Original research Articles

Antibacterial activity of the rosewood (*Aniba rosaeodora* and *A. parviflora*) linalool-rich oils from the Amazon

ABSTRACT

Aims: Evaluation of antibacterial activity and essential oils composition from rosewood species (*Aniba rosaeodora* and *A. parviflora*), sampled in an experimental plantation on Lower Amazon River, Brazil, were performed between July 2014 and June 2015. Rosewood species are threatened with extinction in the Brazilian Amazon.
Methodology: GC and GC-MS analyzed the oils and the *in vitro* antibacterial potential was determined against *Escherichia coli*, *Klesbsiella pneumoniae*, *Staphylococcus aureus*, *S. epidermidis*, *Enterococcus faecalis*, and *Streptococcus pyogenes*, using the disk-diffusion and plate microdilution assays.
Results: Showed that linalool was the principal constituent of the oils, being 88.6% and 45.0% to *A. rosaeodora* and *A. parviflora*, respectively. The oils were effective against these pathogenic bacteria, with inhibition zone values ranging from 8.8 ± 0.6 mm to 38.4 ± 1.4 mm (MIC, 1.3 to 10.0 µL/mL) for the oil of *A. rosaeodora* and 9.2 ± 0.4 mm to 15.4 ± 0.9 mm for the oil of *A. parviflora*. The bactericidal effect and the intensity have been assigned to linalool and its percentage content in the oils. Assays performed with the aqueous extracts showed no activity against the same bacteria.
Conclusion: The rosewood oils could be used in pharmaceutical formulations or to prevent food spoilage to control resistant bacteria strains, individually or in combination with traditional antibiotics.

Keywords: Aniba rosaeodora, Aniba parviflora, *Lauraceae, rosewood, linalool, antibacterial activity.*

1. INTRODUCTION

The antimicrobial resistance and the lack of new antibiotic compounds have become a growing health threat to the world population. The need for investment in research aimed at discovering new anti-infective drugs is substantial to avoid a global crisis in public health [1]. Many antimicrobial studies of herbal extracts and essential oils have been carried out for the discovery of new drugs. Significant effects of various essential oils and plant extracts to eliminate some pathogenic microorganisms have been reported [2-5].

Rosewood species are scattered in the Amazon Region of Brazil, Guyana, Peru, Colombia, Venezuela, and Suriname. In Brazil, the rosewood occurs in high areas of rain forest, near small rivers that flow into the basins of the Amazonas and Purus. The rosewood species are trees reaching 15 to 30 m in height and 0.3 to 1.0 m in diameter, with straight cylindrical trunk and brown-yellowish bark. The rosewood oil market fell in the last decades, and several factors have contributed to this decline:

exhaustion of source supplies, logistics and production costs, Brazilian government control against extinction, and the synthetic linalool trade [6].

Two plant sources belonging to Lauraceae have been attributed to the species producing rosewood oil in the Amazon region: *Aniba rosaeodora* Ducke (syn. *A. rosaeodora* Ducke var. *amazonica* and *A. duckei* Kostermans) and *Aniba parviflora* (Meiss.) Mez (syn. *A. fragrans* Ducke) [7]. The oil of *A. rosaeodora* is applied worldwide in the perfumery and cosmetic industry due to its fragrance based on high linalool content (about 85%). *Aniba parviflora* is confused with *A. rosaeodora*, the real rosewood tree, by the small farmers and oil producers. It is also called, "macacaporanga", and its essential oil has only 40% linalool [6,8,9]. Despite the similarity, these species have very distinct scents in the oils of wood and leaves. Olfactory and compositional analysis of both oils, when using enantioselective gas chromatography/olfactometry and two-dimensional gas chromatography, allowed a clear distinction between the two species [10,11].

