyde overtone, trace)
15	2833.52	96.11	0.970	C-H stretching (methoxy/methyl)
16	2917.43	90.93	0.968	C-H stretching (asymmetric methylene)
17	2973.37	89.95	3.273	C-H stretching (asymmetric methyl)
18	3131.54	97.55	0.272	O-H stretching (phenolic/alcoholic)
19	3196.15	97.41	0.071	O-H stretching (phenolic)
20	3248.23	97.26	0.022	O-H stretching (phenolic)
21	3319.60	97.55	0.020	O-H stretching (phenolic/alcoholic)
22	3370.72	97.28	0.067	O-H stretching (phenolic/alcoholic)
23	3412.19	96.73	0.077	O-H stretching (phenolic/alcoholic)
24	3479.70	97.33	0.086	O-H stretching (phenolic/alcoholic)
25	3518.28	96.97	0.151	O-H stretching (phenolic/alcoholic)
26	3593.50	97.78	0.255	O-H stretching (free alcoholic)
27	3674.52	98.26	0.183	O-H stretching (free alcoholic)

No.	Peak (cm ⁻¹)	%T	Corr. Intensity	Functional Group Assignment
28	3715.02	98.02	0.470	O-H stretching (free alcoholic)
29	3813.40	98.30	0.048	O-H stretching overtone
30	3883.80	98.63	0.182	O-H stretching overtone

The FTIR spectrum of the essential oil of *Eucalyptus globulus* had significant absorption peaks in the spectrum at 707.90-3883.80 cm⁻¹ (Table 2). Typical peaks were found in the functional groups of alkenes, alcohols, esters, ethers and methyl groups. Very clear peaks observed at 707.90 cm⁻¹ and 796.63 cm⁻¹ were the C-H out-of-plane aromatic and alkene bending. The high absorption at 984.69 cm⁻¹ was attributed to C=C stretching of the alkenes which were conjugated and the bands at 1084.99-1217.12 cm⁻¹ were believed to be C-O stretching in ethers and alcohols. Strong absorptions were also observed at 1371.43 -1 and 1450.52 cm⁻¹, which indicate C-H bending of methyl groups and methylene groups. Presence of weak band at 1735.03 cm⁻¹ indicated possible presence of trace carbonyl (C=O) group and presence of strong bands at 2917.43 cm⁻¹ and 2973.37 cm⁻¹ indicated the presence of asymmetric C-H groups of methylene and methyl. There were several broad signals 3131.54-3518.28- OH phenolic and alcoholic stretching signals were complemented by free alcohol signals at 3593.50-3715.02 cm⁻¹

on a high scale. O-H stretching overtones consisted of higher frequency overtone bands at 3813.40 and 3883.80 cm⁻¹.

Preponderance of hydroxyl (O-H), C-H and C-O functional groups was observed in FTIR spectrum, which was in agreement with the presence of oxygenated monoterpenes including eucalyptol, α-terpineol, borneol and fenchol as noted in the GC-MS profile. Phenolic and alcoholic groups were also confirmed by broad absorption between 3131-3518 cm⁻¹ and are typical to terpenoids, which have antimicrobial and antioxidant properties [16]. The presence of monoterpene alcohols is also confirmed by the occurrence of free hydroxyl groups in the 3593-3715 cm⁻¹ range and is also associated with the bioactivity and solubility of the oil [17]. The high intensity of peaks at 1371.43 and 1450.52 cm⁻¹ suggests that there is a large proportion of methyl and methylene vibrations, which supports the large proportion of hydrocarbons backbones in monoterpenes like γ-terpinene and β-pinene. Its weak absorption at 1735.03 cm⁻¹ indicates trace ester and carbonyl components, which could be

due to the existence of minor sesquiterpenes and oxidized compounds [18].

Notably, the ether-related peaks (1084-1217 cm^{-1}) and the hydroxyl peaks are a strong indicator of the prevalence of oxygenated monoterpenes, as per the cineole-rich chemotype of the GC-MS data. There are reports of similar FTIR patterns of *E. globuli* essential oils, which serves as proof that FTIR is a dependable complementary method of validating GC-MS compositional data [19]. By and large the FTIR results support the GC-MS result, thus confirming Zaria *E. globulus* chemotype is oxygenated monoterpene-rich, and its functional groups are consistent with its pharmacological potential.

Conclusion

The chemical and functional characterization of *Eucalyptus globulus* essential oil in this study was done using GC-MS and FTIR spectroscopy. Oxygenated monoterpenes, including eucalyptol (1,8-cineole), almost one-third of the composition, and other important constituents, γ -terpinene, α -terpineol, endo-borneol, terpinen-4-ol, etc. dominated the oil. FTIR was used to identify the existence of terpenoids and the findings were supported by the presence of characteristic hydroxyl and ether as well as conjugated double-bond vibrations. These results confirm the designation of the oil as cineole-rich chemotype and underscores its promising

potential as a renewable natural resource, which is applicable in pharmaceutical, food and agro-industrial applications. The future research must be done in bioactivity tests and stability of formulation to confirm therapeutic efficacy and encourage commercialization of this essential oil.

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