



AkiNik

American Journal of Essential Oils and Natural Products

Available online at www.essencejournal.com

A
J
E
O
N
P
American
Journal of
Essential
Oils and
Natural
Products

ISSN: 2321-9114

<https://www.essencejournal.com>

AJEONP 2026; 14(1): 10-14

© 2026 AkiNik Publications

Received: 06-11-2025

Accepted: 08-12-2025

Terer V Cheruiyot

Department of Chemistry and
Biochemistry, School of Science,
University of Eldoret, Eldoret,
Kenya

Tarus K Paul

Department of Chemistry and
Biochemistry, School of Science,
University of Eldoret, Eldoret,
Kenya

Omolo V Maurice

Center for African Medicinal
Flora and Fauna, Masinde
Muliro University of Science and
Technology, Kakamega, Kenya

Wetungu W Martin

Department of Chemistry and
Biochemistry, School of Science,
University of Eldoret, Eldoret,
Kenya

Chemical profiles of essential oils of *Croton dichogamus* and *Croton megalocarpus* from Elkeiyo Marakwet, Kenya

Terer V Cheruiyot, Tarus K Paul, Omolo V Maurice and Wetungu W Martin

DOI: <https://www.doi.org/10.22271/23219114.2026.v14.i1a.286>

Abstract

Essential oils are rich in bioactive compounds which generally contribute to the overall medicinal value of plant species. Euphorbiaceae plants are mostly used by the traditional herbalists to treat different kinds of ailments. This work was aimed at determining the chemical profiles of *Croton dichogamus* and *Croton megalocarpus*. The leaf essential oils were extracted using hydro-distillation in a modified Clevenger apparatus. Gas-chromatography and mass spectrometry was used to determine the chemical constituent of essential oils. Among the major monoterpene hydrocarbons identified from *Croton dichogamus* were β -terpinene (42.19%), *p*-cymene (5.05%), α -pinene (4.04%), (β -pinene (2.45%), β -terpinene (2.42%) and limonene (5.05%), sesquiterpenes identified were (*E*)-caryophyllene (1.38%), α -humulene (1.20%) and α -curcumene (1.82). Oxygenated monoterpenes present were linalool (3.59%), 2-bornanone (2.44%), terpinen-4-ol (10.09%), α -terpineol (1.04%) and terpinen-4-ol (10.09%). Major compounds identified from *Croton megalocarpus*, included monoterpenes; α -pinene (8.04%), sabinene (6.93%), β -pinene (24.62%), *o*-cymene (4.58%), sesquiterpene (*E*)-caryophyllene (7.09%) and oxygenated sesquiterpene caryophyllene oxide (7.09%). α -Humulene (0.08-1.58%), α -pinene (1.38-26.20%), α -cubebene (0.03-0.6%) and caryophyllene oxide (0.24-7.09%) were identified in all the essential oils of plants used in this study. The presence of oxygenated monoterpenes and sesquiterpenes suggests that the essential oils could be effective in managing secondary infections.

Keywords: Essential oils, *croton dichogamus*, *Croton megalocarpus*, chemical profiles and antimicrobials

1. Introduction

The WHO estimates that around 80% of the world population in developing countries relies largely on traditional plant medicine for primary healthcare needs of which a major proportion is attributed to plant extracts^[1]. *Croton* species have been used by many communities across the world for medicinal purposes. For instance; *Croton zambesicus* Müll.Arg. (Syn. *Croton gratissimus* Burch. var. *gratissimus*), which is native to tropical west and Central Africa is used to treat fever, dysentery and convulsions^[2]. The leaf decoction of this plant is used in Benin as anti-hypertensive, anti-microbial (urinary infections) and in treatment of malaria-linked fever^[3, 4]. *Croton arboreous* Millsp. Is native to Mexico and a beverage prepared from its aerial parts, in Tabasco and Chiapas was used as an auxiliary anti-inflammatory in respiratory ailments^[5]. The *Croton* species have been reported to possess biological activities such as anti-inflammatory^[1, 7, 8, 9], anti-bacterial^[10, 11], insecticidal^[12], and antibiotic^[13]. The *Croton* species under this study have also been reported to have medicinal properties. The leaf extract of *C. dichogamus* Pax was widely used for treatment of teeth infections and urinary tract infections^[14]. The smoke from the burnt leaves of *C. dichogamus*, when inhaled, provides relief from fever apart from possessing anti-inflammatory activity^[15, 16]. It is also reported to exhibit insecticidal activity^[12]. The crude powdered leaf extract of *C. dichogamus* is highly effective in protecting the Bambara groundnut seeds against damage by field pests and storage insects like *Callosobruchus maculatus* over a period of 180 days^[14, 17]. Most of the *Croton* species are rich in terpenoids, compounds known to possess insecticidal properties^[18]. The plant species was recently reported to have antimalarial activity^[19].

