

Research Article

Chemical Investigation on Essential Oil Composition of *Tithonia diversifolia* Growing Wild in Côte d'Ivoire

Jérémie Konan N'Goran¹ , Michel Boni Bitchi⁴ , Wognin Esse Leon³,
Tanoh Amenan Evelyne¹, Marie-Laure Fauconnier², Félix Zanahi Tonzibo^{1,*}

¹Laboratory of Constitution and Reaction of Matter, University Felix Houphouët-Boigny, Abidjan, Côte d'Ivoire

²Laboratory of Chemistry of Natural Molecules, University of Liège, Gembloux, Belgium

³Laboratory of Instrumentation Image and Spectroscopy, National Polytechnic Institute Felix Houphouët-Boigny, Yamoussoukro, Côte d'Ivoire

⁴Agriculture Fish Resource and Agro-Industry, University of San Pedro, San Pedro, Côte d'Ivoire

Abstract

Tithonia diversifolia is widely used in African and American traditional medicine. Several biological and pharmacological studies have been carried out, using extract and essential oil of *Tithonia diversifolia*. Considering the numerous medicinal properties that justify the interest of continuing the chemical description of essential oil from this species. The present study aims to investigate essential oils from fresh organs (leaves, flowers, stems, roots) of *Tithonia diversifolia*, growing in four localities of Côte d'Ivoire. The essential oils are extracted by hydrodistillation using a Clevenger-type apparatus. 67 compounds were obtained by GC-MS analysis, with the most dominant being monoterpene hydrocarbons, followed by sesquiterpene hydrocarbons, oxygenated monoterpenes and oxygenated sesquiterpenes. The description of the essential oil (EO) composition from *Tithonia diversifolia*'s roots shown α -pinene (95.05 to 97.01%), modephene (14.59 to 15.77%), β -pinene (1.46 to 10.05%) and α -isocomene (7.03 to 8.43%) as major compounds. Leaves essential oil was characterized by a predominance of α -pinene (8.66 to 29.76%), limonene (8.43 to 49.02%) and *trans*- β -ocimene (18.05 to 28.35%). In addition, stem oil was dominated by α -pinene (68.4 to 88.03%), allowed by β -pinene (2.78 to 15.05%) and limonene (7.39 to 14.29%). Limonene (33.08 to 40.07) was a main compound for flowers oil. In front of the chemical variability of the EO compositions, the results of analysis were submitted to hierarchical cluster. Two groups G1 and G2 were found, dominated by α -pinene and *cis* bisabolene respectively

Keywords

Tithonia diversifolia, Essential Oil Composition Roots, Pinene, Hierarchical Cluster

1. Introduction

The genus *Tithonia* comprises over 13 species in the Asteraceae family, includes herbaceous plants, annuals, invasive perennials and perennial shrubs [1]. This genus is

found in several regions, including southern Mexico, Guatemala, Panama, Honduras, Cuba, Venezuela and Colombia [1]. When *Tithonia diversifolia* (Hemsley) A. Gray,

*Corresponding author: tonzibz@yahoo.fr (Félix Zanahi Tonzibo)

Received: 14 November 2024; Accepted: 6 December 2024; Published: 19 December 2024



Copyright: © The Author(s), 2024. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

pan-tropical plant species, hold a significant place in traditional medicine. Antioxidant [2], anti-inflammatory [3], antidiarrheal [4], antiplasmodial [5, 6] and antihyperglycemic properties [7] have been reported. Its use as an effective fertilizer for soil amendment was studied [8].

In regards to the phytochemistry review of *Tithonia diversifolia*, a wide variety compounds have been identified. Its extracts were the rich source of flavonoids and sesquiterpenes lactone [9]. Moreover, alkaloids, tannins, saponins, steroids, glycosides, terpenoids, proteins and phenols were presents [10].

Concerning essential oils from *Tithonia diversifolia*, several papers reported the most important components as limonene (20.1%), α -copaene (10.3%), o-cymene (10%), isocaryophyllene (8.73%), α -pinene (7.72%; 18.97%), 1,8-cineole (14.6%) from Cameroun [11, 12]; α -pinene (63.64%), β -pinene (15%) and isocaryophyllene (7.62%) from Kenya [13]; piperitone (11.72%), α -pinene (9.9%), limonene (5.40%), (Z)- β -ocimene (4.02%), p-cymen-8-ol (3.0%), (E)-nerolidol (3.78%) and spathulenol (10.8%) [14] from Brazil; α -pinene (63.62%), bicyclo [3.1.0] hexane 4-methylene-1-(1-méthyl éthyl)- (14.68%) from India [15].

Our previous study dealing with aerial parts (leaf, stem) noted the predominance of α -pinene, limonene and (Z)- β -ocimene [16] and shown correlation between chemical composition and the sampling sites.

In continuation of our contribution in knowledge this species essential oil compositions, this paper describes for the first time chemical investigation on essential oil from roots, collected to distinct localities from Côte d'Ivoire. Besides, Statistical analysis (PCA and CAH) was performed on chemical compositions obtained from different organs of *Tithonia diversifolia*, in order to establish the link between different organs.

