

Natural extracts from *Eugenia brasiliensis* Lam leaves to improve the shelf-life of fresh tomatoes

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Natural extracts from *Eugenia brasiliensis* Lam leaves to improve the shelf-life of fresh tomatoes

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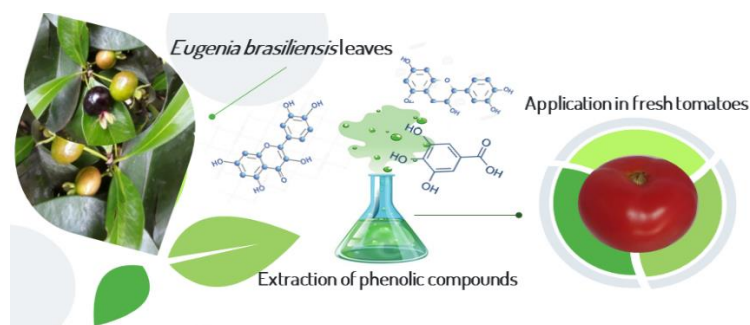
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Abstract

In this work, hydroalcoholic extracts were obtained from leaves of *Eugenia brasiliensis* to be evaluated for the content of bioactive compounds and applied to fresh tomatoes for preservation. Analyzes of total phenolics, flavonoids, antioxidant and antibacterial activity, and toxicity were performed. Tomatoes were treated with the extracts by immersion in an aqueous solution at 200, 600, and 1000 mg/L and evaluated for 28 days for total soluble solids, titratable acidity, maturation index ascorbic acid content, weight loss, and visual test. The presence of gallic acid, rutin, and quercetin was identified in all extracts. The extracts obtained by water and ethanol at 25% e 50% showed better results regarding phenolic compounds; antioxidant and antimicrobial activity. However, the 25 and 50% ethanol extracts were the only ones that showed toxicity. The treatments proposed for the conservation of tomatoes, in concentrations superior to 600 mg/L, showed promising results, mainly in the protection of the fruits regarding the loss of water and, consequently, visual depreciation due to the appearance of wrinkles. Thus, most proposed treatments demonstrated viability because of conserving organoleptic properties of fresh tomatoes.

Graphical Abstract



Keywords:

Solid-liquid extraction; Phenolic compounds; Antioxidant capacity; natural preservatives; Vegetable foods

Statement of Novelty

This work is experimental research to value a native plant of the Brazilian Atlantic Forest, which has leaves rich in phenolic compounds responsible for presenting significant antioxidant and antimicrobial activity. Studies such as these encourage investigations about the applicability of phenolics in different products, including foods. Technological findings such as the present research impact the food industry because they relate the valuation of a matrix without economic value with a viable alternative of application, considering that the industries are looking for high-performance, low-cost solutions that cause less damage to the environment. In this way, this research represents an advance for applying bioactive compounds from grumixameira leaves in foods.

Introduction

The *Eugenia brasiliensis* Lamarck (EBL) is a fruit-bearing plant native from the Atlantic Forest, popularly known as “grumixama” or “Brazilian cherry”. The EBL specie has dense treetop and dark green leaves, which are used in folk medicine for therapeutic and pharmacological purposes [1]. The interest in these leaves concerns their high content of biologically active compounds [2, 3], mainly flavonoids, such as catechin, myricetin, isoquercetin, rutin, quercetin, galangin, and apigenina [4, 5]. Among the benefits conferred to the bioactive compounds from EBL leaves have already been described: antioxidant and antilipemic activity [6], anti-inflammatory [7], and antidepressant [8], as well as have been reported antifungal [9] and antibacterial activity [10].

Besides the healthy benefits, the phenolic compounds from natural sources are potential replacements for some synthetic preservatives used in the food industry, reducing oxidative and microbiological deterioration of the food products, for example [11]. Such effects are essential for maintaining the nutritional and sensory quality of foods, considering that products of plant origin sold *in natura* present greater problems due to their perishability when compared to processed foods.

Natural extracts are potentially interesting in maintaining fresh products' nutritional and sensory quality, as fruits and vegetables have significantly lower shelf-life than processed food. These extracts can be powerful allies to the conventional postharvest technology, extending the shelf-life of the fresh food contributing to their availability to a more significant part of the population [12–16]. However, there are few studies on applying extracts obtained from the leaves of *E. brasiliensis* in foods.

The bioactives' profile on the EBL extracts results from the employed extraction method, the solid-liquid extraction (SLE) techniques preferred due to their low cost and simple operation [17]. Besides being readily removed, water and ethanol stand out as low-cost and biocompatible solvents [7, 18].

Considering the exposure, this work aims to evaluate hydroalcoholic solvents (water, ethanol, and its mixtures) to extract bioactive compounds from the leaves of *Eugenia brasiliensis* Lam. (EBL). For this, the processes conditions were determined regarding the content of total phenolics, total flavonoids, and antioxidant activity of the extracts. The phenolic profile was determined by high-performance liquid chromatography (HPLC) and the toxicity by the *Artemia salina* method. Finally, the extracts were evaluated concerning the ability to improve the shelf-life of fresh tomatoes.

