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GC-MS Chemical Constituents and *in vitro* Activities of the Oil Extract of *Euryops brevipapposus* Leaves used Traditionally for the Management of Some Diseases

ABIODUN ATINUKE ADEGBORIOYE, OYINLOLA OLUWUNMI OLAOKUN, BENSON CHUKS IWERIEBOR* and LARRY CHIKWULU OBI

Department of Biology, School of Science and Technology, Sefako Makgatho Health Sciences University, Molotlegi Street, Ga-Rankuwa 0204, Pretoria, South Africa

*Corresponding author: Tel: +27 786099726; E-mail: benvida2004@yahoo.com

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Euryops brevipapposus (Asteraceae) is a medicinal plant of a local community utilized traditionally for its recognized effectiveness in managing non-communicable diseases, especially asthma. The traditional use of *E. brevipapposus* lacks scientific evidence and the increased burden of asthma makes confirming this claim paramount. The study characterized by GC-MS the bioactive compounds of *E. brevipapposus* essential oil (*Eb*O) extracted with Clevenger apparatus. The antibacterial efficacy and antioxidant activity by free radical scavenging ability were investigated *in vitro* using standard methods. A strong antioxidant IC_{50} value of 6.71×10^{-7} mg/mL of oil was obtained for DPPH. The antibacterial activity against *Escherichia coli* and *Vibrio* spp. (MIC value of 0.055 mg/mL) was superior. GC-MS analysis of *Eb*O showed α-phellandrene, α-pinene, germacrene D, β-pinene, β-mycrene, (*E*)-β-ocimene and bicyclogermacrene as the major compounds. The antioxidant and antibacterial potentials of *E. brevipapposus* may justify the therapeutic claims and local usage of this plant.

Keywords: Antibacterial, Antioxidant, Asteraceae, *Euryops*, Essential oil, GC-MS.

INTRODUCTION

Despite the significant scientific development of the 21st century, there is a rise in the occurrence of non-communicable diseases (NCDs) especially those of chronic respiratory diseases [1]. Chronic respiratory disease is global disease burden and asthma is prominent among children [2]. Asthma is an acute inflammatory lung disease caused by reversible airway obstruction characterized by wheezing, coughing and breathlessness [3]. Oxidative damage of cells initiated by excessive reactive oxygen species (ROS) have been demonstrated by studies to induce diverse human diseases including asthma [4-6]. ROS are implicated in asthma severity through airway inflammation [7], increase in the formation of lipid peroxide and protein carbonyls in plasma [8]. They also react with lipids to produce ethane and isoprostane, which is elevated in the breath of those affected by asthma [9]. During the occurrence of asthma attack, some bacterial pathogens invade the host body due to an immune-compromized state making it susceptible to infections [10]. Some opportunistic microorganisms associated with asthma include those that abound in the upper respiratory such as *Haemophilus influenza*, *Pseudomonas aeruginosa*, *Moraxella catarrhalis* and *Staphylococcus aureus* [3].

Till date no cure for asthma has been found and the available therapies (*e.g.* corticosteroids) are administered for the symptomatic treatment only. Furthermore, the associated side effect in children and glucocorticoids-resistant people gives more cause for concern [11]. Asthma is a chronic diseases and the adverse side effects of conventional drugs are serious health and mortality threats (250,000 deaths yearly) especially for communities within resource constrained countries [12]. Therefore, drugs from alternative sources such as plants, assumed to be safe and with fewer side effects than conventional ones [13,14] are of high need and, thus, are being continuously researched.

Medicinal plants have been utilized by mankind in the treatment of diseases since ancient times [15]. They can act as antimicrobial agents or inhibit, reduce, neutralize free radicals or interfere in reactions to ameliorate conditions generated

during the pathophysiology of diseases [16]. In addition, the secondary metabolites of plants called phytochemicals are natural antioxidants and have been demonstrated to be safe [17,18]. Although great opportunities abound for medicinal plants with long history of traditional use as sources of pharmacological agents, there is a dearth of scientific information of their efficacy and *Euroyps brevipapposus* is included amongst these medicinal plants. *Euroyps brevipapposus* is a herbaceous aromatic plant of about 1 m height distributed all over Africa [19,20]. *Euryops* genus is the third in the family of Asteraceae, in terms of species number and size in Southern Africa [21]. There is a paucity of information regarding the use of *Euroyps brevipapposus* in the management of whooping cough, asthma or as a bronchodilator for which purpose it is used by the traditional health healers in Cala, a community in Eastern Cape, South Africa. Thus, this study aimed at evaluating the antibacterial activity, as well as free radical scavenging potency of the oil extract of *E. brevipapposus* and the phytochemical constituents of the essential oil of *Euroyps brevipapposus* by GC-MS. To the best of our knowledge, this study is the first describing the chemical composition of the essential oil of *E. brevipapposus* and its bioactivities.

