Trop J Nat Prod Res, July 2024; 8(7): 7920-7927 **ISSN 2616-0684 (Print)**
ISSN 2616-0692 (Electronic)

Tropical Journal of Natural Product Research

Available online at https://www.tjnpr.org

Original Research Article

Phytochemical Profiling and GC- MS Analysis of *Lantana camara* Leaf Extract

Ebele A. Orji[1*], Vincent C. Ejere[1] Christian T. Orji[1], Eleazar C. Anorue[2], Nelson I. Ossai[1], Eugene O. Ojua[3], Christopher D. Nwani[1], Joseph E. Eyo[1]

[1]*Department of Zoology and Environmental Biology, University of Nigeria, Nsukka, 410001 Enugu, Nigeria.*
[2]*Department of Veterinary Physiology and Pharmacology, University of Nigeria, Nsukka, 410001 Enugu, Nigeria.*
[3]*Department of Plant Science and Biotechnology, University of Nigeria, Nsukka, 410001 Enugu, Nigeria.*

ARTICLE INFO

Article history:
Received 4 September, 2023
Revised 31 January, 2024
Accepted 29 July 2024
Published online 1 August 2024

ABSTRACT

Identification of the phytochemical composition of plants is vital in new drug discovery and lead compound development for the management of infectious and non-infectious diseases. *Lantana camara* is an important medicinal essential oil-producing plant used in folklore medicine for the treatment of several diseases. This study evaluated the phytochemical composition and profiled the biologically active principles present in *L. camara* leaf extracts collected from Orba, Enugu State of Nigeria. The profiling of *L. camara* leaves methanol and aqueous extracts was done using qualitative and quantitative phytochemical and GC-MS techniques. The phytochemical screening showed the presence of alkaloids, terpenoids, flavonoids and other phenolic compounds. There were no significant differences ($p > 0.05$) in the steroids, saponins, terpenoids, glycosides and phenolic contents of methanol and aqueous extracts. The phenolic content in methanol (1563.85±0.07 mg/100g) and aqueous (1425.23±0.36 mg/100g) were significantly higher than other phytochemicals tested in this study. There was significantly ($p < 0.05$) higher alkaloids (506.74±5.52 mg/100g), flavonoids (372.04±8.39 mg/100g) and tannins (1426.43±7.43 mg/100g) in the methanol compared with the aqueous extracts with 349.92±13.10 mg/100g, 231.99±6.16 mg/100g and 1351.62±20.6 mg/100g respectively. The GC-MS analysis showed the presence of 39 biologically important compounds which included bis(2-ethylhexyl) phthalate, 9,19-cyclolanostan-3-ol-11-one acetate, 4H-1-benzopyran-4-one-5-hydroxy-2-(4-hydroxyphenyl), n-hexadecanoic acid, (Z)-7-hexadecenal, phytol acetate, phytol, 3,7,11,15-tetramethyl-2-hexadecen-1-ol and bicyclo [4.4.0] dec-2-ene-4-ol 2-methyl-9-(prop-1-en-3-ol-2-yl). The phytochemical analysis and the GC-MS profiling of the extracts of *L. camara* showed the presence of biologically important phytochemicals which could be responsible for the ethnomedicinal effects of *L. camara*.

Keywords: *Lantana camara*, Phytochemical screening, Bioactive compounds, Therapeutic effects, New drug, Pharmaceutical industries

Introduction

In several parts of the world and cultural settings, herbs are used as medicine to treat various kinds of ailments.[1] This is due to the existence of phytochemicals also known as specialized metabolites in different parts of plants.[2] Phytochemicals are essential in the pharmaceutical industry for the production of drugs and other treatment agents.[1] The development of drugs begins with the identification of bioactive compounds and other active principles present in plants.[3] This can only be achieved by the screening of plant extracts.[4] Phytochemical screening of plant extract is the best method for finding curatively active principles in plant species.[5] When determining the concentration of certain active compounds in plants used in cosmetics, medicines, the food or pharmaceutical industries, the environment, or forensic applications, the GC-MS approach can be a useful tool.

*Corresponding author. chris4mission@gmail.com
Tel: 234 8063393872

Citation: Orji EA, Ejere VC, Orji CT, Anorue EC, Ossai NI, Ojua EO, Nwani CD and Eyo JE. Phytochemical Profiling and GC- MS Analysis of *Lantana camara* Leaf Extract. Trop J Nat Prod Res. 2024; 8(7):7920-7927 https://doi.org/10.26538/tjnpr/v8i7.40

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria

It combines two analytical methods into one to analyse chemical component combinations. Mass spectroscopy examines each component independently after the gas chromatography process separates the mixture's constituent parts. Several of these active principles in plants have been found to possess anti-inflammatory, anti-diarrhoea, antimutagenic, antiulcerogenic, antimicrobial, antidiabetic, hepatoprotective and cardioprotective activities.[6] Some examples of these phytochemicals are flavonoids, tannins, alkaloids, saponins and terpenoids.[7] *Lantana camara* L. (Lamiales: Verbenaceae) is an important ornamental, and medicinal plant.[8] It is mainly composed of seven species, with six reported from America and one from Ethiopia.[9] It is locally known as bunchberry (England), baraphulnoo (India), red sage, white sage or wild sage Caribbean. Its height is about 1.2 – 2.4 m.[10] The leaf is structurally ovate-oblong, opposite, rough and a little hairy.[11] It grows in tropical, subtropical and temperate regions at a high altitude of up to 2000 m.[12] Traditionally, *L. camara* has been used as a medication to treat various diseases such as cancer, tumours, tetanus, cuts, eczema, catarrh, measles, chickenpox, swellings, bilious fever, fevers, rheumatism, ulcers, malaria, and asthma.[13,14] There are reports of *L. camara* possessing important biological activities, such as anti-inflammatory, anti-ulcerogenic, antioxidant, antibacterial, antiemetic, antispasmodic, antitumoral, antifungal, insecticidal, nematocidal, anthelmintic, antipyretic, antimalarial, anti-hyperglycaemic, analgesic and hepatotoxic activities.[13-22] Considering the medicinal importance of *L. camara*, there is a need to investigate the phytochemical and bioactive

constituents of *L. camara* harvested from Agu-Orba in Udenu Local Government Area of Enugu State, Nigeria, as no such information exists. Therefore, the purpose of this study was to evaluate the phytochemical constituents and identify important biologically active compounds in the plant using standard biochemical techniques and gas chromatography-mass spectroscopy (GC-MS) respectively.

