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Antimicrobial Activity of Essential Oil of *Zingiber officinale* Roscoe (Zingiberaceae)

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Abstract

Zingiber officinale, commonly known as ginger, is a species native of tropical Asia. It is grown and used in tropical countries of America, including Mexico, where it is used for the treatment of throat infections. The aim of this study was to determine the chemical composition of essential oil of *Z. officinale* rhizome and evaluate their antimicrobial activity. The essential oil was obtained by hydrodistillation, and the chemical composition of the oil was determined by GC-MS. To determine the antimicrobial activity diffusion, agar dilution and radial growth inhibition methods were employed. Microbial growth curves were performed on the strains most susceptible. It was identified 28 compounds in the essential oil, the most abundant were eudesmol (8.19%), γ-terpinene (7.88 %), α-curcumene (7.28%), alloaromadendrene (6.56%), zingiberene (6.06 %), α-pinene (5.76 %), δ-cadinene (3.84%), elemol (3.39%), farnesal (3.45%), E-β-farnesene (3.57%), neril acetate (2.8%) and β-myrcene (2.94%). In antimicrobial activity, the essential oil inhibited the growth of 15 bacterial strains, 3 of yeast fungi and 4 of mycelia fungi. The most susceptible strains were *S. aureus* FES-I (MIC = 0.25 mg/mL) *S. epidemidis* FES-C (MIC = 0.5 mg/mL), *E. faecalis* ATCC 14506 (MIC = 1.0 mg/mL), *C. tropicalis* (CMI = 0.125 mg/mL) and *T. mentagrophytes* (CF_{50} = 0.08 mg/mL). In the microbial growth curves the essential oil showed bactericidal effect on *S. aureus* FES-I and *S. marcescens* ATCC 14756 from the first hour of exposure of the strains to oil, eliminating 99.9% of CFU in concentrations of 0.5 and 0.75 mg/mL respectively. The results validate the medicinal use of *Z. officinale* in the treatment of diseases of possible infectious origin.

Keywords

Antibacterial Activity, Antifungal Activity, Essential Oil, *Zingiber officinale*, Monoterpenes, Sesquiterpenes

1. Introduction

Essential oils have been studied for their antibacterial and antifungal potential, because these properties are used in preserving foods in addition to their antioxidant effect [1]. They are obtained from herbs and spices, many of them are used in the human diet to enhance the flavor, colour and aroma of food. An example of this is ginger, which is the rhizome of *Zingiber officinale* Roscoe, a perennial herbaceous plant belonging to Zingiberaceae family [2].

Zingiber officinale is a species native to tropical Asia and generally grown as annual in most tropical countries in Americas, including Mexico. The rhizome (ginger) is one of the best known spices in the world and has been used since ancient times for its health benefits [3], its history of medicinal use dates back 2,500 years in alternative medicine in China and India [2] [4]. Ginger is used in the treatment of gastrointestinal infections and to relieve headache, nausea, vomiting, dizziness and rheumatic diseases [5]. It has analgesic, anti-inflammatory, antioxidant, antiplatelet, hypoglycemic and hepatoprotective properties [6] [7] [8] [9].

Z. officinale is a species that produces oleoresins and essential oil with chemical compounds of diverse nature. Oleoresins have been isolated and characterized mainly gingerols that have been reported analgesic, anti-inflammatory [10], anticancer [11], antipyretic [12], antioxidant [13] and antimicrobial effects [14].

Ginger essential oil is characterized by high percentages of sesquiterpene hydrocarbons, mainly zingiberene, ar-curcumene, β-bisabolene, β-sesquiphellandrene, δ-cadinene and β-eudesmol [4] [15] [16]. In addition monoterpenes camphene, geranial, geranyl acetate, linalool, 1,8-cineole and neral have been reported as major components [4] [17] [18]. The essential oil possesses antioxidant [19], anti-inflammatory [4] and antimicrobial activities [1] [4] [16] [19]. This latter effect is well documented, which is relevant because there is now a priority need to know and characterize new antimicrobial compounds, given the increase in the incidence of infectious diseases. In addition, some of the pathogenic microorganisms have developed resistance to antibiotics for clinical use and many of them can contaminate food, which accelerate its decomposition [1].