EXPERIMENTAL

The leaves of *Euroyps brevipapposus* were collected in Cala community in May 2016 based on the ethnopharmacology information obtained from the traditional health practitioners (THPs) in Cala. The community is located in the northern region of Eastern Cape Province with geographical coordinates of 31.5230ºS, 27.6980ºE, South Africa. *E. brevipapposus* was identified by plant taxonomist Tony Dold, Selmar Schonland herbarium, Botany Department, Rhodes University. The specimen of the voucher was deposited in the Giffen Herbarium, University of Fort Hare under the accession ADE 2016/1. The *E. brevipapposus* leaves were washed to remove dirt, dried in a shade under a stream of cool air, grinded to a fine powder and stored in an airtight Amber bottle. The essential oil of the powdered leaves (200 g) was extracted in Clevenger apparatus using hydrodistillation process. The oil was collected and exposed to anhydrous sodium sulphate p.a. for removal of residual water. The *E. brevipapposus* oil (*Eb*O) yield was calculated per gram (w/w %) of the plant sample. The oil was put into amber tinted vials and kept in the refrigerated at -4 ºC pending further use.

Antioxidant activity assays

1,1-Diphenyl-2-picrylhydrazyl (DPPH) radical scavenging: The spectrophotometric assay was carried out to assess the DPPH radical scavenging activity of *Eb*O as described earlier [22]. DPPH (2.7×10^{-6} M) dissolved in methanol and stored in Amber bottle was used as DPPH radical for the assay. In triplicate into each well of a 96-well plate was dispensed 100 µL of methanol in a predetermined format. Next, in triplicate into the first wells only was aliquoted 100 µL of oil extract or the standard vitamin C onto the methanol and serially diluted to obtain a concentration range of 0.03125-0.5 mg/mL. Then, the pre-made DPPH (100 µL) was added to each mixture, vortexed, kept for 30 min at room temperature in the dark and absorbance taken at 517 nm. The DPPH radical scavenging activity of *Eb*O and vitamin C was determined as percentage (%) inhibition using the equation:

$$\text{Inhibition (\%)} = \frac{\text{Control}_{\text{Abs}} - \text{Sample}_{\text{Abs}}}{\text{Control}_{\text{Abs}}} \times 100 \quad (1)$$

where $\text{Control}_{\text{Abs}} = \text{Abs}_{\text{DPPH radical + methanol}}$ (control sample) and $\text{Sample}_{\text{Abs}} = \text{Abs}_{\text{DPPH radical + oil/vit C}}$.

2,2-Azinobis-(3-ethylbenzothiazoline-6-sulfonic acid)] ($ABTS^{+}$) radical scavenging: The decolorization reaction method of Re *et al.* [23] was used. Potassium persulfate solution (2.45 mM) was reacted with ABTS solution (7.0 mM) (v/v) to produce pre-formed ABTS monocation ($ABTS^{\bullet+}$) after 12 h incubation in the dark at room temperature. Prior to the assay, the $ABTS^{\bullet+}$ solution was calibrated to an optical density of 0.705 ± 0.001 at 734 nm, by diluting 1 mL $ABTS^{\bullet+}$ solution with 60 mL methanol and stored in an amber bottle. First 100 µL of methanol in triplicated was pipetted into the wells of a 96 well plates in a pre-determined format. Next, in triplicate 100 µL of oil extract or vitamin C, the positive control was pipetted in triplicate to the methanol in the wells in the first row. The mixture was serially diluted in two-fold dilution method to obtain a concentration range of 0.03125-0.5 mg/mL concentrations of vitamin C and essential oil in the wells. The 100 µL of the calibrated $ABTS^{\bullet+}$ solution was aliquoted into the mixture in all the wells, incubated for 7 min in the dark and absorbance taken at 734 nm. $ABTS^{\bullet+}$ (%) radical scavenging activity of the oil was also calculated using eqn. 1.

