GSC Biological and Pharmaceutical Sciences, 2018, 05(03), 124–135

Available online at GSC Online Press Directory

GSC Biological and Pharmaceutical Sciences

e-ISSN: 2581-3250, CODEN (USA): GBPSC2

Journal homepage: https://www.gsconlinepress.com/journals/gscbps

(RESEARCH ARTICLE)

Chemical composition, antioxidant and antimicrobial activities of *Lantana camara* Linn leaves essential oil from Burkina Faso

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Publication history: Received on 24 November 2018; revised on 12 December 2018; accepted on 18 December 2018

Article DOI: https://doi.org/10.30574/gscbps.2018.5.3.0142

Abstract

The objective of this study was to determine chemical composition and biological activity of essential oil of the leaves of *Lantana camara* from Burkina Faso. The essential oil was obtained by hydrodistillation and analyzed by GC and GC/MS. Antioxidant activity was determined by 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay and Ferric reduction antioxidant power **(**FRAP) test. Antimicrobial activity was assessed by agar disc diffusion method and microdilution method. The main components of essential oil of *L. camara* were caryophyllene oxide (23.015%), spathulenol (13.421%), humulen-1, 2-epoxide (8.046%), β-caryophyllene (7.93%), E-nerolidol (6.933%) and α-humulene (4.925%). The oil showed good radical scavenging power and moderate reducing power compared with quercetin, ascorbic acid and butylhydroxytoluene (BHT). Essential oil of *L. camara* showed antibacterial activity with inhibition diameters between 08±00 mm and 23.5±2.12 mm. Minimum inhibitory concentration (MIC) values were ranging from 4% to 8% and minimum bactericidal concentration (MBC) were determined for the strains of *Escherichia coli* (8%) only. *L. camara* essential oil had inhibitory action on all fungal strains with MICs of 2% to 4% and minimum fungicidal concentration (MFC) of 4% for *Saccharomyces cerevisiae.* Hence *L. camara* essential oil could be used as antifungal agent, as antioxidant and could be a potential antibacterial agent especially against *Escherichia coli.*

Keywords: *Lantana camara*; Essential oil; Chemical composition; Antioxidant activity; Antimicrobial activity

1. Introduction

Recently there has been a renewed interest in medicinal and aromatic plants and their extracts. *Lantana camara* Linn (Verbenaceae), a native species of tropical America, was introduced in several countries as a hedge and an ornamental shrub [1]. *L. camara* is a woody straggling plant with various flower colors, red, pink, white, yellow and violet. It is an ever green strong smelling shrub, with stout recurred prickles, leaves opposite, ovate, acute or sub-acute, crenate serrate, scab rid on both side [2]. *L. camara* has been used in many parts of the world to treat a wide variety of disorders [3]. In popular medicine, it is used as carminative, antispasmodic, antiemetic agents, and to treat respiratory infections as cough, cold, asthma, and bronchitis. Leaves of the plant are antiseptic, antitumoural, and antimicrobial whereas, roots are used in the treatment of malaria, rheumatism, and skin rashes [4]. In Ghana, an infusion of the whole plant was used for bronchitis and the powdered root in milk was given to children for stomachache [3]. *L. camara* leaves and stems are

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traditionally used in Burkina Faso to treat rheumatism and diabetes [5]. Essential oils of *L. camara* have been studied by several authors and the chemical compositions of the oils differ according to geographic origin. Jawonisi and Adoga [6] found caryophyllene oxide (21.75%), spathulenol (14.95%), D-nerolidol (10.39%), β-caryophyllene (9.90%), α-pinene epoxide (9.07%), davana ether (8.92%), 1-naphthalenol (6.94%), α-caryophyllene (5.89%) and copaene (3.87%) as major components of the essential oil of dried leaves of *L. camara* from Nigeria. Adjou et *al.* [7] identified β-caryophyllene (18.5%), sabinene (13.1%), α-humulene (10%), 1.8-cinéol (9%), δ-guaiene (5%), trans-nerolidol (4%), humulene oxide (2.3%) and germacrene D (2%) as main constituents of the essential oil of *L. camara* fresh leaves from Benin. Davanone (23.37%), E-caryophyllene (22.96%), humulene (14.32%), Z-caryophyllene (8.18%), α-curcumene (6.33%) and copaene (4.43%) were the main constituents of the essential oil of *L. camara* leaves from Egypt [4]. We have found few studies on the essential oil of *L. camara* growing in Burkina Faso. The present work report results of phytochemical analysis, antioxidant and antimicrobial proprieties of *L. camara* essential oil from Burkina Faso. Such a study might help in the contribution of the ongoing search for beneficial uses of this plant to eradicate various resistance infectious diseases.