Materials and Methods

Collection and Identification of plant

Fresh leaves of *L. camara* were collected in March, 2020 from a garden in Orba town (GPS: 6.867 °N, 7.109 °E) in Enugu State, Nigeria. The leaves were identified and authenticated by Mr. Chibuoke J. Onyeukwu a plant taxonomist with the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka, Nigeria. The plant specimen was deposited (Voucher No. UNH – 580) at the departmental herbarium for reference purposes.

Extraction of plant material

The fresh leaves of *L. camara* were shade-dried with regular turning until crispy. The dried leaves were pulverized using a multifunctional grain milling machine (M6FFC-230). The pulverized leaves (3000 g each) were cold-macerated separately in 10 L of absolute methanol and 10 L of distilled water using a maceration flask[23]. The mixtures were left for 72 h with occasional stirring, after which they were filtered into a flat-bottomed flask using a muslin cloth. Further filtration was done using Whatman filter paper No. 1 to remove fine residues. The filtrates were concentrated under vacuum and freeze respectively to obtain the crude methanol (LCM) and aqueous (LCA) extracts. The concentrated extracts were stored in a labelled sterile screw-capped bottle at 5 ± 3°C.

Solvent partitioning of extracts

Fractionation of the crude extracts was done using solvent-solvent partition protocol.[23] Ethyl acetate and *n*-hexane were used in the fractionation process. A 20 g each of the crude extracts was weighed and dispersed separately in 250 mL of aqueous methanol (20%v/v) and transferred to separation funnels. Thereafter, 250 mL of *n*-hexane (GHTECH) was added to the solution in the separation funnels. To ensure adequate separation, the mixture was left to stand for 20 minutes, after which the upper portion was decanted into a 500 ml beaker. The various *n*-hexane fractions were then combined after the methanol and aqueous extracts underwent several *n*-hexane partitioning. Equal volumes of ethyl acetate were also used to duplicate the previously described process.[24] The combined *n*-hexane (LCH) and ethyl acetate (LCE) fractions were concentrated using a rotary evaporator (RVC 2-25 CD, Martin Christ, Harz) and freeze dryer (Apha 1-4 LDplus, Martin Christ GmbH, Harz) respectively.

Phytochemical screening of the extracts

Qualitative phytochemical analysis

The preliminary qualitative phytochemical screening of the crude extracts (LCM and LCA), ethyl acetate and *n*-hexane fractions of the leaves of *L. camara* was carried out to ascertain the presence of some secondary metabolites. The determinations of saponins, alkaloids, tannins, flavonoids, terpenoids, steroids, phenols, glycosides, and hydrogen cyanide were done using standard protocols as described by Harborne.[25]

Quantitative phytochemical analysis

Quantitative phytochemical tests for saponins, alkaloids, tannins, flavonoids, terpenoids, steroids, and phenols were determined spectrophotometrically using UV- visible spectrophotometer (Thermo Fisher Scientific, China), following the procedures outlined by Ekwueme et al.[26]

Gas chromatography-mass spectrum GC-MS analysis

The GC-MS analysis was carried out in a combined 7890A gas chromatograph system and mass spectrophotometer (GCMS-QP2010 SE, Shimadzu, Japan), fitted with an HP-5 MS fused silica column (5% phenyl methyl siloxane 30.0 m × 250 µm, film thickness 0.25 µm), interfaced with 5675C Inert MSD with Triple-Axis detector. The carrier gas used was helium gas and was adjusted to 1.0 mL/min column velocity flow. Other GC-MS conditions are an ion-source temperature of 230 °C; interface temperature of 300 °C; pressure of 16.2 psi; out time of 1.8 mm; and 1 µL injector in split mode with a split ratio 1:50 with injection temperature of 250 °C. The column temperature began at 36 °C for 5 minutes and transformed to 150 V at the rate of 4 °C/min. The temperature was increased to 250 °C at the rate of 20 °C/min and held for 5 min. The total elution was 47.5 min. The relative percentage amount of each component was calculated by comparing its average peak area to the total area. The MS solution software provided by the manufacturer was used as a system control and for the acquisition of data.

Identification of compounds

Identification of components was achieved based on their retention indices and interpretation of the mass spectrum was conducted using the database of the National Institute of Standards and Technology (NSIT). This database consists of above 62,000 patterns of known compounds. The spectra of the unknown components of the *L. camara* extract obtained were compared with the standard mass spectra of known components stored in the NIST library.[27]

Statistical analysis

The data collected from the study were subjected to a one-way analysis of variance (ANOVA). Significant means were separated using a posthoc test (*Tukey's* Honest significant difference *test) at a 0.05 probability level. Results were presented as mean ± standard error of the mean.* All data analyses were done using SPSS version 23.0.

Results and Discussion

Phytochemicals content of L. camara

The qualitative phytochemical screening of *L. camara* showed the presence of phenolic compounds, alkaloids, flavonoids and terpenoids in all the extracts and fractions except for LCH (Table 1). Tannins were absent in the LCE while terpenoids and flavonoids were present in the four extracts/fractions. In the quantitative phytochemical screening of *L. camara*, there was a significant difference ($p < 0.05$) in the concentration of the phenolic compounds in the different fractions of the extract. The phenolic content of LCM (1563.85 ± 0.07 mg/100g) was significantly greater ($p < 0.05$) than that of ethyl acetate (1121.25 ± 0.03 mg/100g) and *n*-hexane fractions (102.16 ± 0.06 mg/100g) respectively. There was also a significant difference ($p < 0.05$) but higher contents of alkaloids, flavonoids and tannin in LCM compared with LCA. However, no significant difference ($p > 0.05$) was found between the phenolic content of LCM and LCA (1425.23 ± 0.36 mg/100g) (Table 2). These variations suggest that both water and methanol could serve as suitable extracting solvents, especially for polar compounds of *L. camara*. However, methanol extraction is mostly preferred in most extractions due it its ability to also extract non-polar contents, ease of drying the extract and the potential to preserve the extracts from microbial degradation resulting from residual aqueous environment.[28]