Lipid peroxidation assay: The reported method for the assay [24] was slightly modified as methanol was used as solvent of dilution in this study instead of water. A 0.5 mL homogenate of egg yolk (10%) was aliquoted to 0.1 mL oil extract at different concentrations (0.03125-0.50 mg/mL) in tubes and made up to 1.0 mL with distilled water. Then 0.05 mL of $FeSO_4$ (0.07 M) was added to the mixture to induce the lipid peroxidation. After incubation at 37 ºC for 30 min, 1.5 mL of 10% acetic acid (pH 3.5), 1.5 mL of 0.80% 2-thiobarbituric acid in 1.1% sodium dodecyl sulphate and 0.05 mL of 20% trichloroacetic acid (0.05 mL) were added and heated the mixture on a water bath at 65 ºC for 1 h. After cooling, 0.5 mL of butanol was added and centrifuged for 10 min at 3000 rpm. The absorbance of each organic layer was recorded at 532 nm. The percentage lipid peroxide inhibitory activity was also calculated using eqn. 1.

Antibacterial assay

Preparation of bacterial suspensions: The inhibitory potential of *EbO* was investigated with standard strains *Listeria ivanovii* (ATCC 19119), *Staphylococcus aureus* (ATCC 29213), *Streptococcus uberis* (ATCC 700407), *Mycobacterium smegmatis* (ATCC 19420), *Enterobacter cloacae* (ATCC 13047) and two laboratory identified isolates *Escherichia coli* and *Vibrio* spp. according to CLSI [25]. The test bacterial isolates were inoculated separately into individual tubes containing Mueller Hinton broth and incubated at 37 ºC for 24 h. After incubation period, serial dilution of the bacterial suspensions (inoculums) was

prepared to obtain a McFarland 0.5 standard using normal saline which was then used in the tests. The positive control was ciprofloxacin.

Determination of MIC and MBC assays: Both minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) assays were conducted using the micro-broth dilution method. The *EbO was* dissolved in DMSO and the following dilutions 200, 150, 100 and 50 µL were pipetted into Eppendorf tubes to which was added 800, 850, 900 and 950 µL Mueller-Hinton broth respectively to obtain a volume of 1 mL in each Eppendorf tube. Thereafter, the Eppendorf tubes were vortexed and inoculated with 20 µL cell culture suspension matching 0.5 McFarland of the test microorganisms. The tubes were then vortexed and incubated at 37 ºC for 24 h. The lowest concentration that inhibited microorganism growth was noted as the MIC [26,27]. For the minimum bactericidal concentration (MBC), 10 µL from the MIC assays tubes without turbidity after the assay period, were streaked on Muller-Hinton agar plates and incubation was at 37 ºC for another 24 h. The MBC was recorded as the lowest concentration at which no microbial growth was observed while the agar plates with growth after the incubation period were regarded as having a bacteriostatic effect.

GC-MS Characterization of *E. brevipapposus* essential oil: GC system (7890B) and a mass selective detector (Agilent 5977A) Chemettrix Pvt. Ltd.; Agilent Technologies, Deutschland (Germany) coupled with a Zebron-5MS column (ZB-5MS 30 m × 0.25 mm × 0.25 µm) (5% phenylmethylpolysiloxane) was used to characterize the chemical constituents of *E. brevipapposus* essential oil using the reported conditions [28]. The conditions of the column and temperature used were as follows: the injection port, ion source and oven temperatures were set at 280, 280 and 70 ºC, respectively. GC grade helium was at a flow rate of 2 mL/min and while splitless 1 mL injections were used. The ramp settings were; 15 ºC/min to 120 ºC, then 10 ºC/min to 180 ºC, then 20 ºC/min to 270 ºC and held for 3 min. The mass selective detector was used in the documentation of the mass spectra. The compounds of the oil were identified by comparison of the GC-MS analysis with the standards available in-house or with those saved on the database of National Institute Standard and Technology (NIST).

Statistical analysis: All experiments were conducted in triplicate with two replicates. Data was presented as the mean ± standard error of mean (SEM). Statistical analysis was evaluated by one-way analysis of variance (ANOVA) using MINITAB Release 17 statistical package. Result was considered significantly different at $P < 0.05$ confidence level.

RESULTS AND DISCUSSION

Free radical scavenging activity of oil extract of *Euryops brevipapposus*: Hydrodistillation of *E. brevipapposus* leaf powder produced a yellow coloured minty essential oil with a percentage yield of 0.91%. Free radical scavenging capacity of *E. brevipapposus* essential oil (*Eb*O) was investigated using the DPPH, ABTS and lipid peroxidation assays presented as percentage radical scavenging activity. The DPPH radical scavenging activity of *Eb*O and vitamin C (positive control) are comparable (Fig. 1). The percentage *Eb*O DPPH radical scavenging activity at all concentrations was high ranging between 75% and 78% (Fig. 1). The *Eb*O DPPH radical scavenging was significantly different from vitamin C at 0.5 mg/mL but not significantly different at all the other concentrations (Fig. 1). In the ABTS assay, the percentage ABTS radical scavenging ranged between 41% and 76% (Fig. 2). In comparison to vitamin C, the ABTS radical scavenging of *Eb*O was significantly weaker at lower concentrations. However at the concentration of 0.5 mg/mL, *Eb*O exhibited a significantly higher ABTS radical scavenging effect. For lipid peroxide radical inhibitory activity of *Eb*O, the percentage activity ranged between 50% and 68% (Fig. 3). No significant difference was detected between the lipid peroxide radical scavenging of *Eb*O and vitamin C. Furthermore, *Eb*O reduced the DPPH, ABTS and lipid peroxide radicals to neutral molecules effectively with IC_{50} values of 6.71×10^{-7}, 1.06 mg/mL and 1.17 mg/mL, respectively (Table-1).