2. Materiel and Methods

2.1. Materiel

The essential oils are extracted from different plant organs (leaves, flowers, stems, and roots) of *Tithonia diversifolia*. All the organs collected from different locations have been identified at the National Floristic Center of Félix Houphouët-Boigny University (Côte d'Ivoire). The sampling of *Tithonia diversifolia* have been done in four locations: Gagnoa (6°07' 54'' N 5°57' 02'' W), Sikensi (5°40' 34'' N 4°33' W), Attingui é (5°28' 00'' N 4°11' 00'' W) and Adjam é (5°21' 0'' N 4°1' 60'' W).

2.2. Methods

Ten milligrams of essential oil are dissolved in 100 mL of hexane and analyzed by GC-MS (Agilent Santa Clara CA USA). For each essential oil. This manipulation was repeated in three times. GC-MS was performed using an Agilent 7890B GC system (Agilent Santa Clara CA USA) equipped

with a split-less injector and coupled with an Agilent SMD 5977B detector. One microliter of 0.01% essential oil solution was injected and the analytical conditions were set as follows:

- 1) Injection mode: splitless at 300 °C with a HP-5MS capillary column (Agilent Santa Clara CA USA) (30 m x 0.25 mm. df = 0.25 μ m);
- 2) Temperature program: from 50 °C (1 min) to 300 °C (5 min) at a rate of 5 °C/min.

Carrier gas: helium at a flow rate of 1.2 mL/min. Mass spectra were recorded in electron ionization mode at 70 eV (mass scan range: 40–400 m/z). Source and quadrupole temperatures were set at 230 °C and 150 °C respectively. Identification of components was based on chromatographic retention indices (RI) and comparison of recorded spectra with a computerized data library (Pal 600K®) [17, 18]. RI values were measured on an HP-5MS column (Agilent Santa Clara CA USA). RI calculations were performed in temperature program mode. A mixture of n-alkane homologues (C7-C30) was used under the same chromatographic conditions. Major components were confirmed by comparing their retention and MS spectrum data with co-injected pure references (Sigma Darmstadt Germany) when commercially available.

3. Results and Discussion

3.1. Yields

The results shown that EO yields varied between 0.043 to 0.059% for leaves, 0.01 to 0.035% for stems and 0.013% to 0.035% for roots. The flower EO yield varies between 0.033 to 0.035%. However, the leaf EO yield from Attingui é (0.059%) is higher than the other three locations. The yield (0.035%) from stems collected in Sikensi is higher than in other cities. On the other hand, the yield from Attingui é roots (0.013%) is lower than the three other locations. Leaf yields obtained in previous works by Brou et al. [16] (0.02–0.26%) in Côte d'Ivoire, by Lamaty et al. [19] (0.1%) in Cameroon and by Lawal et al. [20] in South Africa (0.21%) are higher than those obtained in our samples (0.043 to 0.059%). For stem yields, our values (0.01 to 0.035%) are higher than those obtained by Brou et al. [16] (0.01 to 0.017%). In the case of flowers, yields obtained by Chukwuka et al. [21] (0.01 to 0.063%) are higher than our yields (0.013 to 0.022%). Roots yield in South Africa (0.08) was higher than our samples (0.013% to 0.035%) [20].

3.2. Chemical Composition of Essential Oils of *Tithonia diversifolia*

3.2.1. Leaves Essential Oil Composition from *Tithonia diversifolia* Harvested in Attingui é Adjam é Gagnoa and Sikensi

Chemical composition of EO samples of the leaves from Attingui é (AT), Adjam é (AD), Gagnoa (GA) and Sikensi (SI)

show 23 compounds corresponding respectively to 98.51 to 99.5% of the total chemical composition (Table 1).

Significant levels of hydrogenated monoterpenes are pre-dominated in these samples, with the most important being α -pinene (8.66 to 29.76%), limonene (8.43 to 49.02%) and *trans*- β -ocimene (18.05 to 28.35%), with dehydro-aromadendrene (2.02 to 8.16%), modephene (0 to 7.59%), spatulenol (0 to 7.08%), *cis* α -bisabolene (0 to 6.5%), 3-carene (0 to 6.06%), (*E*)- β -caryophyllene (0.41 to 6.06%) and caryophyllene oxide (2.2 to 5.08%). It should be noted that 3-methyl-2-(2-methylbutenyl) furan, germacrene D, eucalyptol, camphor, humulene and piperitone present in previous studies, are absent in our samples. β -pinene was the major compound in EOs from Brazil [14], Nigeria [21, 22], South Africa [20] and Kenya [13] with respective values of 21.9%; 10.9%; 10.7%; 15%, is present in low proportions in our samples (4.58%). Furthermore, in the previous study carried out in Côte d'Ivoire [16], α -pinene, limonene and *trans*- β -ocimene had relatively higher content (47.4%; 65.5%; 35.9%) in comparison with the present study. This could be due to the edaphic factor impact.