Material and methods

Preparation of extracts from EBL leaves

The EBL extracts were obtained by solid-liquid extraction at 45 °C with constant stirring for 1h and a solid: solvent ratio of 1:30. The evaluated solvents were water, ethanol, and its mixtures (v/v): 75 % of water + 25 % of ethanol (EtOH 25%); 50 % of water + 50 % ethanol (EtOH 50%); and 25 % of water + 75 % of ethanol (EtOH 75%). Subsequently, the mixtures were centrifuged (Thermo Scientific, Microcentrifuge Heraeus™ Fresco™ 21) at 3500 rpm for 15 min at 20 °C, and the supernatant was collected. The solvents removal was carried out in a rotary vacuum evaporator at 40 °C for the extracts

containing ethanol and an L101 manual lyophilizer (Liotop, Brazil) for the aqueous extracts. The dry samples were stored at 4 °C until use.

Total phenolic content, total flavonoids, and antioxidant activity assays

The dry extracts were resuspended in water and characterized by the following analysis: total phenolic content by the Folin Ciocalteu method [19], total flavonoids content [20], and antioxidant activity through the radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) inhibition and of the iron reduction (FRAP) methods [21, 22]. All analyses were carried out in triplicate. A detailed description of the methods carried out can be found in the Supplementary Material.

Identification of phenolic compounds by HPLC-DAD

The phenolic compounds of the extracts from EBL leaves were identified and quantified by high-performance liquid chromatography equipment equipped with a photodiode detector (DAD) as described by Belmiro et al. [23] with some modifications. The ACE 5 C18 column (Bath V13-7473) (250 mm x 4.6 mm, 5µm particle size, 110Å particle porosity) was used for the chromatographic separation at 35 °C with a constant flow rate of 1.2 mL/min. The sample injection volume was 20 µL. Mobile phase A was composed of 0.1% (v/v) water: formic acid and mobile phase B of acetonitrile. The column was eluted following a gradient system: 0-15 min, 8% to 30% B (5 min); 22-35 min, 30% to 70% B (10 min); and 35-40 min, B from 70% to 8%. DAD recorded spectra from 200 to 400 nm, and quantification of phenolic compounds was performed using standard curves for gallic acid, rutin, and quercetin.

Antibacterial activity

The antimicrobial activity of the extracts was evaluated by the disk diffusion method as described by Bauer et al. [24]. The standard strains evaluated were: *Bacillus cereus* (ATCC® 10876™) (Gram-positive), *Escherichia coli* (ATCC® 25922™) (Gram-negative), *Staphylococcus aureus* (ATCC® 25923™) (Gram-positive) and *Salmonella enteritidis* (ATCC® 13076™) (Gram-negative). The microorganisms were reactivated in Muller Hinton broth (Kasvi) at 37°C for 24 h, then transferred to the saline solution (0.9%) until reaching approximately 10⁸ CFU / mL, equivalent to a standard McFarland solution of 0.5 absorbance units recorded by spectrophotometer at 600 nm. Microbial cultures were seeded evenly onto sterile Petri dishes on Mueller Hinton agar (Kasvi). After completely absorbing the inoculum, sterile filter paper discs of 5 mm diameter were deposited and impregnated with 10 µL of dry extracts previously diluted in sterile distilled water at 100, 50, and 20 mg/mL. The antibiotic Chlorophenicol (3%) was used as a positive control and sterile distilled water and ethanol as a negative control. The plates were incubated at 37°C for 24 h, and in sequence, the diameters of the inhibition halos were measured and reported as millimeters of the inhibition zone.

***Artemia salina* toxicity test**

The extracts of EBL leaves were evaluated in a toxicity test with *Artemia salina* larvae as described by Fonseca et al. [25]. For this, 0.2 g of *Artemia salina* eggs were added to 200 mL of 3.5% (w/v) sea salt solution and incubated at 37°C for 48 h under constant lighting. After hatching, the larvae were captured with a Pasteur pipette and transferred to test tubes containing 5 mL of saline solution, totaling 10 individuals of *Artemia* in each tube. The extracts, previously diluted in sterile distilled water, were added to the tubes at 0.05, 0.1, 0.25, 0.50, and 1 mg/mL concentrations. A potassium dichromate solution ($K_2Cr_2O_7$) (mg/mL) was used as a positive control, and only saltwater was used as a negative control. The tubes were incubated at 37°C for 24 h, and the dead and alive individuals were counted to calculate the survival percentage. The lethal doses of each extract for 50% of the *Artemia salina* larvae (LD50) population were estimated with logarithmic curve fitting using the Statistica 10 software. Dose-response curves were constructed using linear regression by graphing sample concentration versus the percentage of dead larvae.

Preservative effect on fresh tomatoes

The tomatoes used for the preservation trial were purchased from a vegetable supply center (CEASA) in Curitiba, Paraná. Fruits of uniform red color and free from any visible injury were chosen. The tomatoes were washed with a 2% (v/v) hypochlorite solution, in sequence with running water and air-dried.

The five types of dry extracts from EBL leaves were diluted in distilled water at 200 mg/L, 600 mg/L, and 1000 mg/L for the treatment. Tomatoes were immersed in the different solutions for 5 min and then dried at room temperature. Tomato samples used as control were immersed only in distilled water. All samples remained exposed on a bench at room temperature for 28 days, and analyses to assess tomatoes' preservation were carried out on the first day (day 0) and after 7, 14, 21, and 28 days of storage.