Table 1: Qualitative phytochemical compositions of *L. camara*

Phytochemicals	LCM	LCA	LCH	LCE
Phenols	+	+	-	+
Alkaloids	+	+	-	+
Flavonoids	+	+	-	+
Tannins	+	+	-	+
Saponins	-	-	-	-
Steroids	-	-	-	-
Terpenoids	+	+	+	-

Glycosides	-	-	-	-
HCN	-	-	-	-

present (+), absent (-)

This observation was in line with previous reports of high content of phenolic extraction using polar solvent such as methanol which could account for the diverse therapeutic benefits of *L. camara* such as antioxidant, anti-inflammatory, anti-allergic, anti-carcinogenic, antihypertensive, cardioprotective, anti-arthritic and antimicrobial activities.[29]

The presence of alkaloids was detected in LCM, LCA and LCE with trace amounts in LCH (Table 1). There was a significant difference ($p < 0.05$) in the concentration of the alkaloids in all the extracts and fractions *L. camara*. The alkaloids in the LCM (506.74 ± 5.52 mg/100g) were significantly higher ($p < 0.05$) than that of LCA (349.92 ± 13.10 mg/100g), LCE (227.32 ± 4.42 mg/100g), and LCH (102.90 ± 10.0 mg/100g) (Table 2). There was a significant difference ($p < 0.05$) in the flavonoid content of the different fractions of LCM. The flavonoids in LCM (372.04 ± 8.39 mg/100g) were significantly higher ($p < 0.05$) than that of LCE (265.05 ± 6.16 mg/100g), LCA (231.99 ± 6.16 mg/100g) and LCH (132.26 ± 4.27 mg/100g) (Table 2). Tannins and terpenoids were detected in both LCM and LCA. However, there were traces of both LCE and LCH respectively (Table 1). The study showed that there was no significant difference ($p > 0.05$) in the concentration of the tannins in LCM (1426.43 ± 7.43 mg/100g) and LCE (1403.49 ± 4.94 mg/100g). However, there was a significant difference ($p < 0.05$) in the concentration of tannins in LCM, LCA (1351.62 ± 20.60 mg/100g) and LCH (716.08 ± 2.50 mg/100g). The terpenoid content of LCM (122.26 ± 0.10 mg/100g) was significantly greater ($p < 0.05$) than the LCE (82.52 ± 4.14 mg/100g) and LCH (14.97 ± 2.31 mg/100g) (Table 2). Saponins, steroids and glycosides were not detected in the qualitative phytochemical analysis (Table 1). However, traces of the phytochemicals were quantified (Table 1). There was low saponins content in LCM (0.20 ± 0.01 mg/100g) and LCA (0.19 ± 0.01 mg/100g) differing significantly ($p < 0.05$) in the LCE (0.15 ± 0.01 mg/100g) and LCH (0.08 ± 0.01 mg/100g) (Table 2). The results showed no significant difference ($p > 0.05$) in the steroid concentration of all the fractions except the LCE (0.08 ± 0.01 mg/100g). The glycosidic content of the plant extract was significantly different ($p < 0.05$) in all the fractions. However, there was no significant difference ($p > 0.05$) in the LCM (0.20 ± 0.01 mg/100g) and LCA (0.19 ± 0.01 mg/100g). Both extracts differed significantly ($p < 0.05$) from the LCE (0.15 ± 0.01 mg/100g) and LCH (0.08 ± 0.01 mg/100g) (Table 2).

Table 2: Quantitative phytochemical compositions of *L. camara*

Phytochemical	LCM	LCA	LCH	LCE
Phenolics	1563.85±0.07^{a}	1425.23±0.36^{ab}	102.16±0.06^{c}	1121.25±0.03^{b}
Alkaloids	506.74±5.52^{a}	349.92±13.10^{b}	102.90±10.0^{d}	227.32±4.42^{bc}
Flavonoids	372.04±8.39^{a}	231.99±6.16^{b}	132.26±4.27^{c}	265.05±6.16^{b}
Tannins	1426.43±7.43^{a}	1351.62±20.6^{b}	716.08±2.50^{c}	1403.49±4.94^{a}
Saponins	0.20±0.01^{a}	0.19±0.01^{a}	0.08 ±0.01^{b}	0.15±0.01^{ab}
Steroids	0.26±0.04^{a}	0.25±0.01^{a}	0.08±0.01^{b}	0.25±0.01^{a}
Terpenoids	122.26±0.10^{a}	100.88±1.57^{a}	14.97±2.31^{c}	82.52±4.14^{b}
Glycosides	0.20±0.01^{a}	0.19±0.01^{a}	0.08±0.01^{c}	0.15±0.01^{b}
HCN	0.39±0.00^{a}	0.25±0.24^{b}	0.24±0.06^{b}	0.12±0.05^{c}

Data expressed as Mean ± SE (n = 3), data in the same row with the same letter superscript (a-c) are not significantly different; the phytochemical content is expressed in mg/100g