In Mexico *Z. officinale* is used in traditional medicine for the treatment of throat infections. However, being a cultivated species, there is not enough research to support its use. The aim of this study was to determine the chemical composition of essential oil of *Z. officinale* rhizome and evaluate their antimicrobial activity to validate its medicinal use.

2. Materials and Methods

2.1. Plant Material

The rhizome of *Z. officinale* was obtained in June 2015 in Iztacalco (Mexico City). The species was identified in the IZTA herbarium (Voucher no. 2579IZTA).

2.2. Extraction and Analysis of Essential Oil

Essential oil was obtained by hydrodistillation starting from 5 kg of fresh and fragmented root. Extraction was performed for 4 hours in the Cleavenger-type apparatus and stored at 4˚C until tested and analyzed. The yield of the essential oil was 0.06% (w/w), $d^{25} = 0.87$ g/mL.

The essential oil was analyzed in an Agilent Technologies 6850 gas chromatograph equipped with a HP-5MS capillary column (30 m × 0.25 mm; film thickness 0.25 μm). The temperature of the column was 325˚C. Injector and detector temperatures were set at 230˚C and 280˚C, respectively. Oven temperature was kept at 70˚C for 2 min, then programmed to 280˚C at a rate of 8˚C/min and finally raised to 280˚C. Helium was the carrier gas at a flow rate of 1 mL/min. The injection of the sample was manually in the split mode and a volume of 1 μL. Peak areas were measured by electronic integration. The relative amount of the individual components was based on the peak areas. Mass analysis was performed on an Agilent Technologies 5975C. The temperature of the column and the injector were the same as those from GC. Mass spectra were recorded at 70 eV. The oil components were identified by comparison of their retention indices and mass spectra with the NIST08.L Mass Spectral Library (Match ≥ 90%). Retention indices, calculated by linear interpolation relative to retention times of a series of *n*-alkanes (alkanes standards Sigma-Aldrich) and through the determination of the respective Kovats retention indices (KI). The KI were compared with those reported in [20].

2.3. Microbial Strains

The bacterial strains used were: *Staphylococcus aureus*cc, *S. aureus* 23MR, *S. aureus* FES-I, *Escherichia coli* FES-I, *E. coli* 82MR (donated by the Clinical Analysis Laboratory of FES-Iztacala), *S. aureus* FES-C, *S. epidermidis* FES-C (donated by the Microbiology Laboratory of FES-Cuautitlán), *S. aureus* ATCC 29213, *S. epdermidis* ATCC 12228, *Enterococcus faecalis* ATCC 14506, *Enterobacter aerogenes* ATCC 13048, *E. gergoviae* ATCC 33028, *Klebsiella oxytoca* ATCC 8724, *K. penumoniae* ATCC 13883, *Micrococcus luteus* ATCC 10240, *Pseudomonas aeruginosa* ATCC 27853, *Salmonella enterica* ATCC 7251, *S. typhi* ATCC 19430, *Serratia marcescens* ATCC 14756 y *Vibrio cholerae* ATCC 39540 (obtained from the strain collection of CINVESTAV-IPN). These strains were maintained at 4˚C in Mueller Hinton agar (Bioxon), submitted to sensitivity tests (multidiscs Bigaux) and were subcultured twice before and after bioassays.

The yeasts tested were: *Candida albicans*17MR (donated by the Clinical Analysis Laboratory of FES-Iztacala), *C. glabrata* and *C. tropicalis* (isolated from a clinical case and donated by Hospital Angeles Metropolitano). The filamentous fungi tested were: *Aspergillus niger*, *Fusarium moniliforme*, *F. sporotrichum* (donated by the Laboratory of Plant Physiology of FES Iztacala) and *Trichophyton mentagrophytes* CDBB-H-1112. The stock culture was maintained at 4˚C in potato dextrose agar (PDA) and were subcultured twice before and after bioassays.

2.4. Antibacterial Activity

The antibacterial activity of essential oil was measured by disk-diffusion method [21]. Bacterial inocula were prepared in 10 mL of Müller-Hinton broth (Bioxon) and incubated at 37˚C for 24 h. The inoculums were adjusted with sterile saline to obtain turbidity of the McFarland standard No. 0.5 (10^8 CFU/mL). Bacterial inocula were planted on Muller-Hinton agar plates. On the surface of agar, filter paper disks (5 mm diameter) impregnated with 4 µL of essential oil (3.48 µg/disc) were placed in triplicate. As a positive control, disks impregnated with 25 µg of chloramphenicol and as negative control disks with 10 µL of olive oil were used. The plates were incubated at 37˚C for 24 h. Inhibition zones were reported in mm.