Croton megalocarpus Hutch is considered an important medicinal plant species in Kenya as shown by the Kipsigis community which use leaf decoction in the treatment of diabetes^[20]. The decoction from the leaf and root bark is applied topically on wounds^[21, 22, 23] this could

Corresponding Author:**Terer V Cheruiyot**

Department of Chemistry and
Biochemistry, School of Science,
University of Eldoret, Eldoret,
Kenya

Be attributed to the fact that the plant has been found to possess antibacterial and inflammatory activity^[24].

Although most Euphorbiaceae plants are not known to be aromatic, some *Croton* species contain essential oils. Other species have not been reported as bearing essential oils, though they were shown to contain sesquiterpenes commonly found in essential oils. The essential oils of several species of *Croton* have been reported to be rich in hydrocarbons, monoterpene and oxygenated sesquiterpenes^[25, 26, 27, 28, 29]. For instance essential oils of *Croton adipatus* Kunth, *Croton collinus* Kunth (syn. *Croton ferrugineus* Kunth), and *Croton thurifer* Kunth were found to contain reasonable amounts of α -thujene, α -pinene, sabinene, α -phellandrene, limonene and germacrene-D^[26]. Some *Croton* species have been shown to contain essential oils in their leaves and stems but there is no reported work on *C. megalocarpus* and *C. dichogamus* other than a recent study that showed the two species possess antiviral activity^[29].

2. Materials and Methods

2.1 Collection and Identification of plant materials

The leaves of *Croton dichogamus* and *Croton megalocarpus* were collected from Kolol view point, Elkeiyo Marakwet County in Kenya (0.5561°N and 35.5346°E). All the plants' leaves were collected in June 2020 and identified by a taxonomist, and the voucher specimens; MUH/CRD/013/17 and MUH/CRM/02/18 respectively were kept at Herbarium, University of Eldoret, Kenya.

2.2 Experiment site

The extraction of essential oils was conducted in Center for African Medicinal and Nutritional Flora and Fauna laboratory at Masinde Muliro University of Science and Technology (MMUST), Kakamega County, Kenya.

2.3 Extraction of essential oils from the selected species

Fresh leaves of each species were put in 5-litres double-necked round bottom flask. Distilled water was added until it covered the plant materials. The leaves were then subjected to hydro-distillation for 3 hours. The essential oil distillate were dried over anhydrous sodium sulfate, packed in sealed glass vials and kept at 4 °C^[7 & 15].

2.4 Analysis of the essential oil constituents of the selected plant species

Analyses of the oils and identification of the components were Carried out by GC, GC-MS and GC co-injection of the

Essential oils with authentic samples. Analyses were performed on a capillary gas chromatograph, Hewlett Packard (HP) 5890 Series II, equipped with a split-less capillary injector system, 50 m $\times$ 0.2 mm (i.d) cross-linked methyl silicone made by Huntsman Chemical Corporation, (0.33 film thickness), capillary column and FID coupled to HP 3393A Series II integrator. The carrier gas was N₂ at 280 °C at 5 °C/min and a hold at this temperature for 10 min. GC-MS analyses were carried out on a HP 8060 Series II Gas chromatograph coupled to a VG platform II Mass Spectrometer. The MS was operated in the EI mode at 70 eV and an emission current of 200 A. The temperature of the source was held at 180°C and the multiplier voltage at 300V. The pressure of the ion source and MS detector were held at 9.4×10^{-6} and 1.4×10^{-5} bar respectively. The MS had a scan scale cycle of 1.5 s (scan duration of 1 s and inter-scan delay of 0.5 s). The instrument was calibrated using heptacosafuorotributyl amine, [CF₃ (CF₂)₃]N, (Apollo Scientific Ltd., UK). The column used for GC-MS was the same as the one described for GC analysis except for the film thickness. The temperature programe involved an initial temperature of 50 °C (5 min), to 90 °C at 5 °C/min, to 200 °C at 2 °C/ min, to 280 °C at 20 °C/min and a hold at this temperature for 20 min. Identification of the components was made by comparison of mass spectra and retention index with published data (NIST, Wiley libraries) and confirmed, where possible by GC co-injection with authentic samples^[31, 32].