2. Material and methods

2.1. Plant material

The leaves of *Lantana camara* were collected during the months of July and August 2015 in the campus of University Ouaga I. After identification at the Laboratory of Plant Biology and Ecology, voucher specimen was kept in the herbarium of Biodiversity Information Center under the number ID16966. The harvested leaves were dried in the laboratory at room temperature and crushed.

2.2. Extraction of essential oil

The extraction of essential oil from the dried leaves of *L. camara* was done by hydrodistillation for 4 h using a Clevenger-type apparatus [8]. The essential oil obtained was then dried over anhydrous sodium sulfate and stored at 4 °C waiting for analyzes. The extraction yield was determined by the following equation:

$$R\ (\%) = \frac{V}{W} \times 100$$

Where V is the volume of essential oil (ml) and W the weight of dry leaves (g).

2.3. GC and GC/MS analyzes

Chemical composition of the essential oil of dried leaves of *L. camara* was determined by gas chromatography (GC) and gas chromatography coupled with mass spectrometry (GC/MS). Gas chromatography analysis was carried out using a Hewlett-Packard 6890 type apparatus equipped with a split/splitless injector (280 °C), a 1:10 division ratio, using an HP-5 capillary column (25 m x 0.25 mm, film thickness 0.25 µm). The oven temperature was programmed from 50 to 300 °C at a rate of 5 °C / min. Helium was used as carrier gas at a flow rate of 1.1 ml / min. The injected sample consisted of 1.0 µl of essential oil diluted 10% (V/V) with acetone.

GC/MS analysis was performed on a Hewlett-Packard 5973/6890 system operating in EI mode (70 eV) using two different columns: a fused silica HP-5MS capillary column (25 m x 0.25 mm, film thickness 0.25 µm) and an HP-Innowax capillary column (60 m x 0.25 mm, film thickness 0.25 µm). The temperature program for the HP-5MS column was 50 °C (5 min) rising to 300 °C at a rate of 5 °C / min and for the HP-Innowax column from 50-250 °C at a rate of 5 °C / min. Helium was used as carrier gas at a flow rate of 1.1 ml / min.

Identification of the constituents of the essential oil of *L. camara* leaves was done by comparison of their mass spectra and their retention indices with those of reference compounds and with literature data [9, 10].

2.4. Antioxidant activity

Antioxidant activity of the essential oil of *L. camara* leaves was evaluated using two methods: DPPH radical scavenging assay and Ferric Reduction Antioxidant Power (FRAP) test.

2.4.1. DPPH radical scavenging assay

Radical scavenging power of the essential oil of *L. camara* leaves was determined by the DPPH radical scavenging assay. This test was performed as described previously by Joshi et *al.* [11]. Different amounts of the essential oil of *L. camara*

(5, 10, 15, 20 and 25 µl) were mixed with 5 ml of an ethanolic solution of DPPH (0.004%). This mixture was incubated in the dark for 30 min and the absorbance read at 517 nm using a spectrophotometer (JASCO V-530 UV/VIS Spectrophotometer). BHT (0.005 M), ascorbic acid (0.005 M) and quercetin (0.005 M) used as reference antioxidants and a negative control were included in each test. Low absorbance indicates high inhibitory power. Inhibition percentage of the DPPH radical is calculated according to the following equation:

$$\% \, Inhibition = \frac{A_{blank} - A_{sample}}{A_{blank}} \times 100$$

Where A_{blank} is the absorbance of the negative control and A_{sample} the absorbance of the essential oil or reference antioxidants.

Antioxidant activity of the essential oil of *L. camara* leaves were expressed as inhibitory concentration 50 (IC50) which is defined as the amount of essential oil necessary to reduce by 50% the initial concentration of DPPH. The IC50 was calculated graphically using a linear regression (% inhibition = f [essential oil concentration]). The assay was performed in triplicate.

2.4.2. Ferric reduction antioxidant power (FRAP) test

Reducing power of essential oil of *L. camara* leaves was determined by FRAP test. The test was carried out as describe by Singh et *al.* [12]. Different amounts of the essential oil (5, 10, 15, 20 and 25 µl) were mixed with 2.5 ml of phosphate buffer (200 mM, pH 6.6) and 2.5 ml of potassium ferricyanide (1%). The mixture was then incubated at 50 °C for 30 min and then 2.5 ml of trichloroacetic acid (10%) were added to the mixture followed by centrifugation at 600 G for 10 min. The supernatant was collected (5 ml), mixed with 5 ml of distilled water and 1 ml of iron chloride (0.1% $FeCl_3$) was added and the absorbance immediately measured at 700 nm with a spectrophotometer (JASCO V-530 UV/VIS Spectrophotometer). Ascorbic acid (0.1 M) and quercetin (0.1 M) were used as positive control; a negative control was included in each test. The higher the absorbance measured, the greater the reduction power.