The following uses are attributed to rosewood oil: analgesic, anticonvulsant, antidepressant, antimicrobial, antiseptic, aphrodisiac, bactericidal, cellular stimulant, cephalic, stimulant, tissue regenerator, tonic, sleeplessness, and pain [12,13]. The sedative and anticonvulsant properties of linalool from *A. roseadora* oil in glutamate-related seizure model, in inhibition of the compound action potential in rodents, and inhibition of adenylate cyclase in chick retina, were previously reported [14-18]. The linalool-rich rosewood oil induces vago-vagal bradycardia and depressor reflex in rats [19]. The selective induction of apoptosis in precancerous cells and cancer of the skin by rosewood oil demonstrates its potential anticancer activity and linalool against other cancer cells [20,21]. The antimicrobial activity of rosewood oil against several bacteria and fungi was investigated [22,23]. The *in vitro* synergistic bacterial action of rosewood oil in combination with gentamicin was reported [4]. Linalool has showed stronger antimicrobial activity against Gram-positive bacteria when it was tested solely or in combination with the oil of *Ocimum basilicum* L [24].

This study aimed to investigate the antibacterial activity of the essential oils and aqueous extracts of leaves from *A. rosaeodora* and *A. fragrans* against human pathogenic bacteria. Also, to identify the volatile composition of these two oils, which were produced from specimens sampled in an experimental plantation existing on Lower Amazon River, Pará state, Brazil.

2. MATERIAL AND METHODS

2.1 Plant material

The samples of aerial parts (leaves and thin stems) of *A. rosaeodora* and *A. parviflora* were collected during the crop management of these two species in the experimental plantation located at the Curuá farm (Pematec Co.). It is located in the Curuá-Una road, municipality of Santarém, Pará state, Brazil, with the coordinates 2º33’45.68 S and 54º37’00.37 W, between July and November 2009. Both species were deposited in the herbarium of EMBRAPA/PA, under the numbers IAN 184,529 and IAN 184,897, respectively.

2.2 Plant processing and extraction of the essential oils

The aerial parts of the plants were air-dried for 48 h, ground and submitted to hydrodistillation using a Clevenger-type apparatus (100 g, 3 h). The oils were dried over anhydrous sodium sulfate, and their percentage contents were calculated based on the plant dry weight. The moisture contents of the samples were calculated using a balance with infrared moisture measurement. The oils were kept in amber vials and stored at 5ºC before GC and GC-MS analysis and the bioassays. The procedure was performed in triplicate.

2.3 Aqueous extracts

The aerial parts of the plants were dried at 40ºC under airflow in a stove and then macerated in a mortar. Fifty grams of the powdered plants were extracted with distilled water (1:10 w/v) at 70 ± 5℃ for 3 h, under constant agitation. The aqueous solution was then filtered, frozen and submitted to a lyophilization process.

2.4 Oil composition analysis

The oils were analyzed on a GC-MS Thermo Focus DSQ II, under the following conditions: DB-5ms (30 m x 0.25 mm; 0.25 µm film thickness) fused-silica capillary column; programmed temperature: 60–240℃ (3ºC/min); injector temperature: 250ºC; carrier gas: helium, adjusted to a linear velocity of 32 cm/s (measured at 100℃); injection type: split (2 µl of a 1:1000 hexane solution); split flow was adjusted to yield a 20:1 ratio; septum sweep was a constant 10 ml/min; EIMS: electron energy, 70 eV; temperature of ion source and connection parts: 200℃. The quantitative data regarding the volatile constituents were obtained by peak area normalization using a GC-FID Thermo Focus operated under similar conditions to the GC-MS, except for the carrier gas, which was nitrogen. The retention index was calculated for all the volatiles constituents using an *n*-alkane (C8-C40, Sigma/Aldrich) homologous series. Individual components were identified by comparison of both mass spectrum and GC retention data with authentic compounds which were previously analyzed and stored in a private library, as well as with the aid of commercial libraries containing retention indices and mass spectra of volatile compounds commonly found in the essential oils [25,26].

