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Chemical Composition and Biological Activity of *Guarea cedrata* (A. Chev.) Pellegr. Leaf and Root Bark Essential Oil

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study aims, on the one hand, to establish the chemical composition and to evaluate the antioxidant potential of essential oils (EO) of *Guarea cedrata* leaves and root bark, and on the other hand, to determine the antimicrobial activity of the leaf EO.
Methodology: The EOs were analyzed by a combination of GC (Ir), GC-MS and ^{13}C NMR. The antibacterial and antifungal activity of the essential oils was determined and then the antioxidant activity was also evaluated.
Results: 40 hydrocarbon (19.8%) and oxygenated (73.3%) sesquiterpenes were identified from root bark EO, representing 93.1% of the total composition, and 55 compounds were identified from leaf EO, representing 91.5% of the total composition, with 58.1% sesquiterpene hydrocarbons, 32.4% oxygenated sesquiterpenes and 1.0% hydrocarbon monoterpenes. An evaluation of the

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antioxidant potential of these EOs revealed moderate free radical scavenging activity of *G. cedrata* leaf EO compared to quercetin. Leaf EO tested on bacteria and yeast showed bacteriostatic activity against bacterial strains of *Escherichia coli*, *Salmonella typhimurium*, *Bacillus subtilis* and *Candida albicans* at a concentration of 6.3 mg/ml and bactericidal activity at a concentration of 50 mg/ml.
Conclusion: This study highlighted the chemical composition, the antiradical and biological activity of the essential oils of two organs (leaf and trunk bark) organs of *G. cedrata*.

Keywords: Guarea cedrata; essential oil; 13C NMR; GC-MS; antioxidant; antimicrobial and antifungal activities.

1. INTRODUCTION

Over the past few decades, the use of medicinal plants in therapy has become increasingly popular. Due to the development of resistance to many drugs in microorganisms and their ineffectiveness, as well as the growing desire to use environmentally friendly products, more and more people are choosing natural methods of treatment and prevention [1]. Due to the presence in its composition of many bioactive compounds (mono- and sesquiterpenes, phenolic derivatives), essential oils (EO) have a wide range of pharmacological activities: antibacterial, fungicidal, anti-inflammatory [2-6].

There are many aromatic plants, whose chemical composition and therapeutic activity of their EO are little or not studied. However, they can be important new sources of bioactive compounds. For example, Guarea cedrata is a tropical woody plant belonging to the Meliaceae family. It is one of the species of the genus Guarea, producing a wide range of secondary metabolites, including limonoids, triterpenes, diterpenes and sesquiterpenes. According to the literature, these are the main components of EOs of the genus Guarea [7]. *G. cedrata*, also known as "Bossé", is a large forest tree, easily recognized by its pale gray-brown bark, sinuous concentric ridges and strong cedar scent. The stem reaches a height of 40 m and a diameter of up to 2 m. The top is dense, spherical, with twisted branches [8].

G. cedrata is often used in traditional medicine to treat various conditions such as abdominal pain, food poisoning, gonorrhea, rheumatism, postpartum hemorrhage, leprosy and as a poultice for kidney pain [9]. Studies conducted on *G.cedrata* bark by John A. Akinniyi et al, isolated three new triterpenoids: 3,4-secotirucalla-4(28),7,24-trien-3,21 dioic acid, its methyl ester and 2'-hydroxyrohitukin [10]. The methanolic extract of the trunk bark of this species is a food attractant for adults of *Sitophilus granarius* L. (food insect pest) [11]. Chantal Menut et al showed that the EO of *G. cedrata* trunk bark is composed exclusively of sesquiterpenes [8]. To our knowledge, only one paper has been published on the chemical composition of EO from the trunk of *G. cedrata* [8], and not a single paper has been published on the chemical composition of EO from the bark of leaves and roots. Therefore, the purpose of this work was to (i) investigate the chemical composition of leaf and root bark EO, (ii) evaluate the antioxidant potential, and (iii) determine the antimicrobial activity of *G. cedrata* leaf EO.

2. MATERIALS AND METHODS

2.1 Plant Material and EO Extraction

Leaves and roots of *G. cedrata* were collected on July 13, 2019 at Adiopodoumé (5°20'12" N and 4°7'57" W) in the district of Abidjan. The identification of this species was confirmed by the systematic botanist Dr. Malan Djah François, NANGUI ABROGOUA University, Côte d'Ivoire. The plant organs were dried at room temperature for 7 days and subjected to hydrodistillation using a Clevenger type still for 4 hours. The oil samples were dried over anhydrous $MgSO_4$ and stored in a refrigerator (4°C) in tightly closed brown glass bottles until analysis.