3. Results

Considering only constituents present in >0.5%, γ -terpinene (0.64-3.76%), α -humulene (0.08-1.58%), α -pinene (1.38-26.20%), α -cubebene (0.03-0.6%) and caryophyllene oxide (0.24-7.09%) were identified in all the essentials oils.

3.1 *Croton dichogamus*

A total of 88 compounds were identified in *C. dichogamus* fresh leaf oil which accounted for 90% of the total leaf oil composition of the plant. The major constituents present in >0.5%, are shown in figure 1 and listed in table 1. Some of them were; α -thujene (1.02%), α -pinene (4.04), β -terpinene (42.19%), β -pinene (2.45%), *p*-cymene (5.05%), limonene (2.42%), γ -terpinene (1.18%), linalool (3.89%), camphor (2.44%), terpinen-4-ol (10.09%), l- α -terpineol (1.04%), (*E*)-caryophyllene (1.38%), α -humulene (1.20%), *ar*-curcumene (1.82%) and β -cubebene (2.00%).

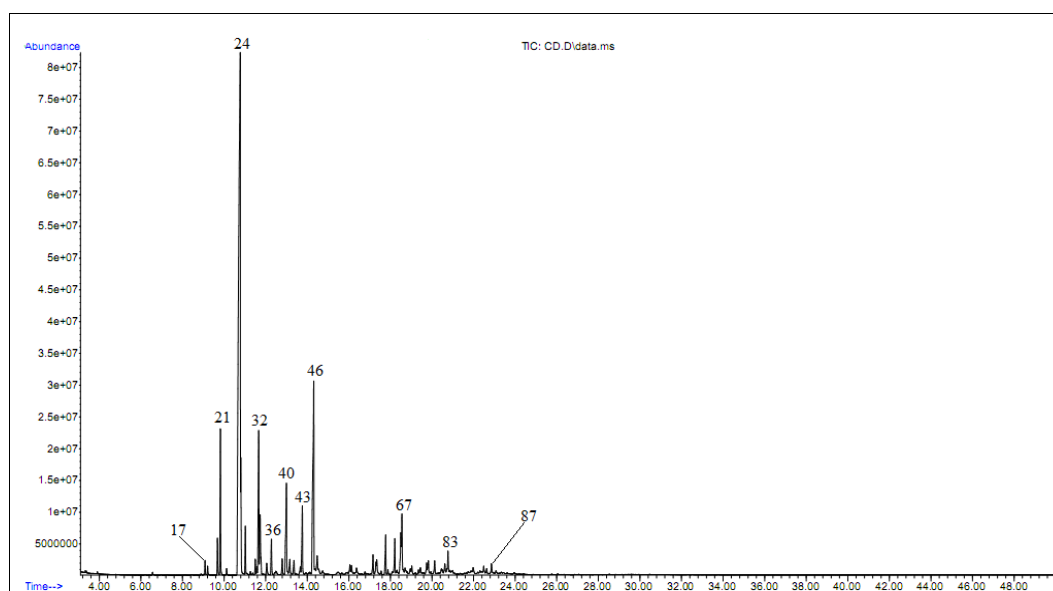


Fig 1: Total ion chromatogram of the leaf essential oil of *Croton dichogamus*

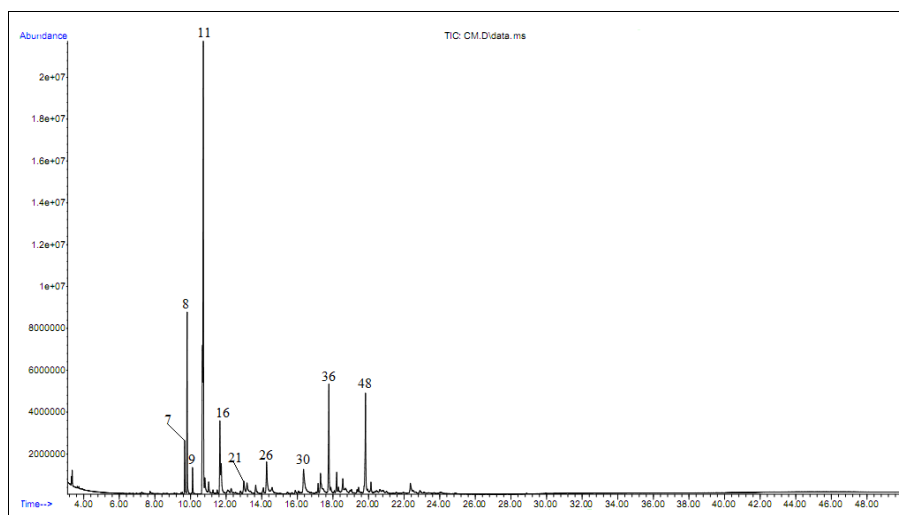
Table 1: Major Chemical constituent of the leaf essential oil of *Croton dichogamus*