Alkaloids are polar compounds whose relative partitioning in polar solvents has been established.[30] The roles of alkaloids such as quinine (antimalarial), vincristine (anticancer), ephedrine (anti-asthmatic), and morphine (analgesic) in phytomedicine originated from several chemotherapeutic alkaloids that have been discovered from plants.[31] Flavonoids are polar to moderately polar compounds and extraction with methanol and ethyl acetate has been reported.[32] Flavonoids possess antioxidant, anticonvulsant, antidepressant, antiproliferative, anti-inflammatory, sedative, anticancer, antiulcerogenic, antimicrobial, antidiabetic, hepatoprotective and cardioprotective activities which are in line with the ethnomedicinal uses of *L. camara*.[33] Previous studies had reported high tannins and terpenoid content *L. camara* extract.[34,35] Tannins are medically important due to their styptic and astringent properties.[35] They facilitate the healing and formation of new tissues on wounds and inflamed mucosa.[35] Tannins are also used in the treatment of frostbite, minor burns, haemorrhoids, varicose ulcers and inflamed gums.[35] Terpenoids have been found to possess antitumor, antimalarial, antifungal, antiviral, antibacterial, anti-inflammatory, cardioprotective and anti-glycaemic potentials.[34] Despite the trace amounts of saponins, steroids and glycosides in *L. camara*, their importance in phytomedicine is pronounced. Saponins lower cancer risks, decrease blood lipids and lower blood glucose response. Saponins saponins-rich diet can be used in the treatment of hypercalciuria, in the inhibition of dental caries and platelet aggregation, and as an antidote against acute lead poisoning.[36] It is also commonly known that steroids lessen inflammation, or redness and swelling. This can aid in inflammatory problems linked to a variety of illnesses. The body's natural defence against disease and infection, the immune system, is likewise less active when steroids are taken.[37] Glycosides possess anti-inflammatory, antinociceptive and analgesic effects via cyclooxygenase and lipoxygenase pathways, and thus marked inhibition of various pain mediators. These findings can be useful in identifying new candidates which can be clinically developed as analgesics with better bioavailability and reduced side effects.[38]

GC-MS analysis of an extract of L. camara

To further identify the phytochemical compounds that could be responsible for the therapeutic potential of *L. camara* leaf extracts, GC-MS analysis of LCM was performed. The results of the GC-MS analysis showed the presence of 39 phytochemical compounds, all of which have different pharmacological potentials. The GC-MS chromatogram showed 39 peaks representing 39 compounds (Figure 1). The identified compounds with their retention time R_t, molecular formula, molecular weight MW and peak area are presented in Table 3. The first and last elutes were identified as dimethyl phthalate and Vitamin E with R_t of 10.021 and 23.121 minutes respectively. The most abundant compound was bis-2-ethylhexylphthalate (peak area of 12.72%) while the least compound was tetradecanamide (peak area of 0.36%). Other compounds detected are presented in Table 3.

Some of these compounds have been found to possess significant biological activities. For instance, 4H-1-benzopyran-4-one5-hydroxy-

2-4-hydroxyphenyl is known for its antibacterial activity.[39] Squalene is a well-known antioxidant.[40] Vitamin E is known to prevent coronary heart disease, support immune function, prevent inflammation, promote eye health and lower the risk of cancer.[41] The compound 9,19-cyclolanostan-3-ol-11-one acetate is known for its antimicrobial activity.[42] Octadecanal is an aldehyde which helps in hormonal development and functions, such as the development and function of pheromones in animals.[43] Carbamic acid has been identified to possess fungicidal, algicidal and antimicrobial activity.[44] Hexadecanamide possesses tissue regenerative ability and anti-convulsant activity and is active in reducing oedema formation and inflammatory hyperalgesia.[45]

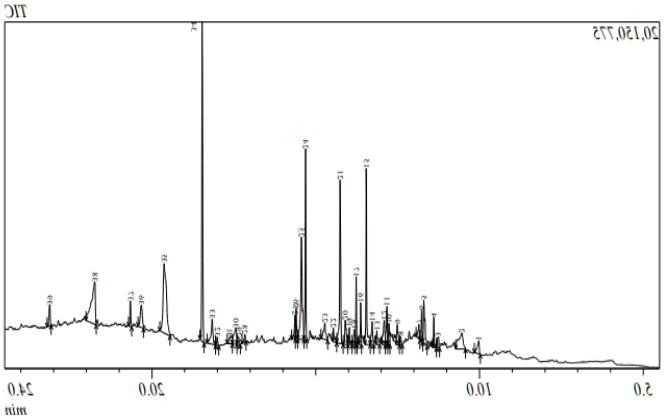

Figure 1: GC-MS chromatogram of crude extract of *L. camara* leaves

Z-7-Hexadecenal possesses antibacterial activity.[46] Phytol is known for its anti-ageing, anti-inflammatory, antihyperalgesic and anti-mutagenic activities.[47] Hexadecanoic acid, ethyl ester and Hexadecanoic acid possess antimicrobial activities.[48] Phthalic acid, nonyl tridec-2-yn-1-yl ester and bis2-ethylhexyl phthalate are reported to possess allelopathic, antimicrobial and insecticidal activities.[49-50] Hexadecanoic acid ethyl ester possesses antioxidant, hypocholesterolemic, nematocidal and pesticidal activities.[51] Octadecanoic acid possesses antimicrobial and anti-inflammatory activities. Globulol possesses antimicrobial, sedative and anaesthetic activities.[52] The compound 3,7,11,15-Tetramethyl-2-hexadecen-1-ol possesses antimicrobial and antioxidant activities.[53] Phytol acetate has antibacterial, antinociceptive, immune-modulating, cytotoxic, metabolism-modulating, autophagy- and apoptosis-inducing, and antinociceptive properties.[54] Bicyclo 4.4.0 dec-2-ene-4-ol 2-methyl-9-prop-1-en-3-ol-2-yl possesses antimicrobial activity. 3-Butylindolizidine is known for its hormonal activity.[55] Tetradecanoic acid has been found to possess diverse biological action against fungi, viruses, cancerous cells and parasitic microbes.[56] There are suggestions that longifolenaldehyde may possess antifungal, anti-inflammatory and anticancer activities. Cycloheptane, 4-methylene-1-methyl-2-2-methyl-1-propen-1-yl-1-vinyl- possess anti-inflammatory activities.[57] o-Mentha-17,8-dien-3-ol is known for its antimicrobial activity.[58] The compound 1,6-Octadien-3-ol, 3,7-dimethyl-formate possesses antimicrobial and antifungal properties.[59] The compound 1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl- has been reported to possess anti-schistosomal activity.[60] The compound 1H-Cyclopropeazulen-7-ol,decahydro-1,1,7-trimethyl-4-methylene-,1ar 1aalpha,4aalpha,7beta,7abeta,7balpha possesses antimicrobial activity.[61] Diethyl phthalate possesses antibacterial activity; also, it has been found useful in making plastics, insecticides, cosmetics and aspirin.[62] β-D-Glucopyranose, 1,6-anhydro is known for its role in the production of ATP in humans.[58] Not much is known about the pharmacological activities of erythro-9,10-dibromopentacosane, 3-debenzoyloxy-anhydrocarpesteerol, naphthalene 2,3,4,4a,5,6,7,8-octahydro-2-, tetradecanamide 2,2-dimethyl-3-3,7,16,20-tetramethyl-hen and 4-oxazolecarboxylic acid, 4,5-dihydro-2-p.