From the strains that were sensitive to essential oil, the minimum inhibitory concentration (MIC) was determined by agar dilution method [21] for which 24-well plates were used. Eight concentrations of the essential oil (0.0125 to 2.0 mg/mL) were prepared in triplicate on Müller-Hinton agar. The bacterial inoculums were adjusted to 10^5 CFU/mL and aliquots of 20 µL of inoculum were placed on agar surface in each well. As positive control, different concentrations of chloramphenicol (1 to 15 µg/mL) were used and olive oil (2.0 mg/mL) as negative control. The plates were incubated for 24 h at 37˚C. The MIC was considered as the lowest concentration of essential oil that visibly inhibited the development of microorganisms tested.

2.5. Antifungal Activity

Antifungal activity of the essential oil of filamentous fungi was performed by the method of inhibition of radial growth [22]. Petri dishes with potato-dextrose agar (PDA) inoculated the mycelium (1 mm diameter) in center of each plate. Filter paper discs (5 mm diameter) were placed in triplicate with 4 µL of essential oil three cm apart from the mycelium. As a positive control, discs impregnated with ketoconazole (60 µg) and discs with 4 µL of olive oil were used as negative controls. The plates were incubated at 28˚C for 72 to 96 h, until the mycelium covered the agar surface. The disks with the extracts showing areas of inhibition of mycelial growth were considered to have antifungal activity and were reported as positive.

The bioassays on yeast fungi were performed by the Kirby-Bauer agar diffusion method [23] in the same way as for bacteria; in this case PDA agar was used. The fungal inoculum was diluted with saline solution (0.9%) to obtain 10^5 UFC/mL. The discs were impregnated with 4 µL of essential oil, the positive control was Nystatin (30 µg/disc) and as a negative controldiscs with 4 µL of olive oil were used. All bioassays were performed in triplicate.

The mean fungicidal concentration (CF_{50}) and MIC were determined in 24-well plates. Different concentrations of essential oil (0.0625 to 2.0 mg/mL) were prepared in triplicate on potato dextrose agar, for tests with mycelia fungi, an inoculum of 1 mm diameter of mycelium was placed in the center of each well. The plates were incubated at 28˚C for 48 - 72 h, until mycelial growth cov-

ered the agar surface in control wells, which represented 100% growth of the fungus. The diameter of mycelium was measured; percent inhibition and CF_{50} were determined [22].

For yeast inocula were diluted with saline solution (0.9%) to obtain 10^5 CFU/mL. 20 µL of inoculum was added to center of each well, the plates were incubated at 37˚C for 24 h. Concentrations that showed an evident decrease in development of microorganisms were considered as MIC.

2.6. Microbial Growth Kinetics Assays

The effect of essential oil on growth kinetics in microbial population was evaluated on most susceptible strains. Tubes with the appropriate concentrations for each microorganism were prepared in 10 mL of broth. The concentrations evaluated were:1/2 MIC, MIC, MBC (minimum bactericidal concentration) and MFC (Minimum fungicidal concentration). Tubes without essential oil were prepared as controls. The microbial inoculums (0.1 mL) were added to each tube and incubated for 24 h at 37˚C, during which time aliquots (50 µL) were taken every hour and placed on agar plates, which were incubated for 24 h. The number of UFC represented the number of survivors and was expressed in $\log_{10}$ [24].

2.7. Statistical Analysis

The statistical significance of the results was determined by one-way ANOVA, was considered statistically significant p-values of 0.05 or less. To determine the FC_{50}linear regression analysis was performed.

3. Results and Discussion

3.1. Chemical Composition of the Essential Oil

In the essential oil 28 compounds corresponding to 79.73% of the total were identified (**Table 1**), most are sesquiterpenes (53.57%) and monoterpenes (21.87%). The most abundant components were eudesmol (8.19%), γ-terpinene (7.88%), α-curcumene (7.28%), alloaromadendrene (6.56%), zingiberene (6.06%), α-inene (5.76%), δ-cadinene (3.84%), elemol (3.39%), farnesal (3.45%), E-β-farnesene (3.57%), neril acetate (2.8%) and β-myrcene (2.94%).

