Composition and *in vitro* antimicrobial activity of pink pepper fruit essential oils

Composição e atividade antimicrobiana *in vitro* de óleos essenciais de frutos de pimenta-rosa

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ABSTRACT
The fruit of Aroeira, popularly called pink pepper, has aroused researchers interest due to the effects of the different constituents present in its essential oil. In Espírito Santo, the largest producer and exporter in the world since 2012, most pink pepper production is spontaneous and of great importance to rural producers. The aim of this work was to identify the chemical constituents and evaluate the antibacterial action of essential oils extracted from ripe pink pepper fruits (PPEO) obtained from six rural properties located in São Mateus-ES, coded as P5, P6, P7, P8, P9 and P10. Through chromatographic analysis (CG/MS), 13 compounds were detected, 10 monoterpenes and 3 sesquiterpenes, of which limonene (31.28%), delta3carene (28.71%) and alpha-pinene (15.01%) were the majority. In the agar diffusion test, the PPEO from the six farms showed inhibition against *S. aureus*, especially for the P6, P7, P8 and P10 oils, which did not differ significantly from the antibiotic Ampicillin used as a control. However, the essential oils tested were ineffective against *E. coli*. In the Minimum Inhibitory Concentration (MIC) test, the bacteria most sensitive to all oils was *S. aureus*, presenting the lowest values and, in contrast, *P. aeruginosa* showed greater resistance to their action. The PPEO that showed the greatest effect compared to the others against all bacteria was P7.

Keywords: *Schinus terebinthifolius*; Piperculture; Natural antimicrobials; Food pathogens; Phytochemical profile.

RESUMO
O fruto da aroeira, chamado popularmente de pimenta-rosa, tem despertado interesse de pesquisadores pelos efeitos dos diferentes constituintes presentes em seu óleo essencial. No Espírito Santo, o maior produtor e exportador do mundo desde 2012, a maior parte da produção de pimenta-rosa é espontânea e de grande importância para os produtores rurais. Objetivou-se neste trabalho identificar os constituintes químicos e avaliar a ação antibacteriana de óleos essenciais extraídos de frutos maduros de pimenta-rosa (OEPR) obtidos de seis propriedades rurais localizadas em São Mateus-ES codificados como P5, P6, P7, P8, P9 e P10. Através da análise cromatográfica (CG/MS), detectou-se 13 compostos, 10 monoterpenos e 3 sesquiterpenos, dos quais limoneno (31,28%), delta3careno (28,71%) e alfa-pineno (15,01%) foram os majoritários. No teste de difusão em ágar os OEPR das seis propriedades rurais apresentaram inibição contra *S. aureus*, com destaque para os óleos P6, P7, P8 e P10 que não diferiram significativamente do antibiótico Ampicilina usado como controle. Todavia, os óleos essenciais testados foram ineficazes frente à E. coli. No teste de Concentração Inibitória Mínima (MIC) a bactéria mais sensível a todos os óleos foi a *S. aureus*, apresentando os menores valores e, em

contrapartida, a *P. aeruginosa* demonstrou maior resistência à ação dos mesmos. O OEPR que demonstrou maior efeito comparado aos outros frente a todas as bactérias foi o P7.

Palavras-chave: *Schinus terebinthifolius*; Pipericultura; Antimicrobianos naturais; Patógenos alimentares; Perfil fitoquímico.

1 INTRODUCTION

Schinus terebinthifolius Raddi, known as Aroeira, belonging to the Anacardiaceae family, is found from the South to the Northeast of Brazil (CARVALHO et al., 2017). The fruit of the Aroeira or Aroeirinha, popularly called pink pepper, is small, round and reddish in color, and has aroused the interest of researchers concerning the properties of the chemical constituents present in its essential oil, as they exert antimicrobial and antifungal (DANNENBERG, 2017; JOHANN et al., 2010; LIMA et al., 2006; NEVES et al., 2016; RIBEIRO, 2015), antioxidant (BENDAOUD et al., 2010; BERNARDES, et al., 2011; RIBEIRO, 2015) and antitumor (ROVEDA, 2010) effects.

In Espírito Santo, most of the production of pink pepper is spontaneous, as in the municipality of São Mateus, located in the northern region of the state, and considered the largest producer and exporter in the world since 2012. Aroeira is of great importance to rural producers and local families, as a large part of the fruit production is sent to a processing industry in the city and exported (INCAPER, 2016).

