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Effect of Mediterranean Oils and Spices against Food-Related Pathogenic Bacteria

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Research Article

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ABSTRACT

Essential oils and spices recovered from plants are known for their ancient and empiric medicinal or therapeutic properties. The evolution of the science and the discovery of antimicrobial compounds in their own composition made them essential in food industry as adjuvant molecules against food-spoilage. The benefits associated with this type of natural products as antimicrobial agents may be a promising base to replace chemical additives in foods. This work aims to investigate the antimicrobial properties of essential oils (garlic, cinnamon, coriander, cumin, lemon, bay, ginger, marjoram, nutmeg, salsa seeds), other condiments used in food (olive oil, commercial lemon juice, rangpur lime, Sicilian lemon, vinegar) and also a commercial disinfectant. Pathogenic bacteria were selected to study the antimicrobial properties of these compounds: *Listeria monocytogenes*, *Clostridium perfringens*, *Bacillus cereus*, *Staphylococcus aureu*s, *Enterococcus faecium*, *Enterococcus faecalis*, *Staphylococcus epidermidis*), *Salmonella enterica*, *Escherichia coli* and *Pseudomonas aeruginosa*. In this study, the extracts of spices and condiments were blotted into blank sterile paper disks by the disk diffusion method. Minimal inhibitory concentration was tested for each essential oil/spice. Results revealed that most essential oils and spices considered in this study showed a significant inhibitory effect. In the collection of essential oils, cinnamon stood out, with the highest antimicrobial activity. In conclusion, all essential oils and spices are highly effective and could be used to control food-borne bacterial pathogens. Poisoning and food spoilage caused by microorganisms are important issues that food industry and consumers still face every day. Currently, essential oils and spices with antimicrobial activity are ideal to overcome this problem.

INTRODUCTION

Foodborne zoonotic diseases are illnesses directly caused by the ingestion of food or water contaminated with pathogenic microorganisms, such as bacteria and their toxins, viruses and parasites. The contamination could emerge from a biological, chemical or physical source of origin and it may occur on the different phases of food chain [1]. The clinical picture usually includes gastrointestinal disorders; although, it may also include other less frequent symptoms, such as operating organ failure and several complications that may lead to patient dead [2]. Approximately 30% of all emerging infections over the past 60 years were caused by pathogens commonly transmitted through food [3]. Therefore, foodborne zoonotic diseases represent a highly

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increasing public health threat. In fact, it has been estimated that known pathogens considered as foodborne agents can cause 9.4 million illness cases, annually [4]. The Center for Disease Control (CDC) estimates that in United States of America (USA) each year, one in six Americans get sick, 128,000 are hospitalized, and 3,000 die of foodborne diseases [5]. Moreover, European Food Safety Authority (EFSA) reports that in the European Union (EU), a total of 5,550 foodborne outbreaks were reported, causing 48,964 human cases, 4,356 hospitalizations and 46 deaths, during 2009 [6]. These data highlights the importance of microbial inactivation in foods as an issue, even in developing and industrialized countries, regardless the technological developments for food preservation.

Essential oils (EOs) are aromatic oily liquids with volatile aroma compounds that can be obtained from different plant materials. The method of steam distillation is the most commonly used for its commercial production. They can also be obtained by fermentation or solvent extraction [7,8]. Natural products, like EOs and other plant extracts, have important properties such as antibacterial, antifungal, antiviral and insecticide [9]. Therefore, several industries such as pharmaceutics, sanitary, cosmetics, agricultural and food technologies have been showing some interest in using bioactive plant extracts or derived compounds as natural antimicrobials, antioxidants and flavour enhancement [10]. Nowadays, essential oils have been exploited as potential sources of novel antimicrobial compounds to treat infectious agents promoting food preservation [11]. The antimicrobial activity of essential oils depends on plant genotype, agronomic and environmental conditions, and its geographical origin. All these variants together are crucial to determine essential oils chemical composition [12]. The hydrophobicity of essential oils components enables the lipids rupture of the bacterial cell membrane. Therefore, the cell structure is more permeable, allowing an extensive pouring of molecules and ions from bacterial cells leading them to death. Some compounds of essential oils modulate drug resistance in several gram-negative bacteria by targeting efflux mechanisms. Moreover, it is known that Gram-positive bacteria are more resistant to essential oils than Gram-negative bacteria [11].

