Journal of Essential Oil & Plant Composition

JEOPC, 1(3), 239-245, 2023
https://doi.org/10.58985/jeopc.2023.v01i03.30
ISSN (Print): 2958-9630

Research Article

Constituents of the essential oils from members of Nigerian Meliaceae: *Trichilia monadelpha* (Thonn.) J. J. de Wilde and *Trichilia prieuriana* A. Juss

Akintayo Ogundajo[1*], **Olulana Olajide**[1], **Adeleke Adebayo**[2], **Sunmisola Balogun**[1], **Moses Owolabi**[1] and **William N. Setzer**[3]

1. Department of Chemistry, Natural Products Research Unit, Faculty of Science, Lagos State University, Badagry-Expressway, P.M.B. 0001 LASU Post Office, Ojo, Lagos, Nigeria.
2. Department of Basic Sciences, Adeleke University, Ede, Osun State, Nigeria.
3. Department of Chemistry, University of Alabama in Huntsville, Huntsville, AL 35803, USA.

Article Information
Received: 29 May 2023
Revised: 19 June 2023
Accepted: 28 June 2023

Academic Editor
Radosław Kowalski

Corresponding Author
Prof. Dr. Akintayo Ogundajo
E-mail: ogundajotayo@yahoo.com
Tel.: +234- 806 245 6932

Keywords
Trichilia monadelpha, *Trichilia prieuriana*, hydrodistillation, essential oils, GC-MS

Abstract

Trichilia monadelpha (Thonn.) J. J. de Wilde and *Trichilia prieuriana A.* Juss are medicinal plants traditionally used in the treatment of several ailments and diseases. The current study investigated the chemical compositions of the essential oils from *T. monadelpha* and *T. prieuriana*. Essential oils of these plants were obtained by hydrodistillation and analyzed by gas chromatography–mass spectrometry. The major components in the essential oil of *T. monaldepha* were (E)-β-caryophyllene (26.2%), caryophyllene oxide (18.2%), δ-cadinene (8.5%), α-copaene (5.1%) and α-humulene (4.7%). The dominant constituents in the oil of *T. prieuriana* were α-santalene (44.4%), caryophyllene oxide (11.1%), trans-α-bergamotene (8.4%) and 6-methyl-α-ionone (5.4%). Some of these identified components of essential oils from *T. monadelpha* and *T. peruriana* were reported to have diverse pharmacological activities, which might be responsible for their usefulness in folklore medicine.

1. Introduction

The genus *Trichilia* is known to be the largest genus belonging to the family *Meliaceae,* consisting of over 90 species known to be extensively dispersed throughout the tropical and subtropical regions [1]. *Trichilia monadelpha* (Thonn.) J. J. de Wilde, locally called *Otanduro* (Twi) or *Tenuba* (Nzema), meaning hatred medicine, is a medium-sized tree that grows 12-20 m high and propagates itself well in lowland high forests and evergreen semi-deciduous secondary jungles, often near river banks [2]. Ethnomedicinally, *T. monadelpha* has been used in traditional medicine in the treatment of numerous ailments in the human body. The stem bark of *T. monadelpha* has traditionally been used in the treatment of a number of central nervous system (CNS) conditions, such as depression, epilepsy, psychosis, pain, and inflammation [3]. The bark decoction is also used as an analgesic and anthelminthic and is also drunk to pacify cough [4]. Reports have also shown that *T. monadelpha* possesses pharmacological properties, including anti-trypanosomal, antiplasmodial [5], antidepressant [6], anti-inflammatory, antitumor and antioxidant properties [7, 8].

Phytochemical analysis of *T. monadelpha* bark revealed the presence of an array of plant constituents, such as saponins, tannins, alkaloids, cardiac glycosides, anthraquinones, reducing sugars, flavonoids, coumarin, triterpenoids and steroidal compounds, which are known to possess biological properties that could contribute to its traditional therapeutic value [8, 9]. Monadelphin A and B, which are lemonioid derivatives, and trichins A and B, which are sesquiterpene derivatives, were isolated from the leaves and stem extracts of *T. monadelpha* [10]. The isolated compounds were also reported to be strongly cytotoxic against mouse lymphoma [10].