These results coincide with other studies in which it has been reported that the essential oil of rhizome of *Z. officinale* is characterized by high percentages of sesquiterpenes [1] [25] [26] [27]; among the most abundant has been mentioned zingiberene, curcumene, β-eudesmol, farnesene, δ-cadinene, sesquiphellandrene, as well as geranial and neralmonoterpenes [4] [16] [28]. Most of the mentioned compounds were present in the essential oil of this work and were found in relatively high percentages. However, sesquiphellandrene, geranial and neralwere not found, suggesting variations in the chemical composition of the essential oil of *Z. officinale*. These variations are due to the diversity in the climatic, seasonal and geographical conditions of the regions in which the species

Table 1. Chemical composition of essential oil of *Z. officinale*.

No	Compounds	RI	RIr	Percentage (%)
1	5-methyl-2-hexanol	876	-	0.87
2	*α*. Pinene	909	917	5.76
3	Camphene	952	951	0.46
4	*β*-Myrcene	958	962	2.94
5	*α*-Phellandrene	995	1000	0.31
6	*γ*. Terpinene	1056	1060	7.88
7	Linalool	1098	1098	2.34
8	cis-Verbenol	1143	1141	0.84
9	*α*-Citral	1267	1269	0.13
10	2-Undecanol	1306	1303	1.01
11	Citronellyl acetate	1347	1348	0.48
12	Neryl acetate	1377	1372	2.80
14	cis-*α*-Bergamotene	1419	1415	1.74
15	2-ethylidene-6-metyl-3,5-heptadienal	1434	-	0.34
16	*γ*-Elemene	1447	1441	1.88
17	(E)-*β*-Famesene	1460	1459	3.57
18	Dehydroaromadendrene	1467	1459	0.36
19	Alloaromadendrene	1474	1467	6.56
20	*α*-Curcumene	1483	1483	7.28
21	Zingiberene	1495	1495	6.06
22	*δ*-Cadinene	1523	1524	3.84
23	*α*-Sesquiphellandrene	1527	1526	2.67
24	Nerolidol	1547	1535	2.48
25	Elemol	1553	1547	3.39
26	Eudesmol	1643	1650	8.19
27	*α*-Cadinol	1670	1673	2.10
28	Farnesal	1716	1719	3.45
	Total			79.73

Compounds listed in order of elution from a non-polar HP-5 MS capillary column. RI: Retention indices relative to *n*-alkanes on non-polar HP-5MS column. RIr: Kovats Index references.

is grown, the maturity of the plant, the time of harvest, the physical conditions of the plant material (e.g. dry or fresh) and the methods of obtaining the oil [7] [25] [28] [29].

3.2. Antibacterial Activity

Essential oil of *Z. officinale* inhibited the growth of 15 bacterial strains: six Gram-positive and nine Gram-negative strains (Table 2). The Gram-positive were the most susceptible when presenting the highest inhibition halos (*S. au-*

Table 2. Antibacterial activity of essential oil of *Z. officinale*.

Organism	Positive control Chloramphenicol		Essential oil	
	Inhibition zone (mm) (25 µg/disc)	MIC (µg/mL)	Inhibition zone (mm) (4.55 mg/disc)	MIC (mg/mL)
S. aureus cc*	16.33 ± 0.047	2.0	32.66 ± 2.01	0.5
S. aureus 23MR*	22.33 ± 0.047	7.0	17.33 ± 2.57	0.5
S. aureus FES-C*	22.33 ± 0.47	4.0	30.0 ± 3.48	0.5
S. aureus FES-I*	23.33 ± 0.47	4.0	24.0 ± 0.00	0.25
S. epidermidis ATCC 12228*	18.00 ± 0.82	2.0	21.00 ± 1.41	0.5
S. epidermidis FES-C*	28.00 ± 0.00	2.0	16.00 ± 2.82	0.5
E. faecalis ATCC 14506*	16.00 ± 0.82	3.0	22.00 ± 2.16	1.0
E. aerogenes ATCC 13048**	21.00 ± 0.82	2.0	6.33 ± 0.57	2.0
E. coli FES-I**	23.00 ± 0.00	4.0	9.66 ± 1.54	1.0
E. coli 82MR**	22.67 ± 0.47	4.0	13.66 ± 1.54	0.75
*K. oxytoca*ATCC 8724**	20.67 ± 0.47	1.0	15.33 ± 3.51	1.0
*K. pneumoniae*ATCC 13383**	27.00 ± 0.00	1.0	9.66 ± 0.57	1.0
S. enterica ATCC 7251**	19.33 ± 0.47	1.0	18.00 ± 0.00	1.0
*S. typhi*ATCC 19430**	20.00 ± 0.00	8.0	9.66 ± 0.57	1.0
*S. marcescens*ATCC 14756**	19.67 ± 0.47	2.0	10.33 ± 1.52	0.75