Tomatoes preservation assessments

The parameters of total soluble solids (°Brix) were determined using a bench-top refractometer (Abbemat 500, Germany). The total acidity expressed as citric acid content, maturation index (°Brix / total acidity), and ascorbic acid content was determined according to Lutz et al. [26] for fruit analyses. According to Kamel [27], Tomato weight loss was evaluated from the difference between the initial and final fruit weight and was expressed as a percentage. The visual test was performed as described by Ishkeh et al. [28], with 10 raters, who selected scores on a scale of 1-10 for the visual attributes of tomatoes. Attributes include 1-2 = Excellent (Firm and bright in color), 3-4 = Good (Only firm), 5-6 = Acceptable (Slightly shrunk), 7-8 = Poor (Shrunk and with other depreciations such as black spots and cracks), 9-10 = Unacceptable (Very compromised surface with the appearance of rot). The results of the visual analysis were presented in terms of the reported mean score.

Statistical analysis

All experimental results were obtained in triplicate and analyzed statistically using the *Statistica 10 software*. Data were analyzed by one-way analysis of variance (ANOVA) and then by *Duncan's* mean comparison test ($p < 0,05$).

Results and discussion

Extracts characterization

The dry extracts resuspend in water and were characterized concerning their total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activity (DPPH and FRAP assays), as shown in Figure 1. The TPC of the extracts decreases in the opposite way of the ethanol concentration in the mixture (Figure 1A). No statistical difference was observed for the solvents from pure water until EtOH 50%, being the highest TPC yield achieved of $370.55 \text{ mg GAE g}^{-1}$ dry extract when the solvent was EtOH 25%.

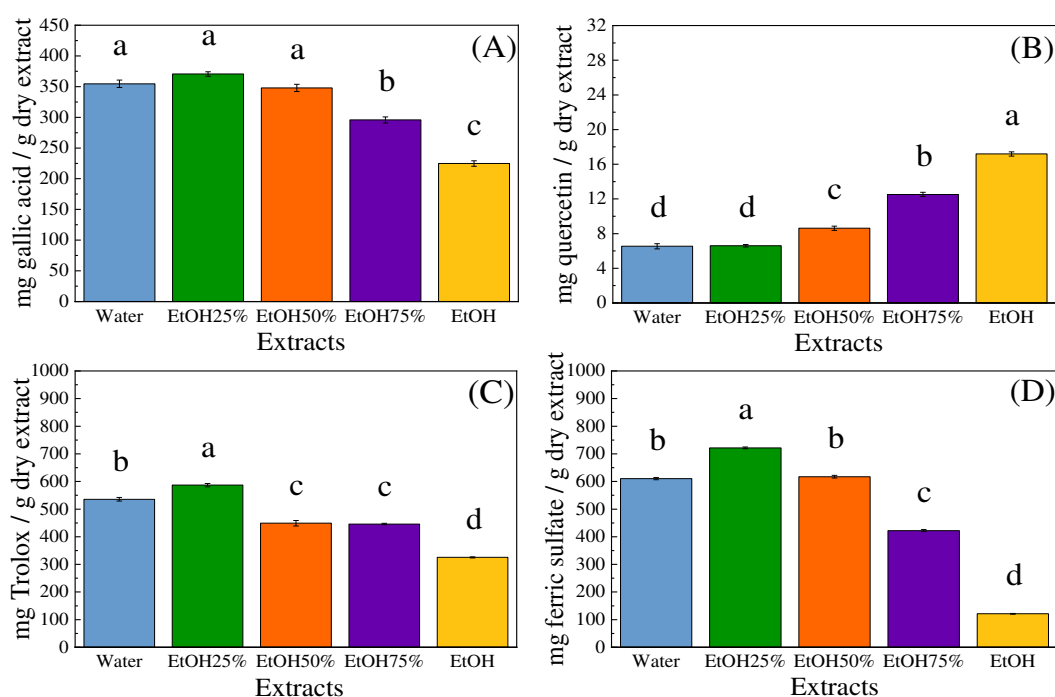


Fig. 1 Content of total phenolics (A), total flavonoids (B), DPPH (C), and FRAP (D) from extracts of EBL leaves obtained with the solvents water, EtOH 25%, EtOH 50%, EtOH 75%, and EtOH. Different letters represent significant differences among extracts (Duncan's test; $p < 0,05$)

On the other hand, the TFC increased with the higher ethanol amount on the mixtures, achieving an amount of $17.19 \text{ mg quercetin g}^{-1}$ of dry extract where ethanol was the solvent (Fig. 1B). Flavonoids, such as quercetin and rutin, which are the significant bioactives on EBL leaves [5], have a hydrophobic character being the extraction favored by low polar solvents, such as ethanol (in comparison to water). This behavior can also be represented as a function of the logarithm of the biomolecules' octanol-water partition coefficient ($\log K_{ow}$). The $\log K_{ow}$ values for quercetin and rutin, as an example, are 1.82 and 0.85,

respectively Rothwell et al. [29] and Pedriali et al. [30], positive values of $\log K_{OW}$ related to hydrophobic compounds, the non-polar behavior increases with higher values of $\log K_{OW}$.