2.5 Antibacterial bioassay

The oils were assayed by the agar disk diffusion method [27,28]. The following strains were used: *Escherichia coli* (ATCC 35218), *Pseudomonas aeruginosa* (ATCC 27853), *Klesbsiella pneumoniae* (ATCC 13883), *Staphylococcus aureus* (ATCC 25923), *Enterococcus faecalis* (ATCC 29212), *Streptococcus pyogenes* (ATCC 19615) and *Staphylococcus epidermidis* (ATCC 12228). The microorganisms were commercially obtained in lyophilized form, rehydrated in nutrient broth (NB, Difco) (24 h, 36 ± 1℃) and then seeded in Petri dishes containing Mueller Hinton agar (MHA, Difco) (24 h, 36 ± 1ºC). The inocula (24 h) diluted in sterile saline were prepared to achieve the turbidity standard of 0.5 on the McFarland scale, containing the suspensions approximately 1.5 x 10^8 CFU/ml. Filter

paper disks (6 mm diameter) were embedded in 10 µl of undiluted oils or 10 µl of aqueous extracts, at concentrations of 60 mg/ml. The paper disks were laid upon the cultures of bacteria in MHA and incubated as mentioned above. Control cultures of each strain were treated with disks of gentamicin and ampicillin (10 µg/disk) (Cefar, Brazil). Inhibition caused by the oils and the standards were compared (n = 3). Samples with an inhibition halo ≥ 8 mm were highlighted to determine the minimum inhibitory concentration (MIC) or minimum bactericidal concentration (MBC).

The MIC was determined by the plate microdilution method [29]. The oils were serially diluted with 0.5% Tween 80 (Vetec, Brazil) resulting in concentrations from 0.07 µl/ml to 10 µl/ml. Each well was inoculated with the microorganisms (MH broth medium, 1.5 x 10^4 CFU/ml), followed by the addition of the oils, at different concentrations. Plates were then incubated at 36ºC, for 24 h. After incubation, 20 µl of resazurin 0.02% (Vetec, Brazil) were added to the wells and the plates incubated for another 3 h. The MIC was determined by the blue color of the resazurin dye. The wells with no apparent microbial growth were selected to assess the MBC, by cultures in Petri dishes (MHA medium).

2.6 Statistical analysis

Results are expressed as means ± standard deviations. The Tukey test was used at the significance level of $P = .05$. The software Prism 3.0 program was used at the confidence level of 95%.

3. RESULTS AND DISCUSSION

3.1 Analysis and characteristics of the oils

The oils of the aerial parts (leaves and thin stems) of *Aniba rosaeodora* and *A. parviflora* yielded 1.0% and 0.5%, respectively. A yield variation of 0.7% to 1.5% has been reported for the wood oil of *A. rosaeodora*, which is sold in the international market and used in cosmetics [6]. Also, the wood oil of *A. parviflora* has showed a yield of about 0.5%, and it is sold in the local market for cleaning products and aromatic sachets. The leaf oils of both species presented pale yellow color. The leaf oil of *A. rosaeodora* presented a floral and woody note while the leaf oil of *A. parviflora* has showed the same scent, plus a peppery and citrusy note.

GC and GC-MS analyzed the compositions of the oils and the identified fifty-one volatile constituents are listed in Table 1. The oil of *A. rosaedora* was dominated by linalool (88.6%) while the main components in the oil of *A. parviflora* were linalool (45.0%), β-phellandrene (17.3%), α-phellandrene (4.1%) and (*E*)-caryophyllene (3.9%).

Table 1. Constituents of rosewood leaf oils: *Aniba rosaeodora* (EOAR) and *A. parviflora* (EOAP).