In Brazil, the use of plants with medicinal properties for therapeutic purposes is increasing, whether in the prevention or treatment of diseases (BERTINI et al., 2005; SILVA et al., 2009). Several bioactive compounds are extracted from these plants, such as essential oils, which have specific functions in plants and are also used by the pharmaceutical, cosmetic, perfumery and hygiene industries (MILLEZI et al., 2013) and with prospecting for use in the food industry (BAJ; BARYLUK; SIENIAWSKA, 2018; HOSSAIN et al., 2019; OLIVEIRA et al., 2011; RIBEIRO, 2015; SILVA, et al., 2021).

Essential oils are aromatic products with volatile and lipophilic characteristics, obtained from the secondary metabolism of plants, and can be extracted from several parts such as roots, stems, leaves, flowers, seeds or fruits (SANTOS et al., 2010; SARTO; JUNIOR, 2014). These compounds are widely studied and used for their diverse properties, amongst them, anti-inflammatory, antioxidant, antifungal and antibacterial activities stand out (GEROMINI et al., 2012; MILLEZI et al., 2013; SILVA et al., 2021).

The increasing dissemination of undesirable microorganisms in food, especially pathogenic bacteria, harms the health of the population and the food industry (POMBO et al., 2018; VALERIANO et al., 2012). Research on the use of essential oils is very important in the investigation of their inhibitory action against pathogens as a less toxic alternative to drugs and pesticides (MARQUES et al., 2019; PEREIRA et al., 2008; SILVA et al., 2021). The antimicrobial activity of an essential oil can suffer interference from several factors, causing changes to occur. This action may depend on conditions such as the chemical composition and constituents of the oil, its concentrations, climatic and soil conditions in which the plant developed, the type of microorganism and the strain used (FENNEL et al., 2004).

The Aroeira-vermelha (*S. terebinthifolius*) presents antibacterial and antifungal action against several species of bacteria and fungi (GHANNEY; RHOUMA, 2015; GOMES et al., 2013; JOHANN et al., 2010; LEITE et al., 2011; MALCA-GARCÍA et al., 2017). Lima (2009), in studies with pink pepper essential oil, showed significant results of antibacterial activity for microorganisms such as *Bacillus cereus* and *Staphylococcus aureus*, bacteria that can cause several damages to the food industry and outbreaks of food-borne diseases.

Ribeiro (2015) evaluated the effect of adding microencapsulated pink pepper essential oil to Minas Frescal cheese, which showed antioxidant and antimicrobial characteristics for the development of *S. aureus*, in addition to its sensory acceptance, being a viable and useful alternative for this dairy product.

Erstwhile, the human beings depended mostly on nature for their survival. Medicinal plants were widely used in the treatment of illnesses, and to this day their use is common in several cultures (ALMEIDA, 2011), including through public policies such as the National Policy for Integrative and Complementary Practices in the Single System of Health (BRAZIL, 2006).

The use of herbal medicines and medicinal plants has gained greater space in consumer preference, especially among those trying healthier habits and treatments and less environmental impact (OLIVEIRA et al., 2007). Among these natural products, there are the essential oils, which have shown adequate antimicrobial function in several studies (GEROMINI et al., 2012).

The red mastic tree (*Schinus terebinthifolius* Raddi) is a perennial species that can reach up to 15 meters in height, has a short and tortuous trunk, thick and rough bark and green leaves. Its ripe fruits are round and reddish in color known as pink pepper (NEVES et al., 2016). This tree native to Brazil, found mainly in coastal areas, is an alternative for income generation, as its fruits can be marketed by farmers and exported to countries such as Italy, France and Portugal (CARMINATE et al., 2014; FLEIG, 1987; GILBERT; FAVORETO, 2011).

Aroeira occurs naturally in several states in Brazil, including Espírito Santo, and is a very important crop for the population, due to its contribution to local income, as in the municipality of São Mateus, the largest producer and exporter of pink pepper around the world since 2012 (INCAPER, 2016).