FES-I = strains donated by the Clinical Analysis Laboratory of FES Iztacala, FES-C = strains donated by the Laboratory of Microbiology of FES Cuautitlan. *Gram positive strains, **Gram negative strains. nd = no determinated.

reus cc: 32.66 ± 2.01 mm, *S. aureus* FES-C: 30.0 ± 3.48 mm, *S. aureus* FES-I: 24.0 ± 0.00 mm, *S. epidemidis* ATCC 12228: 21.00 ± 1.41 mm and *E. faecalis* ATCC 14506: 22.00 ± 2.16 mm) and lower MIC values, including the multiresistant *S. aureus* 23 MR species. CMI values for gram positive strains were found between 0.25 and 0.5 mg/mL, except for *E. faecalis* ATCC 14506 for which a MIC value of 1.0 mg/mL was obtained.

Antibacterial effect of essential oil showed significant differences in the inhibition of Gram-positive and Gram-negative bacteria ($p < 0.0001$), being most susceptible Gram positive strains, suggesting that one of microbial targets of oil is wall Cell, since Gram positive bacteria have a cell wall composed of a thick layer of peptidoglycan surrounding the cytoplasmic membrane [30]. However, it may have other microbial targets, such as plasma membrane, which explains the inhibitory effect of oil on Gram negative bacteria, as the constituents of essential oils have been reported to have lipophilic properties, which interact with the membranes by altering their fluidity and permeability [31].

In other studies it has been reported that essential oil of *Z. officinale* is more active on Gram positive bacteria, including *S. aureus* [1] [16] [18]. However, there are reports of outstanding susceptibility in Gram negative strains, mainly in *P. aeruginosa*, *E. coli*, *Enterobacter sp.*, *K. pneumoniae* and *Proteus vulgaris* [13] [16] [18] [32] [33].

Antibacterial effect of essential oil on Gram positive bacteria is of great relevance, because these strains are of medical importance. The genus *Staphylococcus* has been considered one of major responsible for infectious diseases in humans such as endocarditis, food poisoning, skin infections, among others [34] [35].

3.3. Antifungal Activity

In evaluation of antifungal activity, all three strains of *Candida* were sensitive to essential oil, as were the four strains of filamentous fungi (**Table 3**). C. tropicalis was the most susceptible of yeast strain with the highest inhibition halos (30 ± 0.00 mm) and lowest MIC (0.125 mg/mL). *T. mentagrophytes* was the most susceptible strain of filamentous fungi (CF50 = 0.08 mg/mL)

Antifungal activity of *Z. officinale* essential oil is well documented, mainly in filamentous fungi such as *Penicillium spp.*, *Rhizopus sp.*, *A. flavus, A. solani*, *A. oryzae*, *A. niger*, *F. moniliforme*, *F. verticillioides* [13] [15] [19] [28] and in yeast fungi such as *Saccharomyces cerevisiae* and *C. albicans* [14] [15]. However, the results of this study provide novel antifungal activity results in oil being the first report of activity *on C. tropicalis* and *T. mentagrophytes*, given the medical significance represented by these strains. *C. tropicalis* is responsible for 3 to 66 percent of gynecological infections in tropical countries [36], it is commonly associated with the development of systemic fungal infections and presents a considerable biological potential as an opportunistic agent in patients with cancer, leukemia and neutropenia [35]. Meanwhile, *T. metagrophytes* can cause inflammatory skin diseases, affecting the epidermis and skin appendages [37].