3.2.2. Stems Essential Oil Composition from *Tithonia diversifolia* Harvested in Attingui é Adjam é Gagnoa and Sikensi

A total of 14 compounds have been identified from the analysis of all 8 EO samples of *Tithonia diversifolia* stems, representing 98.90-99.43% of the total chemical composition (Table 1).

Essential oils are dominated by hydrocarbon monoterpenes (83.45 to 99.10%). The predominant compound is α -pinene (68.4 to 88.03%), followed by β -pinene (2.78 to 15.05%) and limonene (7.39 to 14.29%). Eucalyptol (0 to 9.83%) is the major component of oxygenated monoterpenes (13.02 to 14.09%).

Most important compounds such as *trans*- β -ocimene, spathulenol and limonene reported in our previous paper [16] with respective values of 39.3%, 11.8% and 36.5% are absent in those samples.

α -pinene present more abundant proportion in the EO from Gagnoa (88.03%) than those from Sikensi (80.05%), Adjam é (75.99%) and Attingui é (68.4%). However, β -pinene is dominant in Attingui é (15.05%) in comparison with Adjam é (6.29%), Sikensi (4.50%) and Gagnoa (2.78%). Moreover, α -pinene content (89.8%) obtained in previous studies [16], was close to that obtained in our essential oils (68.4 to 88.03%).

3.2.3. Flowers Essential Oil Composition from *Tithonia diversifolia* Harvested in Adjam é and Gagnoa

The EO of this species from Adjam é and Gagnoa revealed a total of 16 compounds (Table 1), representing 99.10 to 99.90% of each chemical analysis respectively.

Among the 16 compounds identified, monoterpene and

sesquiterpene hydrocarbons can be observed. The proportions of hydrocarbons and oxygenated monoterpenes accounting from 79.79 to 97.83% and from 0.53 to 5.23% respectively. Among sesquiterpene hydrocarbons content ranges from 0.74 to 13.18% and oxygenated content from 0 to 1.7% of EO.

Indeed, samples from Gagnoa had most important monoterpene hydrocarbon (97.83%) than those from Adjam é (79.79%).

Monoterpene hydrocarbons were dominated by α -pinene, limonene and *trans*- β -ocimene. The main compound in flower samples was limonene. It was found a higher value in Gagnoa (33.08%) and Adjam é (40.07%). α -pinene proportion is higher in Gagnoa samples (42.04%) than Adjam é (35.08%). In addition, *trans*- β -ocimene (18.93%) present in Gagnoa sample was absent in the Adjam é sample. For sesquiterpene hydrocarbons, α -cubebene (0.74 to 11.29%) was the dominant compound, with low proportion (0.74%) in Gagnoa samples than Adjam é (11.29%). Indeed, germacrene D (20.3%), β -caryophyllene (20.1%), 1,8 cineole (8.76%) and bicyclogermacrene (8%) found in Nigerian samples were absent in our samples [22-23]. Limonene proportion in our samples was higher than those Cameroon [24].

3.2.4. Roots Essential Oil Composition from *Tithonia diversifolia* Harvested in Attingui é Adjam é Gagnoa and Sikensi

Chemical profile of EO obtained from *Tithonia diversifolia* shown 14 compounds corresponding to 99.5- 99.94% of the total chemical composition (Table 1).

It was dominated by hydrocarbon monoterpenes (61.82 to 98.86%) followed by sesquiterpene hydrocarbon (1.02 to 34.8%) and oxygenated monoterpenes (0 to 3.18%). Oxygenated sesquiterpenes were absent in our samples. Monoterpene hydrocarbons were composed by α -pinene (51.04 to 97.01%) and β -pinene (1.46 to 10.05%). The main sesquiterpene hydrocarbon was modephene (1.08 to 15.77%). Content of α -pinene is significantly higher in the Gagnoa sample (97.01%) than this from Attingui é (51.04%), Adjam é (67.01%) and Sikensi (95.50%). Attingui é (10.05%) have higher proportion of β -pinene than Adjam é (1.46%), Gagnoa (1.47%) and Sikensi (1.69%). In the case of sesquiterpene hydrocarbon, the modephene content is important in Attingui é (15.77%) and Gagnoa (14.59%). While it is low in Sikensi (1.08%). In South Africa samples, modephene was absent [20]. It was found that our EO was different from those cited in literature.

In addition, to our knowledge, it was the first time that the roots essential oil was investigated in Côte d'Ivoire.