The aim of the present study was to evaluate *in vitro*, the antimicrobial activity of essential oils extracted from a variety of aromatic plants (*Allium sativum*, *Cinnamomum zeylacium*, *Coriandrum sativum*, *Cuminum cyminum*, *Citrus limon*, *Pimenta racemosa*, *Zingiber officinale*, *Origanum marjorama*, *Myristica fragrans* and *Petroselinum sativum*) and condiments frequently used in the Portuguese gastronomy (olive oil, extra-virgin olive oil with garlic, commercial lemon juice, rangpur lime, sicilian lemon and wine vinegar) against a diverse range of food spoilage and foodborne pathogenic bacteria.

METHODOLOGY

Essential Oils, Condiments and Food Disinfectant

Commercial essential oils of cumin (*Cuminum cyminum*), bay (*Pimenta racemosa*), parsley seeds (*Petroselinum sativum*), cinnamon (*Cinnamomum zeylancium*), ginger (*Zingiber officinale*), lemon (*Citrus limon*), coriander (*Coriandium sativum*), nutmeg (*Myristica fragans*) and marjoram (*Origanum marjorama*) were purchased from the supplier *"Venus in Ferns"* in 10 ml vials while the EO of garlic (*Allium sativum*) was purchased on the store *"Origem Ancestral"*. Other products like virgin olive oil, extra virgin olive oil with garlic, food disinfectant, commercial lemon juice, vinegar, lemon and lime were purchased from physical stores in Vila Real city, Portugal.

Bacterial Strains

The essential oils of different plant species were individually tested against 10 foodborne and food spoilage bacterial strains obtained from American Type of Culture Collection (ATCC): *Bacillus cereus* (ATCC 1247); *Clostridium perfringens* (ATCC 1324); *Enterococcus faecalis* (ATCC 29122); *Enterococcus faecium* (ATCC 10541); *Escherichia coli* (ATCC 25922); *Listeria monocytogenes* (ATCC 7644); *Pseudomonas aeruginosa* (ATCC 27853); *Salmonella enterica* (ATCC 13076); *Staphylococcus aureus* (ATCC 25923) and *Staphylococcus epidermidis* (ATCC 12228).

Antibacterial Activity Assays

Screening of essential oils for antimicrobial activity was performed by the disk diffusion method on Brain Heart Infusion (BHI) agar medium [13]. Briefly, bacterial cultures were adjusted to McFarland turbidity standard (0.5) with sterile saline solution, and spread over the plates containing BHI agar using a sterile cotton swab in order to get a uniform microbial growth on both control and test plates. Sterile paper discs (6 mm diameter) were impregnated with 20 µl of pure essential oils and placed on the surface of the inoculated BHI agar plates. The plates were incubated at 37ºC for 24 h under aerobic conditions, except for *C. perfringens* that was incubated in anaerobic conditions, and the zones of inhibition were measured. After the incubation period, the zone of inhibition was measured and classified as following: >20 mm zone of inhibition corresponded to ''strongly inhibitory''; 10–20 mm zone of inhibition to ''moderately inhibitory'' and <10 mm was considered as ''not inhibitory'' [14]. A standard disc containing ciprofloxacin (CIP–5 µg) was used as reference control, a common commercial disinfectant for food use. A disk blotted with ethanol was used as a negative control, as it is the EO and condiment diluents to test several concentrations. Studies were performed in triplicate, and mean value was calculated.

Minimum Inhibitory Concentration Assay

The minimum inhibitory concentration (MICs) of essential oils was evaluated through the disc diffusion method. Briefly, a bacterial suspension (McFarland 0.5) of each tested microorganism was spread on the BHI agar plate. For each aromatic plant under study, the essential oil was dissolved in an ethanol solution, to achieve the following final oil concentration: 50, 25, 15, 5 and 1% v/v [15]. Then, sterilized discs (6 mm diameter) were impregnated with 20 µl of each of these mixtures and placed on the agar surface [16]. Positive and negative controls (ciprofloxacin and ethanol, respectively) were included in the antimicrobial activity assays. The plates were incubated at 37°C for 24 h under aerobic conditions, except for *C. perfringens* incubated in anaerobic conditions, followed by the measurement of the diameter of the inhibition zone expressed in millimeter. Each assay was performed in triplicate in three separate experimental runs. MIC was taken from the concentration of the lowest dosed disc visually showing no growth after 24 h.