RT	Compound identified	Chemical formula	Peak area%
9.68	α -thujene	C ₁₀ H ₁₆	1.02
9.83	α -pinene	C ₁₀ H ₁₆	4.04
10.77	β -terpinene	C ₁₀ H ₁₆	42.19
10.80	β -pinene	C ₁₀ H ₁₆	2.45
11.66	<i>p</i> -cymene	C ₁₀ H ₁₄	5.05
11.73	limonene	C ₁₀ H ₁₆	2.42
12.28	γ -terpinene	C ₁₀ H ₁₆	1.18
13.00	linalool	C ₁₀ H ₁₈ O	3.89
13.76	camphor	C ₁₀ H ₁₆ O	2.44
14.31	terpinen-4-ol	C ₁₀ H ₁₈ O	10.09
14.48	α -terpineol	C ₁₀ H ₁₈ O	1.04
17.16	α -copaene	C ₁₅ H ₂₄	0.77
17.34	β -copaene	C ₁₅ H ₂₄	0.70
17.77	(<i>E</i>)-caryophyllene	C ₁₅ H ₂₄	1.38
18.21	α -humulene	C ₁₅ H ₂₄	1.20
18.50	<i>ar</i> -curcumene	C ₁₅ H ₂₂	1.82
18.55	β -cubebene	C ₁₅ H ₂₄	2.00
19.75	spathulenol	C ₁₅ H ₂₄ O	0.50
19.83	caryophyllene oxide	C ₁₅ H ₂₄ O	0.67
22.86	platambin	C ₁₅ H ₂₆ O ₂	0.66

3.2 *Croton megalocarpus*

A total of 54 compounds were identified in the oils of *C. megalocarpus* fresh leaf (figure 2; table 2) which accounted for 94% of the total oil. Monoterpene hydrocarbons were found in higher amounts of the identified constituents accounting for 69% of the oil

while sesquiterpenes accounted for 20% of the total oil. The major constituents present in >0.5% are shown in total ion chromatogram (figure 2) and listed in table 2. Some of them includes; α -pinene (8.04%), sabinene (6.93%), β -pinene (24.62%), *p*-cymene (4.58%) (*E*)-caryophyllene (7.09%) and caryophyllene oxide (7.09%)

**Fig 2:** Total ion chromatogram of the leaf essential oils of *Croton megalocarpus***Table 2:** Major Chemical constituent of *Croton megalocarpus* leaf essential oils

RT	Compound identified	Chemical formula	peak area%
9.81	α -Pinene	C ₁₀ H ₁₆	8.04
10.12	Camphene	C ₁₀ H ₁₆	1.29
10.67	Sabinene	C ₁₀ H ₁₆	6.93
10.72	β -Pinene	C ₁₀ H ₁₆	24.62
11.02	β -Phellandrene	C ₁₀ H ₁₆	1.05
11.65	<i>p</i> -Cymene	C ₁₀ H ₁₄	4.58
12.28	γ -Terpinene	C ₁₀ H ₁₆	0.64
13.00	Linalool	C ₁₀ H ₁₈ O	1.49
14.10	Borneol	C ₁₀ H ₁₈ O	0.64
14.28	Terpinen-4-ol	C ₁₀ H ₁₈ O	3.57
14.58	α -Thujenal	C ₁₁ H ₁₆ O	1.42
17.17	α -Copaene	C ₁₅ H ₂₄	0.75
17.31	β -Bourbonene	C ₁₅ H ₂₄	2.17
17.77	(<i>E</i>)-Caryophyllene	C ₁₅ H ₂₄	7.09
18.22	α -Humulene	C ₁₅ H ₂₄	1.58
18.31	Aromadendrene	C ₁₅ H ₂₄	0.55
18.56	Germacrene D	C ₁₅ H ₂₄	1.43
19.83	Caryophyllene oxide	C ₁₅ H ₂₄ O	7.09
20.64	α -Guaiene	C ₁₅ H ₂₄	0.68