3.3. Chemical Variability of Essential Oil from Leaves, Roots and Stems of *Tithonia diversifolia*

The results of oil obtained from leaves, roots and stems from *Tithonia diversifolia* were submitted to hierarchical

cluster, principal components analysis and discriminant factorial analysis. Its principal factors F1 and F2 accounted for 52.2%, of the total variance of chemical composition. Two groups were observable on the dendrogram from hierarchical cluster analysis (HCA) **Figure 1**. In addition, the principal component analysis (PCA) confirmed two groups from HCA **Figure 2**. Stems and roots samples were collected at Gagnoa, Sikensi, Attingui é and Adjam é (TTAT; TTAD; TTGA; TTSI; RTAT; RTAD; RTGA and RTSI), are constituted the

group G1. This group is characterized by α -pinene, β -pinene, isocomene, modephene and eucalyptol **Figure 3**. However, leaves and flowers samples collected at Gagnoa, Sikensi, Attingui é and Adjam é (FTAT; FTAD; FTGA; FTSI; FITAD and FITGA), are composed the second group G2. It was dominated by *cis*-bisabolene, caryophyllene oxide, trans-ocimene, spatulenol, 3- carene, (*E*) β -caryophyllene, limonene, dehydroaromadendrene, cubene and spatulenol **Figure 3**.

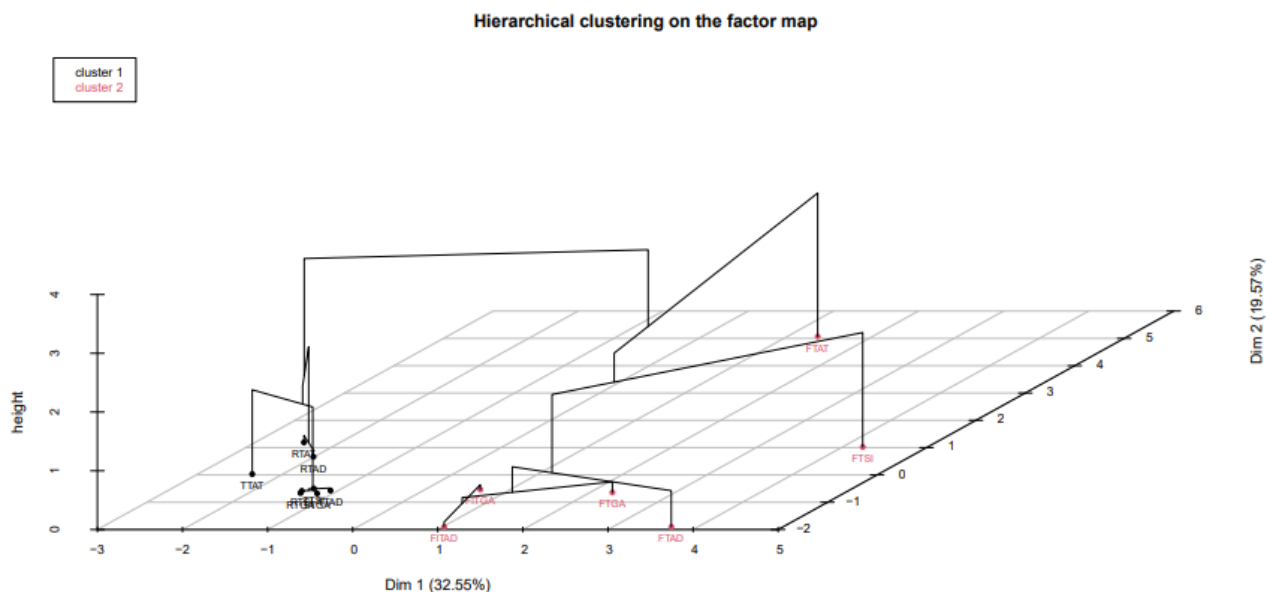


Figure 1. Dendrogram obtained by hieraichical cluster analysis of leaf, flower, steams and roots oil from *Tithonia diversifoli*.