Table 3: Bioactive compounds in crude extract of *Lantana camara*

S/No	R_t (min)	% Peak area	Compound name	Molecular formula	Weight (g/mol)	SI
1	10.021	1.1	Dimethyl phthalate	$C_{10}H_{10}O_4$ CAS:131-11-3	194	95
2	10.537	3.30	.β.-D-Glucopyranose-1,6-anhydro	$C_6H_{10}O_5$ CAS:498-07-7	162	75
3	11.270	0.75	Diethyl phthalate	$C_{12}H_{14}O_4$ CAS:84-66-2	222	78
4	11.393	0.98	1H-Cyclopropeazulen-7-ol, decahydro-1	$C_{15}H_{24}O$ CAS:6750-60-3	220	93
5	11.698	2.64	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-	$C_{15}H_{26}O$ CAS:7212-44-4	222	76
6	11.763	1.34	1,6-Octadien-3-ol, 3,7-dimethyl-	$C_{10}H_{18}O$ CAS:78-70-6	154	75
7	11.849	0.93	o-Mentha-1(7),8-dien-3-ol	$C_{10}H_{16}O$ CAS:15358-81-3	152	69
8	12.412	0.48	Cycloheptane, 4-methylene-1-methyl-2-(2-methyl-1-propen-1-yl)-1-vinyl-	$C_{15}H_{24}$ CAS:0-00-0	204	80
9	12.512	1.37	Longifolenaldehyde	$C_{15}H_{24}O$ CAS:19890-84-7	220	76
10	12.763	1.09	Tetradecanoic acid	$C_{14}H_{28}O_2$ CAS:544-63-8	228	78
11	12.827	1.86	Bicyclo[4.4.0]dec-2-ene-4-ol 2-methyl-9-(prop-1-en-3-ol-2-yl)	$C_{15}H_{24}O_2$ CAS:0-00-0	236	79
12	12.907	1.80	3-Butylindolizidine	Formula:$C_{12}H_{23}N$ CAS:0-00-0	181	82
13	13.134	0.89	Naphthalene 2,3,4,4a,5,6,7,8-octahydro-2-	$C_{12}H_{20}O$ CAS:0-00-0	180	79
14	13.278	1.36	Bicyclo[4.4.0]dec-2-ene-4-ol 2-methyl-	Formula:$C_{15}H_{24}O_2$ CAS:0-00-0	236	76

			9-(prop-1-en-3-ol-2-yl)			
15	13.456	6.37	Phytol, acetate	Formula:$C_{22}H_{42}O_2$ CAS:0-00-0	338	93
16	13.625	1.39	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	Formula:$C_{20}H_{40}O$ CAS:102608-53-7	296	93
17	13.765	2.14	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	$C_{20}H_{40}O$ CAS:102608-53-7	296	92
18	13.817	0.95	Globulol	:$C_{15}H_{26}O$ CAS:51371-47-2	222	74
19	13.976	0.70	Hexadecanoic acid, methyl ester	$C_{17}H_{34}O_2$ CAS:112-39-0	270	92
20	14.098	1.56	Phthalic acid, nonyl tridec-2-yn-1-yl ester	$C_{30}H_{46}O_4$ CAS:0-00-0	470	85
21	14.255	7.85	*n*-Hexadecanoic acid	$C_{16}H_{32}O_2$ CAS:57-10-3	256	95
22	14.459	0.81	Hexadecanoic acid, ethyl ester	$C_{18}H_{36}O_2$ CAS:628-97-7	284	88
23	14.721	1.60	4-Oxazolecarboxylic acid, 4,5-dihydro-2-p	$C_{13}H_{15}NO_3$ CAS:37592-54-4	233	84
24	15.309	5.85	Phytol	$C_{20}H_{40}O$ CAS:150-86-7		96
25	15.437	7.23	7-Hexadecenal, (Z)-	$C_{16}H_{30}O$ CAS:56797-40-1	238	86
26	15.598	1.32	Octadecanoic acid	$C_{18}H_{36}O_2$ CAS:57-11-4	284	87
27	15.633	1.06	Hexadecanamide	$C_{16}H_{33}NO$ CAS:629-54-9	255	86
28	17.163	0.36	Tetradecanamide	$C_{14}H_{29}NO$ CAS:638-58-4	227	85
29	17.350	0.42	2,2-Dimethyl-3-(3,7,16,20-tetramethyl-hen	$C_{29}H_{48}O$ CAS:0-00-0	412	71
30	17.441	1.96	Carbamic acid, N-phenyl-, 1-methyl-1-(4-methylcyclohex-3-enyl) ethyl ester	$C_{17}H_{23}NO_2$ CAS:1224-46-0	273	75
31	17.633	0.91	Octadecanal	$C_{18}H_{36}O$ CAS:638-66-4	268	79
32	18.008	0.50	erythro-9,10-Dibromopentacosane	$C_{25}H_{50}Br_2$ CAS:59907-02-7	508	55
33	18.161	2.22	Bis(2-ethylhexyl) phthalate	$C_{19}H_{38}O_4$ CAS:23470-00-0	330	77
34	18.465	12.72	Bis(2-ethylhexyl) phthalate	$C_{24}H_{38}O_4$ CAS:117-81-7	390	96
35	19.626	10.14	9,19-Cyclolanostan-3-ol-11-one, acetate	$C_{32}H_{52}O_3$ CAS:0-00-0	484	59
36	20.322	2.04	3-Debenzoyloxy-anhydrocarpesteerol	$C_{30}H_{48}O$ CAS:0-00-0	424	52
37	20.658	1.04	Squalene	Formula:$C_{30}H_{50}$ CAS:111-02-4	410	95
38	21.745	7.50	4H-1-Benzopyran-4-one, 5-hydroxy-2-(4-hy	$C_{17}H_{14}O_6$ CAS:6601-62-3	314	63