Regarding the antioxidant activity of the extracts, the same tendency of the TPC was observed for both analyses, being the highest antioxidant activity by DPPH of 586.82 mg Trolox g^{-1} of dry extract 610.40 mg ferric sulfate. g^{-1} of the dry extract by FRAP assays, when EtOH 25% was the solvent. The higher values obtained by the FRAP assay are related to the different mechanisms of both analyses. Compounds such as gallic acid present in EBL leaves tend to have a higher ability to reduce the ferric complex; the same was observed by Rotili et al. [31].

Bioactive compounds identification by HPLC-DAD

Table 1 presents the major identified compounds on the EBL leaves extracts: gallic acid, rutin, quercetin, etc. The concentration of these compounds was determined through calibration standard curves, which showed good linearity according to regression analysis ($R^2 > 0.9972$).

Table 1 Concentration of phenolic compounds from extracts of EBL leaves ($\mu g/mL$)

Solvents	Bioactive compound ($\mu g/mL$) / retention time (min)		
	Gallic acid ($\mu g/mL$) / 4.07 (min)	Rutin ($\mu g/mL$) / 12.25 (min)	Quercetin ($\mu g/mL$) / 20.09 (min)
Water	0.99 ± 0.01^d	3.19 ± 0.01^c	0.44 ± 0.01^e
EtOH 25%	1.33 ± 0.00^a	4.41 ± 0.01^a	1.27 ± 0.01^c
EtOH 50%	1.25 ± 0.01^b	3.54 ± 0.03^b	1.55 ± 0.02^a
EtOH 75%	1.14 ± 0.03^c	1.78 ± 0.05^d	1.43 ± 0.02^b
EtOH	0.86 ± 0.02^e	0.97 ± 0.03^e	1.12 ± 0.02^d

According to Duncan's test, different letters in the same column represent significant differences between samples ($p < 0.05$).

The solvent EtOH 25 % stands out in the gallic acid and rutin extraction, agreeing with the TPC analysis. Quercetin, the most hydrophobic among the identified compounds, in its turn, was found in higher concentrations for the EtOH 50% and EtOH% 75 % solvents.

Antibacterial activity

Investigations regarding the antimicrobial activity of plant extracts have fomented interest in its application in food processing to replace chemical additives. Considering this, the disc diffusion method evaluated the EBL leaves extracts. Concerning its ability to inhibit four different bacteria strains, which are commonly associated with food industry problems.

According to Oliveira et al. [32], there is no single evaluation criterion for the size of inhibition halos observed for plant extracts. However, when applying plant extracts to foods, inhibition halos between 8 and 13 mm can be considered moderately inhibitory, while halos above 14 mm can be regarded as highly inhibitory. The inhibition halos of the extracts on the evaluated microorganisms are shown in Table 2. In

general, inhibition halos from 5.87 to 14.11 mm were found, which varied as a function of the concentration from the resuspended extract, being 100 mg/mL the most appropriated for this purpose.

Those obtained when EtOH 25% and EtOH 50% were the solvents, at a concentration of 100 mg/mL, inhibited the growth of the four bacteria tested. It agrees with the high bioactive compounds amount present in these extracts. Additionally, the finds of this work reinforced the assumption that the antimicrobial activity of an extract is directly related to its antioxidant activity.

All the extracts effectively inhibit the gram-positive microorganisms *Staphylococcus aureus* and *Bacillus cereus* and gram-negative *Salmonella* sp. (Table 2). It is known that gram-positive bacteria are more susceptible to the mechanisms of action of antimicrobial agents due to the absence of the lipid barrier in their cellular structure. Gram-negative bacteria, in its turn, have a complex cell structure composed of peptidoglycan, which usually makes it difficult for antimicrobials to penetrate their nucleus [33].

The antimicrobial action of plant extracts in the function of the TPC contain had already been reported in the literature. The inhibition activity can occur in different ways, such as impairing the enzymatic action of bacterial cells by directly linking with the enzyme, interfering in the processes cell's metabolic due to complexing essential metal ions, or modifying metabolic pathways by intercepting electrons [34, 35]. So, it is believed that the inhibitory effect of the extracts on *Salmonella* sp. (negative gram) was caused by the action of the flavonoids, catechin, and quercetin. It agrees with the previously described literature, when these flavonoids showed inhibitory activity against *Salmonella* sp., while any effect was observed against *Escherichia coli* strains [36, 37].

Table 2 Antibacterial activity of the extracts obtained from EBL leaves.