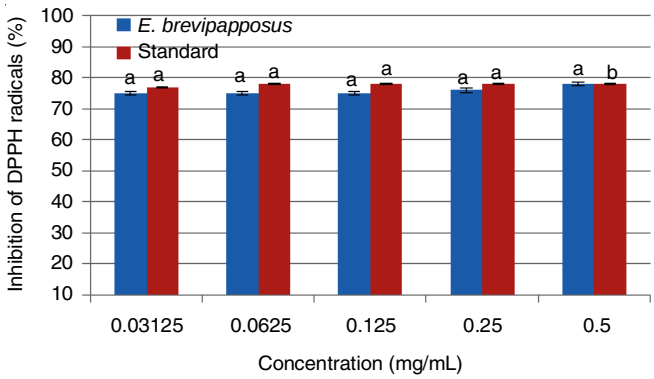


Fig. 1. DPPH radical scavenging by *E. brevipapposus* essential oil and the standard antioxidant, vitamin C. Bar graphs with different letter superscript in the same concentration are significantly different ($p < 0.05$)

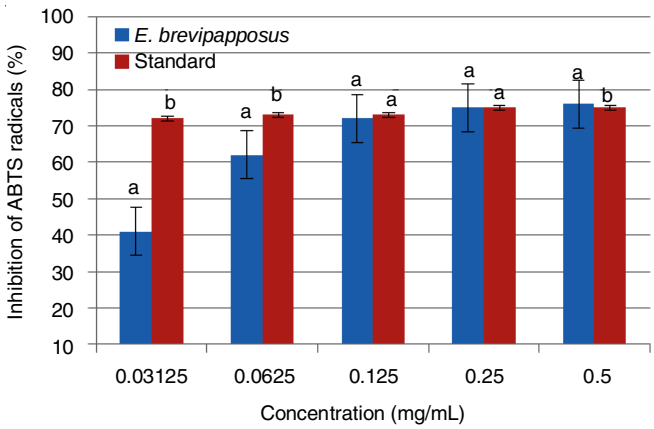


Fig. 2. ABTS radical scavenging by *E. brevipapposus* essential oil and the standard antioxidant, vitamin C. Bar graphs with different letter superscript in the same concentration are significantly different ($p < 0.05$)

Antibacterial activity of *E. brevipapposus* oil: The inhibitory potential of *Eb*O against the seven bacterial strains is presented in Table-2. The antibacterial activity observed was appreciable with MICs values ranging between 0.055 to 0.335

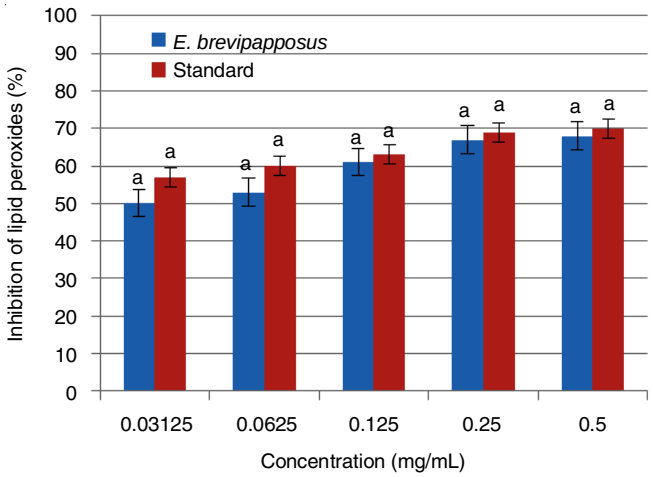


Fig. 3. Lipid peroxide radical scavenging by *E. brevipapposus* essential oil and the standard antioxidant, vitamin C. Bar graphs with different letter superscript in the same concentration are significantly different ($p < 0.05$)