Table 3. Antifungal activity of essential oil of *Z. officinale.*

Organism	Positive controls				Essential oil		
	Inhibition zone (mm)		MIC (µg/mL)	FC_{50} (µg/mL)	Inhibition zone (mm)	MIC (mg/mL)	FC_{50} (mg/mL)
	Nystatin (30 µg/disc)	Ketoconazole (56 µg/disc)			(4.55 mg/disc)		
*C. albicans*17MR	10.00 ± 0.00	-	4.0	-	14.50 ± 12.12	0.25	nd
C. tropicalis HA	20.33 ± 0.47	-	9.0	-	30.00± 0.00	0.125	nd
C. glabrata HA	22.00 ± 0.00	-	8.00	-	16.00 ± 0.00	0.75	nd
*A. niger*FES I	-	+	-	15	+	nd	0.80
F. moniliforme FES I	-	+	-	2	+	nd	0.10
F. sporotrichum FES I	-	+	-	2	+	nd	1.5
T. mentagrophytes FES I	-	+	-	2	+	nd	0.08

FES I = strains donated by the Laboratory of Plant Physiology of FES Iztacala, HA = strains isolated from a clinical case donated by Hospital Angeles (Metropolitano). +: positive to test inhibition of radial growth. nd: not determined.

3.4. Microbial Growth Kinetics

Microbial survival curves were performed on *S. aureus* FES-I, *S. marcescens* ATCC 14756 and *C. albicans* 17 MR, as representative strains of each group of microorganisms. In these tests, the antimicrobial effect of the essential oil was evident when showing bactericidal effect in concentrations equal to CBM on the evaluated strains. For *S. aureus* FES-I (Figure 1) and *S. marcescens* ATCC 14756 (Figure 2) the bactericidal effect was observed from the first hour of exposure of the bacteria to oil, since it eliminated 99.99% of CFU in concentrations of 0.5 and 0.75 mg/mL respectively. In *C.albicans* 17 MR (Figure 3) fungicidal effect was observed after two hours exposure of the microorganism to essential oil in the concentration of 0.75 mg/mL.

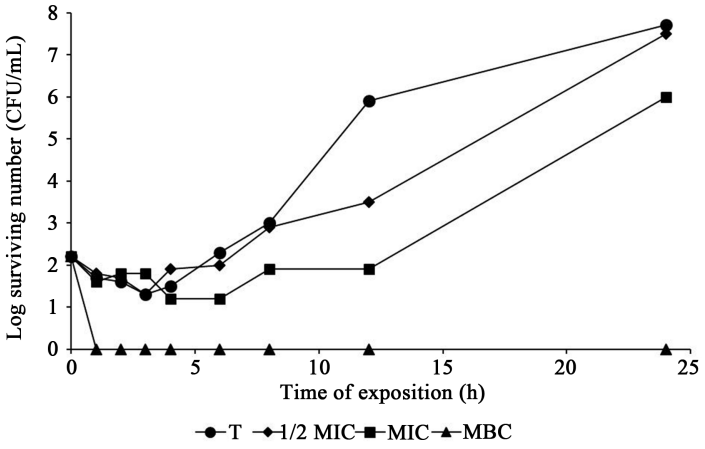

Figure 1. Survival curve of *S. aureus* FES-I exposed to essential oil of *Z. officinale.* The essential oilwas added to each experimental culture in zero time. The concentrations used were 0.125 mg/mL (½ MIC), 0.25 mg/mL (MIC) and 0.5 mg/mL (MBC). The control tube did not contain essential oil. MIC = Minimal Inhibitory Concentration. MBC = Minimum Bactericidal Concentration.

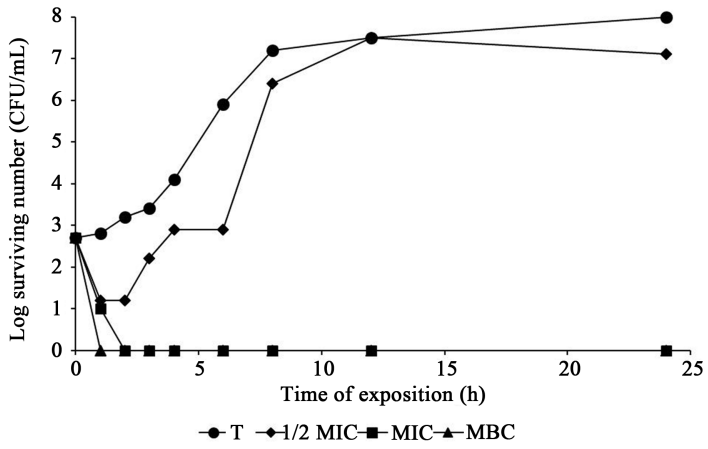

Figure 2. Survival curve of *S. marcescens* ATCC 14756 exposed to essential oil of *Z. officinale.* The essential oilwas added to each experimental culture in zero time. The concentrations used were 0.375 mg/mL (½ MIC), 0.75 mg/mL (MIC) and 1.0 mg/mL (MBC). The control tube did not contain essential oil. MIC = Minimal Inhibitory Concentration. MBC = Minimum Bactericidal Concentration.