Trichilia prieuriana A. Juss. *(Meliaceae)* is an evergreen shrub or tree with a dense, hemispherical crown that can grow up to 30 m tall and sometimes to a height of 40 m. It is commonly found in rainforests and savanna woodlands [11]. The ethnomedicinal usage of *T. prieuriana* Juss. includes the treatment of malaria, trypanosomiasis, syphilis, pneumonia and colds. Additionally, the treatment of various bacterial infections with water decoctions and infusions from *T. prieuriana* has been in use for many years [12]. Pagna *et al*. [13] isolated 22 compounds from hydroethanol extracts of *T. prieuriana* which include: 2β,3β,4β-trihydroxypregnan-16-one, prieurianin, flindissone, deoxyflindissone, and picraquassin E, among others. The isolated compounds were reported to exhibit noticeable antibacterial capability [13]. Additionally, two new triterpenoids, namely, 12-acetyloxy-β-oxotirucalla-7,24-dien-21,23-oxide and 29-hydroxy-piperone, were previously reported from the leaves of *T. prieuriana* [14]. In addition, Kuglerova *et al*. [15] reported that ethanol extracts of *T. prieriana* displayed promising antimicrobial properties against strains of gram-positive bacteria. However, despite the wide ethno-medical usage of the plant, there is little information on the chemical composition of the essential oil of *T. monadelpha* and *T. prieuriana.* Therefore, the current study aimed to investigate the chemical compositions of the essential oils from *T. monadelpha* and *T. prieuriana*.

2. Materials and methods

2.1 Sample collection

T. monadelpha and *T. prieuriana* leaves were collected from farmland in Egbeda Village, Ibadan Oyo State, Nigeria, in May 2022. The plant samples were authenticated at the Herbarium section of Forestry Research Institute of Nigeria (FRIN), Ibadan Nigeria, where voucher specimens FHI: 113153 and FHI: 113142 were deposited for *T. monadelpha* and *T. prieuriana*, respectively.

2.2 Sample preparation and hydrodistillation

The collected fresh leaves of *T. monadelpha* and *T. prieuriana* were air dried under the shade and pulverized with a blender to increase the surface area. 500 grams of each pulverized sample of *T. monadelpha* and *T. prieuriana* was subjected to hydrodistillation for 4 h using an all-glass modified Clevenger-type apparatus according to the British pharmacopeia [16]. The essential oils of *T. monadelpha* and *T. prieuriana* obtained from the hydrodistillation were stored in a labeled sealed glass bottle with a screw lid cover and kept in a refrigerator. Oil yield was calculated on a dry weight basis.

2.3 Gas chromatographic–mass spectral analysis

The chemical composition of essential oils from *T. monadelpha* and *T. prieuriana* was determined using gas chromatography–mass spectrometry (GC–MS). This was achieved on a Shimadzu GCMS-QP2010 Ultra operated in the electron impact (EI) mode (electron energy = 70 eV), scan range = 40–400 atomic mass units, with a scan rate of 3.0 scans per s, with GC–MS solution software. The GC column was a ZB-5 fused silica capillary column (30 m length ×0.25 mm inner diameter) with a 5% phenyl-polymethylsiloxane stationary phase and a film thickness of 0.25 μm. Helium gas was used as a carrier gas with a column head pressure of 552 kPa at a flow rate of 1.37 mL/min. The injector temperature was 250 °C, and the ion source temperature was 200 °C. The oven temperature of 50 °C was initially programmed for the GC and gradually increased at 2 °C/min to 260 °C. The sample (5% w/v) was dissolved in dichloromethane, and 0.1 μL of the solution was injected using a split injection technique (30:1). Each constituent of the essential oils was identified by injection of pure samples and by comparison of the retention index values, through calibration using a series of n-alkanes, in addition to MS fragmentation comparisons with those found in the databases [17-20].