TABLE-1
ANTIOXIDANT ACTIVITY OF
ESSENTIAL OILS OF *E. brevipapposus*

Activity	Concentration (mg/mL)	Inhibition (%)	IC_{50}	R^2
DPPH	0.03125	75 ± 0.04	6.71×10^{-7}	0.517
	0.06250	53 ± 0.03		
	0.12500	61 ± 0.01		
	0.25000	67 ± 0.03		
	0.50000	68 ± 0.02		
ABTS	0.03125	41 ± 0.04	1.05	0.95
	0.06250	75 ± 0.04		
	0.12500	75 ± 0.04		
	0.25000	76 ± 0.04		
	0.50000	78 ± 0.04		
LP	0.03125	50 ± 0.01	1.170	0.921
	0.06250	62 ± 0.04		
	0.12500	72 ± 0.01		
	0.25000	75 ± 0.03		
	0.50000	76 ± 0.01		

$DPPH^{\bullet}$ = 2,2-diphenylpicrylhydrazyl radicals, $ABTS^{\bullet}$ = 2,2'-azino-bis diammonium salt radicals, $LP^{\bullet}$ = lipid peroxide radical, Values are %inhibition ± SD.

mg/mL. The lowest MIC value of *Eb*O (0.055 mg/mL) against *E. coli* and *Vibrio* spp., showed the oil to possess potent antibacterial activity. However, the highest MIC value (0.335 mg/mL) against *S. aureus* showed *Eb*O to exhibit weak antibacterial activity against the strain. *Eb*O is bacteriocidal against all the bacterial strains as it had MBCs values ranging from 0.125 to 0.5 mg/mL (Table-2), with the exception of *S. uberis* for which it was bacteriostatic.

Chemical compounds of *Euryops brevipapposus* oil: The percentage values of the chemical compounds of *Eb*O are presented in Table-3 while their corresponding peaks are shown in Fig. 4. The *E. brevipapposus* essential oil analysis recorded about 95 compounds, which could have contributed to the medicinal potential of the essential oil. The mass spectrum of *Eb*O showed 10 prominent peaks including α-phellandrene, α-pinene, β-pinene, β-phellandrene, β-mycrene, germacrene D and (E)-β-ocimene. The less prominent peaks revealed the minor components identified at other retention times, their peak areas are given in Fig. 4.

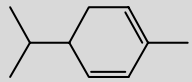
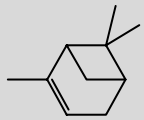
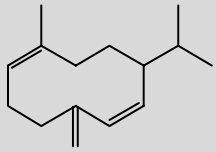
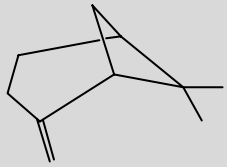
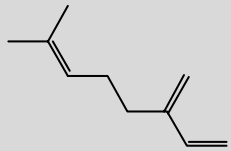
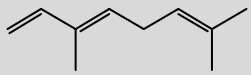
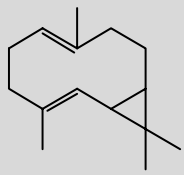
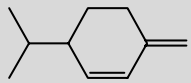
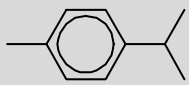
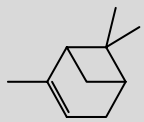
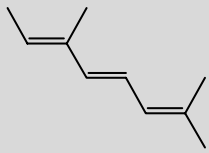
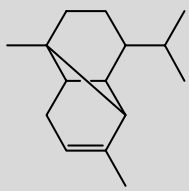
A yellow coloured minty essential oil was obtained by hydrodistillation of *Euryops brevipapposus* leaf powder with a percentage yield of 0.91%. This yield agrees with the report [29], which suggested that the oil content of a normal cut should average 0.25-0.50%, but with proper management the yield could increase to 0.66-0.90%. The *Eb*O obtained was evaluated for antioxidant activity by free radical scavenging assays. The *Eb*O was as potent as the standard vitamin C as a DPPH radical scavenger in all the tested concentrations. It attained an IC_{50} value (6.71×10^{-7} mg/mL) stronger than the IC_{50} value for vitamin C (1.05 mg/mL), an indication that *Eb*O exhibit high DPPH antioxidant activity (Table-1). Also, *Eb*O neutralized the ABTS radicals in all the tested concentrations (Fig. 2) with the activity being stronger at the concentration of 0.5 mg/mL than vitamin C. Conversely, *Eb*O lipid peroxidase radical scavenging activity was not significantly different from those of vitamin C (Table-1). The effectiveness of *Eb*O as DPPH radical scavenger could be related to the capacity of the oil as a proton donor [30]. Antioxidant activity assays by DPPH and ABTS radical scavenging do not correlate and the degree of the interaction of *Eb*O in the DPPH and ABTS may be related the difference in solubility of the ABTS and DPPH reagents [31], variation in oil composition or the stereo-selectivity of radicals [32]. Therefore, the antioxidant activity of *Euryops brevipapposus* oil may be accounted for by the presence of the diverse compounds in the oil such as monoterpenes and sesquiterpene and these results can be corroborated by previous studies [33,34].