Statistical Validation: Tukey's HSD (Honest Significant Difference) Test

Statistical analysis was made in Statistical Package for the Social Sciences (SPSS), to assess whether the products tested had significant antimicrobial activity compared to the positive control, and given the nature of the variables (quantitative variables) involved in the study, we turn to an analysis of variance, ANOVA, with two factors in interaction, then testing multiple comparisons, HSD (Honest Significant Difference) Tukey. The Tukey's test is a single-step multiple comparison procedure and statistical test to evaluate whether the factors studied have a statistical significant effect on the variable under study [17]. It was considered statistically significant effects whose value test (*p*) was less than 5%.

RESULTS AND DISCUSSION

The antimicrobial properties of ten essential oils, six spices and one food disinfectant are shown in **Table 1**. The results represent the average results of inhibition zone of the triplicate assays, including the diameter (6 mm) of the paper disk. In none case, inhibition of bacterial growth was observed with the negative control (ethanol) and all bacteria tested showed to be susceptible to the positive control (ciprofloxacin antibiotic). In this study, we observed a wide variation in the antimicrobial properties of substances under review. However, it should be noted that, in general, the bacteria tested were sensitive to the majority of essential oils and spices, and the full panoply of tests resulted in significant antimicrobial activity against at least two strains of bacteria. Several studies have reported the antimicrobial activity of essential oils against foodborne pathogenic bacteria [12,14,18].

Table 1. Antimicrobial activity of essential oils against several food-borne and spoilage bacteria.

	B. cereus	*C. perfringens*	*E. faecalis*	*E. faecium*	*E. coli*	*L. monocytogenes*	*P. aeruginosa*	*S. enterica*	*S. aureus*	*S. epidermidis*
	ATCC1247	**ATCC1324**	**ATCC29122**	**ATCC10541**	**ATCC25922**	**ATCC7644**	**ATCC27853**			
Essential oils	**Zone diameter in (mm)a**									
Garlic	13.33 ± 1.15	19.33 ± 0.58	11.33 ± 0.58	11.00 ± 0.00	-	9.00 ± 0.00	-	-	9.00 ± 0.00	10.00 ± 0.00
Cinnamon	31.67 ± 0.58	38.33 ± 0.58	18.00 ± 2.00	20.67 ± 0.58	17.67 ± .58	21.67 ± 2.52	23.00 ± 0.00	18.00 ± 1.73	17.33 ± 2.52	21.67 ± 3.52
Coriander	18.33 ± 0.58	32.33 ± 0.58	14.67 ± 2.31	15.67 ± 0.58	-	15.00 ± 0.00	-	12.70 ± 0.58	13.00 ± 0.00	14.00 ± 1.00
Cumin	19.33 ± 1.53	19.00 ± 0.00	11.00 ± .00	9.00 ± 0.00	10.00 ± .00	9.33 ± 0.58	10.00 ± 0.00	13.00 ± 0.00	9.00 ± 0.00	-
Lemon essence	12.33 ± 0.58	34.33 ± 0.58	-	-	-	-	-	-	-	-
Bay	30.33 ± 0.58	20.33 ± 0.58	14.00 ± .65	13.33 ± 0.58	16.00 ± .00	10.00 ± 0.00	12.67 ± 0.58	16.00 ± 1.73	12.00 ± 0.00	-
Ginger	-	18.67 ± 0.58	9.33 ± 0.58	10.00 ± 0.00	-	10.67 ± 0.58	-	12.33 ± 0.58	10.33 ± 0.58	11.00 ± 0.00
Marjoram	38.00 ± 0.00	31.00 ± 1.00	14.33 ± 1.15	13.33 ± 1.15	22.33±0.58	14.33 ± 0.58	17.33 ± 0.58	16.00 ± 0.00	12.00 ± 0.00	-
Nutmeg	11.33 ± 0.58	21.00 ± 0.00	-	-	10.33 ± .58	9.33 ± 0.58	9.00 ± 0.00	9.00 ± 0.00	-	12.00 ± 0.00
Parsley seeds	17.00 ± 0.00	13.67 ± 0.58	9.00 ± 0.00	9.33 ± 0.58	8.33 ± 0.58	9.00 ± 0.00	9.00 ± 0.00	9.33 ± 0.58	9.00 ± 0.00	-
Spices										
Olive oil	12.00 ± 0.00	-	-	9.00 ± 0.00	10.00 ± .00	9.33 ± 0.58	10.33 ± 0.58		11.00 ± 0.00	-
Extra-virgin olive oil with garlic	-	-	-	10.33 ± 0.58	9.33 ± 0.58	10.00 ± 0.00	11.33 ± 0.58		9.00 ± 0.00	-
Commercial lemon juice	12.33 ± 0.58		12.00 ± 0.00	11.33 ± 0.58	-	13.67 ± 0.58	-		17.33 ± 0.58	
Lime	11.00 ± 0.00	13.00 ± 0.00	11.67 ± 0.58	10.33 ± 0.58	-	14.33 ± 0.58	-		17.33 ± 1.55	
Lemon	14.33 ± 0.58	10.00 ± 1.00	12.33 ± 0.58	9.67 ± 0.58	10.00±0.00	12.33 ± 1.55	9.33 ± 0.58		12.33 ± 0.58	
Vinegar	12.33 ± 0.58	10.33 ± 0.58	11.00 ± 0.00	11.33 ± 0.58	14.33±0.58	15.00 ± 1.00	9.00 ± 0.00		13.33 ± 0.58	
Food disinfectant	20.00 ± 0.00	10.00 ± 0.00	13.00 ± 0.00	13.00 ± 0.00	13.67±0.58	12.67 ± 0.58	9.00 ± 0.00		12.33 ± 0.58	
Control										
Ciprofloxacin[b]	30.33 ± 0.58	24.00 ± 0.00	22.67 ± 0.58	18.67 ± 0.58	18.67±0.58	25.00 ± 1.00	34.67 ± 0.58		20.00 ± 1.00	
Ethanol[c]	-	-	-	-	-	-	-		-	