2.5. Antimicrobial activity

Antimicrobial activity of essential oil of *L. camara* leaves was determined by agar disc diffusion method and broth microdilution method.

2.5.1. Microbial strains

To determine antimicrobial activity of the essential oil, ten Gram-positive bacterial strains, ten Gram-negative bacterial strains and four fungal strains were used (table 1).

2.5.2. Agar disc diffusion method

Antimicrobial activity of the essential oil of *L. camara* leaves was demonstrated by agar disc diffusion method. The tests were carried out on Mueller Hinton Agar for bacterial strains and Sabouraud Agar for fungal strains [13].

Overnight broth cultures (18-24 h) of each strain were prepared in nutrient broth for the bacterial strains and in Sabouraud broth for the fungal strains. The density of the inoculums was adjusted with sterile saline solution (0.9% NaCl) to McFarland standard 0.5 corresponding to 10^8 CFU / ml. Petri dishes containing sterile Mueller Hinton Agar or sterile Sabouraud Agar were inoculated with this microbial suspension. Sterile neutral discs (6 mm diameter) were impregnated with essential oil of *L. camara* (15 µl per disc) and then placed on the surface of the previously inoculated agar. The dishes were then aerobically incubated at 30 °C for the fungal strains and 37 °C for the bacterial strains for 24 h. The sensitivity of the microbial strains to the essential oil was determined by measuring the diameter of the inhibition zone appearing around the disc. Criteria used by Carovic-Stanko et *al.* [14] were considered to evaluate the inhibition diameters (ID) of the essential oil:

ID > 15 mm: the essential oil had high inhibitory action

10 ≤ ID ≤ 15 mm: the essential oil had moderate inhibitory action

ID < 10 mm: the essential oil had low inhibitory action

Tetracycline (30 µg), ciprofloxacin (5 µg) was used as a positive control for bacterial strains and nystatin (100 IU) for fungal strains. The tests were carried out in duplicate.

Table 1 List of microbial strains used for the study

Bacterial strains	Gram's nature	Origin
Bacillus cereus LMG13569	Positive	Culture Collection of London Metropolitan University
Bacillus subtilis ssp subtilis ATCC6051	Positive	American Type Culture Collection
Clostridium perfringens	Positive	CRSBAN
Enterococcus faecalis ATCC19433	Positive	American Type Culture Collection
Escherichia coli 81 nr.149 SKN 541	Negative	Culture Collection of Copenhagen University
Escherichia coli ATCC25922	Negative	American Type Culture Collection
Listeria monocytogenes NCTC9863	Positive	Culture Collection of London Metropolitan University
Micrococcus luteus SKN 624	Positive	Culture Collection of Copenhagen University
Pseudomonas aeruginosa ATCC9027	Negative	American Type Culture Collection
Salmonella enteridis P167807	Negative	Culture Collection of London Metropolitan University
Salmonella infantis SKN 557	Negative	Culture Collection of Copenhagen University
Salmonella typhimurium SKN 1152	Negative	Culture Collection of Copenhagen University
Salmonella nigeria SKN 1160	Negative	Cocoa beans
Shigella dysenteria 370	Negative	Culture Collection of London Metropolitan University
Shigella flexneri USCC2007	Negative	Culture Collection of London Metropolitan University
Staphylococcus aureus ATCC2523	Positive	American Type Culture Collection
Staphylococcus aureus ATCC25923	Positive	American Type Culture Collection
Staphylococcus aureus toxine A+B	Positive	Culture Collection of Copenhagen University
Staphylococcus hominis B246	Positive	Maari (fermented baobab seeds)
Yersinia enterocolitica 8A30 SKN 601	Negative	Culture Collection of Copenhagen University
Fungal strains		**Origin**
Candida albicans		Blood sample
Candida kefir		Fura (fermented millet food)
Candida tropicalis		Fura (fermented millet food)
Saccharomyces cerevisiae KVL 013		Culture Collection of Copenhagen University

2.5.3. Minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC) and minimum fungicidal concentration (MFC)

Broth microdilution method [15] was used to determine the MIC, the MBC and the MFC of essential oil of *L. camara* leaves. The tests were carried out in Mueller Hinton broth for bacterial strains and in Sabouraud broth for fungal strains. A double serial dilution of essential oil of *L. camara* was carried out in 96-well microplate to obtain concentrations of

0.03% to 8% (V/V). The broth was supplemented with Tween 80 at a concentration of 0.5% (V/V) in order to improve the solubility of the essential oil.

Overnight broth cultures (18-24 h) of each strain were prepared in nutrient broth for bacterial strains and in Sabouraud broth for fungal strains. The density of inoculums was adjusted with sterile saline solution (0.9% NaCl) to McFarland standard 0.5 corresponding to 10^8 CFU / ml. Then 10 µl of these diluted inoculums were added in the well. For each microbial strain a positive growth control (no essential oil added in the well) and a negative growth control (no inoculum, no essential oil added in the well) were included in the test. The microplate thus seeded was incubated aerobically at 30 °C for fungal strains and 37 °C for bacterial strains and the MICs determined after 24 h of incubation. The lowest concentration of the essential oil showing no visible growth in the broth after 24 h of incubation is considered to be the MIC.