Extracts	Resuspended extracts concentration (mg mL ⁻¹)	Bacteria strains			
		<i>Staphylococcus aureus</i>	<i>Escherichia coli</i>	<i>Salmonella</i> sp.	<i>Bacillus cereus</i>
Water	20	8.49 ^{cde} ± 1.79	-	9.60 ^{efgh} ± 0.01	8.15 ^{ef} ± 0.80
	50	9.27 ^{bcd} ± 0.45	-	11.09 ^{bcd} ± 0.48	8.32 ^{ef} ± 1.05
	100	10.32 ^{bc} ± 0.52	7.20 ^c ± 0.47	10.58 ^{cdefgh} ± 0.32	8.93 ^{cdef} ± 0.44
EtOH25%	20	7.51 ^{de} ± 1.03	-	8.40 ^{gh} ± 0.81	7.99 ^{ef} ± 0.62
	50	8.87 ^{cd} ± 0.01	-	12.92 ^{bc} ± 0.08	8.04 ^{ef} ± 1.12
	100	10.34 ^{bc} ± 0.42	8.29 ^b ± 0.16	13.58 ^b ± 0.97	14.11 ^b ± 0.83
EtOH50%	20	7.98 ^{cde} ± 0.85	-	9.51 ^{efgh} ± 0.36	7.29 ^f ± 0.61
	50	7.24 ^{de} ± 1.11	-	11.27 ^{bcdef} ± 0.96	9.65 ^{cdef} ± 1.41
	100	11.81 ^b ± 0.63	8.71 ^b ± 0.13	11.80 ^{bcdef} ± 0.68	11.37 ^{bcd} ± 0.78
EtOH75%	20	7.71 ^{cde} ± 0.72	-	9.83 ^{defgh} ± 0.93	8.74 ^{def} ± 0.18
	50	9.61 ^{bcd} ± 0.26	-	11.98 ^{bcde} ± 0.62	11.52 ^{bc} ± 0.52
	100	9.85 ^{bcd} ± 0.75	-	12.57 ^{bcd} ± 0.75	9.54 ^{cdef} ± 0.12
EtOH	20	5.87 ^e ± 0.01	-	8.13 ^h ± 0.93	8.78 ^{cdef} ± 0.16
	50	9.17 ^{bcd} ± 0.07	-	9.20 ^{fgh} ± 0.08	9.63 ^{cdef} ± 0.81
	100	9.61 ^{bcd} ± 0.24	-	11.73 ^{bcdef} ± 1.41	10.47 ^{cde} ± 0.56

Controls				
Antibiotic	21.39 ^a ± 0.01	19.79 ^a ± 0.04	33.57 ^a ± 0.53	28.02 ^a ± 0.06
Water	0.0 ^f	0.0 ^d	0.0 ⁱ	0.0 ^g
Ethanol	0.0 ^f	0.0 ^d	0.0 ⁱ	0.0 ^g

According to Duncan's test, different letters represent significant differences between the inhibitory effects of the extracts for each pathogen ($p < 0.05$).

Extracts' Toxicity

Considering the interest in applying the EBL leaves extracts to preserve fresh tomatoes, a preliminary test concerning its toxicity on *Artemia salina* larvae was carried out, as shown in Figure 2. This test is based on the sensibility of the *Artemia salina* larvae to physicochemical changes caused when exposed to toxic components, being a low-cost and straightforward technique to evaluate plants' extracts [9, 25, 38].

As can be seen, the extracts obtained from water, EtOH 75%, and EtOH showed similar percentage survival compared to the control solution (saltwater). It was also calculated the lethal concentration (LC₅₀) for all solvents. The LC₅₀ values and respective regression lines are shown in Table 3. According to the scale proposed by Clarkson et al. [39], extracts from plants with LC₅₀ above 1000 µg/mL are not considered toxic, and from 500 to 1000 µg/mL are low-toxic.

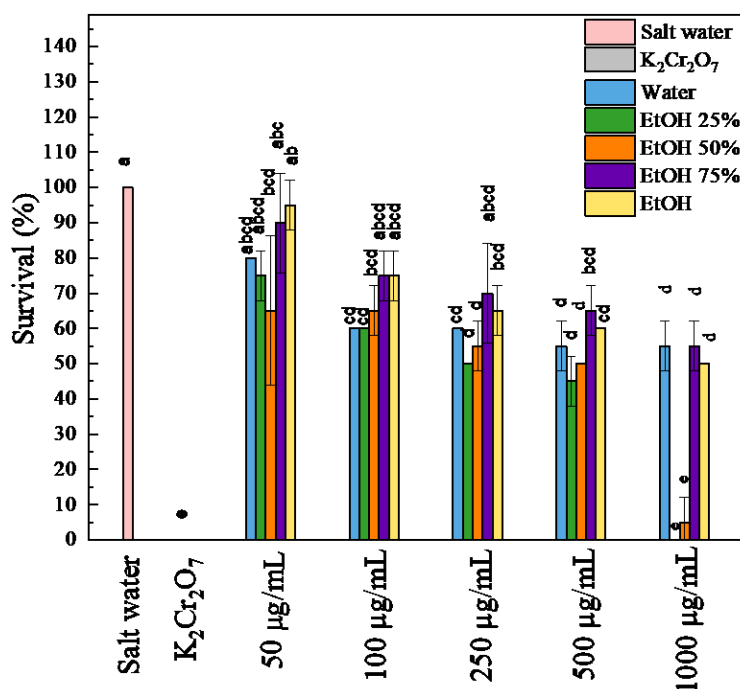


Fig. 2 Toxicity effect of the extracts from EBL leaves in *Artemia salina* cultures. Different letters represent significant differences among treatments (Duncan's test; $p < 0.05$).

Table 3 LC₅₀ values of the extracts from EBL leaves in *Artemia salina*.