[a] Values are the mean of three replicates; [b]Comparative control; [c]Negative control (-) No inhibition zone formation

Among the essential oils and spices evaluated in this study, the greatest effectiveness was achieved by cinnamon and lemon essence, respectively, that showed inhibitory activity against all assayed bacterial strains **(Figure 1)**. It is important to underline that these substances are commonly used in cooking. On the order hand, the essential oil of lemon extra virgin olive oil and garlic

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showed the weakest activity. When compared with positive control, cinnamon results showed a higher antimicrobial activity then the antibiotic itself against *B. cereus*, *C. perfringens* and *E. faecium*; also, cinnamon was the essential oil with greater inhibitory power against *E. coli*. Nevertheless, the commercial food disinfectant showed antimicrobial activity against all bacteria. In the case of cinnamon, all bacteria with exception of *E. faecalis* (18.00 mm), *E. coli* (17.67 mm), *S. enterica* (18.00 mm) and *S. aureus* (17.33 mm), showed a strongly inhibitory activity (inhibition diameter of >20 mm). Both lemon and the food disinfectant showed an inhibitory activity against all bacteria; however, for *P. aeruginosa* in both cases, and for *E. faecium* and *S. enterica* on lemon, the result should be considered as not inhibitory (inhibition diameter of <10 mm). On the other hand, paisley seeds essence was the essential oil with lower antimicrobial activity performance. Among the spices, the extra virgin olive oil with garlic revealed the lowest antimicrobial profile, not inhibitory or with a diameter of around 10 mm on all tested bacteria.