2.2 GC Analysis

0.5 µL of sample solutions containing 50 µL of EO in 350 µL of $CDCl_3$ were injected and analyzed. Analyses were performed on a PerkinElmer Clarus 500 chromatograph (PerkinElmer, Courtaboeuf, France), equipped with a Flame Ionization Detector (FID) and two fused silica capillary columns (50 m × 0.22 mm, film thickness 0.25 µm), BP- 1 (polydimethylsiloxane) and BP-20 (polyethylene glycol). The oven temperature was programmed from 60°C to 220°C at 2°C/min, then maintained

at isothermal temperature at 220°C for 20 min; injector temperature: 250°C; detector temperature: 250°C; carrier gas: hydrogen (0.8 mL/min); distribution: 1/60. Retention indices (RIs) were determined relative to the retention times of the n-alkane series (C8-C29) by linear interpolation (PerkinElmer "Target Compounds" software).

2.3 GC-MS Analysis

0.2 µL of the sample solutions containing 50 µL of EO in 350 µL of $CDCl_3$ are injected and analyzed using a Clarus SQ8S PerkinElmer TurboMass detector (quadrupole) directly connected to a Clarus 580 PerkinElmer Autosystem XL (PerkinElmer, Courtaboeuf, France), equipped with a fused silica Rtx-1 (polydimethylsiloxane) capillary column (60 m × 0.22 mm i.d, film thickness 0.25 µm). The oven temperature was programmed from 60 to 230°C at a rate of 2°/min, then the isothermal temperature was maintained for 45 min; injector temperature, 250°C; ion source temperature, 250°C; carrier gas, He (1 mL/min); split ratio, 1:80; ionization energy, 70 eV. Electron ionization (EI) mass spectra were obtained in the 35-350 Da mass range.

2.4 Analysis by ^{13}C NMR

The ^{13}C NMR spectra were recorded on a Fourier transform spectrometer Bruker AVANCE (Bruker, Wissembourg, France) 400 operating at 100.623 MHz, equipped with a 5 mm probe. 40 mg of EO are dissolved in 0.5 mL of $CDCl_3$; all chemical shifts relating to the internal tetramethylsilane (TMS). The ^{13}C NMR spectra of oil samples were recorded with the following parameters: pulse width = 4 µs (rotation angle 45°); relaxation time D1 = 0.1 s, acquisition time = 2.7 s for a 128K datasheet with a spectral width of 25,000 Hz (250 ppm); CPD mode decoupling; digital resolution = 0.183 Hz/pt. The cumulative number of scans was 3000 for each sample.

2.5 Identification of Compounds

Identification of individual compounds was achieved by (i) comparison of their retention indices (RIs) in GC on polar and apolar columns [12]; (ii) computer matching with commercial mass spectral libraries [12-15]; and (iii) comparing the signals from the ^{13}C NMR spectra of the samples with those of reference spectra compiled in the laboratory's spectral library, using software developed in the laboratory [16,17].

2.6 Evaluation of Antioxidant Activity

The in vitro antioxidant activity was evaluated using a spectrophotometer by measuring the scavenging capacity of the DPPH- (1,1-diphenyl-2-picrylhydrazyl) radical according to the method described by Blois [18] with slight modification. $DPPH^{\bullet}$ is dissolved in absolute ethanol to give a solution at a concentration of 0.003 mg/mL. Different concentration ranges of EO are prepared in absolute ethanol (5 mg/mL; 2.5 mg/mL; 1.25 mg/mL; 0.625 mg/mL; 0.313 mg/mL; 0.156 mg/mL). Into dry, sterile tubes, 0.5 mL of prepared extracts and 0.75 mL of $DPPH^{\bullet}$ ethanolic solution are introduced. After an incubation period of 30 min at laboratory temperature and protected from light, the absorbance is read at 517 nm against a control sample prepared from 1.25 mL of $DPPH^{\bullet}$ ethanolic solution. The positive reference control is quercetin prepared under the same conditions as the test extracts. The percentage reduction (PR) of $DPPH^{\bullet}$ radical by the extracts was calculated according to the following formula:

$$PR\ (\%) = [(A_{DPPH} - A_e) / A_{DPPH}] \times 100$$

A_{DPPH}: absorbance of DPPH•; A_e: absorbance of the extract

The effectiveness of the samples against $DPPH^{\bullet}$ was assessed by graphical determination of the CR_{50} (concentration that reduces 50% of $DPPH^{\bullet}$) [19].