Aroeira fruits can be sold *in natura* or the essential oil can also be extracted for use in international cuisine (BAGGIO, 1988; FAES; SENAR, 2009; SILVA-LUIZ; PIRANI, 2012). In ripe fruits, analyzes of the essential oil of pink pepper demonstrate the presence of 73 compounds in total (BENDAOUD et al., 2010; RICHTER et al., 2010) with a predominance of compounds such as monoterpenes (α-3-carene and α -pinene) and sesquiterpenes (β-gurjunene, trans-calamene, trans-β-guaiene, α-muurolene, cubenol, cis-β-guaiene and epi-α-muurolol) (GEHRKE et al., 2007), as well as the presence of other compounds such as elemol, α-cadinol and germacrene-D (BARBOSA et al., 2007).

The essential oil extracted from this species has several medicinal properties, including anti-inflammatory (RIBAS et al, 2006; SOARES et al., 2010), antioxidant (BENDAOUD et al., 2010; BERNARDES et al., 2010); 2011; SALES, 2013), antifungal (JOHANN et al., 2010), insecticide (KWEKA et al., 2011; SALES, 2013) and antimicrobial (LIMA et al., 2006) activities.

Essential oils extracted from medicinal, aromatic and seasoning plants are compounds of great importance and can be alternatives in microbiological control in foods through the development of new natural antimicrobial products, increasing their shelf life and decreasing the likely negative effects of synthetic chemical additives (SANTOS et al., 2010). In addition, several authors have demonstrated the satisfactory antimicrobial effects of applying essential oils (EO) amidst food matrices, proving its ability to act as an antibacterial in a real system (DANNENBERG et al., 2016; GUO et al., 2017; LOU et al., 2017).

The aim of the present work was to identify the chemical constituents and evaluate the antibacterial action of essential oils extracted from ripe pink pepper fruits against pathogenic bacteria of interest to the food industry.

2 MATERIAL AND METHODS

2.1 MATERIAL

Samples of ripe pink pepper fruits were acquired from six rural properties based on family farming, randomly chosen, belonging to the municipality of São Mateus, northern region of Espírito Santo in Brazil.

2.2 METHODS

2.2.1 Extraction of essential oils

In order to extract the essential oil from ripe pink pepper fruits, three replications were performed for each sample from each farm, using the hydrodistillation process (AOAC, 1992) in a Clevenger apparatus adapted to a round-bottomed flask with 2 L capacity. In each extraction, 250 mL of distilled water and 100 g of ripe fruit crushed in a knife mill, were added to the flask, starting the hydrodistillation process. The extraction lasted 2 hours and 30 minutes. After each extraction, the oil yield was calculated by the difference between the final weight of the flask containing the oil and the initial weight of the flask without oil, thus obtaining the yield for 100 g of fruits. Oil samples were stored at 4°C in an amber glass bottle with screw cap for further chromatographic analysis, in triplicate.

2.2.2 Identification and quantification of volatile constituents

Identification and quantification of volatile constituents was performed in an Agilent gas chromatograph, model HP-6890, equipped with an Agilent mass selective detector, model HP-5975 and a capillary column HP-5MS (30 mx 0.25 mm x 0.25 µm). The splitless injection mode was used under the following temperature conditions: injector at 220°C, column at 60°C, with heating ramp of 3°C·min-1, final temperature of 240°C and detector at 250°C. Helium was used as a carrier gas at a flow rate of 1 $mL \cdot min^{-1}$. The samples of essential oils were dissolved in ethyl acetate (20 $mg \cdot mL^{-1}$) for analysis. The identification of analytes was performed by calculating the retention indices (RI) of the analytes obtained by co-injecting a mixture of hydrocarbon standards (C-8 to C-24), compared with the equipment database (library NIST-11) and with data from the literature (ADAMS, 2007).

2.2.3 Microorganisms used

The microorganisms were obtained from the collection of cultures at the Food Microbiology Laboratory belonging to the Department of Food Engineering at the Federal University of Espírito Santo, UFES, in Alegre, ES.

The essential oils were tested against five pathogenic bacteria, namely: *Escherichia coli* (ATCC 11229), *Staphylococcus aureus* (ATCC 6538), *Pseudomonas aeruginosa* (ATCC 15442), *Salmonella Typhimurium* (ATCC 14028) and *Bacillus cereus* (ATCC 14579).