For determination of MBC or MFC, 10 µl of microbial suspension was collected from wells with no visible growth and seeded on Mueller Hinton Agar for bacterial strains and on Sabouraud Agar for fungal strains and then incubated for 24 h at 30 °C or 37 °C. The lowest concentration of the essential oil at which no growth is observed on the agar after 24 h of incubation is considered to be MBC or MFC.

Antimicrobial activity of the essential oil of *L. camara* was evaluated, considering that:

- MBC / MIC = 1: the essential oil had absolute bactericidal activity,
- 1 < MBC / MIC ≤ 4: the essential oil had bactericidal activity,
- 8 < MBC / MIC < 16: the essential oil had bacteriostatic activity.

3. Results and discussion

3.1. Chemical analysis

Extraction of the essential oil from dried leaves of *L. camara* by hydrodistillation gave a pale yellow essential oil with a yield of 0.22 ± 0.04%. This extraction yield is higher than the yield of 0.19% obtained by Jawonisi and Adoga [6] in Nigeria, 0.125% by Elansary et *al.* [8] in Egypt and 0.13% by Rabindra and Balendra [16] in India. This yield is less than that of 0.5% obtained by Adjou et *al.* [7] in Benin.

Chemical analysis of the essential oil of *L. camara* allowed the identification of forty-two (42) compounds (table 2), representing 81.519% of the essential oil. The relative abundance of the different compounds is shown in figure 1. Major compounds of essential oil of *L. camara* dried leaves were caryophyllene oxide (23.015%), spathulenol (13.421%), humulen-1, 2-epoxide (8.046%), β-caryophyllene (7.93%), E-nerolidol (6.933%) and α-humulene (4.925%). This chemical composition differs from that reported by other studies. Jawonisi and Adoga [6] found caryophyllene oxide (21.75%), spathulenol (14.95%), D-nerolidol (10.39%), β-caryophyllene (9.90%), α-pinene epoxide (9.07%), davana ether (8.92%), 1-naphthalenol (6.94%), α-caryophyllene (5.89%) and copaene (3.87%) as major components of the essential oil of dried leaves of *L. camara* from Nigeria. Adjou and *al.* [7] identified β-caryophyllene (18.5%), sabinene (13.1%), α-humulene (10%), 1.8-cineol (9%), δ-guaiene (5%), trans-nerolidol (4%), humulene oxide (2.3%) and germacrene D (2%) as main constituents of the essential oil of *L. camara* fresh leaves from Benin. Davanone (23.37%), E-caryophyllene (22.96%), humulene (14.32%), Z-caryophyllene (8.18%), α-curcumene (6.33%) and copaene (4.43%) were the main constituents of the essential oil of *L. camara* leaves from Egypt [4].

These differences in yield and chemical composition of the essential oil could be attributed to the geographical location and condition of the leaves (fresh or dry) of *Lantana camara*. Indeed, Mirhosseini et *al.* [17] reported that drying treatments had effect on color, yield and chemical composition characteristics of an essential oil. In addition, Sousa et *al.* [18] found that collection time of the plant sample had a significant effect on the yield and chemical profile of the essential oil extracted.

Table 2 Chemical composition of the essential oil of *Lantana camara* dried leaves

Number	Retention time (min)	Components	Proportion (%)
1	5.21	α-Pinene	0.083
2	5.57	Camphene	0.789
3	6.01	Sabinene	0.264
4	6.1	β-Pinene	0.054
5	6.2	1-Octene-3-ol	0.587
6	7.01	Para-Cymene	0.063
7	7.09	Limonene	0.078
8	7.15	Eucalyptol	0.969
9	7.25	(Z)-β-Ocimene	0.317
10	7.49	Abusculone-Cis	0.524
11	7.84	Sabinene Cis-Hydrate	0.679
12	8.37	Linalol	0.359
13	9.13	Camphre	0.705
14	9.5	δ-Terpineol	0.246
15	9.53	Borneol	0.946
16	9.65	Terpinene-4-ol	0.574
17	9.88	α-Terpineol	1.114
18	12.02	α-Cubebene	0.078
19	12.41	α-Copaene	0.329
20	12.5	β-Bourbonene	0.063
21	12.59	β-Elemene	0.864
22	13	β-Caryophyllene	7.93
23	13.12	β-Copaene	0.63
24	13.23	γ-Elemene	0.049
25	13.31	(Z)-β-farnesene	0.085
26	13.46	α-Humulene	4.925
27	13.5	Allo-Aromadendrene	0.243
28	13.68	γ-Muurolene	0.501
29	13.76	Germacrene-D	0.159
30	13.87	β-Selinene	0.094
31	13.94	Bicyclogermacrene	0.816
32	13.96	α-Muurolene	0.662
33	14	Davana-ether	0.142
34	14.19	δ-Cadinene	1.485
35	14.25	Davana-ether Isomer	0.192
36	14.62	Germacrene-B	1.034
37	14.72	(E)-Nerolidol	6.933
38	14.96	Spathulenol	13.421
39	15.02	Caryophyllene oxide	23.015
40	15.33	Humulene-1,2-epoxide	8.046
41	15.66	Isopathulenol	1.036
42	15.73	Epi-α-Cadinol	0.436
Total	81.519		