2.7 Determination of Antibacterial and Antifungal Activity

2.7.1 Bacterial and fungal strains and growth conditions

The following microbial and fungal strains were used for this test: GRAM (-) bacteria: *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853, *Salmonella typhimurium* SO 66; GRAM (+): *Staphylococcus epidermidis* CIP. 53124, *Staphylococcus aureus* CIP 4.83, *Bacillus subtilis* ATCC 6633 and yeasts: *Candida albicans* ATCC 10231, *Candida tropicalis* ATCC 13803, *Candida glabrata* ATCC 66032. They were subcultured in tubes with preservative agar (in the central puncture) and incubated at 37°C. After 24 hours of incubation, these tubes were stored at -80°C and at refrigeration temperature

(2 ± 1°C). In order to have strains available at all times, transplants of refrigerated strains are performed every 15 days. Before performing antibacterial and antifungal tests for each strain, two consecutive transplants were performed. They were first inoculated in Mueller Hinton broth and incubated for 24 h at 37 ± 1°C.

The second subculture was performed on solid medium (nutrient agar) one day before the antibacterial and antifungal test. The whole was incubated at 37 ± 1°C for 18 hours so that the bacterial and fungal cells were in exponential growth phase. Several colonies were taken from this fresh bacterial and fungal culture and mixed with sterile distilled water. To normalize the loading of the initial inoculum, we used the method of comparing the bacterial (fungal) density to the density of a Mc Farland reference tube (0.5) assumed to be loaded at 105 CFU/mL.

2.7.2 Well diffusion method

Antibacterial activity and antifungal activity of different EO at different concentrations (50 mg/mL; 25 mg/mL; 12.5 mg/mL; 6.25 mg/mL; 3.13 mg/mL; 1, 56 mg/mL; 0.78 mg/mL; 0.39 mg/mL) were determined for each strain by the method of Berghe and Vlietinck [20], from an 18-20 h culture (105-106 CFU/mL). Inoculation of the 1 mL inoculum was performed on the surface of Mueller-Hinton medium previously poured into Petri dishes. After 15 min, the wells were excised with Pasteur pipettes (6 mm thick tip). The bottom of the wells were sealed with a drop of Mueller-Hinton agar to limit the diffusion of oil under the agar. Then, 50 µl of oil at different dilutions and a reference (gentamicin or amphotericin B respectively for bacteria and fungi) are distributed in each well. After diffusion, the cultures are incubated in ovens at 37°C for 24h. The inhibition rings are measured with a caliper.

2.7.3 Determination of the Minimum Inhibitory Concentration (MIC)

Technique used consists in seeding the EO with a standardized inoculum in a range of decreasing concentrations (50 mg/mL; 25 mg/mL; 12.5 mg/mL; 6.25 mg/mL; 3.13 mg/mL; 1.56mg/mL; 0.78mg/mL; 0.39mg/mL). After incubation, monitoring the range gives access to the Minimum Inhibitory Concentration (MIC), which corresponds to the lowest concentration of EO capable of inhibiting bacterial (fungal) growth after 18 to 24 hours of contact.

3. RESULTS AND DISCUSSION

3.1 Chemical Composition

G. cedrata gave an essential oil from yellowish colored leaves and orange colored root barks with yields of 0.22% and 0.39% (m/m based on fresh plant material) respectively.

The combination of GC (RI), GC-MS and ^{13}C NMR analysis methods applied to the two EO samples identified 55 compounds in the leaf EO and 40 compounds in the root bark EO, representing 91.5% and 93.1% of the total composition respectively. Both EOs are dominated by sesquiterpene compounds. The main compounds in *G. cedrata* leaves are β-selinene (22.9%), α-selinene (15.2%), and β-elemene (8.1%). Two other compounds are present in significant proportions: β-eudesmol (4.6%) and α-eudesmol (4.6%). Monoterpenes are present in proportions of less than 1%: the most abundant is limonene (0.6%). This composition differs quantitatively and qualitatively from those of the leaf EOs of several species of Guarea from Brazil. Indeed, the leaf EO of *G. scabra* is dominated by cis-caryophyllene (33.37%) and trans-α-bergamotene (11.88%) while the species *G. silvatica* is predominantly composed of caryophyllene epoxide (36.54%) and has a diterpene (kaurene) among its compounds [7] and *G. Guidonia* leaf EO is dominated by eudesm-6-en-4β-ol (21.0%), guai-6-en-10β-ol (21.0%) and eudesma-5,7-diene (19.2%) [21,22].