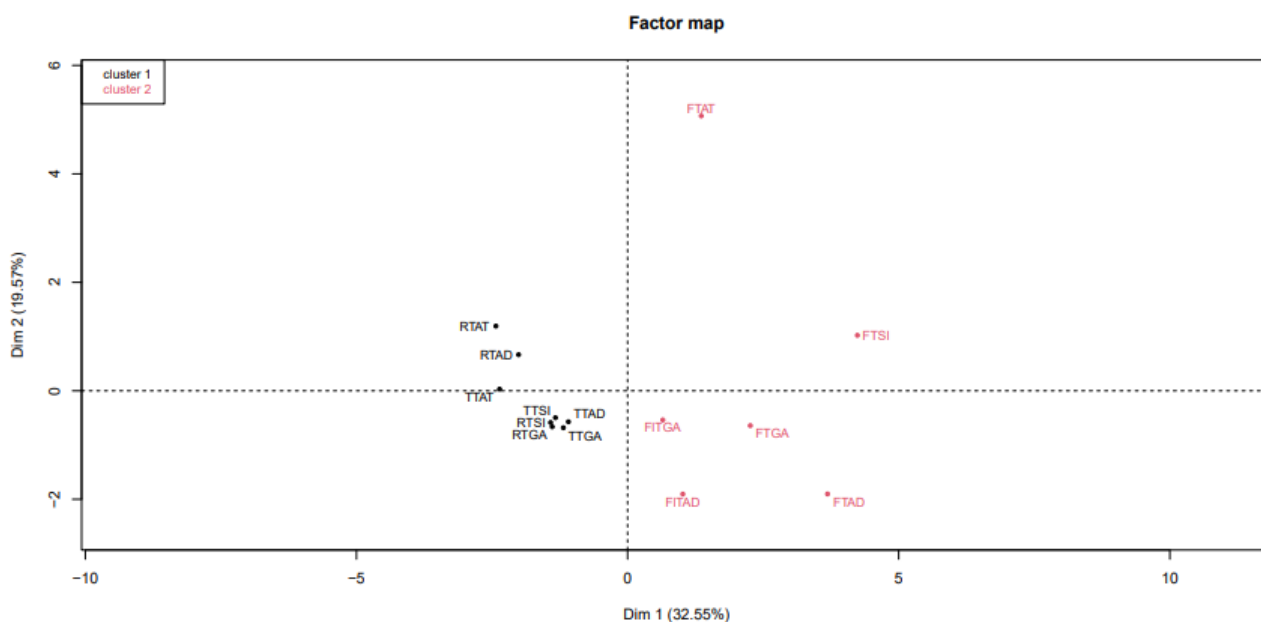


Figure 2. Principal component analysis of leaf, flower, steams and roots oil from *Tithonia diversifolia*.

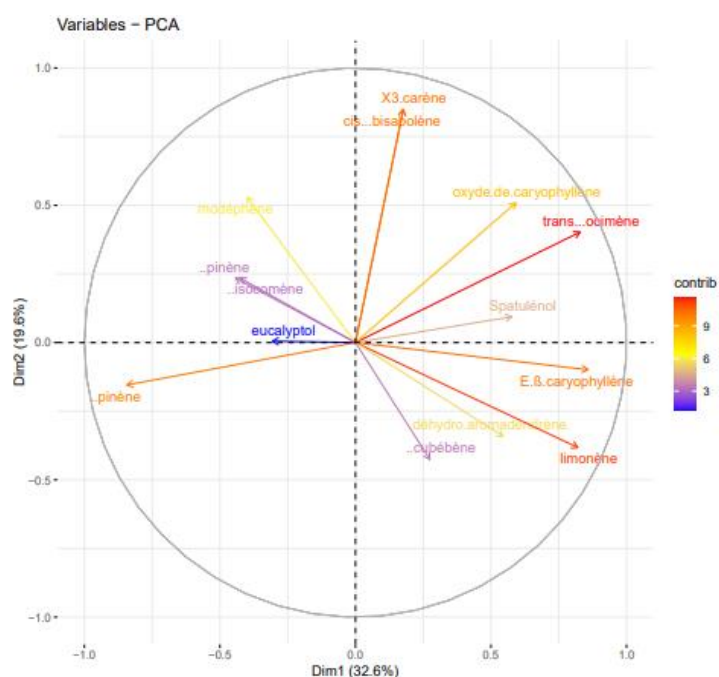


Figure 3. Content components of leaves, stems, flowers and roots oil from *Tithonia diversifolia*.

4. Conclusion

Leaves, stems, roots and flowers essential oils from *Tithonia diversifolia*, collected in Gagnoa, Attingui é Sikensi and Adjame have been analysed by chromatographic and spectroscopic technique. The EO samples were rich in monoterpenes and sesquiterpenes hydrocarbons, as α -pinene, β -pinene, often following by limonen, β -phellandrene, (E) β -caryo-

phyllene, modephene, trans-ocimene. In addition, statistical analysis exhibited distinct chemical group according to origin geographical and organs collected. It was found that the roots and stems of *Tithonia diversifolia*, were strongly linked and constituted the same group, when the second group is formed by the leaves and flowers. The chemical variability could be related to organ and edaphic factor.

Table 1. Chemical composition of essential oil of leaves, stems, flowers, roots of *Tithonia diversifolia* from Attingui é Adjame é Gagnoa and Sikensi.

N°	Compounds	Identification	Leaves				stems				Flowers		Roots				
			IK	FTAT	FTAD	FTG _A	FTSI	TTAT	TTAD	TTG _A	TTSI	FITA _D	FITG _A	RTA _T	RTA _D	RTG _A	RTS _I
1	α -pinene	CPG. SM.IR	935	29.76	8.66	16.82	15.06	68.4	75.99	88.03	80.05	35.08	42.04	51	67.01	97	95.5
2	camphene	CPG. SM.IR	947					-	-	0.9	0.86	0.7	-	0.73	0.99	-	1.67
3	γ -terpinene	CPG. SM.IR	970	-	3.5	2.8	-					-	1.1				
4	β -phellandrene	CPG. SM.IR	973	-	-	-	2.04				2.22	-					
5	β -pinene	CPG. SM.IR	976	4.58	1.49	2.77	2.84	15.05	6.29	2.78	4.5	1.72	2.68	10.1	1.46	1.47	1.69
6	eucalyptol	CPG. SM.IR	1030					9.83	-	-	-						