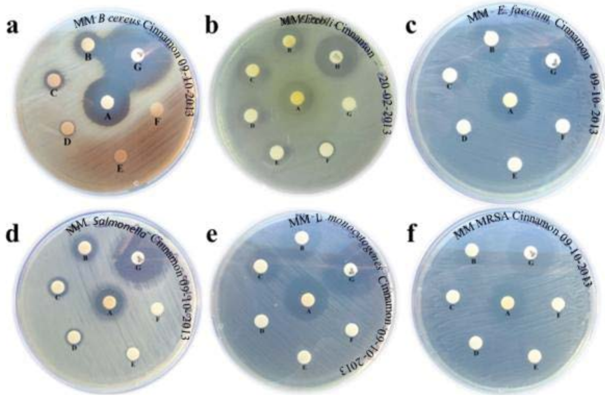

Figure 1. Inhibition halos obtained by the agar diffusion method for cinnamon (Cinnamomum verum) against B. cereus A, E. coli B, E. faecium C, Salmonella Spp. D, l. monocytogenes E, Methicillin-resistant Staphylococcus aureus F. A: A– 6.25%, B– 3.125%, C– 1.56%, D– 0.78%, E– 0.39%, F– ETHANOL, G– CIP5; B: A–12.50%, B–6.25%, C–3.125%, D–1.56%, E–0.78%, F–ETHANOL, G–CIP5; C: A–25.00%, B–12.50%, C–6.25%, D–3.125%, E–1.56%, F–ETHANOL, G–CIP5; D: A–6.25%, B–3.125%, C–1.56%, D–0.78%, E–0.39%, F–ETHANOL, G–CIP5; E: A–25.00%, B–12.50%, C–6.25%, D –3.125%, E–1.56%, F–ETHANOL, G–CIP5; F: A–25.00%, B–12.50%, C–6.25%, D–3.125%, E–1.56%, F–ETHANOL, G–CIP5.

The essential oil of cinnamon presented antimicrobial inhibition against all strains tested. Compared with the inhibition obtained in the positive control, CIP (5 μg), it can be observed that EO obtained higher levels of inhibition against both *B. cereus* and *E. faecium* than the CIP (5 μg) itself. The bacterial strains of *E. coli* and MRSA are near the halos of inhibition of the control, with differences reaching 2 to 3 mm. The remaining strains presented a halo of inhibition smaller than the positive control. Cinnamon was the substance studied with greater inhibitory power against *E. coli*. Still on the cinnamon, but this time against *Salmonella*, equivalent data stating the antimicrobial activity of this essential oil was revealed [19].

MIC assays were performed using the disc diffusion method in order to achieve a more accurate data about the antimicrobial properties of the essential oils. The MIC was defined as the lowest concentration of the sample that inhibited visible growth. **Table 2** shows the results of the variable effect of the essential oil on the tested bacteria. Once again, cinnamon showed to be the essential oil with the highest antimicrobial activity, whose MICs values against all tested bacteria never exceeded 1.56%, and particularly for *Salmonella spp*. It showed values of 0.78% **(Figure 1)**. Although lemon was the only spice that showed antimicrobial activity against all tested bacteria, it was also considered the least potent agent, with MICs above 50% on three bacteria including both Gram-negative *E. coli* and *P. aeruginosa*. Similar results were presented for the food disinfectant that showed antimicrobial activity against all bacteria, with values ranging from 3.125% and 50%.

Table 2. Values of MIC for different essential oils obtained by the disc-diffusion method.

	MIC % (v/v)									
	B. cereus epidermidis	***C. perfringens***	***E. faecalis***	***E. faecium***	***E. coli***	***L. monocytogenes***	***P. aeruginosa***	***S. enterica***	***S. aureus***	***S. epidermidis***
Plants										
Garlic	3.125	0.78	>50.00	50.00	-	50.00	-	-	50.00	25.00
Cinnamon	0.39	<0.39	1.56	1.56	0.78	1.56	0.78	1.56	1.56	0.78
Coriander	3.125	<0.39	6.25	3.125	-	6.25	-	6.25	3.125	1.56
Cumin	0.78	1.56	50.00	>50.00	25.00	50.00	25.00	25.00	50.00	-
Lemon essence	25.00	1.56	-	-	-	-	-	-	-	-
Bay leaf	0.78	0.39	3.125	25.00	1.56	25.00	6.25	3.125	25.00	-
Ginger	-	1.56	50.00	12.50	-	12.50	-	50.00	>50.00	6.25
Marjoram	1.56	0.78	1.56	6.25	1.56	6.25	12.50	12.50	25.00	-
Nutmeg	25.00	1.56	-	-	50.00	>50.00	>50.00	>50.00	-	50.00