Root bark EO is dominated by viridiflorol (55.5%); carotol (5%) and 11-α-himachal-4-ene-1-β-ol (4.0%) are present in appreciable proportions. The most abundant hydrocarbon sesquiterpene in root bark EO is *allo*-aromadendrene (2.7%). No monoterpenes were identified in this EO. Despite the fact that these two EOs are rich in sesquiterpenes, they have different chemical compositions. The leaves contain a greater amount of hydrocarbon sesquiterpenes (58.14%), characterized by β-selinene, while the root barks are richer in oxygenated sesquiterpenes (73.3%) with viridiflorol as the representative. No compounds present in notable proportion are common to both samples. The chemical compositions of the EOs of the leaf and root barks of *G. cedrata* are different from those of the EOs of the trunk barks of this *p*-caryophyllene dominant species [8]. However, the chemical composition of the leaves

is close to this composition by the high percentage of its hydrocarbon compounds: 68.0% for the trunk bark EO against 58.1% for the leaf EO.

It is important to note that in general, the EOs of Guarea species do not contain monoterpenes. Thus, the presence of monoterpene in the leaf EO is unusual. However, its low proportion relative to sesquiterpenes confirms previous findings that the predominance of hydrocarbon and oxygenated sesquiterpenes and the near total absence of monoterpenes is a marker of EOs of the genus Guarea [1].

Table 1. Chemical composition of EO from leaf and root bark

Compounds	RIa	RIp	Relative proportion (%)	
			Leaf	Root bark
α-pinene	931		0,1	-
β-pinene	971	1 116	0,3	-
limonene	1 022	1 205	0,6	-
α-longipinene	1 351	1 469	-	0,7
(+)-himachala-2,4-diene	1 358	1 597	-	0,9
cyclosativene	1 369	1 483	-	0,8
longicyclene	1 372	2 166	-	0,2
α-copaene	1 375	1 500	0,4	0,2
daucene	1 379	1 493	-	0,4
β-elemene	1 387	1586	8,1	0,4
iso-caryophyllene	1 403	1 576	0,4	0,8
α-ionone	1 407	1 849	0,1	-
α-bergamotene cis	1 410	1 569	-	0,1
(E)-β-caryophyllene	1 416	1 591	2	0,4
β-gurjunene	1 420	1 603	-	0,1
dauca-5,8-diene	1 431	1 612	-	1,6
trans-α-bergamotene	1 432	1 580	0,3	0,1
α-guaiene	1 434		0,3	-
α-humulene	1 449	1 669	2,4	0,4
allo-aromadendrene	1 457	1 645	-	2,7
carota-1,4-diene	1 464	1 650	-	1,0
drima-7,9(11)-diene	1 465	1 680	0,6	-
selina-4,11-diene	1 470	1 676	3,1	-
β-curcumene	1 475	1 757	-	0,9
β-selinene	1 482	1 715	22,9	0,1
ledene	1 490	1 695	-	1,0
α-selinene	1 491	1 725	15,2	-
α-germacrene	1 492		-	2,5
β-himachalene	1 495	1 708	-	1,1
α-bulnesene	1 498	1 718	0,4	0,3
β-bisabolene	1 502	1 721	-	0,1
γ-cadinene	1 505	1 744	0,3	-
γ-humulene	1 508	1 731	-	2,4
trans-calamenene	1 508	1 832	0,1	-
7-epi-α-selinene	1 511	1 762	0,9	-
γ-cadinene	1 513	1 757	0,2	-
ar-himachalene	1 522	1 696	0,1	0,7
selina-4(15),7(11)-diene	1 528	1 804	0,2	-
elemol	1 533	2 077	2,8	-
selina-3,7(11)-diene	1 536	1 777	0,3	-
(E)-nerolidol	1 547	2 040	0,2	-
spathulenol	1 563	2 119	0,1	1,8
caryophyllene oxide	1 569	1 978	0,6	2,0
globulol	1 574	2 070	0,2	0,8
guaiol	1 584	2 086	3	-