4. Discussion

The analysis of *C. dichogamus* fresh leaf oil revealed a complex composition. Among the identified compounds, twenty were considered major constituents, each present in amounts greater than 0.5%. The monoterpenes α -pinene, α -thujene, β -terpinene, β -pinene, *p*-cymene, limonene, linalool, terpinen-4-ol, γ -terpinene, camphor and α -terpineol were identified in the essential oil of *C. dichogamus* for the first time. Similarly the most dominant sesquiterpene hydrocarbons reported for the first time included (*E*)-caryophyllene, α -humulene, and *ar*-curcumene, among others. The findings are in line with those of other *Croton* species such as *Croton zambesicus* is known to contain compounds such as α -pinene, sabinene, β -pinene and limonene as major constituents [33]. The specific monoterpenes and sesquiterpenes identified in this study may have implications for the potential biological activities and therapeutic properties associated with *C. dichogamus*.

Monoterpenes identified in the leaf oil of *C. megalocarpus* included α -pinene, camphene, sabinene, β -pinene, *p*-cymene, β -phellandrene, linalool, terpinen-4-ol, and α -thujenal. These monoterpenes have been previously reported in various essential oils and are known for their diverse biological activities [34, 35, 36, 37]. In addition, the most dominant sesquiterpene hydrocarbons identified in the essential oil of *C. megalocarpus* included (*E*)-caryophyllene, germacrene-D, α -humulene, β -bourbonene, and caryophyllene oxide [35, 37]. These sesquiterpenes contribute to the overall aroma and potential therapeutic properties of the essential oil [38]. The findings from this study provide valuable information about the major constituents present in Kenyan species of *C. megalocarpus* fresh leaf oil. The variation in the chemical composition of the major compound in the plant oil could be attributed to the difference in soil type and climatic conditions of the localities where the plants were collected. [39] Reports that the presences of germacrene-D in essential oils contribute to its anti-inflammatory effect.

5. Conclusion

The chemical profile of *Croton megalocarpus* and *Croton dichogamus* are rich in monoterpenes and sesquiterpenes and especially oxygenated constituents which have been shown in other studies to possess biological activities. The reported biological activities of the two plant species could be linked to the major terpenoid compounds identified in this study. The two plants belong to the same family but they do have different essential oil composition.

6. Acknowledgement

The authors acknowledge Masinde Muliro University of Science and Technology (MMUST) under the Centre for African Medicinal and Nutritional Flora and Fauna (CAMNFF) and Alupe Kenya Medical Research Institute (KEMRI), for availing their laboratories to be used in this research work. A special acknowledgement to National Research Fund (NRF) for funding this research.