Constituents	RI	EOAR (%)	EOAP (%)

α-Thujene	921		0.2
α-Pinene	939	0.4	
β-Pinene	973	0.1	
Myrcene	983		1.6
α-Phellandrene	1002		**4.1**
p-Cymene	1019		1.6
Limonene	1024	0.2	
β-Phellandrene	1025		**17.3**
(*E*)-β-Ocimene	1044		1.4
γ-Terpinene	1054		0.1
cis-Linalool oxide (furanoid)	1064	1.5	0.1
Terpinolene	1072		0.2
trans-Linalool oxide (furanoid)	1081	1.4	
Linalool	1098	**88.6**	**45.0**
Borneol	1165		0.2
trans-Linalool oxide (pyranoid)	1168	0.1	
Terpinen-4-ol	1174		0.2
α-Terpineol	1189	0.2	0.8
Geraniol	1244		0.1
α-Cubebene	1344		0.9
α-Ylangene	1366		0.1
α-Copaene	1372	0.1	0.9
β-Elemene	1387	0.1	0.4
(*E*)-Caryophyllene	1415		**3.9**
γ-Elemene	1426		0.4
α-Humulene	1452		0.5
β-Chamigrene	1469	0.1	0.5
Germacrene D	1476		0.4
β-Selinene	1484	0.8	2.0
α-Selinene	1496	0.7	2.1
γ-Cadinene	1508		0.2
δ-Cadinene	1513		0.6
Hedycaryol	1543		0.1
trans-Dauca-4(11),7-diene (tent.)	1548	0.1	
Germacrene B	1552		0.3
(*E*)-Nerolidol	1558	0.1	0.2
Spathulenol	1576		0.9
Caryophyllene oxide	1575	0.2	1.1
Guaiol	1591	0.1	0.2
Humulene epoxide II	1603	0.1	0.2
Globulol (tent.)	1611	0.1	0.2
10-*epi*-γ-Eudesmol	1624		0.6
γ-Eudesmol	1627		2.1
Selin-3,11-dien-6-α-ol	1642	0.6	0.2
α-Eudesmol	1648		1.6

14-Hydroxy-9-*epi*-(*E*)-caryophyllene	1663	0.6	0.4
Amorpha-4,9-dien-2-ol	1701	0.5	
Nootkatol (tent.)	1704	0.1	
(*E*)- Nerolidyl acetate	1713	1.5	1.1
Eremophilone (tent.)	1731	0.1	
Benzyl benzoate	1746	0.1	0.1
Unidentified sesquiterpenes			2.6
Monoterpene hydrocarbons		0.7	26.5
Oxygenated monoterpenes		91.8	46.4
Sesquiterpene hydrocarbons		1.8	13.2
Oxygenated sesquiterpenes		4.1	8.9
Unidentified sesquiterpenes			2.6
Aromatic compounds		0.1	0.1
Total		**98.5**	**97.7**

RI = Retention index on DB-5ms capillary column.

3.2 Antibacterial bioassay

Aniba rosaeodora oil has showed bactericidal activity against 86% of the tested microorganisms. The inhibition halo to *Streptococcus pyogenes* (ATCC 19615) was superior to 40 mm diameter. The oil of *A. rosaeodora* oil against the other microorganism strains showed inhibition halos ranging of 8.8 to 38.4 mm diameter. Although less efficient, the oil of *A. parviflora* was effective against 71% of the tested microorganisms, with inhibition halos varying from 8.5 to 15.4 mm diameter. The oils showed MIC values between 1.3 and >10.0 µl/ml and MBC values between 5.0 and >10.0 µl/ml (Table 2). The aqueous extracts of *A. rosaeodora* and *A. parviflora* showed no antimicrobial activity against the microorganisms tested.

Based on the results, it was seen that the leaf oils of *A. rosaeodora* and *A. parviflora* showed significant antibacterial activity. As the aqueous extracts were inactive, the antibacterial activity observed could be attributed to the volatile components of the oils, which presented a lipophilic character. The composition of the leaf oil of *A. rosaeodora* was not much different from those previously described, with a predominance of linalool in the range 81-96% [6,30,31]. Linalool occurs as a racemic mixture of the oil of *A. rosaeodora*, with the enantiomers (-)-linalool and (+)-linalool in almost equal proportions and a slight predominance of the levorotatory isomer [18]. The literature related to the oil chemical composition of *A. parviflora* is very scarce. Two papers have mentioned only its main constituents and are related to *Aniba fragrans* Ducke, its botany synonymy [8,32]. A more recent paper has utilized the *A. parviflora* oil to highlight the chromatographic method in comprehensive two-dimensional gas phase for identification of its constituents, but without informing their percentage values [11]. Therefore, the total chemical composition analysis of the *A. parviflora* oil is being reported for the first time (Table 1), whose main component is also linalool, with a percentage (45.0%), which is half of that found for the *A. rosaeodora* oil (88.6%). Also, the monoterpene hydrocarbons α- and β-phellandrene contributed more than 20% for the composition of *A. parviflora* oil, resulting in the peppery-citrusy note presented for this oil.