Extract	Regression equation	R ²	LC ₅₀ (µg/mL)	Toxicity status
Water	$y = 0.4643x + 3.5847$	0.8174	1230.27	Non-toxic
EtOH 25%	$y = 1.8942x + 0.8392$	0.8455	158.49	Toxic
EtOH 50%	$y = 1.3213x + 2.0289$	0.8103	177.83	Toxic
EtOH 75%	$y = 0.7778x + 2.5671$	0.9458	1318.26	Non-toxic
EtOH	$y = 1.1197x + 1.7683$	0.9216	758.58	Low toxic

The non-toxicity evidenced when water was the solvent explains the use of leaves of the EBL species by traditional medicine in the form of an infusion due to the report of their therapeutic and pharmacological properties, which are associated with the presence of the phenolic compounds revealed in this study. On the other hand, the lower concentration of phenolics found for the EtOH 75% and EtOH extracts reflect a lower antioxidant activity, which did not exhibit significant toxicity against *A. salina*.

The extract obtained using water didn't present toxicity on *A. Salina*, similar to the negative control. It is important to note that when EtOH 25% and EtOH 50% were the solvents, the extracts (1000 µg/L) presented some toxicity. The results reveal that these extracts may show toxicity when used in high concentrations; however, the application proposed in this work concerning the application on the surface of fruits or vegetables, which require sanitation practices before consumption, seems to be a promising alternative.

Effect of treatments with extracts of EBL leaves on the shelf life of tomatoes

The preservative effect of the extract on the tomatoes' shelf-life was evaluated through the following parameters: weight loss, visual analysis of fruit appearance, total soluble solids (Brix°), acidity titratable in citric acid, maturation index, and ascorbic acid content. The treatments were performed using the five extracts at 200 mg/L, 600 mg/L, and 1000 mg/L.

According to Table 4, the weight loss of all samples increases over the days, achieving up to 27.33 % for the control sample (without any treatment). The protective barrier and lower weight loss were observed in the treated samples. The weight loss directly affects the sensory characteristics of the tomatoes and is associated with the loss of water from the fruits. Consequently, the fruits' surface of the fruits takes on a wrinkled appearance. Besides, changes in the firmness profile were also observed. These factors directly interfere with consumer acceptance and market value since visual attributes measure the quality of plant-based products.

Ten evaluators carried out the sensory analysis of the tomatoes by visual analysis (Table 4). After 28 days, most of the treated fruits had lower values in evaluating the decay of the attributes compared with the control sample (9.70). The dehydrated aspect, the presence of stains, and the visible microbial deterioration were determining factors in the classification of the attributes of the tomatoes. Part of the samples is shown in Figure 3. The complete figure can be found in the Supplementary Material. The resuspend extracts on a concentration of 1000mgL⁻¹ extract contributed to the slightest reduction in weight loss (7.76%) and decay of the visual attributes of the fruits (4.10).

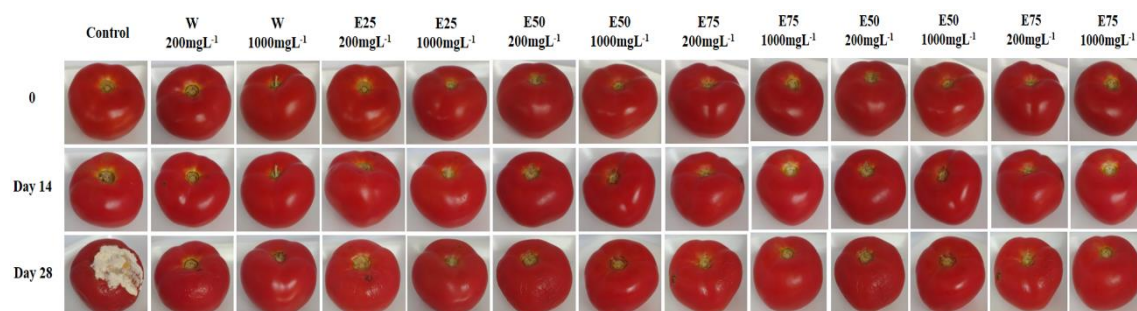


Fig. 3 Effect of different treatments with dry extracts of EBL leaves on the visual features of tomatoes stored for 28 days at 25 °C. Control refers to untreated tomatoes.

Table 4 Weight loss and decay of the visual quality of the treated tomatoes with leaves dry extracts of EBL leaves during storage.