viridiflorol	1 584	2 083	-	55,5
carotol	1 587	2 014		5
ledol	1 592	2 024	-	0,3
humulene oxide II	1 593	2 010	0,8	-
β-himachalene oxide	1 596	1 986	-	0,3
neo intermedeol	1 598	2 133	1	-
1,10-di-epi cubenol	1 614	2 060	-	0,1
eremoligenol	1 614	2 182	0,9	-
cubenol	1 617	2 034	-	0,8
γ-eudesmol	1 617	2 164	2,7	-
caryophylla-4(12),8(13)-dien-5- α-ol	1 619	2 292	0,5	-
daucol	1 620	2 287	-	0,5
hinesol	1 624	2 206	0,4	-
τ-cadinol	1 625	2 173	-	0,2
α-muurolol	1 628	1 727	-	0,9
τ-muurolol	1 628	2 182	0,6	-
cubenol	1 630	2 034	0,3	-
11α-himachal-4-en-1β-ol	1 633	2 103	-	4,0
β-eudesmol	1 634	2 224	4,6	-
pogostol	1 637	2 194	-	1,0
intermedeol	1 637	2 247	2,9	-
α-eudesmol	1 639	2 215	4,6	-
eudesm-11-en-4-α-ol	1 642	2 301	0,9	-
bulnesol	1 651	2 198	2,0	-
ledene oxide II	1 700	2 279	1,0	-
α-cyperone	1 724	2 338	2,1	-
valerenal	1 742	2 210	0,2	-
neophytadiene	1 835	1 925	0,1	-
hydrogenated monoterpenes			1,0	-
hydrogenated sesquiterpenes			58,1	19,8
oxygenated sesquiterpenes			32,4	73,3
total			91,5	93,1

The order of elution and the percentages are given on apolar column. RIa and RIp: retention indices measured respectively on apolar (BP-1) and polar (BP-20) column

3.2 Antioxidant Activity

Fig. 1 shows the results of the *in vitro* antioxidant assay of *G. cedrata* leaf and root bark EOs against the $DPPH^{\bullet}$ radical, using quercetin as a reference. From these results, it can be seen that the reduction potential of $DPPH^{\bullet}$ radicals by EOs increases progressively with the increase of the EO concentration, as well as for quercetin. The same is true for quercetin. However, the percentages of $DPPH^{\bullet}$ reduction by EO are lower than those of quercetin for all the concentrations used.

In order to better appreciate the reducing power of $DPPH^{\bullet}$ by the tested samples, the RC_{50}, i.e. the concentration that reduces the radical activity of $DPPH^{\bullet}$ by 50%, was determined graphically by linear regression (Table 2). Indeed, the lower the RC_{50} value, the higher the activity [23].

G. cedrata leaf EO exhibits antioxidant activity with an RC_{50} of 0.227 mg/mL about 10 times higher than that of root bark EO. The antioxidant activity of G. cedrata leaf EO can be considered as very moderate compared to the RC_{50} value of quercetin (0.005mg/mL), used as a reference.

3.3 Antibacterial and Antifungal Activities

The EOs were tested on 9 multi-resistant pathogenic microorganisms including 3 Gram+ bacteria, 3 Gram- bacteria and 3 yeasts, provided by the Bacteriology Virology Laboratory of the Institut Pasteur of Côte d'Ivoire. Thus it was tested: bacteria often responsible for food, skin, nasal, urinary and septicemia infections; such as *Echerichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and yeasts responsible for candidiasis or skin infection.

The results of the inhibition diameter measurements of the antibacterial and antifungal tests are reported in Table 3.

The diameters generated by the essential oils, are clearly inferior to those produced by the reference antibiotics (25-35 mm) and variable according to the microbial strain used. The activity of essential oils, which are complex mixtures of several molecules, are generally lower than that exerted by antibiotics. Also according to Ponce et al. [24], essential oil is considered inactive if it produces inhibition diameters less than or equal to 8 mm, weak for diameters between 8 and 14 mm, moderately effective for a diameter between 14 and 20 mm and very effective for a diameter greater than or equal to 20 mm. Thus, for the antibacterial tests, the EO of *G. cedrata* had a medium activity against *Escherichia coli* (i.d = 16 mm), weak against *Bacillus subtilis* and *Salmonella typhimurium* (i.d = 9 mm for each strain) and for the antifungal tests, the EO showed a weak activity against *Candida albicans* with an inhibition diameter of 13 mm. All other microbial strains: yeasts; *Candida tropicalis*, *Candida glabrata* and bacteria; *Pseudomonas aeruginosa*, *Staphylococcus epidermidis* and *Staphylococcus aureus* showed resistance to the EO of *G. cedrata* leaf.

The MIC determined against the sensitive strains all have the same value (6.25 mg/mL). This MIC value is significantly higher than that of the reference antibiotic and antifungal.