Table 2. Antibacterial potential of leaf oils and aqueous extracts of rosewood: *Aniba rosaeodora* (EOAR) and *A. parviflora* (EOAP).

	Standard Antibiotics		Essential Oils					
Microorganisms	**AMP[a]**	**GEN[b]**	**EOAR**			**EOAP**		
	DDM		**DDM**	**MIC**	**MBC**	**DDM**	**MIC**	**MBC**
(-) *E. coli*	> 10	21.9 ± 0.2	13.2 ± 0.5 [a,b]	> 10	> 10	na	nd	nd
(-) *P. aeruginosa*	> 10	21.4 ± 0.1	na	nd	nd	na	nd	nd
(-) *K. pneumoniae*	> 10	20.7 ± 0.1	11.6 ± 0.1 [a,b]	> 10	nd	9.20 ± 0.4 [a,b]	> 10	> 10
(+) *S. aureus*	34.9 ± 0.3	22.3 ± 0.1	26.7 ± 1.9 [a,b]	1.3	10	15.4 ± 0.9 [a,b]	> 10	> 10
(+) *E. faecalis*	23.4 ± 0.6	14.2 ± 0.4	8.80 ± 0.6 [a,b]	5	> 10	11.2 ± 0.9 [a,b]	> 10	> 10
(+) *S. epidermidis*	20.7 ± 0.1	25.4 ± 0.1	38.4 ± 1.4 [a,b]	5	> 10	13.3 ± 0.8 [a,b]	> 10	> 10
(+) *S. pyogenes*	39.1 ± 0.5	27.1 ± 0.4	> 40[b]	1.3	5	13.3 ± 1.0 [a,b]	1.3	5

[a,b] $P = .05$ for comparison of means; AMP = ampicillin, GEN = gentamicin; DDM = Disk Diffusion Method (Mean inhibition zone diameter ± SD, mm); MIC = Minimum Inhibitory Concentration (µl/ml); MBC = Minimum Bactericidal Concentration (µl/ml); na = not active; nd = not determined.

As mentioned earlier, the rosewood oil producers do not distinguish these two species in the field easily. Another important aspect in rosewood oils is that the older the leaves, the greater the percentage of components of the oxidation process of the linalool, such as α-terpineol, terpinen-4-ol and linalool oxides, which leads to changes in the bouquet of the oils. In this respect, the different scents of the rosewood oils have helped the producers in the collection of plants, propagation and cultivation, given that this task becomes more difficult without a previous analyzing the composition of the oils.

Essential oils are natural compounds that protect plants against microbial attack, and it is suggested that their constituents, alone or synergistically, are more efficient than those found in aqueous plant extracts [3]. Under the experimental conditions, the aqueous extracts of *A. rosaeodora* and *A. parviflora* showed no antimicrobial activity against the microorganisms tested, suggesting absence or insufficient concentration of active compounds. The antimicrobial efficiency exhibited against Gram-positive and Gram-negative bacteria might be due to the presence of linalool in both species of *Aniba*. Accordingly, the different antibacterial actions observed for these oils can be due to the different percentages found for linalool. However, the possibility of a synergistic interaction amongst linalool and others minor constituents of the oils cannot be discarded. For example, beta-phellandrene showed content of 17.3% in the oil of *A. parviflora* and essential oils with a significant percentage of this constituent has displayed bactericidal activity [33,34].