Parsley seeds	1.56	1.56	50.00	>50.00	>50.00	50.00	50.00	50.00	50.00	-
Condiments										
Olive oil	25.00	-	-	50.00	50.00	50.00	50.00	50.00	25.00	-
Extra-virgin olive oil with garlic	-	-	-	50.00	50.00	50.00	25.00	25.00	50.00	-
Commercial lemon juice	25.00	6.25	25.00	25.00	-	12.50	-	-	12.50	50.00
Rangpur lime	50.00	25.00	12.50	50.00	.	6.25	-	-	1.56	50.00
Sicilian lemon	>50.00	50.00	25.00	25.00	>50.00	12.50	>50.00	25.00	50.00	50.00
Vinegar	50.00	25.00	25.00	25.00	25.00	50.00	>50.00	-	25.00	50.00
Food disinfectant	>50.00	3.125	12.50	25.00	25.00	12.50	50.00	50.00	50.00	>50.00

A statistical overview of the observed EO's antimicrobial activity registered values, statistics is relevant to grade or rank these ingredients tested, giving them an order of importance for their inhibitory capacity to control microorganisms, as a consequence of this ranking some demonstrated potential for use in food as preservatives. This is relevant to confirm the potential use of these ingredients by the food industry. The Tukey test resulted in 13 distinct groups for all substances studied based on the average of observations **(Table 3)**. By this test, it was possible to access significant differences between the positive control and all tested products. It appears that the positive control was placed in the latter group with the highest level of efficiency and antibacterial activity, with 25.420. However, it should be noted, the antibacterial activity of cinnamon, the higher power against the studied bacteria (23,500). The following higher values were from marjoram, food disinfectant, bay leaf and coriander. This test proved once more the excellence antimicrobial power of the essential oil of cinnamon against all studied bacterial strains, placing him very close to registered value for the antibiotic control. This test also allowed agglomerate essential oils that behave identically in its antimicrobial power against the studied bacteria. One of these groups includes ginger, nutmeg and lemon-clove. In future studies such information may be important the extent that these products can be used in a single group. The results for the tests performed with essential oil of coriander revealed, with the exception to *E. coli* and *P. aeruginosa*, antimicrobial activity

Table 3. Multiple comparisons for antimicrobial activity made by turkey HSD test.

Antimicrobial activity														
Turkey HSD^{a,b}		**Subsets**												
Tested products	**N**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Lemon essence	50	5.200												
Extra-virgin olive oil with garlic	50		6.480											
Olive oil	50			7.940										
Ginger	50				8.760									
Nutmeg	50				8.869	8.860								
Rangpur lime	50				8.960	8.960								
Garlic	50					9.444	9.444							
Commercial lemon juice	50						9.680							
Paisley seeds	50						9.980							
Vinegar	50							11.500						
Cumin	50							11.580						
Sicilian lemon	50							11.680						
Coriander	50								14.200					
Bay leaf	50									15.020				
Food disinfectant	50										16.880			
Marjoram	50											18.380		
Cinnamon	50												23.500	
Antibiotic	50													25.420
Sig	50	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed, the error term is Mean Square (Error)=0.823;
a) Uses Harmonic Mean Sample Size=90,000; b) Alpha=0.05

against all studied bacteria. Linalool, a major constituent of the EO of coriander seeds, showed beneficial effects in several cellular pathways, like reduction of lipid peroxidation [20], protection of DNA from its anti-mutagenic action [9], and antimicrobial and anti-inflammatory effects [21]. This fact highlights the importance of using coriander in cooking as a flavouring herb [22]. The essential oil of cumin had antimicrobial activity against 9 of the 10 bacterial strains studied, only getting out of this range *S. epidermidis*, which was resistant even to pure oil. None halo was bigger than that formed by the positive control. Cumin is used as condiments, in sauces, cheeses, liqueurs and in the typical cuisine [23]. The association of the general use of cumin in cuisine and the relevant antimicrobial activity of this EO, proved in this study, can't be underestimated and must be applied as an efficient food disinfectant by the food industry.

Regarding the essential oil of ginger only *B. cereus*, *E. coli* and *P. aeruginosa* were resistant. The results of the ginger antimicrobial activity against *E. coli* are in accordance with those obtained in other study that reported no evidence of antimicrobial activity [19]. The EO of ginger presented lower antimicrobial activity than the positive control in all cases.

For the tests with the essential oil of marjoram only *S. epidermidis* presented to be resistant. There is still to note, that the halo of inhibition of *B. cereus* was equals to the positive control. The inhibition results summarize the importance of the applicability of the marjoram, which is used as a preservative in food and germicide, in the meat industry, as flavouring soups, stews and even in the production of liqueurs, protecting large population of possible foodborne illnesses [23].