3. Results

3.1 Trichilia monadelpha

The GC–MS analysis of essential oil from *T. monadelpha* revealed 43 compounds representing 99.1% of the total constituents of the oil. The constituents displayed were sesquiterpene

Table 1. The chemical constituents of *T. monadelpha* leaf essential oil

S/N	RI calc	RI db	Compounds	Composition (%)
1	981	982	6-Methyl-5-hepten-2-one	0.4
2	1066	1067	*cis*-Linalool oxide	0.4
3	1087	1086	*trans*-Linalool oxide	0.7
4	1101	1101	Linalool	0.6
5	1193	1190	Methyl salicylate	1.7
6	1346	1348	α-Cubebene	0.6
7	1375	1375	α-Copaene	5.1
8	1389	1390	*trans*-β-Elemene	0.3
9	1403	1405	(*Z*)-β-Caryophyllene	0.2
10	1412	1416	*cis*-α-Bergamotene	0.2
11	1418	1417	(*E*)-β-Caryophyllene	26.2
12	1421	1421	(*E*)-α-Ionone	1.0
13	1425	1427	β-Duprezianene	0.6
14	1432	1432	*trans*-α-Bergamotene	2.0
15	1448	1447	Geranyl acetone	2.3
16	1454	1454	α-Humulene	4.7
17	1458	1458	*allo*-Aromadendrene	2.2
18	1471	1472	*cis*-Cadina-1(6),4-diene	0.4
19	1475	1475	γ-Muurolene	1.0
20	1480	1481	(*E*)-β-Ionone	0.5
21	1489	1489	β-Selinene	2.2
22	1496	1497	α-Selinene	1.3
23	1499	1500	α-Muurolene	0.9
24	1509	1508	β-Bisabolene	0.3
25	1513	1512	γ-Cadinene	0.9
26	1519	1518	δ-Cadinene	8.5
27	1522	1519	*trans*-Calamenene	1.1
28	1533	1533	*trans*-Cadine-1,4-diene	0.4
29	1537	1538	α-Cadinene	0.2
30	1542	1541	α-Calacorene	0.9
31	1550	1555	*iso*-Caryophyllene oxide	1.0
32	1563	1561	(*E*)-Nerolidol	0.3
33	1578	1576	Spathulenol	1.0
34	1583	1582	Caryophyllene oxide	18.2
35	1604	1605	Ledol	0.8
36	1610	1613	Humulene epoxide II	2.4
37	1622	1623	Humulane-1,6-dien-3-ol	0.2
38	1628	1628	1-*epi*-Cubenol	1.9
39	1643	1643	τ-Cadinol	1.5
40	1645	1644	τ-Muurolol	0.6
41	1647	1643	δ-Cadinol	0.4
42	1656	1655	α-Cadinol	0.7
43	1659	1660	Selin-11-en-4α-ol	2.0
			Total identified (%)	**99.1**

RI_{calc}, retention index calculated with respect to a homologous series of n-alkanes on a ZB-5 ms column; RI_{db}, reference retention index from the databases.

hydrocarbons (60.3%), oxygenated sesquiterpenoids (31.1%), oxygenated monoterpenoids (1.7%) and nonterpenoids (6.0%). The major components identified were (E)-β-caryophyllene (26.2%), caryophyllene oxide (18.2%), δ-cadinene (8.5%), α-copaene (5.1%) and α-humulene (4.7%). Compounds present in a significant amount included humulene epoxide II (2.4%), geranyl acetone (2.22%), allo-aromadendrene (2.14%), β-selinene (2.2%) and selin-11-en-4α-ol (2.0%). Table 1 displays the constituents of the leaf essential oil of *T. monadelpha* while Fig. 1 and 2 displayed the structure of the major components and the chromatogram of *T. monadelpha* oils respectively.