N°	Compounds	Identification	Leaves				stems				Flowers		Roots				
			IK	FTAT	FTAD	FTG A	FISI	TTAT	TTAD	TTG A	TISI	FITA D	FITG A	RTA T	RTA D	RTG A	RTS I
7	limonene	CPG. SM.IR	1031	8.43	49	44.06	26.18	-	14.29	7.39	-	40.07	33.08				
8	<i>trans</i> - β -ocimene	CPG. SM.IR	1037	28.35	18.1	27.02	25.58					-	18.93				
9	3-carene	CPG. SM.IR	1040	6.06	-	-	-										
10	cymene	CPG. SM.IR	1052	-	-	-	3.05	-	-	-	1			-	1.44	-	-
11	<i>trans</i> -verbenol	CPG. SM.IR	1107					-	-	-	3.74						
12	α -campholenal	CPG. SM.IR	1126											0.9	-	-	-
13	carveol	CPG. SM.IR	1144									-	0.53				
14	(1R)- <i>cis</i> -verbenol	CPG. SM.IR	1145					1.36	-	-	2.72	0.66	-	1.3	-	-	-
15	2-isopropylidene-3-methylhexa-3,5-dienal	CPG. SM.IR	1161									1.2	-				
16	<i>cis</i> -chrysanthenol	CPG. SM.IR CPG. SM.IR	1164									2.27	-				
17	pinocarvone	CPG. SM.IR	1164					0.7	-	-	1.1						
18	<i>cis</i> -myrtenal	CPG. SM.IR	1198					0.86	-	-	1.31						
19	L-verbenone	CPG. SM.IR	1211					1.34	-	-	3.06			0.98	-	-	-
20	1,2:8,9-diepoxy-p-menthane	CPG. SM.IR	1262					-	-	-	1.09						
21	thymol	CPG. SM.IR	1327									1.1	-				
22	(-)-aristolene	CPG. SM.IR	1344											2.61	1.81	-	-
25	α -cubebene	CPG. SM.IR	1380	-	3.55	-	-	-	0.8	-	-	11.29	0.74	0.91			
26	modephene	CPG. SM.IR	1384	7.59	-	-	-	1.36	1.63	-	-			15.8	14.59	-	1.08
	α -isocomene	CPG. SM.IR	1391														
27	β -isocomene	CPG. SM.IR	1411											6.61	5.37	-	-

N°	Compounds	Identification	Leaves				stems				Flowers		Roots				
			IK	FTAT	FTAD	FTG A	FTSI	TTAT	TTAD	TTG A	TTSI	FITA D	FITG A	RTA T	RTA D	RTG A	RTS I
28	<i>E-β</i> -caryophyllene	CPG. SM.IR	1424	0.41	5.92	3.01	6.06										
29	<i>β</i> -cedrene	CPG. SM.IR	1426									0.47	-	1.02	-		
30	<i>cis-α</i> -bisabolene	CPG. SM.IR	1458	6.5	-	-	-										
31	humulene	CPG. SM.IR	1458	0.35	-	-	0.3										
32	eremophilene	CPG. SM.IR	1493								0.89	-					
33	<i>β</i> -guaiene	CPG. SM.IR	1499	-	-	0.6	-										
34	bicyclogermacrene	CPG. SM.IR	1501	-	-	-	2										
35	<i>β</i> -curcumene	CPG. SM.IR	1504	-	-	-	-										
36	<i>δ</i> -cadinene	CPG. SM.IR	1525	0.7	1.15	-	-				1						
38	nerolidol	CPG. SM.IR	1573	1.1	-	-	1.11										
39	dehydro-aromadendrene.	CPG. SM.IR	1582	-	8.16	2.02	-										
40	Spatulenol	CPG. SM.IR	1584	-	-	-	7.08				1.7	-					
41	oxyde de caryophyllene	CPG. SM.IR	1590	2.2	-	-	5.08										
42	isopatulene	CPG. SM.IR	1645	2.67	-	-	0.53										
43	neointermedeol	CPG. SM.IR	1663	-	-	-	1.6										
Monoterpenes hydrocarbons (%)				77.18	80.7	93.47	74.75	83.45	96.57	99.1	86.41	79.79	97.83	61.8	70.9	98.5	98.9
Monoterpenes oxygenated (%)				0.00	0	0	0	14.09	0	0	13.02	5.23	0.53	3.18	0	0	0
Sesquiterpenes hydrocarbons (%)				18.22	18.8	5.63	8.89	1.36	2.43	0	0	13.18	0.74	34.8	28.8	1.02	1.08
sesquiterpenes oxygenated (%)				3.3	0	0	14.87	0	0	0	0	1.7	0	0	0	0	0
Total (%)				98.7	99.5	99.1	98.51	98.9	99	99.1	99.43	99.9	99.1	99.8	99.7	99.5	99.9

Identification methods: IK. Theoretical Kovat indices (Pubchem and NIST); SM. Comparison of mass spectra with PAL 600® libraries; STD. comparison of retention time and mass spectra with commercially available standards; IR. comparison of retention index with literature; reference; -. Under perception threshold