Treatments	Storage periods							
	7th day		14th day		21st day		28th day	
	Weight loss (%)	Decay	Weight loss (%)	Decay	Weight loss (%)	Decay	Weight loss (%)	Decay
Control	2.72 ^b ±	3.40 ^{bc} ±	5.92 ^a ±	3.60 ^c ±	11.42 ^a ±	7.60 ^a ±	27.33 ^a ±	9.70 ^a ±
	0.26	0.97	0.08	0.97	0.29	0.52	0.61	0.48
W 200mgL⁻¹	2.25 ^{de} ±	3.60 ^b ±	4.73 ^{ef} ±	7.10 ^a ±	8.40 ^{fg} ±	7.30 ^a ±	11.12 ^g ±	7.80 ^{bc}
	0.55	1.26	0.18	1.45	0.17	0.48	0.22	± 0.42
W 600mgL⁻¹	1.96 ^f ±	2.40 ^{cdefg}	4.10 ^h ±	3.50 ^c ±	7.72 ^h ±	3.90 ^d ±	10.65 ^h ±	5.60 ^{ef} ±
	0.78	± 0.97	0.36	0.53	0.03	0.74	0.53	0.52
W 1000mgL⁻¹	1.55 ^h ±	1.60 ^{fg} ±	3.38 ^j ±	3.30 ^{cd} ±	5.81 ⁱ ±	3.20 ^e ±	7.76 ^k ±	4.10 ^f ±
	0.32	0.97	0.08	0.95	0.58	0.63	0.94	0.57
E25 200mgL⁻¹	2.81 ^a ±	3.20 ^{bcd} ±	5.73 ^b ±	5.10 ^b ±	10.13 ^c ±	7.20 ^a ±	13.47 ^c ±	7.90 ^b ±
	0.09	1.03	0.02	1.45	0.79	0.63	0.21	0.74
E25 600mgL⁻¹	2.40 ^c ±	2.60 ^{bcd}	4.92 ^d ±	5.40 ^b ±	8.78 ^e ±	5.30 ^c ±	11.85 ^f ±	7.80 ^{bc}
	0.14	± 0.84	0.39	0.84	0.46	0.67	0.06	± 0.79
E25 1000mgL⁻¹	2.01 ^f ±	1.80 ^{efg} ±	4.30 ^g ±	3.20 ^{cd} ±	7.88 ^h ±	5.40 ^c ±	10.67 ^h ±	5.90 ^e ±
	0.81	1.03	0.72	1.14	0.28	0.70	0.48	0.74
E50 200mgL⁻¹	2.73 ^{ab} ±	3.30 ^{bc} ±	5.77 ^b ±	5.60 ^b ±	10.72 ^b ±	6.10 ^b ±	14.52 ^b ±	5.90 ^e ±
	0.42	0.48	0.41	0.97	0.36	0.57	0.55	0.57
E50 600mgL⁻¹	2.64 ^b ±	1.80 ^{efg} ±	5.42 ^c ±	3.20 ^{cd} ±	9.84 ^d ±	5.20 ^c ±	13.12 ^d ±	7.10 ^d ±
	0.87	1.03	0.23	1.40	0.41	0.42	0.16	0.74
E50 1000mgL⁻¹	2.32 ^{cd} ±	1.70 ^{fg} ±	4.80 ^e ±	3.80 ^c ±	8.90 ^e ±	3.60 ^{de}	12.26 ^e ±	5.70 ^{ef} ±
	0.35	0.95	0.02	1.75	0.49	± 0.70	0.62	0.48
E75 200mgL⁻¹	2.32 ^{cd} ±	5.00 ^a ±	4.75 ^{ef} ±	7.40 ^a ±	8.22 ^g ±	7.70 ^a ±	11.00 ^g ±	8.10 ^b ±
	0.56	1.33	0.85	0.97	0.09	0.67	0.32	0.57
E75 600mgL⁻¹	1.90 ^{fg} ±	2.80 ^{bcd} ±	4.12 ^h ±	3.20 ^{cd} ±	7.78 ^h ±	5.60 ^{bc}	10.63 ^h ±	7.30 ^{cd}
	0.62	1.75	0.91	1.03	0.67	± 0.52	0.09	± 0.48
E75 1000mgL⁻¹	1.82 ^g ±	2.20 ^{defg} ±	3.86 ⁱ ±	2.30 ^d ±	6.93 ^j ±	3.60 ^{de}	9.26 ^j ±	5.60 ^{ef} ±
	0.09	1.03	0.03	0.47	0.07	± 0.52	0.74	0.52
E 200mgL⁻¹	2.21 ^e ±	1.60 ^{fg} ±	4.64 ^f ±	4.10 ^c ±	8.40 ^f ±	5.40 ^c ±	13.05 ^d ±	9.50 ^a ±
	0.84	0.97	0.25	0.88	0.91	0.52	0.85	0.53
E 600mgL⁻¹	1.93 ^f ±	5.30 ^a ±	4.07 ^h ±	5.50 ^b ±	7.30 ⁱ ±	5.30 ^c ±	9.86 ⁱ ±	5.80 ^{ef} ±
	0.16	0.48	0.18	0.71	0.14	0.48	0.41	0.79
E 1000mgL⁻¹	1.54 ^h ±	1.40 ^g ±	3.45 ^j ±	3.60 ^c ±	6.01 ^k ±	5.10 ^c ±	7.84 ^k ±	5.20 ^f ±
	0.50	0.84	0.11	0.52	0.38	0.32	0.96	0.82

According to Duncan's test, different letters represent significant differences between the values of the columns (p < 0,05).

The titratable acidity of the tomatoes was expressed in citric acid, and the results obtained after the different treatments with the EBL leaf extracts can be seen in Figure 4.

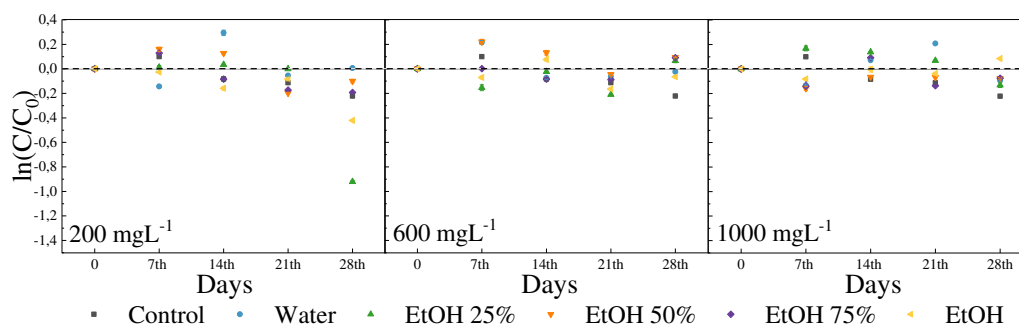


Fig. 4 Effect of treatments with extracts from EBL leaves on the titratable acidity of tomatoes during 28 days of storage.