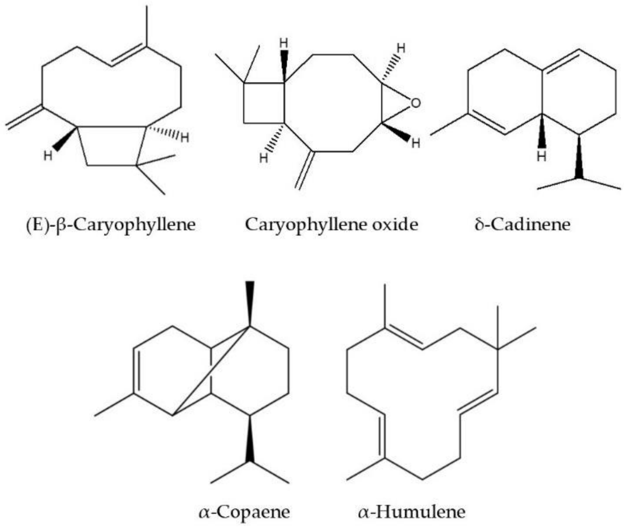

Figure 1. Major components of essential oils from *T. monaldepha.*

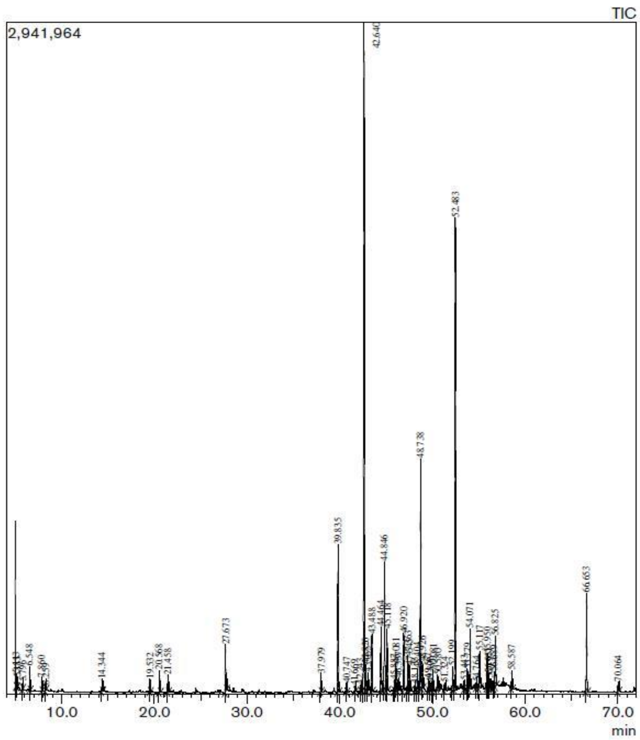

Figure 2. Gas chromatogram of *T. monadelpha* oil on a ZB-5 column (30 m ×0.25 mm) with helium carrier.

Table 2. Chemical constituents of *T. prieuriana* leaf essential oil

S/N	RI_{calc}	RI_{db}	Compounds	Composition (%)
1	1363	1371	α-Ylangene	0.3
2	1369	1375	α-Copaene	0.8
3	1407	1416	*cis*-α-Bergamotene	0.4
4	1413	1418	α-Santalene	44.4
5	1416	1421	(*E*)-α-Ionone	0.2
6	1423	1433	β-Copaene	0.1
7	1427	1432	*trans*-α-Bergamotene	8.4
8	1434	1439	(*Z*)-β-Farnesene	0.2
9	1440	1446	*epi*-β-Santalene	1.6
10	1443	1447	Geranyl acetone	0.4
11	1448	1454	α-Humulene	2.0
12	1453	1457	β-Santalene	2.8
13	1468	1478	γ-Muurolene	0.5
14	1473	1481	(*E*)-β-Ionone	0.2
15	1476	1481	γ-Himachalene	1.4
16	1477	1483	*trans*-β-Bergamotene	1.6
17	1482	1492	β-Selinene	0.1
18	1485	1495	γ-Amorphene	0.1
19	1489	1498	*epi*-Cubebol	0.4
20	1492	1500	α-Muurolene	0.3
21	1501	1508	β-Bisabolene	2.6
22	1504	1511	(*Z*)-γ-Bisabolene	0.1
23	1506	1512	γ-Cadinene	0.5
24	1509	1519	Cubebol	0.2
25	1512	1520	6-Methyl-α-ionone	5.4
26	1515	1527	*trans*-Calamenene	0.6
27	1520	---	Unidentified[d]	1.1
28	1535	1544	α-Calacorene	0.2
29	1544	1551	Isocaryphyllene oxide	0.5
30	1568	1576	*trans*-Sesquisabinene hydrate	0.1
31	1570	1578	Spathulenol	0.4
32	1575	1587	Caryophyllene oxide	11.1
33	1602	1613	Humulene epoxide II	1.3
34	1621	1631	1-*epi*-Cubenol	0.1
35	1635	1643	τ-Cadinol	0.4
36	1638	1645	τ-Muurolol	0.3
37	1641	1647	Campherenone	0.7
38	1653	---	Unidentified [d]	1.7
			Total Identified (%)	**90.6**

RI_{calc}, retention index calculated with respect to a homologous series of n-alkanes on a ZB-5 ms column; RI_{db}, reference retention index from the databases; d MS(EI): 205(2%), 177(3%), 147(7%), 138(40%), 121(40%), 105(43%), 95(43%), 93(100%), 91(53%), 79(38%), 77(26%), 67(19%), 55(20%), 43(31%), 41(40%); d MS(EI): 222(4%), 179(10%), 137(18%), 122 (54%), 109(40%), 96(38%), 94(100%), 82(29%), 71(37%), 69(51%), 67(40%), 55(28%), 43(99%), 41(55%).