Previously, the essential oils of wood and leaf of *A. rosaeodora* inhibited the growth of *E. coli*, *K. pneumoniae*, *S. aureus* and *E. faecalis* [22,23]. The results are very close to this work, including linalool, which was tested separately. A synergistic interaction was observed against some pathogenic strains using a combination of *A. rosaeodora* oil and gentamicin, with improvement in the antimicrobial effectiveness, particularly against Gram-negative bacteria [4]. Those authors concluded that there was a synergistic effect between the oil and the antibiotic, mainly due to the presence of linalool. In another paper, the antifungal activity of the wood oil of *A. rosaeodora* showed MIC and MFC values between 0.5 to 20 µL/mL for more resistant fungi, such as *Aspergillus flavus* (ATCC 9170), *A. terreus* (ATCC 16792) and *Trichoderma viride* (IAM 5061) [30]. In said oil, linalool was the main

component, with the percent of 81.3%. Also, it was observed that the oil of *Ocimum basilicum* (Lamiaceae) and linalool, its main constituent (50-60%), showed greater activity against bacterial strains than against fungal strains. Also, the oil of *O. basilicum* and linalool have showed stronger antimicrobial activity against Gram-positive bacteria than against Gram-negative bacteria [24].

In some experiments, (-)-linalool has showed greater efficacy in physiological parameters stress than the racemic mixture (±)-linalool that occurs in the oils of *A. rosaeodora* and *A. parviflora* [35]. In this work, the antibacterial assay was tested also with a commercial sample of (-)-linalool and the bactericidal efficiency was slightly higher than the (±)-linalool existing in the *A. rosaeodora* oil. However, these results should also be compared with the separate enantiomers of *A. rosaeodora* oil, which will be done in future studies.

The antimicrobial action mechanism of the oils of *A. roseadora* and *A. parviflora* can be explained by the lipophilic character of the mono- and sesquiterpenoid compounds contained in these oils. These compounds act by disrupting the cytoplasmic membrane or perturbation of the lipidic fraction of the plasmid membrane. This action results in alteration of the membrane properties, such as dissipation of the proton motive force, inhibition of several enzymes due to leakage of essential ions, and the active transport and the coagulation of cell contents [36-39]. The synergistic effect between chemical components present in some essential oils has been evaluated [40,41]. Those authors have concluded that essential oils showed higher antibacterial activity than the isolated mixture of its main components. Thus, components present in low concentrations can be essential to enhance the biological effect given by these oils.

4. CONCLUSION

Based on the results, it is assumed that the rosewood oils could be used in pharmaceutical formulations or to prevent food spoilage to control resistant bacteria strains, individually or in combination with traditional antibiotics.

REFERENCES

[1] Carlet J, Jarlier V, Harbarth S, Voss A, Goossens H, Pittet D.. Ready for a world without antibiotics? The Pensières Antibiotic Resistance Call to Action. Antimicrob Resist Infect Control. 2012;1: 11.

[2] Aslim B, Yucel N. In vitro antimicrobial activity of essential oil from endemic *Origanum minutiflorum* on ciprofloxacin-resistant Campylobacter spp. Food Chem**.** 2008;107:602-606.

[3] Bakkali F, Averbeck S, Averbeck D, Idaomar M. Biological effects of essential oils - A review. Food Chem Toxicol. 2008;46:446-475.

[4] Rosato A, Piarulli M, Corbo F, Muraglia M, Carone A, Vitali ME, Vitali C. In vitro synergistic action of certain combinations of gentamicin and essential oils. Curr Med Chem. 2010;17:3289-329.