2.2.4 Agar diffusion test - Halo test

For this test, the methodology of the Clinical and Laboratory Standards Institute (CLSI, 2012) was used with modifications. *Escherichia coli* and *Staphylococcus aureus* were previously activated in BHI broth (Brain Heart Infusion) at 35°C for 24h, and then transferred to Petri dishes with PCA (Plate Count Agar) medium by single streak, and incubated at 35°C for growth, until testing. The tests started by taking the plates with PCA medium and the colonies of the grown microorganisms. A platinum loop was used to remove a small part of the colony and introduce it into a tube of 0.85% saline solution. Then, this suspension was compared to the McFarland 0.5 standard. Afterwards, plates containing Mueller Hinton Agar were inoculated with the suspension of each bacteria using a sterile Swab. In sequence, sterilized paper discs were added to the center of each plate with the aid of a flamed metal tweezer, sterilized and subsequently soaked with 5 µL of the pure oils to be tested. In the control plates, Ampicillin and Tetracycline antibiotics were used. All plates were incubated inverted in a BOD oven at 35°C for 48h. Tests and controls were performed in duplicate.

2.2.5 Determination of Minimum Inhibitory Concentration (MIC)

For this test, the broth microdilution method with 96-well Elisa plates was used and the microorganisms used were *Staphylococcus aureus*, *Salmonella typhimurium*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Bacillus cereus*. From a tube containing 0.85% saline solution with cells of each microorganism, which was previously compared to the McFarland 0.5 standard, two dilutions were carried out until the initial inoculum was approximately 10^6 CFU/mL. Then, 0.1 ml of BHI broth was transferred to each well of the plate. Subsequently, in the first horizontal row of wells on the plate, 0.1 mL of each pure oil to be tested was added, in duplicate. The first well was homogenized, and from it 0.1 ml of the content was transferred to the well below, and this procedure was done in all vertical wells of the plate. Oil concentrations ranged from 50% to 0.78% (v/v). Then, 0.1 mL of the suspension of each microorganism was added separately (BASSANETTI et al., 2017). The Minimum Inhibitory Concentration is defined as the lowest concentration of the antimicrobial agent that inhibits the multiplication of the tested microorganisms.

2.2.6 Experimental design and statistical analysis of results

The experiment was carried out according to a completely randomized design (CRD) with three replications. The diameters of the inhibition halos obtained in the agar diffusion test were submitted to analysis of variance (ANOVA), followed by Tukey's mean tests and Student's t test at 5% probability. The tests were performed in the Statistica software (TIBCO, 2019).

3 RESULTS AND DISCUSSION

The results of the characterization of chemical constituents in essential oils are shown in Table 1.

Table 1 – Chemical constituents identified in essential oils extracted from ripe pink pepper fruits from 6 family properties in São Mateus-ES

t_R (min)	IR	Chemical constituent	P5(%)	P6(%)	P7(%)	P8(%)	P9(%)	P10(%)
5.15	926	tricyclene	0.39	-	-	-	-	-
5.39	936	alpha-pinene	20.56	21.49	9.96	12.76	12.44	12.87
6.36	974	sabine	7.21	-	0.82	-	-	-
6.47	979	beta-pinene	7.79	0.58	1.05	0.90	0.88	0.99
6.82	993	beta myrcene	6.91	1.28	2.97	3.48	2.91	2.80
7.24	1007	alpha-phelandrene	4.30	12.01	3.88	6.67	6.14	6.16
7.48	1014	delta-3-carene	20.90	1.15	44.76	32.78	35.56	37.11
7.87	1026	para-cement	5.79	-	4.67	8.60	9.03	8.03
8.08	1032	Limonene	17.31	55.53	27.72	29.53	30.09	27.51
9.99	1088	terpinolene	0.57	0.40	0.54	-	0.39	0.43
23.39	1417	trans-caryophyllene	1.26	0.76	1.19	1.81	1.21	1.64
25.91	1479	germacrene D	2.46	1.27	0.83	1.30	0.69	0.90
27.56	1522	delta-cadinene	0.61	3.59	-	-	-	-

It was found in this work that the average content of essential oil (3%) extracted from ripe fruits harvested in the six areas of conventional family producers did not show any statistical difference and the uniformity of this content can be justified by the standardization of conditions in the six growing areas. In general, all samples of oils extracted from fruits from the six growing areas had the same major compounds: alpha-pinene (10-21%), limonene (17-56%) and delta-3-carene (21- 45%), with the exception of the values found in the P-6 sample which presented alpha-phellandrene as one of the major compounds, however there were small variations in the minor constituents of the samples in overall.