Reference

- World Health Organization. Traditional medicine. Geneva: World Health Organization; 2008. Fact sheet No. 134.
- Ngadjui BT, Abegaz BM, Keumedjio F, Folefoc GN, Kapche GW. Diterpenoids from the stem bark of *Croton zambesicus*. *Phytochemistry*. 2002;60(4):345-349.
- Block S, Baccelli C, Tinant B, Van Meervelt L, Rozenberg R, Jiwan JLH, Quetin-Leclercq J. Diterpenes from the leaves of *Croton zambesicus*. *Phytochemistry*. 2004;65(8):1165-1171.
- Block S, Stevigny C, De Pauw-Gillet MC, de Hoffmann E, Llabres G, Adjakidjé V, Quetin-Leclercq J. Ent-trachyloban-3 β -ol, a new cytotoxic diterpene from *Croton zambesicus*. *Planta Medica*. 2002;68(7):647-649.
- Aguilar-Guadarrama AB, Rios MY. Three new sesquiterpenes from *Croton arboreus*. *Journal of Natural Products*. 2004;67(5):914-917.
- Abreu LS, do Nascimento YM, do Espirito-Santo RF, Meira CS, Santos IP, Brandão RB, et al. Phenylpropanoids from *Croton velutinus* with cytotoxic, trypanocidal and anti-inflammatory activities. *Fitoterapia*. 2020;145:104632.
- Bezerra FW, do N Bezerra P, de Oliveira MS, da Costa WA, Ferreira GC, de Carvalho RN. Bioactive compounds and biological activity of *Croton* species (*Euphorbiaceae*): An overview. *Current Bioactive Compounds*. 2020;16(4):383-393.
- Martins AOBPB, Rodrigues LB, Cesário FRAS, de Oliveira MRC, Tintino CDM, Castro FF, et al. Anti-edematogenic and anti-inflammatory activity of the essential oil from *Croton rhamnifolioides* leaves and its major constituent 1,8-cineole (eucalyptol). *Biomedicine and Pharmacotherapy*. 2017;96:384-395.
- Oliveira Brito Pereira Bezerra Martins A, Wanderley AG, Alcântara IS, Rodrigues LB, Cesário FRAS, Correia de Oliveira MR, et al. Anti-inflammatory and physicochemical characterization of the *Croton rhamnifolioides* essential oil inclusion complex in β -cyclodextrin. *Biology*. 2020;9(6):114-114.
- Daouda T, Prevost K, Gustave B, Joseph DA, Nathalie G, Raphaël O, et al. Terpenes, antibacterial and modulatory antibiotic activity of essential oils from *Croton hirtus* (*Euphorbiaceae*) from Ivory Coast. *Journal of Essential Oil Bearing Plants*. 2014;17(4):607-616.
- de Almeida TS, Rocha JBT, Rodrigues FFG, Campos AR, da Costa JGM. Chemical composition, antibacterial and antibiotic modulatory effect of *Croton campestris* essential oils. *Industrial Crops and Products*. 2013;44:630-633.
- Vunda SLL, Sauter IP, Cibulski SP, Roehe PM, Bordignon SAL, Rott MB, von Poser GL. Chemical composition and amoebicidal activity of *Croton pallidulus*, *Croton ericoides* and *Croton isabelli* (*Euphorbiaceae*) essential oils. *Parasitology Research*. 2012;111:961-966.
- Leite TR, Silva MAPD, Santos ACBD, Coutinho HDM, Duarte AE, Costa JGMD. Antimicrobial, modulatory and chemical analysis of the oil of *Croton limae*. *Pharmaceutical Biology*. 2017;55(1):2015-2019.
- Qwarse M, Mihale MJ, Joseph S, Mugoyela V, Henry L, Sunghwa F. Ethnobotanical survey of medicinal and pesticidal plants used by agro-pastoral communities in Mbulu District, Tanzania. *Tanzania Journal of Science and Technology*. 2018;1:22-35.
- Secco RDS, Cordeiro I, Senna-Vale LD, Sales MFD, Lima LRD, Medeiros D, Bigio NC. An overview of recent taxonomic studies on *Euphorbiaceae* in Brazil. *Rodriguésia*. 2012;63:227-242.
- Xu WH, Liu WY, Liang Q. Chemical constituents from *Croton* species and their biological activities. *Molecules*. 2018;23(9):2333.
- Tlankka NS, Mbega ER, Ndakidemi PA. Potential of