39	23.121	1.21	Vitamin E	$C_{29}H_{50}O_2$ CAS:59-02-9	430	96

Conclusion

The study evaluated the phytochemical composition and GC-MS analysis of extracts of *L. camara*, Alkaloids, terpenoids, flavonoids and other phenolic compounds were detected in varying amounts of both methanol and aqueous extracts. The GC-MS analysis identified 39 potential bioactive compounds of variable peak areas and retention times in the methanol extract. The study has provided useful insights into the phytochemistry of *L. camara* which could be useful in the bioassay-guided isolation and characterization of important bioactive compounds in *L. camara*.

Acknowledgements

The authors thank the technical staff of the Department of Pharmacognosy and Environmental Medicine, University of Nigeria, Nsukka for their assistance in the phytochemical screening and GC-MS analysis of *Lantana camara* leaf extract. We also acknowledge the inputs of Dr. Charles Nnadi.

Funding/Support

The study was self-financed by the first author towards the award of a Ph.D. in Animal and Environmental Physiology.

Conflict of Interests

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be answered by them.

References

1. Ayoka TO, Nnadi CO. Lesser-known leafy vegetables of Southeastern Nigeria (*Vitex doniana* and *Zanthoxylum zanthoxyloides*). Not Sci Biolo. 2022; 14(2): 11777.
2. Nnadi CO, Ngwu SO, Ohagwu MBZ. *In-vivo* and *in-silico* evidence of antitrypanocidal activities of selected plants from Asteraceae family against *Trypanosoma brucei brucei*. Bioint Res Appl Chem. 2023; 13(1): 30.
3. Ayoka TO, Nwachukwu N, Ene AC, Igwe CU, Nnadi CO. Hepatocurative and histopathological evaluations in albino rats exposed to *Vitex doniana* alkaloids. Lett Appl NanoBioSci. 2023; 12(2): 56
4. Okorie NH, Ali IJ, Nnadi CO, Ani DI. Anti-ulcer activity of crude extract and fractions of Acanthus montanus (Nees) T. Anderson on indomethacin-induced ulcer. Trop J. Nat Prod Res. 2023; 7(5): 3017-3021.
5. Ayoka TO, Nwachukwu N, Ene AC, Igwe CU, Nnadi CO. The hepatocurative effects of Zanthoxylum zanthoxyloides alkaloids on tetrachloromethane-induced hepatotoxicity on albino rats. Indian J. Clin Biochem. 2024; 39(2): 186-197.
6. Odoemelam EI, Ugorji CO, Ezema EE, Agbo MO, Nnadi CO, Orjiocha SI, Okonkwo VI, Nwafor FI, Ugwu GN, Chukwuma MO. Estimation of total phenolics, total flavonoids content and in vitro antioxidant activities of extract and fractions of *Asplenium platyneuron* (Carl Linnaeus). Trop J. Nat Prod Res. 2024; 8(3): 6723-6730.
7. Yusuf ATM, Shaikat MAM, Bhuiya MAM, Dutta M, Nath AK, Dash PR. Utilizing the medicinal properties of Delonix regia for diseases and beyond: a review of its phytochemistry and pharmacology. Trop J Nat Prod Res. 2023; 7(12): 5355-5365.
8. Priyanka N, Joshi PK. A review of *Lantana camara* studies in India. Int J Sci Res Pub. 2013; 3(10): 42-52.
9. Vardien W, Richardson DM, Foxcroft LC, Thompson GD, Wilson JR, Le Roux JJ. Invasion dynamics of *Lantana camara* L. (sensu lato) in South Africa. S Afr J Bot. 2012; 81: 81-94.
10. Zheng H, Wei N, Wang L, He P. Effects of *Lantana camara* leaf extract on the activity of superoxide dismutase and accumulation of H2O2 in water hyacinth leaf. J Plant Physiol Mol Bio. 2006; 32(2): 189-194.
11. Jyothi MJ, Vamsi S, Satish C, Nagaveni K. *Lantana camara* Linn: a review. Int J Phytother. 2012; 2(2): 66-73.
12. Bhuvaneswari E, Giri RS. Physicochemical and phytochemical screening in *Lantana camara* leaves. J Pharmacogn Phytochem. 2018; 7(6): 1962-1966.
13. Ganjewala D, Sam S, Khan KH. Biochemical compositions and antibacterial activities of *Lantana camara* plants with yellow, lavender, red and white flowers. Eurasia J Biosci. 2009; 3(1): 69-77.
14. Ganesh T, Sen S, Thilagam E, Thamotharan G, Loganathan T, Chakraborty R. Pharmacognostic and anti-hyperglycemic evaluation of *Lantana camara* (L.) var. aculeate leaves in alloxan-induced hyperglycemic rats. Int J Res Pharm Sci. 2010; 1(3): 247-252.
15. Pour BM, Srinivasan S, Jegathambigai RN, Suresh R. A comparative study: antimicrobial activity of methanol extracts of *Lantana camara* various parts. Pharmacogn Res. 2009; 1(6): 348-351.
16. Ahmad F, Rather MA, Siddiqui MA. Nematicidal activity of leaf extracts from Lantana camara L. against Meloidogyne incognita (Kofoid and White) chitwood and its use to manage roots infection of *Solanum melongena* L. Braz Arch Biol Technol. 2010; 53(3): 543-548.
17. Ogba OM, Nyambi ES, Olorode OA, Asemota E. Antibacterial activity of *Lantana camara* montevidensis leaf extract on wound isolates using animal models. Trop J Nat Prod Res. 2021; 5(12): 2160-2164.
18. Thamotharan G, Sekar G, Ganesh T, Sen S, Chakraborty R, Kumar SN. Antiulcerogenic effects of *Lantana camara* Linn. leaves on in vivo test models in rats. Asian J Pharm Clin Res. 2010; 3(3): 57-60.
19. Sathish R, Vyawahare B, Natarajan K. Antiulcerogenic activity of *Lantana camara* leaves on gastric and duodenal ulcers in experimental rats. J Ethnopharmacol. 2011; 134(1):195-197.
20. Falodun A, Siraj R, Choudhary MI. GC-MS Analysis of insecticidal leaf essential oil of *Pyrenacantha staudtii* Hutch and Dalz (Icacinaceae). Trop J Pharm Res. 2009; 8(2): 139-143.
21. Sousa EO, Rocha JB, Barros LM, Barros AR, Costa JG. Phytochemical characterization and in vitro antioxidant properties of *Lantana camara* L. and Lantana montevidensis Briq. Ind Crops Prod. 2013; 43: 517-522.
22. Bashir S, Jabeen K, Iqbal S, Javed S, Naeem A. *Lantana camara*: phytochemical analysis and antifungal prospective. Planta Daninha. 2019; 37: e019193526.
23. Nnadi CO, Okorie HN, Nwodo NJ. Evaluation of in vitro antiprotozoal and cytotoxic Activities of selected medicinal plants used in Nigerian folk medicine. Trop J. Nat Prod Res. 2021; 5(4): 609-612.