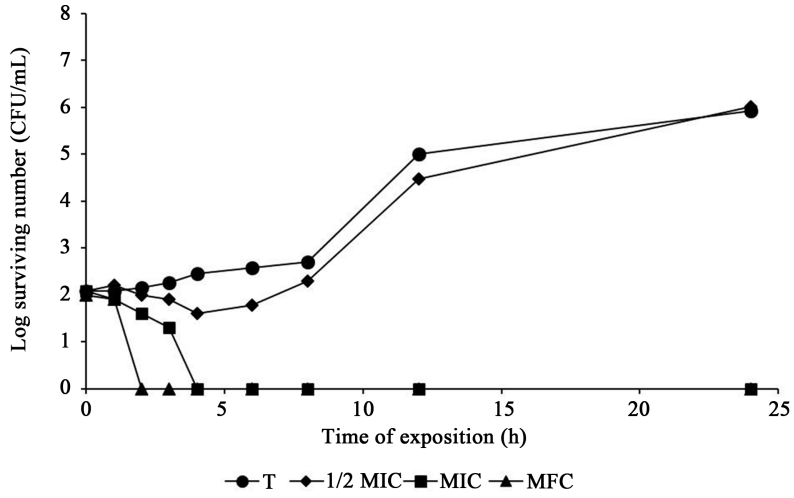

Figure 3. Survival curve of *C. albicans* 17MR exposed to essential oil of *Z. officinale*. The essential oilwas added to each experimental culture in zero time. The concentrations used were 0.125 mg/mL (½ MIC), 0.25 mg/mL (MIC) and 0.75 mg/mL (MBC). The control tube did not contain essential oil. MIC = Minimal Inhibitory Concentration. MFC = Minimum Fungicidal Concentration.

Moreover, the MIC showed bacteriostatic effect on microbial growth by showing a decrease in the population growth of strains evaluated compared with control, except for *S. marcescens* in which the oil showed bactericidal effect in the corresponding concentration CMI (0.75 mg/mL) after three hours of exposure of the bacteria to essential oil.

The results of curves microbial growth suggest that essential oil has a potent antimicrobial effect and a broad spectrum of activity, to show microbicidal effect in a relatively short time (1 to 2 hours) on microorganisms tested, which have clinical importance. *S. aureus* causes localized and invasive suppurative infections, toxic shock syndrome, scalded skin syndrome, and food poisoning [35]; *S. marcescens* is the causative agent of conjunctivitis, keratitis, urinary tract infections, meningitis, and endocarditis [38]. For its part, *C. albicans* is the main causative agent of vaginal infections [39].

The susceptibility of microorganisms to essential oil can be attributed to monoterpenes and sesquiterpenes that constitute it, this type of secondary metabolites have the property of altering the permeability and fluidity of plasmatic membrane of microorganisms. The lipophilic character of its hydrocarbon backbone and hydrophilic character of some of its functional groups confer this property [31] ([28]. The authors mention that essential oils with high concentrations of sequiterpenes possess greater antibacterial and antifungal activity. In this work this effect was observed when the essential oil presented a high percentage of sesquiterpenes (53.57%), which explains its effect on the variety of microbial species evaluated.

4. Conclusion

Essential oil *Z. officinale*is composed mainly of sesquiterpenes (53.57%), and

their main components are: eudesmol, γ-terpinene, α-curcumene, alloaromadendrene and zingiberene. In addition, the essential oil showed antimicrobial effect in 22 strains: 15 bacterial strains, 3 of yeast molds and 4 of filamentous fungi. These results allow considering the essential oil as a potential alternative in the treatment of diseases caused by microorganisms used in bioassays, given the medical importance they represent, which validates its medicinal use in the treatment of diseases of possible origin infectious. In addition, it can be considered a potential ingredient in the food industry as a natural preservative to delay the deterioration of food caused by microorganisms and foodborne pathogens. However, further research is needed to isolate the active compounds and to evaluate their action mechanism.

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