- indigenous pesticidal plants in the control of field and post-harvest arthropod pests in Bambara groundnuts in Africa: A review. *American Journal of Plant Science*. 2020;11(5):1-28.
18. Endris YA, Mekonnen KD. Formulation of neem leaf and *Croton* seed essential oils as a natural insecticide tested on mosquitoes and cockroaches. *ACS Omega*. 2023;8(17):15052-15061.
 19. Hashim D, Umer S, Hymete A, Mekonnen Y. *In vivo* anti-malarial activity of 80% methanol leaf extract of *Croton dichogamus* Pax and *Ehretia cymosa* Thonn in *Plasmodium berghei* infected mice. *Journal of Experimental Pharmacology*. 2024;16:221-229.
 20. Keter LK, Mutiso PC. Ethnobotanical studies of medicinal plants used by traditional health practitioners in the management of diabetes in Lower Eastern Province, Kenya. *Journal of Ethnopharmacology*. 2012;139(1):74-80.
 21. Njoroge GN, Bussmann RW. Ethnotherapeutic management of skin diseases among the Kikuyus of Central Kenya. *Journal of Ethnopharmacology*. 2007;111(2):303-307.
 22. Nanyingi MO, Mbaria JM, Lanyasunya AL, Wagate CG, Koros KB, Kaburia HF, *et al.* Ethnopharmacological survey of Samburu district, Kenya. *Journal of Ethnobiology and Ethnomedicine*. 2008;4(1):1-12.
 23. Kamau LN, Mbaabu PM, Mbaria JM, Gathumbi PK, Kiama SG. Ethnobotanical survey and threats to medicinal plants traditionally used for the management of human diseases in Nyeri County, Kenya. *CellMed*. 2016;6(3):21-21.
 24. Langat MK, Djuidje EF, Ndunda BM, Isyaka SM, Dolan NS, Ettridge GD, *et al.* The phytochemical investigation of five African *Croton* species: *Croton oligandrus*, *Croton megalocarpus*, *Croton menyharthii*, *Croton rivularis* and *Croton megalobotrys*. *Phytochemistry Letters*. 2020;40:148-155.
 25. Coutinho HDM, Matias EFF, Santos KKA, Tintino SR, Souza CES, Guedes GM, *et al.* Enhancement of the norfloxacin antibiotic activity by gaseous contact with the essential oil of *Croton zehntneri*. *Journal of Young Pharmacists*. 2010;2(4):362-364.
 26. Cucho-Medrano JLL, Mendoza-Beingolea SW, Fuertes-Ruitón CM, Salazar-Salvatierra ME, Herrera-Calderon O. Chemical profile and antimicrobial activity of essential oils from *Croton adipatus*, *Croton thurifer* and *Croton collinus*. *Antibiotics*. 2021;10(11):1387.
 27. Donati M, Mondin A, Chen Z, Miranda FM, do Nascimento BB Jr, Schirato G, *et al.* Radical scavenging and antimicrobial activities of *Croton zehntneri*, *Pterodon emarginatus* and *Schinopsis brasiliensis* essential oils and their major constituents. *Natural Product Research*. 2015;29(10):939-946.
 28. Luu-Dam NA, Le CVC, Satyal P, Le TMH, Bui VH, Vo VH, Setzer WN. Chemistry and bioactivity of *Croton* essential oils: Literature survey and *Croton hirtus* from Vietnam. *Molecules*. 2023;28(5):2361.
 29. Suárez AL, Vásquez LJ, Taddei A, Arvelo F, Compagnone RS. Antibacterial and cytotoxic activity of leaf essential oil of *Croton malambo*. *Journal of Essential Oil Bearing Plants*. 2008;11(2):208-213.
 30. Terefe EM, Okalebo FA, Derese S, Langat MK, Mas-Claret E, Aljarba NH, *et al.* *In vitro* anti-HIV and cytotoxic effects of compounds from *Croton macrostachyus*. *BMC Complementary Medicine and Therapies*. 2022;22(1):159.
 31. Adams JC. Thrombospondins: Multifunctional regulators of cell interactions. *Annual Review of Cell and Developmental Biology*. 2001;17(1):25-51.
 32. Yang J, Manolio TA, Pasquale LR, Boerwinkle E, Caporaso N, Cunningham JM, *et al.* Genome partitioning of genetic variation for complex traits using common SNPs. *Nature Genetics*. 2011;43(6):519-525.
 33. Moremi MP, Makolo F, Viljoen AM, Kamatou GP. A review of biological activities and phytochemistry of six ethnomedicinally important South African *Croton* species. *Journal of Ethnopharmacology*. 2021;280:114416.
 34. Atabani AE, Mahlia TMI, Masjuki HH, Badruddin IA, Yussof HW, Chong WT, Lee KT. Comparative evaluation of biodiesel properties from edible and non-edible oils. *Energy*. 2013;58:296-304.
 35. Kivevele TT, Mbarawa MM. Fuel properties of biodiesel from *Croton megalocarpus* oil. *Energy and Fuels*. 2010;24(11):6151-6155.
 36. Sadgrove NJ. Purely Australian essential oils: Chemical diversity, authenticity, bioactivity, and commercial value. *Diversity*. 2022;14(2):124.
 37. Sadgrove NJ, Madeley LG, Van Wyk BE. Volatiles from African species of *Croton* (*Euphorbiaceae*), including new diterpenes in *Croton gratissimus*. *Heliyon*. 2019;5(10):e02600.
 38. Djilani A, Dicko A. The therapeutic benefits of essential oils. *Nutrition, Well-Being and Health*. 2012;7:155-179.
 39. Mssillou I, Agour A, El Ghouzi A, Hamamouch N, Lyoussi B, Derwich E. Chemical composition, antioxidant activity, and antifungal effects of essential oil from *Laurus nobilis* L. flowers growing in Morocco. *Journal of Food Quality*. 2020;2020:1-8.