3.2 *Trichilia prieuriana*

The hydrodistillation of *T. prieuriana* yielded a pale-yellow essential oil, which was made up of sesquiterpene hydrocarbons (68.9%) and oxygenated sesquiterpenoids (15.5%). The major components in the essential oil were α-santalene (44.4%), caryophyllene oxide (11.1%), trans-α-bergamotene (8.4%) and 6-methyl-α-ionone (5.4%). Compounds found to be significantly present were β-Santalene (2.8%), β-bisabolene (2.6%), α-humulene (2.0%), epi-β-santalene (1.6%), trans-β-bergamotene (1.6%), γ-himachalene (1.4%) and humulene epoxide II (1.3%). Table 2 displays the constituents of the leaf essential oil of *T. prieuriana* while Fig. 3 and 4 displayed the structure of the major components and the chromatogram of *T. prieuriana* oils respectively

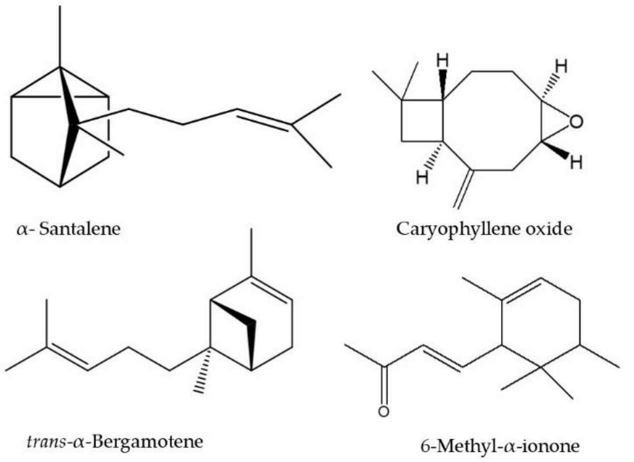

Figure 3. Major components of essential oils from *T. prieuriana.*

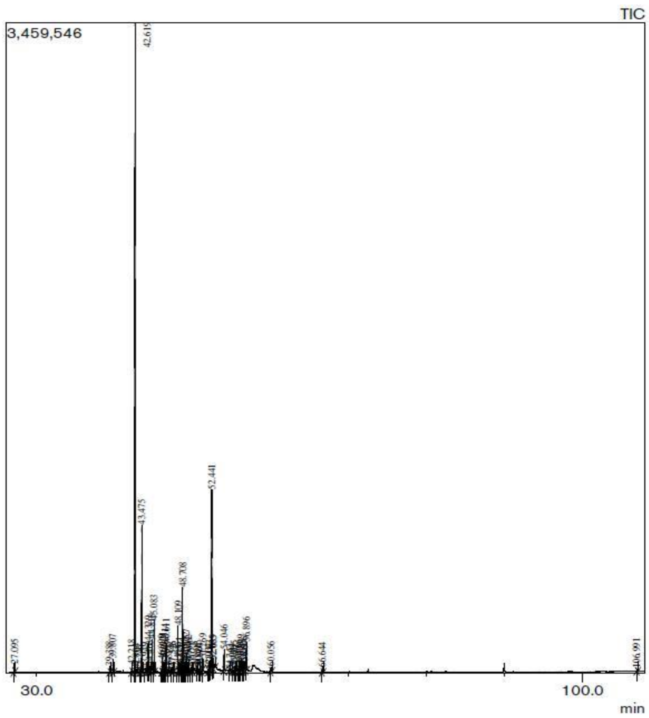

Fig. 4: Gas chromatogram of *T. prieuriana* oil on a ZB-5 column (30 m ×0.25 mm) with helium carrier.