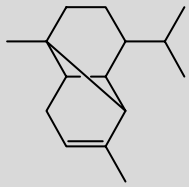
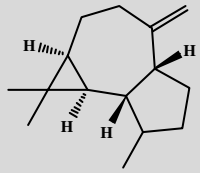
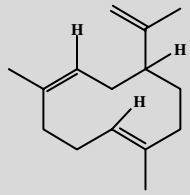
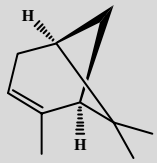
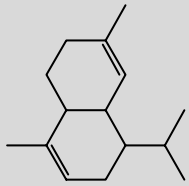
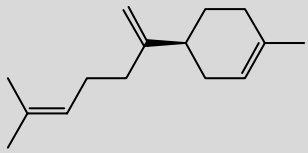
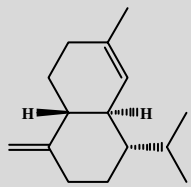
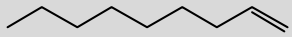
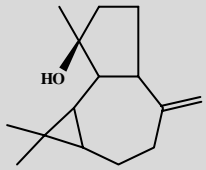
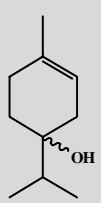
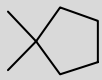
The study (Table-2) showed that the oils demonstrated strong antibacterial activities against the assorted microorganisms tested in the panel as it had inhibitory activities against the growth of the microorganisms (MIC values of 0.125 and

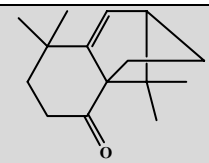
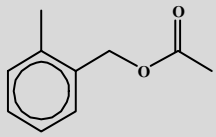
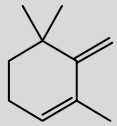
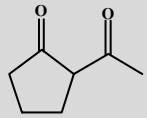
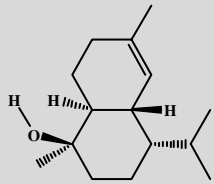
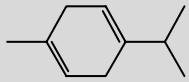
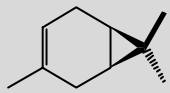
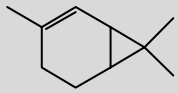
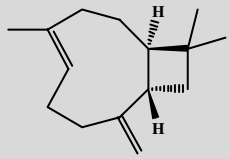
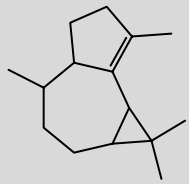
TABLE-2
MIC AND MBC VALUES FOR *E. brevipapposus*

Microorganism	Gram +/-	Culture collection and Ref. No.	*E. brevipapposus* (mg/mL)		Antibiotic
			MIC	MBC	
Enterobacter cloacae	–	(ATCC 13047)	0.125	0.215	> 0.125
Listeria ivanovii	+	(ATCC 19119)	0.215	0.335	> 0.125
Staphylococcus aureus	+	(ATCC 29213)	0.335	0.500	> 0.125
Streptococcus uberis	+	(ATCC 700407)	0.500	> 0.500	> 0.125
Mycobacterium smegmatis	+	(ATCC 19420)	0.215	0.335	> 0.125
Escherichia coli	–	Lab isolate	0.055	0.125	> 0.125
Vibro sp.	–	Lab isolate	0.055	0.125	> 0.125

TABLE-3
MAJOR COMPOSITION OF BIOACTIVE COMPOUNDS IDENTIFIED USING GC-MS

S. No.	Retention time (min)	Compounds	m.f.	Structure	m.w.	Peak area (%)
1	4.565	α-Phellandrene	$C_{10}H_{16}$		136.23404	14.72
2	3.986	α-pinene	$C_{10}H_{16}$		136.23404	13.01
3	8.169	Germacrene D	$C_{15}H_{24}$		204.35110	9.72
4	4.393	β-Pinene	$C_{10}H_{16}$		136.23404	7.51
5	4.393	β-Mycrene	$C_{10}H_{16}$		136.23404	7.51
6	4.809	(E)-β-Ocimene	$C_{10}H_{16}$		136.23404	6.31
7	8.271	Bicyclogermacrene	$C_{15}H_{24}$		204.35106	5.39
8	4.904	β-Ocimene	$C_{10}H_{16}$		136.23400	4.67
9	4.320	β-Phellandrene	$C_{10}H_{16}$		136.23400	4.49
10	4.771	*p*-Cymene	$C_{10}H_{14}$		134.21820	3.78
11	4.771	1,3-Dimethyl-2-ethylbenzene	$C_{10}H_{16}$		136.23400	3.78
12	5.496	Allo-Ocimene	$C_{10}H_{16}$		136.23400	3.36
13	7.428	α-Copaene	$C_{15}H_{24}$		204.35110	2.31