The values of MIC of *G. cedrata* leaf EO determined against the yeast *Candida albicans* and the bacteria *Bacillus subtilis*, *Salmonella typhimurium* and *Escherichia coli* are indicated in Table 4.

MIC values are generally consistent with inhibition diameters. The chemical composition of *G. cedrata* leaf EO is dominated by the presence of hydrocarbon molecules. The ratio linking the antibacterial activity of an EO to its main constituents is not applicable to *G. cedrata* leaf oil because the hydrocarbon compounds (59.1%) are not very, if at all, active [25]. The antimicrobial activity of this essential oil would then be attributable to one or more active molecules present in low proportion. In particular, the oxygenated sesquiterpenes (32.4%) in particular eudesmol, an oxygenated compound with a strong antimicrobial activity [26].

Table 2. RC_{50} of *G. cedrata* leaf and root bark EOs samples

	Quercetin	Leaf EO	Root bark EO
RC_{50} (mg/mL)	0,005	0,227	2,137

Table 3. Inhibition diameters of leaf EO on bacteria and fungi (mm)

	Strains	Inhibition diameters (mm)		
		Leaf EO	Gentamicin	Amphotericin B
Antifungal tests	*Candida albicans*	13		30
	Candida tropicalis	0		30
	Candida glabrata	0		30
Antibacterial tests	*Bacillus subtilis*	09	35	
	Staphylococcus aureus	0	35	
	Staphylococcus epidermidis	0	35	
	Pseudomonas aeruginosa	0	30	
	Salmonella typhimurium	09	25	
	Escherichia coli	16	33	

GRAM (-): Escherichia coli ATCC 25922; Pseudomonas aeruginosa ATCC 27853; Salmonella typhimurium SO 66. GRAM (+) : Staphylococcus épidermidis CIP. 53124 ;Staphylococcus aureus CIP 4.83 ; Bacillus subtilis ATCC 6633. YEASTS/ MOLDS: Candida albicans ATCC 10231; Candida tropicalis ATCC 13803 ; Candida glabrata ATCC 66032

Table 4. Antibacterial and antifungal parameters of *G. cedrata* leaf EO

Strains	Leaf EO	Amphotericin B	Gentamicin
	MIC (mg/mL)	MIC (mg/mL)	MIC (mg/mL)
Candida albicans	6,25	0,0003	
Bacillus subtilis	6,25		0,0007
Salmonella typhimurium	6,25		0,003
Escherichia coli	6,25		0,003

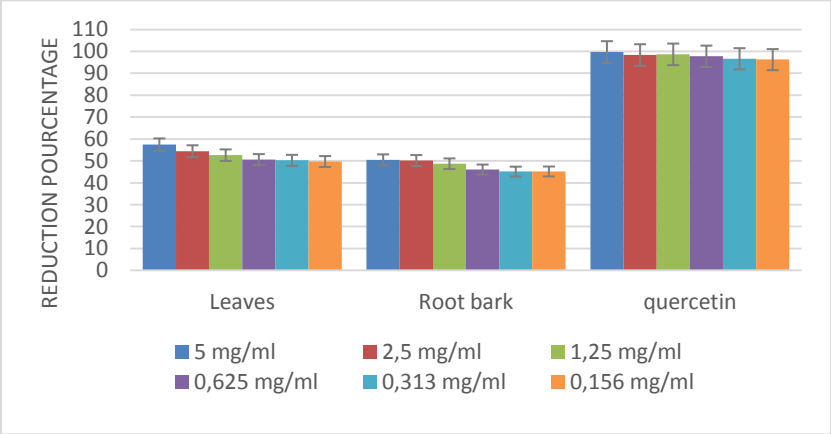

Fig. 1. Antioxidant profiles of *G. cedrata* leaf and root bark EOs and quercetin

4. CONCLUSION

Analysis of *G. cedrata* leaf and root bark EOs by GC (RI), GC-MS and ^{13}C NMR showed that these EOs are very rich in sesquiterpenes. The root bark EO is dominated by viridiflorol while the leaf EO is represented by the β-selinene/α-selinene pair. Leaf EO showed better antioxidant activity than root bark EO against DPPH$^{\bullet}$, but this activity was moderate compared to quercetin. Leaf EO also showed antifungal activity against *Candida albicans* and antibacterial activity against *Bacillus subtilis*, *Salmonella typhimurium* and *Escherichia coli*. Nevertheless, these antimicrobial capacities are average. The antioxidant and antimicrobial potentials of *G. cedrata* leaf EO are certainly moderate but constitute significant assets in the use of this species.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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