4. Discussion

Few literature reports have described the chemical compositions of essential oils from the genus *Trichilia*. Odeja and Onocha [21] reported 15 compounds from the leaf essential oil of *T. monadelpha*, with β-caryophyllene (35.41%) as the most abundant component. The report also revealed that the essential oils of *T. monadelpha* possess antioxidant and antimicrobial potentials. The report is similar to the current finding with β-caryophyllene (26.2%) as the most abundant constituent of *T. monadelpha*. However, the current findings reported 43 compounds from the essential oils of *T. monadelpha* against the 15 reported in the literature [21]. Additionally, caryophyllene oxide (18.2%), δ-cadinene (8.5%), α-copaene (5.1%) and α-humulene (4.7%), which were part of the major compounds in the current report, were absent from previous findings [21]. These variations in the compositions of the oils might be due to several factors, including geographical origin, genetic differences, part of the plant used, method of extraction, age/stage of maturity, and season of harvest [22-23].

Furthermore, α-Santalene (44.4%) was the most abundant compound in the oil of *T. peruriana*, while the other major components included β-bisabolene (2.6%), α-humulene (2.0%), epi-β-Santalene (1.6%), trans-β- bergamotene (1.6%), and γ-himachalene (1.4%). This is in contrast to the composition of *T. monaldepha*, with β-caryophyllene (26.2%) as the most abundant compound together with the other major compounds δ-cadinene (8.5%) and α-copaene (5.1%). However, caryophyllene oxide and α-humulene were present in both oils. Ewansiha et al [22] reported factors that might be responsible for variations in the components of essential oils. Meanwhile, some of the identified components of essential oils from *T. monadelpha* and *T. peruriana* were reported to have diverse pharmacological activities. Analgesic and anti-inflammatory activities of caryophyllene oxide have been reported [24] while β-caryophyllene exhibits antimicrobial, antioxidant, anesthetic, anti-inflammatory and anticancer activities [25-29]. The anti-inflammatory property of humulene was also reported [30]. Moreover, santalol, which has santalene as a precursor, displays antidepressant, Alzheimer's, and antipsychotic potentials [31-32]. The presence of these bioactive volatile constituents in the oils of *T. monadelpha* and *T. prieuriana* are likely responsible for their usefulness in folklore medicine.

5. Conclusions

The essential oil of *T. monadelpha* and *T. prieuriana* contain bioactive compounds with diverse pharmacological activities, indicating their potential as sources of future lead drugs that may be useful in combating various diseases and health challenges. However, further studies need to be performed on the essential oils of *T. monadelpha* and *T. prieuriana* to establish their biological potential.

Authors' contributions

Designed of the research, A.O. and M.O.; Executed the research, A.O., O.O., A.A., S.B., M.O. and W.S.; Analyses the data and interpreted the results, A.O., O.O., A.A., S.B., M.O. and W.S.; Wrote the first draft of the manuscript writing, A.O., O.O. and S.B.

Acknowledgements

The authors acknowledge Dr. Niyi Odewo of the Herbarium section, Forestry Research Institute of Nigeria (FRIN), Ibadan Nigeria for his technical assistance.

Funding

Authors did not receive any fund to execute the study.

Conflicts of interest

Authors declared no conflicts of interest

References

1. Xie, Y.S.; Isman, M.B.; Gunning, P.; Mackinnon, S.; Arnason, J.T.; Taylor, D.R.; Sánchez, P.; Hasbun, C.; Towers, G.H.N. Biological activity of extracts of Trichilia species and the limonoid hirtin against lepidopteran larvae. Biochem. Syst. Ecol. 1994, 2, 129-136. Doi.org/10.1016/0305-1978(94)90003-5
2. Abbiw, D.K. Useful Plants of Ghana. London, UK: Royal Botanic Gardens.
3. Hutchinson, J. The Flora of West Tropical Africa. London, UK: Royal Botanic Gardens. 1985.
4. Dos Santos, D.A.; Fukui, M.D.J.; Nanayakkara, N.D.; Khan, S.I.; Sousa, J.P.B.; Bastos, J K.; Andrade, S.F.; da Silva Filho, A.A.; Quintão, N.L. Anti-inflammatory and antinociceptive effects of *Baccharis dracunculifolia* DC (Asteraceae) in different experimental models. J. Ethnopharmacol. 2010, 127(2), 543-550. Doi.org/10.1016/j.jep.2009.09.061