24. Udeh NE, Nnadi CO, Anaga AO, Asuzu IU. Bioactivity-guided fractionation of a methanol leaf extract from *Gnetum africanum* with potential anti-diabetic activity: (-)-Epicatechin as the active principle. J. Res Pharm. 2021; 25(1): 72-79
25. Harborne JB. Textbook of phytochemical methods. A guide to modern techniques of plant analysis. (3rd ed.). London: Chapman and Hall Limited; 1998. 302 p.
26. Udeani TK, Ugwu LO, Nnadi CO, Okwuosa CN. Evaluation of anti-microbial activity and proximate composition of alkaloids from *Vitex doniana* seed. Dhaka Univ J. Pharm Sci. 2021; 20(1): 81-86.
27. Obonga WO, Omeje EO, Nnadi CO and Ocheme WG. Phytochemical evaluation of extracts and GC-MS analysis of oil from *Monodora myristica* seed. Dhaka Univ J. Pharm Sci. 2019; 18(1): 69-73.
28. Obonga WO, Nnadi CO, Okafor SN, Omeje EO, Igbinnaduwa P, Okoli CO, Osadebe PO (2019). Anti-inflammatory activity and accelerated stability studies of crude extract syrup of *Cannabis sativa*. Trop J. Pharm Res. 2019; 18(2): 295-301.
29. Ngassoum MB., Yonkeu S, Jirovetz L, Buchbauer G, Schmaus G, Hammerschmidt FJ. Chemical composition of essential oils of *Lantana camara* leaves and flowers from Cameroon and Madagascar. Flavour Fragr J. 1999; 14(4): 245-250.
30. Ayoka TO, Ngwu N, Ene AC, Igwe CU, Nnadi CO. Liquid Chromatography-Mass Spectrometric Analyses of Potential Antioxidant Constituents from *Zanthoxylum zanthoxyloides* Leaves: Probing into the Role of Alkaloids. Trop J. Nat Prod Res. 2020; 4(10): 817-823.
31. Nnadi CO, Ozioko LU, Eneje GC, Onah CM, Obonga WO. In-vivo antitrypanosomal effect and *in-silico* prediction of chronic toxicity of *N*-methylholaphyllamine in rats. Trop J. Pharm Res. 2020; 19(11), 2369-2375.
32. Nnadi CO, Onoja SO, Ezeh GC, Ikpa CB, Ezeja MI, Udem SC, Anaga AO, Asuzu IU. Antioxidant and antidiabetic potentials of a dimethoxylated flavone obtained from *Helianthus annuus* L. leaf extract. Pak J. Pharmacol. 2022; 37(2): 59-69.
33. Munhoz VM, Longhini R, Souza JR, Zequi JA, Mello EV, Lopes GC, Mello JC. Extraction of flavonoids from *Tagetes patula*: process optimization and screening for biological activity. Rev Bras Farmacogn. 2014; 24: 576-583.
34. Kalita S, Kumar G, Karthik L, Rao KVB. Phytochemical composition and in vitro hemolytic activity of *Lantana camara* L. (Verbenaceae) leaves. Pharmacologyonline. 2011; 2011(1): 59-67.
35. Patil SP, Kumbhar ST. Evaluation of terpene-rich extract of *Lantana camara* L. leaves for antimicrobial activity against mycobacteria using Resazurin Microtiter Assay (REMA). Beni-Suef Univ J Basic Appl Sci. 2018; 7(4): 511-515.
36. Obonga WO, Nnadi CO, Agbo MO, Kenechukwu FC, Nwodo U. (2014). Distribution of methicillin resistant Staphylococcus aureus (MRSA) in apparently healthy population and its susceptibility to saponins from *Dialium guineense*. Br J. Pharm Res (now J. Pharm Res Int). 2014; 4(18): 2200-2209.
37. Nnadi CO. Nwodo NJ, Kaiser M, Brun R, Schmidt TJ. Steroid alkaloids from Holarrhena africana with strong activity against Trypanosoma brucei rhodesiense. Molecules. 2017; 22(7): 1129.
38. Khan H, Pervaiz A, Intagliata S, Das N, Nagulapalli Venkata KC, Atanasov AG, Najda A, Nabavi SM, Wang D, Pittalà V, Bishayee A. The analgesic potential of glycosides derived from medicinal plants. DARU J. Pharm Sci. 2020; 28: 387-401.
39. Tracanna MI, Amani SM, Romano E, Raschi AB, Molina LR, Piro OE, Castellano EE, Benavente AM. Crystal structure, spectroscopic properties and antimicrobial activity of 4h-1-benzopyran-4-one, 5-hydroxy-2-(4-hydroxyphenyl)-7-methoxy-6, 8-dimethyl from *Miconia ioneura* Griseb. Melastomataceae. Mol Med Chem. 2010; 21: 94-104.
40. Huang Z, Lin Y, Fang J. Biological and pharmacological activities of squalene and related compounds: potential uses in cosmetic dermatology. Molecules. 2009; 14(1): 540-554.
41. Brigelius-Flohé R. Bioactivity of vitamin E. Nutr Res Rev. 2006; 19(2): 174-186.
42. Penduka D, Buwa L, Mayekiso B, Basson AK, Okoh AI. Identification of the antilisterial constituents in partially purified column chromatography fractions of *Garcinia kola* seeds and their interactions with standard antibiotics. Evid Based Complement Alternat Med. 2014; 2014: 850347.
43. Kumar D, Karthik M, Rajakumar R. GC-MS analysis of bioactive compounds from ethanolic leaves extract of *Eichhornia crassipes* (Mart) Solms. and their pharmacological activities. Pharma Innov J. 2018; 7(8): 459-462.
44. Zanatta N, Borchhardt DM, Alves SH, Coelho HS, Squizani AM, Marchi TM, Bonacorso HG, Martins MA. Synthesis and antimicrobial activity of new (4, 4, 4-trihalo-3-oxo-but-1-enyl)-carbamic acid ethyl esters, (4, 4, 4-trihalo-3-hydroxy-butyl)-carbamic acid ethyl esters, and 2-oxo-6-trihalomethyl-[1, 3] oxazinane-3-carboxylic acid ethyl esters. Bioorg Med Chem. 2006; 14(9): 3174-3184.
45. Mazzari S, Canella R, Petrelli L, Marcolongo G, Leon A. N-(2-hydroxyethyl) hexadecanamide is orally active in reducing edema formation and inflammatory hyperalgesia by down-modulating mast cell activation. Eur J Pharmacol. 1996; 300(3): 227-236.
46. Kim BR, Kim HM, Jin CH, Kang SY, Kim JB, Jeon YG, Park KY, Lee IS, Han AR. Composition and antioxidant activities of volatile organic compounds in radiation-bred *Coreopsis cultivars*. Plants. 2020; 9(6): 717.
47. Santos CC, Salvadori MS, Mota VG, Costa LM, de Almeida AA, de Oliveira GA, Costa JP, de Sousa DP, de Freitas RM, de Almeida RN. Antinociceptive and antioxidant activities of phytol *in vivo* and *in vitro* models. Neurosci J. 2013; 2013: 949452.
48. Guerrero RV, Vargas RA, Petricevich VL. Chemical compounds and biological activity of an extract from *Bougainvillea x Buttiana* (var. rose) Holttum and Standl. Int J Pharm Pharm Sci. 2017; 9(3): 42-46.
49. Thomas JA, Thomas MJ, Gangolli SD. Biological effects of di-(2-ethylhexyl) phthalate and other phthalic acid esters. Crit Rev Toxicol. 1984; 13(4): 283-317.
50. Huang L, Zhu X, Zhou S, Cheng Z, Shi K, Zhang C, Shao H. Phthalic acid esters: natural sources and biological activities. Toxins. 2021; 13(7): 495.
51. Tan M, Zhou L, Huang Y, Wang Y, Hao X, Wang J. Antimicrobial activity of globulol isolated from the fruits of *Eucalyptus globulus* Labill. Nat Prod Res. 2008; 22(7): 569-575.
52. Nithya M, Ragavendran C, Natarajan D. Antibacterial and free radical scavenging activity of a medicinal plant *Solanum xanthocarpum*. Int J Food Prop. 2018; 21(1): 313-327.
53. Kohoude MJ, Gbaguidi F, Agbani P, Ayedoun M, Cazaux S, Bouajila J. Chemical composition and biological activities of extracts and essential oil of *Boswellia dalzielii* leaves. Pharm Biol. 2017; 55(1): 33-42.
54. Vyas S, Pandya D, Mankad A. A review on Prosopis cineraria as an important plant of arid regions of India. EPRA Int J Multidiscip Res. 2020; 6(3): 1-6.
55. Abubakar MN, Majinda RRT. GC-MS analysis and preliminary antimicrobial activity of *Albizia adianthifolia* (Schumach) and *Pterocarpus angolensis* (DC). Medicines. 2016; 3(1): 3.
56. Priya ES, Selvan PS, Tamilselvan R. Phytochemical investigation of *Allophylus serratus* Kurz leaves by UV and GC-MS analysis. Res J Phytochem. 2012; 6(1): 17-24.