[5] Sheikh M, Malik AR, Meghavanshi MK, Mahmood I. Studies on some plant extracts for their antimicrobial potential against certain pathogenic microorganisms. Am J Plant Sci. 2012;3:209-213.
[6] Maia JGS, Andrade EHA, Couto HAR, Silva ACM, Marx F, Henke C. Plant sources of Amazon rosewood oil. Quim Nova. 2007;30:1906-1910.
[7] Kubitzki K, Renner S. Lauraceae 1 (*Aniba* and *Aiouea*). Flora Neotropica, Monograph 31. New York: New York Botanical Garden; 1982.
[8] Maia JGS, Zoghbi MGB, Andrade EHA. Plantas Aromáticas na Amazônia e Seus Óleos Essenciais. Belém: Museu Paraense Emílio Goeldi; 2001.
[9] Maia JGS, Andrade EHA. Database of the Amazon aromatic plants and their essential oils. Quim Nova. 2009;32:595-622.
[10] Zelner BD, Lo Prest M, Barata LES, Lugo P, Lugo G, Mondello L. Evaluation of leaf-derived extracts of an environmentally sustainable source of essential oils by using gas chromatography-mass spectrometry and enantioseletive gas chromatography-olfactometry. Anal Chem. 2006;78:883-890.
[11] Tranchida PQ, Souza RCZ, Barata LES, Mondello M, Dugo P, Dugo G, Mondello L. Analysis of macacaporanga (*Aniba parviflora*) leaf essential oil by using comprehensive two-dimensional gas chromatography combined with rapid-scanning quadrupole mass spectrometry. Chromatogr Today. 2008;1(4):5-9 (September/October).
[12] Price S, Price L. Aromatherapy for health professionals. London: Churchill Livingstone; 1999.
[13] Lawless J. The encyclopedia of essential oils. London: Thorsons; 2002.
[14] Elisabetsky E, Coelho-de-Souza GP, Santos, MAC, Siqueira IR, Amador TA. Sedative properties of linalool. *Fitoterapia*. 1995;66:407-414.
[15] Elisabetsky E. Brum LFS, Souza DO. Anticonvulsant properties of linalool in glutamate-related seizure models. Phytomedicine. 1999;6:107-113.
[16] Almeida RN, Araújo DAM, Gonçalves JCR, Montenegro FC, Sousa DP, Leite JR, Mattei R, Benedito MAC, Carvalho JGB, Cruz JS, Maia JGS. Rosewood oil induces sedation and inhibits compound action potential in rodents. J Ethnopharmacol. 2009;124:440-443.
[17] Souza DP, Nóbrega FF, Santos CC, Almeida RN. Anticonvulsant activity of the linalool enantiomers and racemate: investigation of chiral influence. Nat Prod Commun. 2010;5:1847-1851.
[18] Sampaio LFS, Maia JGS, Parijós AM, Souza RZ, Barata LES. Linalool from rosewood (*Aniba rosaeodora* Ducke) oil inhibits adenylatecyclase in the retina, contributing to understanding its biological activity. Phytother Res. 2011;26:73-77.
[19] Siqueira RJ, Rodrigues KMS, Silva MLB, Correia Junior CAB, Duarte GP, Magalhães PJC, Santos AA, Maia JGS, Sousa PJC, Lahlou S. Linalool-rich rosewood oil induces vago-vagal bradycardic and depressor reflex in rats. Phytother Res. 2014;28:42-48.
[20] Souer J, Marrot L, Perez P, Iraqui I, Kienda G, Dardalhon M, Meunier J-R, Averbeck D, Huang M-E. Selective cytotoxicity of *Aniba rosaeodora* essential oil towards epidermoid cancer cells through induction of apoptosis. Mutat Res. 2011;718:24-32.
[21] Loizzo MR, Tundis R, Menichini F, Saab AM, Statti GA, Menichini F. Antiproliferative effects of essential oils and their major constituents in human

renal adenocarcinoma and amelanotic melanoma cells. Cell Prolif. 2008;41:1002-1012.

[22] Lobato AM, Ribeiro A, Pinheiro MFS, Maia JGS. Atividade antimicrobiana de óleos essenciais da Amazônia. Acta Amaz. 1989;19:355-363.

[23] Hammer KA, Carson CF, Riley TV. Antimicrobial activity of essential oils and other plant extracts. J Appl Microbiol. 1999;86:985-990.

[24] Hussain AI, Anwar F, Sherazi STH, Przybylski R. Chemical composition, antioxidant and antimicrobial activities of basil (*Ocimum basilicum*) essential oils depends on seasonal variations. Food Chem. 2008;108:986-995.