There were three bacteria that were resistant to EO nutmeg: *E. faecalis*, *E. faecium* and MRSA. The antimicrobial activity of the essential oil of marjoram to *Escherichia coli* and *Staphylococcus aureus* has been stated in a previous study [24].

The lemon and orange are a major source of fibre, since they are very rich in pectin [25]. The lemon can be fully exploited: the essential oil, the epicarp and fruit pulp are used as flavourings in foods, pastries and beverages [26]. The commercial lemon juice used has revealed antimicrobial capacity in seven of the 10 studied strains bacteria, except against *E. coli*, *P. aeruginosa* and *Salmonella.* spp. The lemon was the most effective, with antimicrobial activity against all tested strains. On the other hand, the essential oil of lemon showed the lowest efficiency in the desired inhibition. Should also be noted that the Rangpur lime and lemon juice commercial showed exactly the same qualitative results and that only the lemon had the ability to inhibit *E. coli*, *P. aeruginosa* and *Salmonella.spp*. The food sanitizer has demonstrated antimicrobial activity against all tested microorganisms. It is very important to note that this result refers to the test with an undiluted food sanitizer. For the concentrations or dilutions recommend by the manufacturers, the trade food sanitizer had no activity. This result further highlights the antimicrobial activity of the essential oils used in this study.

For the tests made with virgin olive oil results reveal resistance of *C. perfringens*, *E. faecalis* and *S. epidermidis*. The antimicrobial activity observed can be explained by the oil composition, its fatty acid, characterized by a high percentage of oleic acid and the presence of natural antioxidants such as tocopherols and phenolic compounds. Extra virgin olive oil with garlic had no antimicrobial power for *B. cereus*, *C. perfringens*, *E. faecalis* and *S. epidermidis*. Extra virgin olive oil is considered a garlic flavoured oil which when compared with the common olive oil, show that the quality parameters thereof can be improved or maintained. Overall, the flavour of olive oil does not significantly alter the parameters of qualities of oils, which may favour an increase in its strength and consequently an increase in the shelf life of the product [9]. Thus, one would expect scented oil results in slightly more significant than with the refined oil. But, what occurred in practice was the exact opposite. This fact can be explained by the use of olive oil to be flavoured and of different brands.

Some results have no way of comparing and/or are disparate with studies of other authors, which may indicate the use of essential oils with different compositions or distinct techniques. There is a gap in this sense, because there is no internationally standardized technique for evaluation of essential oils and plant extracts, which allows different protocols to be used, and therefore undertakes comparisons of results [27]. However, the use of essential oils remains minimal, even proven, due to the high costs of purification of the extract and the fact that the antioxidant properties are subject to fluctuations due to external factors such as temperature, humidity, pH necks of antimicrobial activity, sun exposure, among.

Most essential oils and spices considered in this study showed a significant inhibitory effect. Cinnamon had the highest antimicrobial activity. Regarding the condiments, lemon showed the highest antimicrobial activity and cinnamon oil the higher inhibitory activity even at very low concentrations, revealing its potential as a natural preservative in foods against several causative agents of foodborne illness and spoilage. The excellent antimicrobial activity presented, in this study, by the essential oil of cinnamon to a wide range of bacteria is an impressive result, which was also backed up by the statistical analysis. Based on these results, the potential of a successful application, by the food industry, of this EO and others, as a versatile disinfectant and food preservative can't be discarded.

In general, the results demonstrate that in addition to food flavouring, the use of herbs and other spices/condiments can also contribute to bacteriostatic effect against pathogens, constituting an asset when incorporated in cooking. Thus, the tested products can be made natural as antimicrobials and can be used as an alternative to chemical disinfectants or preservatives. This work has yet to confirm the idea that the species, external factors, mode of harvesting and extraction of essential oil and other products, influence the antimicrobial activity, which can be confirmed by the differences found in comparison with other studies. This investigation has also found that the disk diffusion method on agar plate, using the BHI and diluted with ethanol and acetone, is a safe, fast, and simple technique to achieve quantitative results.

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In short, assuming that they are safe for food use, essential oils have proven antimicrobial activity. However, more studies in order to determine, exposure time, and method of oil extraction, minimal inhibitory concentrations and strains that are inhibited by the essential oil are required.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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