57. Ambrosio CM, Diaz-Arenas GL, Agudelo LP, Stashenko E, Contreras-Castillo CJ, Da Gloria EM. Chemical composition and antibacterial and antioxidant activity of a citrus essential oil and its fractions. Molecules. 2021; 26(10): 2888.
58. Ibrahim EA, Wang M, Radwan MM, Wanas AS, Majumdar CG, Avula B, Wang YH, Khan IA, Chandra S, Lata H, Hada GM, Abdel Salam RA, Ibrahim AK, Ahmed SA, Elsohly MA. Analysis of terpenes in *Cannabis sativa* L. using GC/MS: method development, validation, and application. Plant Med. 2019; 85(5): 431-438.
59. Chan WK, Tan LT, Chan KG, Lee LH, Goh BH. Nerolidol: a sesquiterpene alcohol with multi-faceted pharmacological and biological activities. Molecules. 2016; 21(5): 529.
60. Akpuaka A, Ekwenchi MM, Dashak DA, Dildar A. Biological activities of characterized isolates of n-hexane extract of *Azadirachta indica* A. Juss (Neem) leaves. Nat Sci. 2013; 11(5): 141-147.
61. Premjanu N, Jaynthy C. Antimicrobial activity of diethyl phthalate: an *in-silico* approach. Asian J Pharm Clin Res. 2014; 7(4): 141-142.
62. Jahan I, Tona MR, Sharmin S, Sayeed MA, Tania FZ, Paul A, Chy MN, Rakib A, Emran TB, Simal-Gandara J. GC-MS phytochemical profiling, pharmacological properties, and in silico studies of *Chukrasia velutina* leaves: a novel source for bioactive agents. Molecules. 2020; 25(15): 3536