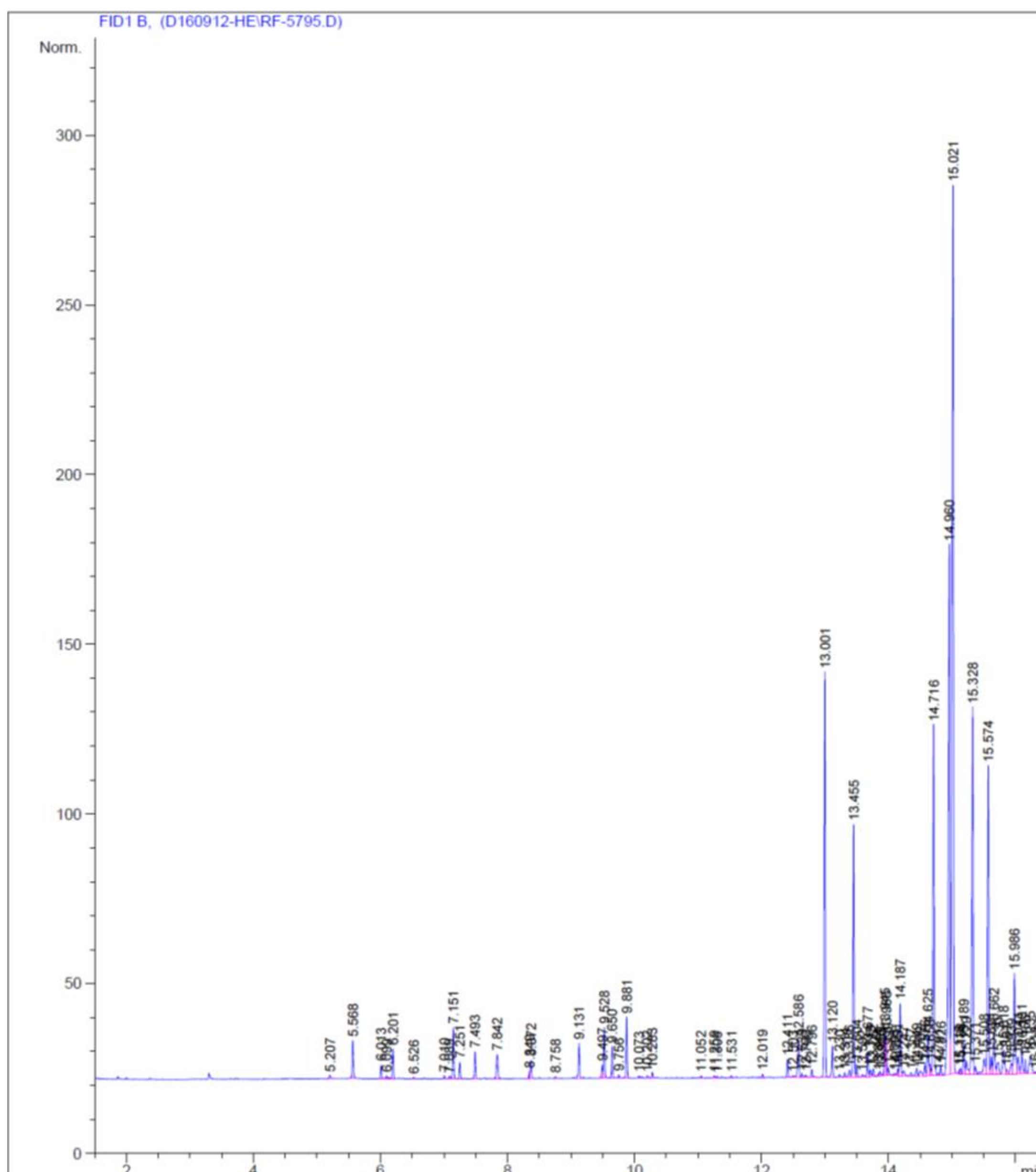

Figure 1 chromatogram of the essential oil of *Lantana camara* dried leaves

3.2. Antioxidant activity

Antioxidant activity of essential oil of *Lantana camara* was assessed by DPPH radical scavenging assay and FRAP test. Quercetin, ascorbic acid and BHT were used for comparison.