5. Kamanzi, A.K.; Schmid, C.; Brun R.; Kone, M.W.; Traore, D. Antitrypanosomal and antiplasmodial activity of medicinal plants from Cote d'Ivoire. J. Ethnopharmacol. 2004, 90(2-3), 221-227 Doi.org/10.1016/j.jep.2003.09.032
6. Kenedy, K.E.; Jeffrey, A.M.; Patrick, A.; Seth, K.A.; Benoit, B.N.; Isaac, J.A. Antidepressant potentials of components from *Trichilia monadelpha* (Thonn.) J.J.de Wilde in murine models. Evid. based Complement. Alt. Med. 2018, 1-11, Article ID 6863973. Doi.org/10.1155/2018/6863973
7. Ainooson, G.F.K.; Owusu, G.; Woode, E.; Ansah, G.; Anah, K. *Trichilia monadelpha* extracts inhibit carrageenan-induced oedema in the 7-Day old chick and the oedema associated with adjuvant-induced arthritis in Rats. Afr. J. Trad. Complement Altr. Med. 2012. 9(1), 8-16. Doi: 10.4314/ajtcam.v9i1.2.
8. Ben, I.O.; Woode, E.; Abotsi, W.K.; Boakye-Gyasi, E. Preliminary phytochemical screening and in vitro antioxidant properties of *Trichilia monadelpha* (Thonn.) J.J.de Wilde (Meliaceae). J. Med. Biomed. Sci. 2013, 2(2), 6-15.
9. Clark, P.D.; Omo-Udoyo, E. A Comparative assessment on antioxidant and phytochemical of *Trichilia monadelpha* (Thonn) J.J. De Wilde (Meliaceae) plant extracts. Chem. Sci. Int. J. 2021, 30(10), 24-33. DOI: 10.9734/CSJI/2021/v30i1030257
10. Nangmo, K.P.; Tsamoa, T.A.; Zhenb, L.; Mkounga, P.; Akone, S.H.; Tsabang, N.; Müller, W.E.G.; Marat, K.; Proksch, P.; Nkengfac, A.E. Chemical constituents from leaves and root bark of *Trichilia monadelpha* (Meliaceae). Phytochem. Lett. 2018, 23, 120–126. Doi.org/10.1016/j.phytol.2017.11.020.
11. Darbyshire, I.; Kordofani, M.; Farag, I.; Candiga, R.; Pickering, H. The Plants of Sudan and South Sudan An Annotated Checklist. London, UK: Royal Botanic Gardens. 2015.
12. Vieira, I.J.C.; Terra, W.; da, S.; Milena, D.S.T.; Goncalves, M.D.S.; Braz-Filho, R. Secondary metabolites of the genus Trichilia: Contribution to the chemistry of meliaceae family. Am. J. Anal. Chem. 2014, 5(2), 91–121. DOI: 10.4236/ajac.2014.52014.
13. Pagna, J.I.M.; Mbekou, I.M.K.; Tsamo, A.T.; Mkounga, P.; Frese, M.; Stammler, H.; Fekam, F.B.; Lenta, B.N.; Sewald, N.; Nkengfack, A.U. Antibacterial activity of some chemical constituents from *Trichilia prieuriana* (Meliaceae). Z. Naturforsch. 2021, 76(8)b, 439–446. Doi.org/10.1515/znb-2021-0057.
14. Olugbade, T.A. Tetracyclic triterpenoids from *Trichilia prieuriana* Leaves. Phytochem. 1991, 30(2), 698-700.
15. Kuglerova, M.; Halamova, K.; Kokoska, L.; Van Damme, P.; Grade. J. Antimicrobial activity of Ugandan medicinal plants. Planta Med. 2007, 73(9), 113. DOI: 10.1055/s-2007-986895
16. British Pharmacopoeia, Vol. II, H.M. Stationary Office, London (1980).
17. Adams, R.P. Identification of Essential Oil Components by Gas Chromatography/Quadrupole Mass Spectrometry. 4th Edn., Allured Publishing Corporation, Carol Stream. 2007.
18. Mondello L. FFNSC 3. Shimadzu Scientific Instruments; 2016.
19. National Institute of Standards and Technology, NIST/EPA/NIH Mass Spectral Library (NIST 17), 2017.
20. Satyal, P. Development of GC-MS database of essential oil components by the analysis of natural essential oils and synthetic compounds and discovery of biologically active novel chemotypes in essential oils, Ph.D. dissertation. 2015.
21. Odeja O.O.; Onocha P.A. Antioxidant and antimicrobial activities of *β*-caryophyllene dominated leaf essential oil of *Trichilia monadelpha* (Thonn.) JJ De Wilde. 2020, 11(16), 35-42.
22. Ewansiha, J.U.; Garba, S.A.; Mawak, J.D.; Oyewole, O.A. Antimicrobial activity of *Cymbopogon citratus* (lemon grass) and its phytochemical properties. Front. Sci. 2012, 2, 214–220.
23. Idrees, M.; Naeem, M.; Khan, M.; Aftab, T.; Tariq, M. Alleviation of salt stress in lemon grass by salicylic acid. Protoplasma. 2012, 249, 709–720.
24. Chavan, M.J.; Wakte, P.S.; Shinde, D.B. Analgesic and anti-inflammatory activity of caryophyllene oxide from *Annona squamosa* L. bark. Phytomed. 2010, 17(2), 149-151. Doi: 10.1016/j.phymed.2009.05.016.
25. Medeiros, R.; Passos, G.F.; Vitor, C.E.; Koepp, J.; Mazzuco, L.T.L.; Pianowski, F. Effect of two active compounds obtained from the essential oil of *Cordia verbenacea* on the acute inflammatory responses elicited by LPS in the rat paw. Br. J. Pharmacol. 2007, 151(5), 618– 627. Doi:10.1038/sj.bjp.0707270.
26. Langhasova, L.V.; Hanusova, J.; Rezek, B.; Stohanslova, M.; Ambroz, V.; Kralova, V.; Lou, T. D.; Yun, Z.L.; Yang, J.; Skalova, L. Essential oil from *Myrica rubra* leaves inhibits cancer cell proliferation and induces apoptosis in several human intestinal lines. Ind. Crops Prod. 2014, 59, 20–26. Doi: 10.1016/j.indcrop.2014.04.018.
27. Sabulal, B.; Dan, M.; Kurup, R.; Pradeep, N.S.; Valsamma, R.K.; George, V. Caryophyllene-rich rhizome oil of *Zingiber nimmonii* from South India: chemical characterization and antimicrobial activity. Phytochem. 2006, 67(22), 2469–24. Doi:10.1016/j.phytochem.2006.08.003.
28. Singh, G.; Marimuthu, P.; De Heluani, C. S.; Catalan, C. A. Antioxidant and biocidal activities of *Carum nigrum* (seed) essential oil, oleoresin, and their selected components. Ind. Crops Prod. 2006, 54(1), 174–181. Doi:10.1021/jf0518610.

