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

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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 recurved 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%), sabine (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:

\[
\text{% Inhibition} = \frac{A_{\text{blank}} - A_{\text{sample}}}{A_{\text{blank}}} \times 100
\]

Where \( A_{\text{blank}} \) is the absorbance of the negative control and \( A_{\text{sample}} \) 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% FeCl₃) 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 10⁸ 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 BA30 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:

- \(\text{MBC} / \text{MIC} = 1\): the essential oil had absolute bactericidal activity,
- \(1 < \text{MBC} / \text{MIC} \leq 4\): the essential oil had bactericidal activity,
- \(8 < \text{MBC} / \text{MIC} < 16\): 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%), \(\beta\)-caryophyllene (7.93%), E-nerolidol (6.933%) and \(\alpha\)-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%), \(\beta\)-caryophyllene (9.90%), \(\alpha\)-pinene epoxide (9.07%), davana ether (8.92%), 1-naphthalenol (6.94%), \(\alpha\)-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 \(\beta\)-caryophyllene (18.5%), sabinene (13.1%), \(\alpha\)-humulene (10%), 1.8-cineol (9%), \(\delta\)-guaiane (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%), \(\alpha\)-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 3-ol                | 0.317          |
| 10     | 7.49                 | Abusculone-Gis                    | 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-Cubebeke                        | 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**                      |                |
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. Figure 2 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 (IC₅₀) of the essential oil and standards are shown in table 3. The lowest IC₅₀ (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).
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.

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 nigerina*) 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 nigerina*, *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 nigerina* 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

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Disclosure of conflict of interest

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

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