3.2.1. DPPH radical scavenging power

DPPH is a stable free radical and accepts an electron or hydrogen radical to become a stable diamagnetic molecule. DPPH radical scavenging assay was used to evaluate free radical scavenging power of the investigated essential oil.

DPPH radical scavenging power of essential oil of *L. camara* and reference antioxidants is shown in figure 2. Figure2 shows that when the concentration of essential oil increases, the DPPH radical scavenging power also increases. DPPH radical scavenging power of essential oil of *L. camara* therefore depends on the concentration.

Inhibitory concentrations (IC_{50}) of the essential oil and standards are shown in table 3. The lowest IC_{50} (11.25 µl) was obtained with essential oil of *L. camara* and the highest one (26.93 µl) with BHT. The essential oil of *L. camara* had a better radical scavenging power than BHT (0.005 M), ascorbic acid (0.005 M) and quercetin (0.005 M).

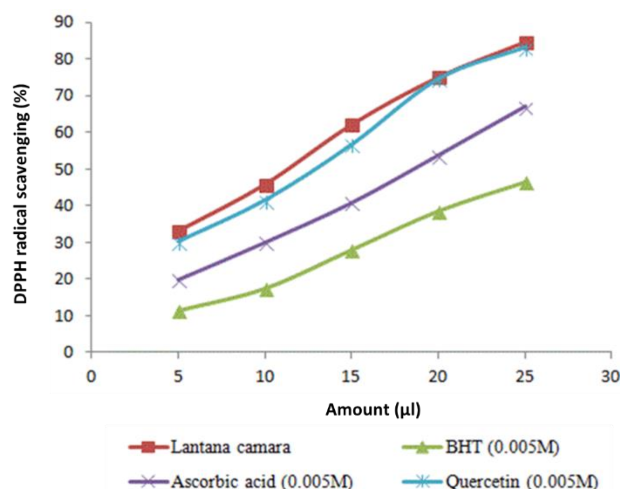

Figure 2 Radical scavenging power of essential oil of *Lantana camara* and standards

Table 3 Inhibitory concentration 50 (IC_{50}) of *L. camara* essential oil and standards

Essential oil / Standards	Regression equation	R^2	IC_{50} (µl)
Lantana camara	y= 2.6484x + 20.216	0.99	11.25 ± 0.17
BHT (0.005 M)	y= 1.8255x + 0.8298	0.99	26.93 ± 0.32
Ascorbic acid (0.005 M)	y= 2.3558x + 6.8831	0.99	18.33 ± 0.65
Quercetin (0.005 M)	y= 2.7794x + 15.387	0.99	12.19 ± 0.41

3.2.2. FRAP test

The results of FRAP test are shown in figure 3. These results indicate that reducing power of essential oil of *L. camara* and standards increases as concentration increases. Thus the reducing power of essential oil of *L. camara* is concentration dependent. Contrary to the results of DPPH radical scavenging assay, in this test the essential oil had a low reducing power compared to ascorbic acid (0.1 M) and quercetin (0.1 M). This difference is due to the concentration of standards which is higher.

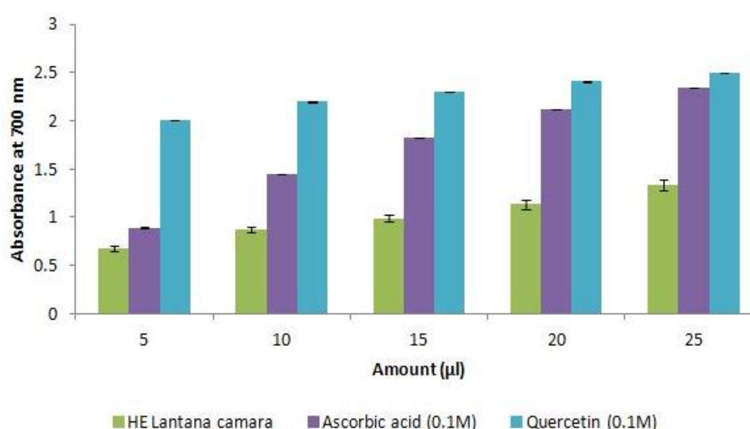

Figure 3 Ferric reducing antioxidant power of essential oil of *Lantana camara* and standards

Previous studies have shown that the essential oil of *L. camara* leaves possesses antioxidant activity when using DPPH or ABTS radical scavenging assay [4, 8, 19]. Antioxidant activity of the essential oil of *L. camara* dried leaves could be attributed to its main compounds which are caryophyllene oxide (23.015%), spathulenol (13.421%), humulen-1, 2-epoxide (8.046%), β-caryophyllene (7.93%), E-nerolidol (6.933%) and α-humulene (4.925%). Indeed, β-caryophyllene,

spathulenol and caryophyllene oxide were among the most powerful scavenging compounds of the essential oil of *Marrubium peregrinum* [20].