29. Klauke, A.L.; Racz, I.; Pradier, B.; Markert, A.; Zimmer, A.M.; Gertsch, J.; Zimmer, A. The cannabinoid CB 2 receptor-selective phyto-cannabinoid beta-caryophyllene exerts analgesic effects in mouse models of inflammatory and neuropathic pain. Eur. Neuropsychopharmacol. 2014, 24(4), 608–620. Doi: 10.1016/j.euroneuro.2013.10.008.
30. Rogerio, A.P.; Andrade, E.L.; Leite, D.F.P.; Figueiredo, C.P.; Calixto, J. B. Preventive and therapeutic anti-inflammatory properties of the sesquiterpene α-humulene in experimental airways allergic inflammation, Br. J. Pharmacol. 2009, 158(4), 1074–1087. Doi:10.1111/j.1476-5381.2009.00177x.
31. Okugawa, H.; Ueda, R.; Matsumoto, K.; Kawanishi, K.; Kato, K. Effects of sesquiterpenoids from "Oriental incenses" on acetic acid-induced writhing and D2 and 5-HT2A receptors in rat brain. Phytomedicine. 2000, 7(5), 417-422. Doi: 10.1016/S0944-7113(00)80063-X.
32. Misra, B.B.; Dey, S. TLC-bioautographic evaluation of in vitro anti-tyrosinase and anti-cholinesterase potentials of sandalwood oil. Nat. Prod. Commun. 2013, 8(2), 253-256. DOI: 10.1177/1934578X1300800231.