14	7.428	α-Cubebene	$C_{15}H_{24}$		204.35110	2.31
15	8.034	Alloaromadendrene	$C_{15}H_{24}$		204.35110	2.20
16	7.508	Germacrene A	$C_{15}H_{24}$		204.35110	2.09
17	4.095	1R-α-Pinene	$C_{10}H_{16}$		136.23400	1.94
18	8.363	α-Amorphene	$C_{15}H_{24}$		204.35110	1.88
19	8.034	β-Bisabolene	$C_{15}H_{24}$		204.35110	1.67
20	8.084	γ-Cadinene	$C_{15}H_{24}$		204.35110	1.67
21	3.577	1-Nonene	C_9H_{18}		126.23920	1.55
22	8.763	Spatulenol	$C_{15}H_{24}O$		220.35050	1.46
23	5.949	Terpinen-4-ol	$C_{10}H_{18}O$		154.25000	1.22
24	3.111	1,1-Dimethylcyclopentane	C_7H_{14}		98.18610	1.14

25	7.898	Neoisolongifolene	$C_{15}H_{22}O$		218.33460	1.03
26	6.847	Benzenemethanol, 2-methyl-, acetate	$C_{10}H_{12}O_2$		164.20110	0.87
27	7.130	1,5,5-Trimethyl-6-methylene-cyclohexene	$C_{10}H_{16}$		136.23400	0.76
28	6.966	2-Acetylcyclopentanone	$C_7H_{10}O_2$		126.15310	0.74
29	9.094	T-Cadinol	$C_{15}H_{26}O$		222.36630	0.73
30	5.014	γ-Terpinene	$C_{10}H_{16}$		136.23400	0.73
31	5.014	3-Carene	$C_{10}H_{16}$		136.23400	0.73
32	6.029	2-Carene	$C_{10}H_{16}$		136.23400	0.70
33	7.757	Caryophyllene	$C_{15}H_{24}$		204.35110	0.69
34	7.676	α-Gurgujene	$C_{15}H_{24}$		204.35110	0.67

0.05 mg/mL). The *Eb*O inhibitory activity against the tested microorganisms was observed to be variable and concentration dependent. To the best of our knowledge, there is no previous research regarding the antibacterial activity of this plant, although *E. arabicus*, the Asteraceae specie was reported to exhibit potent antibacterial activity with MIC values of 0.13-5.25 mg/mL thus supporting their traditional use in wounds treatment [35]. This finding seemed to confirm the *Eb*O antibacterial potential and its use in traditional medicine. Santoyo *et al.* [36] described α-pinene, 1,8-cineole, camphor, verbenone and borneol, present in the oil they studied as being accountable for the antimicrobial activity, with the most potent being borneol, followed by camphor and verbenone. However, among the compounds reported by Santoyo *et al.* [36], only α-pinene was present in this essential oil and the quantity was high in the studied sample. The susceptibility of the tested microorganisms to *Eb*O could be related to the antibacterial activity of the high α-pinene and caryophyllene content of the oil. Furthermore, the overall antibacterial activity of the essential oil may have been improved by other major and minor chemical components have combined synergistic effect. In addition to this, the chemical constituents of essential oils may potentially affect its biological activity [37].

The GC-MS analysis of *Eb*O detected diverse groups of chemical constituents present in it including, monoterpene hydrocarbons, diterpene alcohol, sesquiterpene hydrocarbons, sesquiterpenoids, monoterpenoids whose biological potentials are well known [34,38]. The major chemicals detected in *E.*