Ribeiro (2015) and Clemente (2006), when evaluating the chemical constituents present in the essential oil of *S. terebinthifolius* fruits, observed that delta-carene (42.3%) and beta-phelandrene (14.8%) were the major compounds.

Carvalho et al. (2017) characterized the constituents of essential oils present in *Schinus terebinthifolius* fruits, and the major components found were delta-3-carene (40.53%), sylvestrene (17.63%), beta-phelandrene (14.25 %) and alpha-pinene (11.90%) which were tested on two pathogenic bacteria, *Staphylococcus aureus* and *Escherichia coli*.

Study carried out by Santos et al. (2007) showed that the oil extracted from the leaves of *S. terebinthifolius* specimens from Caxias do Sul, RS, presented distinct major chemical compounds. The authors concluded that, as the studied accessions were in the same region under identical environmental conditions and soil, the observed variations could be related to the genetic character, microenvironmental differences and physiological age of the plants. According to the same authors, in terms of essential oil content, production differs over the months of the year, due to the phenological situation of the plants. In general, just before flowering, the content is maximum, then there is a drop and, when the plant has ripe fruits, the essential oil content in the leaves is minimal. Table 2 shows the results of the diameters of the inhibition halos (agar diffusion test) in the samples of the six essential oils of ripe pink pepper fruits tested against two species of pathogenic bacteria.

Table 2 - Mean diameters of the zones of the halo test inhibition (cm)

Essencial oils	**Diameters of inhibition zones (cm)***	
	S. aureus	***E. coli***
P5	$0.93^{a} \pm 0{,}81$	-
P6	$1.86^{ab} \pm 0{,}55$	-
P7	$2.08^{ab} \pm 0{,}80$	-
P8	$2.02^{ab} \pm 0{,}49$	-
P9	$1.36^{a} \pm 0{,}47$	-
P10	$1.70^{ab} \pm 0{,}60$	-
AMP	$4.36^{bcA} \pm 1{,}60$	$1.39^{aB} \pm 0{,}43$
TET	$5.02^{cA} \pm 0{,}48$	$2.85^{bB} \pm 0{,}02$

*Average of three repetitions.
Means followed by the same lowercase letter, in the same column, do not differ by Tukey's test ($p > 0.05$).
Means followed by the same capital letter, in the same line, do not differ by the t test ($p > 0.05$).
-: no inhibition halo.

In this research, it was found that for the Gram-positive bacterium *S. aureus*, all six oils tested showed formation of an inhibitory halo. Oils P6, P7, P8 and P10 did not differ significantly ($p > 0.05$) from the antibiotic Ampicillin used as a control, and had similar effectiveness in inhibiting this bacterium.

Although the values between the oils tested were statistically equal, it is worth noting that the results obtained from oils P7 (2.08 cm) and P8 (2.02 cm) performed the greatest potentials regarding the size of the halo formed against these bacteria which causes big damages to the food industry and public health. It was not observed the formation of an inhibition halo for the Gram-negative bacteria *E. coli*, which indicates that the pink pepper essential oil did not present an antimicrobial effect against this pathogen.

Carvalho et al. (2017) in a study carried out with pink pepper essential oil by means of the agar diffusion test against the same bacteria used in this work, obtained results that corroborate the present ones, showing the presence of halo (9.17 mm) for *S. aureus* compared with antibiotics (ampicillin: 35.00 mm; tetracycline: 29.17 mm) and there was no visible inhibition of *E. coli* growth.

Table 3 shows the results of the Minimum Inhibitory Concentration (MIC) test for the essential oil of pink pepper from six producers in the municipality of São Mateus against five species of pathogenic bacteria.

Table 3. Values of Minimum Inhibitory Concentration (MIC) of pink pepper essential oils

Essencial oils	**Antimicrobian activity (%)**				
	S. aureus	*E. coli*	*S.* Typhimurium	*P. aeruginosa*	*B. cereus*
P5	<0.78%	50%	25%	50%	>50%
P6	<0.78%	50%	50%	>50%	>50%
P7	<0.78%	50%	50%	50%	25%
P8	<0.78%	50%	50%	50%	>50%
P9	<0.78%	50%	50%	>50%	50%
P10	<0.78%	50%	>50%	>50%	>50%

Subtitle: >50%: MIC above the highest concentration tested (50%); <0.78%: MIC below the lowest concentration tested (0.78%)

It was observed in this work, variation in the MIC values for the six different oils tested against the five pathogens evaluated (Table 3). *S. aureus* was the most sensitive bacterium among all, presenting the MIC value below the lowest concentration tested (0.78%), which means that the essential oils of pink pepper completely inhibited the growth of this microorganism in the lowest concentration tested.