3.3. Antimicrobial activity

Antimicrobial activity of the essential oil of *L. camara* was demonstrated by agar disc diffusion method. The results are presented in table 4. With exception of *Pseudomonas aeruginosa*, *Salmonella enteridis* and *Salmonella typhimurium*, all bacterial strains were susceptible to essential oil of *L. camara*. The inhibition diameters ranged from 08±00 mm (*Salmonella nigeria*) to 23.5±2.12 mm (*Listeria monocytogenes*). Essential oil of *L. camara* was active on all fungal strains with inhibition diameters between 09.5±0.71 mm (*Candida kefir*) and 12.1±1.41 mm (*Saccharomyces cerevisiae*). Essential oil of *L. camara* had, according to the criteria of Carovic-Stanko et *al.* [14]:

- Strong inhibitory action (ID > 15 mm) on *Bacillus subtilis*, *Escherichia coli* strains, *Listeria monocytogenes*, *Shigella flexneri* and *Staphylococcus hominis;*
- Moderate inhibitory action (10 ≤ ID ≤ 15 mm) on *Bacillus cereus*, *Clostridium perfringens*, *Enterococcus faecalis*, *Micrococcus luteus*, *Staphylococcus aureus* strains, *Yersinia enterocolitica*, *Candida albicans*, *Candida tropicalis* and *Saccharomyces cerevisiae;*
- and weak inhibitory action (ID < 10 mm) on *Salmonella infantis*, *salmonella nigeria*, *Shigella dysenteria* and *Candida kefir*.

Table 4 Inhibition zone diameters (mm) of the essential oil of *Lantana camara* dried leaves (15 µl)

Microbial strains	**Inhibition zone diameters (mm) including the disc diameter (6 mm)**			
Bacterial strains	***L. camara***	**Tetracycline (30 µg)**	**Ciprofloxacin (5 µg)**	**Nystatin (100 IU)**
Bacillus cereus LMG 13569	15±1.41	19±1.41	26.5±2.12	-
Bacillus subtilis ssp subtilis ATCC 6051	23±1.41	30±00	34±1.41	-
Clostridium perfringens	13.5±2.12	26.5±2.12	16±1.41	-
Enterococcus faecalis ATCC 19433	13±00	24.5±0.71	24.5±2.12	-
Escherichia coli 81 nr.149 SKN 541	19±1.41	15.5±2.12	32.5±2.12	-
Escherichia coli ATCC 25922	22±1.41	32.5±3.54	22.5±0.71	-
Listeria monocytogenes NCTC 9863	23.5±2.12	21.5±2.12	31±1.41	-
Micrococcus luteus SKN 624	13.5±2.12	16.5±2.12	31.5±2.12	-
Pseudomonas aeruginosa ATCC 9027	6±00	12±1.41	32.5±0.71	-
Salmonella enteridis P167807	6±00	22.5±2.12	30.5±2.12	-
Salmonella infantis SKN 557	8.5±0.71	20.5±2.12	27.5±2.12	-
Salmonella typhimurium SKN 1152	6±00	19.5±2.12	26±1.41	-
Salmonella nigeria SKN 1160	8±00	17±1.41	30±00	-
Shigella dysenteria 370	8.5±0.71	22±2.83	36±1.41	-
Shigella flexneri USCC 2007	16±00	22.5±0.71	31±1.41	-
Staphylococcus aureus ATCC 2523	14.5±0.71	20±1.41	24±1.41	-
Staphylococcus aureus ATCC 25923	13.5±0.71	23.5±0.71	26.5±2.12	-
Staphylococcus aureus toxine A+B	13±00	10.5±0.71	6±00	-
Staphylococcus hominis B246	18±2.83	29±1.41	33±1.41	-
Yersinia enterocolitica 8A30 SKN 601	10±00	15.5±0.71	37±1.41	-
Fungal strains	*L. camara*	-	-	Nystatin (100 IU)
Candida albicans	10±2.83	-	-	22±00
Candida kefir	9.5±0.71	-	-	24±00
Candida tropicalis	11.5±0.71	-	-	20.5±0.71
Saccharomyces cerevisiae KVL 013	12±1.41	-	-	27.5±0.71

ND: Not determined

3.4. MIC, MBC and MFC

MICs, MBCs and MFCs of essential oil of *L. camara* were determined for the sensitive microbial strains by the broth microdilution method. The results are shown in Table 5.