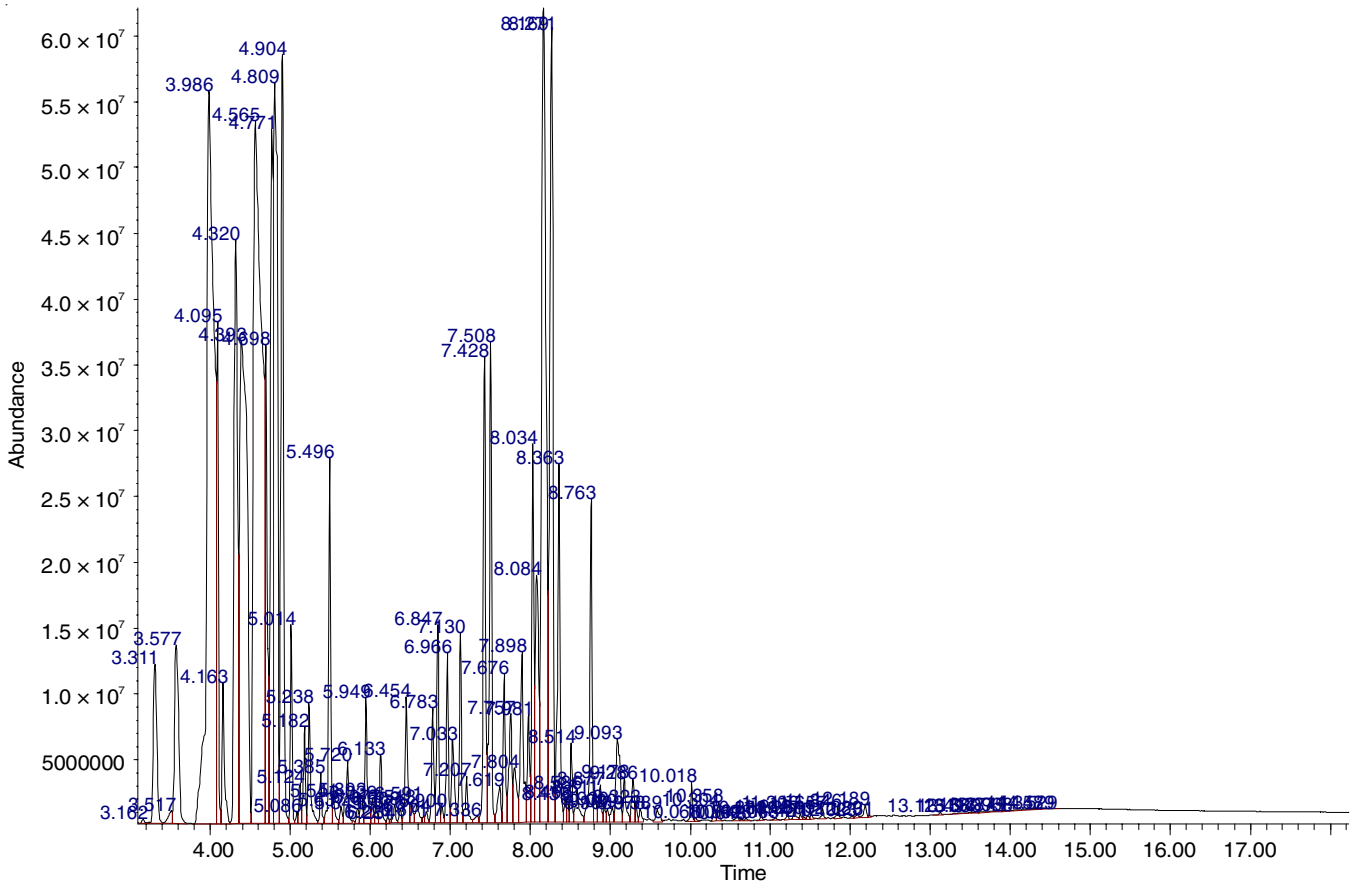


Fig. 4. GC-MS chromatogram of *E. brevipapposus* essential oil

brevipapposus were α-phellandrene (14.78%), α-pinene (13.01 %), germacrene D (7.63%), β-pinene (7.51%), β-myrcene (7.51%), (E)-β-ocimene (6.31%), bicyclogermacrene (5.39%), β-phellandrene (4.49%), while isophytol (0.02%), carvacrol and thymol (0.06%), isoeremophilene (0.07%), α-cubebene (0.25%), nerolidol (0.31%) and β-bisabolene (1.67%) were present in smaller amount (Fig. 4).

Conclusion

The search for alternate therapy has focused much attention in recent times on medicinal plants due to the numerous advantages that medicinal plants have over conventional therapies such as availability, effectiveness, relative cheapness and minimal cytotoxicity. The results obtained from this study showed that the compounds within the essential oil *E. brevipapposus,* could be potential sources of bioactive compounds with potent antioxidant and antibacterial activities. However, immense research needs to be performed to identify and thoroughly evaluate the active compounds that are linked for the observed antimicrobial and antioxidant activities as well as determine the *in vivo* biological efficacy as well as assess the cytotoxicity of the essential oil, in order to fully ascertain and harness its rich therapeutic benefits.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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