For *E. coli*, all essential oils, compared to each other, also performed the same efficacy in inhibiting the growth of this bacterium, presenting the MIC value at the highest concentration tested (50%). In the other bacteria used, the MIC results showed varied values characterized between the presence and absence of bacterial growth, but there was still an inhibitory effect of the P5, P6, P7, P8 and P9 oils against all three bacteria, in at least one concentration of oils (50%), further emphasizing that P5 and P7 also inhibited the growth of *S. typhimurium* and *B. cereus*, respectively, at a concentration of 25% of the oils. In addition, they were the only two essential oils that presented sabinene as one of the minor constituents, the which has broad-spectrum antimicrobial activity, and according to Sellami et al. (2009), contributing to enhance the antimicrobial action against these two microorganisms.

The P7 oil showed the best effect among all the oils tested, since there was growth inhibition of all bacteria at some concentration tested. This oil showed the greatest diversity of chemical constituents, which may have enhanced its antimicrobial action acting in synergism (POMBO et al., 2018).

On the other hand, P10 was the oil that was less effective compared to the others, showing no growth inhibition for *S. typhimurium*, *P. aeruginosa* and *B. cereus*, and MIC value for *E. coli* at the highest concentration tested (50%). The bacterium that proved to be the most resistant among all was *P. aeruginosa*, since only the P5, P7 and P8 oils were efficient in inhibiting its growth, and in the highest concentration tested (50%).

Furthermore, in this work, three of the four bacteria tested that showed the highest MIC values, are Gram-negative. According to Mann, Cox and Markham (2000), Gram-negative bacteria are more likely to be resistant to tests with essential oils. This can be explained by the presence of an outer membrane consisting of lipopolysaccharides, which has a hydrophilic character and consequently makes it difficult the interaction of essential oils that have a hydrophobic character, preventing their entry into the microorganism cell.

The MIC tests performed by Santos et al. (2020) with pink pepper essential oil showed an inhibitory effect against *S. aureus* at concentrations from 0.5%, which is similar to the present study with regard to the high sensitivity of this bacterium to the essential oils of these fruits.

Geromini et al. (2012), working with pure essential oils from leaves of *L. alba*, *M. piperita*, *O. gratissimum* and *R. officinalis*, demonstrated that *P. aeruginosa* was a microorganism that showed high resistance to treatments with the tested oils. This bacterium has a complex defense mechanism, and has shown low sensitivity to most antibiotics used (PALLERONI, 2010).

Different effects on the results of tests with essential oil of pink pepper fruit (EOPP) can be attributed to factors such as the constituents of the oils and their concentrations. The essential oils of pink pepper evaluated in this study presented as major constituents: alpha-pinene, delta-3-carene and limonene. Only P6 oil presented alpha-phellandrene instead of limonene. However, there were differences in the composition and content of minor constituents of the oils, which can show synergistic effects, enhancing the antimicrobial activity of some oils.

4 CONCLUSION

Thirteen chemical compounds, 10 monoterpenes and 3 sesquiterpenes were detected in the essential oils of pink pepper, of which limonene (31.28%), delta3carene (28.71%) and alpha-pinene (15.01%) were the majority.

In the agar diffusion test, the essential oils of pink pepper from the six rural properties showed inhibition against *S. aureus*, with emphasis on the oils P6, P7, P8 and P10, however, they were ineffective against *E. coli*.

In the Minimum Inhibitory Concentration (MIC) test, the most sensitive bacterium to all oils was *S. aureus*, presenting the lowest values. On the other hand, *P. aeruginosa* proved to be very resistant to their action. The essential oil that showed the greatest effect compared to the others against all bacteria was P7 and the least effective was P10. The essential oils extracted from ripe pink pepper fruits showed inhibition in the growth of the tested pathogenic microorganisms, showing their antimicrobial potential.

Hence, the results found in this work open prospects for further studies to be carried out, especially with P7 and P8 oils, which showed greater prominence in their antimicrobial activity. The application of these essential oils in experiments with other food-borne bacteria and subsequent toxicity tests can add other beneficial information as their use may be promising for the food industry.

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