[25] NIST (National Institute of Standards and Technology), Mass Spectral Library, NIST/EPA/NIH, v. 2.0d. The NIST Mass Spectrometry Data Center, Gaithersburg, USA; 2005.

[26] Adams RP. Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry, 4th Edition. Carol stream, IL: Allured Publishing Corporation, USA; 2007.

[27] Bauer AW, Kirby WMN, Sherries JL. Antibiotic susceptibility testing a standard disc method. Am J Clin Pathol. 1996;45:493-496.

[28] CLSI (Clinical and Laboratory Standards Institute). Performance Standards for Antimicrobial Disk Susceptibility Tests, Approved Standard Eighth Edition. CLSI document M2-A8 (ISBN 1-56238-485-6), Wayne, PA: Clinical and Laboratory Standards Institute; 2003.

[29] CLSI (Clinical and Laboratory Standards Institute). Performance standards for antimicrobial susceptibility testing, 16th informational supplement. CLSI document M100-S16., Wayne, PA: Clinical and Laboratory Standards Institute; 2006.

[30] Simic A, Sokovic MD, Ristic M, Grujic-Jovanovic S, Vukojevic J, Marin PD. The chemical composition of some Lauraceae essential oils and their antifungal activities. Phytother Res. 2004;18:713-717.

[31] Fidelis CHV, Sampaio PTB, Krainovic PM, Augusto F, Barata LES. Correlation between maturity of tree and GCxGC–qMS chemical profiles of essential oil from leaves of *Aniba rosaeodora* Ducke. Microchem J. 2013;109:73-77.

[32] Morais AA, Rezende CMAM, von Bülow MV, Mourão JC, Gottlieb OR, Marx MC, Rocha AI, Magalhães MT. Óleos essenciais de espécies do gênero *Aniba*. Acta Amaz. 1972;2:41-44.

[33] Buitrago D, Velasco J, Díaz T, Morales A. Chemical composition and bacterial activity of the essential oil of *Monticalia imbricatifolia* Schultz (Asteraceae). Rev Latinoamer Quím. 2012;40:13-18.

[34] Tomani JC, Murangwa C, Bajyana S, Mukazayire MJ, Ingabire MG, Chalchat JC. Chemical composition, antibacterial and antifungal activity of the essential oil of *Pinus patula* growing in Rwanda. Am J Biomed Life Sci. 2014;2:55-59.

[35] Hoferl M, Krist S, Buchbauer G. Chirality influences the effects of linalool on physiological parameters of stress. Planta Med. 2006;72:1188-1192.

[36] Lambert RJW, Skandamis PN, Coote PJ, Nychas G-JE. A study of the minimum inhibitory concentration and mode of action of oregano essential oil, thymol and carvacrol. J Appl Microbiol. 2001;91:453-462.

[37] Marino M, Bersani C, Comi G. Impedance measurements to study the antimicrobial activity of essential oils from Lamiaceae and Compositae. Int J Food Microbiol. 2001;67:187-195.

[38] Burt S. Essential oils: their antibacterial properties and potential applications in foods - a review. Int J Food Microbiol. 2004;94:223-253.
[39] Cristani M, D'Arrigo M, Mandalari, G, Castelli F, Sarpietro MG, Micieli D, Venuti V, Bisignano G, Saija A, Trombetta D. Interaction of four monoterpenes contained in essential oils with model membranes: implications for their antibacterial activity. J Agric Food Chem. 2007;55:6300-6308.
[40] Gill AO, Delaquis P, Russo P, Holley RA. Evaluation of antilisterial action of cilantro oil on vacuum packed ham. Int J Food Microbiol. 2002;73:83- 92.
[41] Radulovic N, Misica M, Aleksic J, Dokovic D, Palic R, Stojanovic G. Antimicrobial synergism and antagonism of salicylaldehyde in *Filipendula vulgaris* essential oil. *Fitoterapia*. 2007;78:565-570.