Abbreviations

TTAT	Stems Sample from Attingui é
TTAD	Stems Sample from Adjám é
TTGA	Stems Sample from Gagnoa
TTSI	Stems Sample from Sikensi
RTAT	Roots Sample from Attingui é
RTAD	Roots Sample from Adjám é
RTGA	Roots Sample from Gagnoa
RTSI	Roots Sample from Sikensi
FTAT	Leaves Sample from Attingui é
FTAD	Leaves Sample from Adjám é
FTGA	Leaves Sample from Gagnoa
FTSI	Leaves Sample from Sikensi
FITAD	Flowers Sample from Adjám é
FITGA	Flowers Sample from Gagnoa

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Daniela, A., Rejane, B., Bruno, A., Fernando, B. Ethnobotany, Chemistry, and Biological Activities of the Genus *Tithonia* (Asteraceae). *Chemistry and Biodiversity*. 2012, 9(2), 210–235. <https://doi.org/10.1002/cbdv.201100019>
- [2] Mayara, T., Deisiane, D., Christopher, D., Alex, B., Ryan, D., Flavia, D., Paula, S., Távora, N., Moreira, D. Antioxidant effect of plant extracts of the leaves of *Tithonia diversifolia* (Hemsl.) A. Gray on the free radical DPPH. *Journal of Chemical Pharmaceutical Research*. 2016, 8(8): 1182-1189. <https://doi.org/10.5555/20163312469>
- [3] Olukunle, J., Sogebi, E., Aoyewusi, J. Anti-inflammatory and Analgesic potential of aqueous leaf extract of *Tithonia diversifolia* in rodents. *Journal of Natural Science, Engineering and Technology*. 2014, 13(1): 82-90. 17. [https://doi.org/10.1016/S0367-326X\(02\)00118-1](https://doi.org/10.1016/S0367-326X(02)00118-1)
- [4] Mabou, A., Marino, F., Cosentino, M. *Tithonia diversifolia* (Hemsl.) A. Gray as a medicinal plant: A comprehensive review of its ethnopharmacology, phytochemistry, pharmacotoxicology and clinical relevance. *Journal of Ethnopharmacology*. 2018, 220, 94–116. <https://doi.org/10.1016/j.jep.2018.03.025>
- [5] Elufioye, T., Agbedahunsi, J. Antimalarial activities of *Tithonia diversifolia* (Asteraceae) and *Crossopteryx febrifuga* (Rubiaceae) on mice in vivo. *Journal of Ethnopharmacology*. 2004, 93, 167–171. <https://doi.org/10.1016/j.jep.2004.01.009>
- [6] Goffin, E., Ziemons, E., De Mol, P., De Madureira, M. C., Martins A. P., Da Cunha G, Philippe A. P., Tits M., Angenot L., Frederich M. In vitro antiplasmodial activity of *Tithonia diversifolia* and identification of its main active constituent: Tagitinin C. *Planta Medica*; 2002, 68(6): 543-545. 20. <https://doi.org/10.1055/s-2002-32552>
- [7] Suherman, S., Hamzah, B., Pulukadang, S., Rahmawati, S., Hardani, M., Hardani, R., Saifah, A. Antidiabetic effect test of Insulin stem extract (*Tithonia diversifolia*) toward streptozotocin-induced diabetic rats (*Rattus Norvegicus*). *Open Access Macedonian journal of medical sciences*. 2022, 10(A), 1006-1010. <https://doi.org/10.3889/oamjms.2022.8411>
- [8] Akinola, J., Larbi, A., Odedire, J., Aderinola, O., Lakpini, C., Amodu, J., Tanko, J., Musa, A. Effects of NPK Fertilizer application and plant density on forage yield and chemical composition of wild sunflower (*Tithonia diversifolia*). *Nigerian Journal of Animal Production*. 2023, 50(1), 46 – 60. <https://doi.org/10.51791/njap.v50i1.3692>
- [9] Kerebba, N., Oyedeji, A., Byamukama, R., Kuria, S., Oyedeji, O. Pesticidal activity of *Tithonia diversifolia* (Hemsl.) A. Gray and *Tephrosia vogelii* (Hook f.); phytochemical isolation and characterization. *South African Journal of Botany*. 2019, 121, 366–376. <https://doi.org/10.1016/j.sajb.2018.11.024>
- [10] Krüger, A., Lima, P., Ovani, V., Pérez-Marqu é, S., Louvandini, H., Abdalla, A. Ruminant Grazing Lands in the Tropics: Silvopastoral Systems and *Tithonia diversifolia* as Tools with Potential to Promote Sustainability. *Agronomy*. 2024, 14, 1386. <https://doi.org/10.3390/agronomy14071386>
- [11] Cédric, A., Loick, P., Cyrille, N., Estelle, E., Glwadys, C., Francois, E., Lawrence, A., Carole, E. Chemical composition and repellent activity of essential oils of *Tithonia diversifolia* (Asteraceae) leaves against the bites of anopheles coluzzii. *Scientific reports*. 2023, 13, 6001, 137. <https://doi.org/10.1038/s41598-023-31791-6>
- [12] Tcheugoue, J., Mbida, J., Ngaha, R., Awasi, D., Magne, T., Nkouadou, M., Tchoffo, F., Latic, M., Lemofouet, B., Jazet, M., Akono, N. Larvicidal activities of some plants essential oils of the Cameroonian flora against *Anopheles gambiae* S. L. major vector of malaria in the city of Douala. *Journal of Entomology and Zoology Studies*. 2022, 7-12. <https://doi.org/10.22271/j.ento.2022.v10.i4a.9020>
- [13] Ajao, A., Moteete, A. *Tithonia diversifolia* (Hemsl.) A. Gray. (Asteraceae: Heliantheae), an invasive plant of significant ethnopharmacological importance: A review. *South African Journal of Botany*. 2017, 113, 396–403. <https://doi.org/10.1016/j.sajb.2017.09.017>
- [14] Ana, L., Alex, B., Rosany, L., Erica, M., Carlos, W., Sheylla, S. Chemical characterization, antioxidant, cytotoxic and micro-biological activities of essential oil leaf *Tithonia diversifolia* (Heml.) A. Gray (Asteraceae). *Pharmaceuticals*. 2019, 12-14. <https://doi.org/10.3390/ph12010034>
- [15] Thiyam B. Devi., Vishakha R., Dinabandhu S. Y. R. Composition chimique et toxicité fumigante de l'huile essentielle de *Tithonia diversifolia* (Hemsl.) A. Gray contre deux principaux insectes nuisibles aux céréales stockées. *Journal of Plant Diseases and Protection*. 2021, 2, 607-615. <https://doi.org/10.1007/s41348-020-00424-9>
- [16] Florence, A., Koffi, A., Tonzibo, Z. Chemical variability of *Tithonia diversifolia* (hemsl.) A. Gray leaf and stem oil from côte d'ivoire. *International Journal of Pharmaceutical Science and Research*. 2015, 2214-2222. [https://doi.org/10.13040/IJPSR.0975-8232.6\(5\).2214-22](https://doi.org/10.13040/IJPSR.0975-8232.6(5).2214-22)