The MICs of the essential oil of *L. camara* were 4% (V/V) for four bacterial strains, 8% for eight bacterial strains and greater than 8% (the highest concentration tested) for the other strains. The MBC was 8% for the two strains of *Escherichia coli* and greater than 8% for the other tested bacterial strains. The essential oil had a bactericidal action on the two *Escherichia coli* strains (MBC / MIC = 2).

L. camara essential oil inhibited all fungal strains with MICs value of 2% for *Saccharomyces cerevisiae* and 4% for the three strains of *Candida*. The MFC was 4% for *Saccharomyces cerevisiae* and greater than 8% for the *Candida* strains. The essential oil had a fungicidal action on *Saccharomyces cerevisiae* (MFC / MIC = 2).

Table 5 MIC, MBC and MFC of *Lantana camara* essential oil

Microbial strains	***Lantana camara***		
Bacterial strains	MIC	MBC	MBC/MIC
Bacillus cereus LMG 13569	8%	>8%	>1
Bacillus subtilis ssp subtilis ATCC 6051	4%	>8%	>2
Clostridium perfringens	8%	>8%	>1
Enterococcus faecalis ATCC 19433	8%	>8%	>1
Escherichia coli 81 nr.149 SKN 541	4%	8%	2
Escherichia coli ATCC 25922	4%	8%	2
Listeria monocytogenes NCTC 9863	4%	>8%	>2
Micrococcus luteus SKN 624	8%	>8%	>1
Pseudomonas aeruginosa ATCC 9027	NT	NT	NT
Salmonella enteridis P167807	NT	NT	NT
Salmonella infantis SKN 557	>8%	>8%	>1
Salmonella typhimurium SKN 1152	NT	NT	NT
Salmonella nigeria SKN 1160	>8%	>8%	>1
Shigella dysenteria 370	>8%	>8%	>1
Shigella flexneri USCC 2007	>8%	>8%	>1
Staphylococcus aureus ATCC 2523	8%	>8%	>1
Staphylococcus aureus ATCC 25923	8%	>8%	>1
Staphylococcus aureus toxine A+B	8%	>8%	>1
Staphylococcus hominis B246	8%	>8%	>1
Yersinia enterocolitica 8A30 SKN 601	>8%	>8%	>1
Fungal strains	MIC	MFC	MFC/MIC
Candida albicans	4%	>8%	>2
Candida kefir	4%	>8%	>2
Candida tropicalis	4%	>8%	>2
Saccharomyces cerevisiae KVL 013	2%	4%	2

NT: Not Tested

Antimicrobial activity of *L. camara* essential oils has been reported by other authors. El Baroty et *al.* [4] found that the essential oil of *L. camara* fresh leaves was active on *Bacillus subtilis* and *Bacillus cereus* and not active on *Staphylococcus aureus* ATCC 25923, *Escherichia coli*, *Salmonella typhimurium*, *Pseudomonas aeruginosa* ATCC 9027 and *Candida albicans*. Sonibare and Effiong [21] reported that the essential oil of *L. camara* dried leaves has an inhibitory action on *Pseudomonas aeruginosa*, *Proteus mirabilis*, *Bacillus subtilis*, *Bacillus cereus*, *Salmonella typhimurium* and *Candida albicans* with inhibition diameters of 10 to 14 mm and MICs value of 1000 to 10000 ppm. The essential oil of *L. camara*

exhibited antifungal activity against *Aspergillus flavus* and *Aspergillus parasiticus* with MIC value of 2.5 µl / ml and 3.0 µl / ml respectively [7].

Antimicrobial activity of essential oil of *L. camara* leaves could be attributed to its major components. Caryophyllene oxide and spathulenol have been reported to exhibit moderate to strong activities against a wide range of bacteria [22 - 24]. Furthermore, Schmidt et *al.* [25] reported that β-caryophyllene and caryophyllene oxide possessed antibacterial activity and caryophyllene oxide had a high activity against *Candida albicans*. Essential oil of dried leaves of *L. camara* was more active on gram-positive bacteria than gram-negative bacteria.

4. Conclusion

This study is a contribution to the study of chemical composition and biological activities of essential oils of *L. camara*. The essential oil showed good antioxidant activity and good antimicrobial activity against a variety of microorganisms. These results support some traditional uses of the plant. The essential oil of *L. camara* could be used as antifungal agent, as antioxidant and could be a potential antibacterial agent especially against *Escherichia coli*.

Compliance with ethical standards

Acknowledgments

The authors would like to thank MIHIN Henriette Bougnitébiéhin, a PhD student at CRSBAN for her technical support in data collection.

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding publishing this research.

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How to cite this article

Semdé Z, Koudou J, Figueredo G, Zongo C, Somda KM, Sawadogo/Lingani H and Traoré SA. (2018). Chemical composition, antioxidant and antimicrobial activities of *Lantana camara* Linn leaves essential oil from Burkina Faso. GSC Biological and Pharmaceutical Sciences, 5(3), 124-135.