- [17] Bettaieb, R., Bourgou, S., Aidi, W., Hamrouni, S., Saidani, T., Marzouk, B. Comparative assessment of phytochemical profiles and antioxidant properties of Tunisian and Egyptian anise (*Pimpinella anisum L*) seeds. *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology*. 2018, 971-978. <https://doi.org/10.1080/11263504.2017.1403394>
- [18] Evelyne, A., Fatimata, N., Thierry, K., Manon, G., Matthew, S., Zannah, F., Marie, L. Antioxydant and Lipoxygenase Inhibitory Activities of Essential Oils from Endemic Plants of Cote d'Ivoire: *Zanthoxylum mezoneurispinosum* Ake Assi and *Zanthoxylum psammophilum* Ake Assi. *Molecules*. 2019, 24(13), 2445. <https://doi.org/10.3390/molecules24132445>
- [19] Lamaty, G., Menut, C., Zollo, P., Kuate, J., Bessiere, J. Aromatic plants of Tropical Central Africa III. Constituents of the essential oils of the leaves of *Tithonia diversifolia* (Hemsl) A. Gray from Cameroon. *Journal of Essential Oil Research*. 1991, 399-402. <https://doi.org/10.1080/10412905.1994.9698317>
- [20] Lawal, O., Adeleke, A., Andy, R., Adebola, O. Volatile constituents of the flowers, leaves, stems and roots of *Tithonia diversifolia* (Hemsely) A. Gray. *Journal of Essential Oil Bearing Plant*. 2013, 816-821. <https://doi.org/10.1080/0972060X.2012.10644125>
- [21] Chukwuka, K., Ojo, O. Extraction and Characterization of Essential Oils from *Tithonia diversifolia* (Hemsl.) A. Gray. *American Journal of Essential Oils and Natural Products*. 2014, 1-5.
- [22] Moronkola, D., Isiaka, A., Ogunwande, A., Tameka, A., Walker, M., William, A., Setzer, N., Isaac, A., Oyewole, O. Identification of the main volatile compounds in the leaf and flower of *Tithonia diversifolia* (Hemsl) Gray. 2007, 61-66. *Journal of Natural Medicines*. 61, 63-66. <https://doi.org/10.1007/s11418-006-0019-5>
- [23] Oludare, O., Stephen, O., Joshua, O., Abdulwakeel, A., Oladipo, A. Chemical composition and antimicrobial activities of essential oil extracted from *Tithonia diversifolia* (Asteraceae) flower. 2016, *Journal of Bioresources and Bioproducts*. 1(4): 169-176. <https://doi.org/10.21967/jbb.v1i4.60>
- [24] Menut, C., Lamaty, G., Zollo, P., Kuate, J., Bessiere, J. Aromatic Plants of Tropical Central Africa. IX. Chemical composition of Flower Essential oils of *Tithonia diversifolia* (Hemsl.) A; Gray from Cameroon. *Journal of Essential Oil Research*. 1992, 4(6), 651-653. <https://doi.org/10.1080/10412905.1992.9698153>