Beyond the visual changes, the chemical reaction also occurs during the fruit ripening, such as changes in the titratable acidity (AT). In the case of tomatoes, AT tends to decrease since most organic acids are secondary metabolites consumed during respiration and the enzymatic activity of the fruits during storage [12]. In addition, AT is an important parameter to evaluate the fruit quality being desirable to delay these reactions. A 600 mg L⁻¹ was enough for the purposed extracts to reduce the AT changes during all the storage time.

Another important parameter to evaluate the tomatoes' preservation is the concentration of total soluble solids (SST), as shown in Figure 5. In general, the TSS content showed a tendency to increase during storage. However, it was observed that tomatoes treated with extracts at concentrations higher than 600 mg L⁻¹ showed more constant SST levels from the 14th day of storage. The control sample, in its turn, showed a continuous increase in the SST values, indicating the fruit senescence. It occurs due to the combustion of organic acids during respiration, which is also converted into sugars due to the polysaccharides' hydrolysis. In addition, tomatoes are characterized as climacteric fruits, as at the end of maturation, they increase respiratory rate and ethylene production [40].

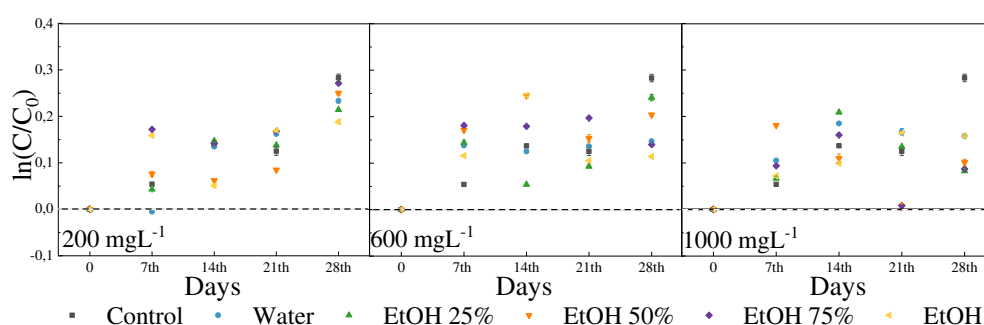


Fig. 5 Effect of treatments with extracts from EBL leaves on tomatoes' total soluble solids (Brix°) during 28 days of storage.

After the AT and TSS determination, the ripening index was calculated (SST/AT), and the results are shown in Figure 6. The results indicated that these treatments delayed the ripening similarly for all evaluated extracts. Tomatoes treated with extracts in concentrations higher than 600 mg L⁻¹ had more constant ripening indices when compared with control tomatoes.

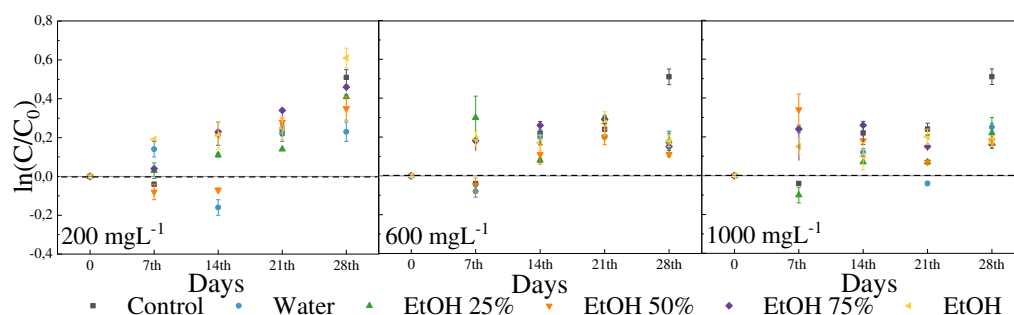


Fig. 6 Effect of treatments with extracts from EBL leaves on the maturation index of tomatoes during 28 days of storage.

The positive effects resulting from the immersion of the tomatoes in the EBL extracts reflected favorable ripening rates. It results from the presence of the phenolic on the extracts and their antioxidant and antimicrobial activities, which contribute directly to the shelf-life of the products. According to Moshari-Nasirkandi et al. [16], immersion treatments of fruits in solutions containing phenolic compounds can preserve the natural phenolic content of the fruits for a long time since these compounds are lost during storage.

A significant decrease can be observed over the 28 days of storage (Figure 7). The extracts obtained with the solvents EtOH 25%, EtOH 75%, and EtOH extracts, at concentrations of 600 and 1000 mg L⁻¹, were the most effective in delaying the losses of ascorbic acid during storage. According to Nair et al. [41], ascorbic acid acts as a protective agent against oxidative damage caused by the ascorbate peroxidase reaction. The results here exposed indicate the capacity of the natural extracts to reduce fruit degradation after a simple immersion treatment.

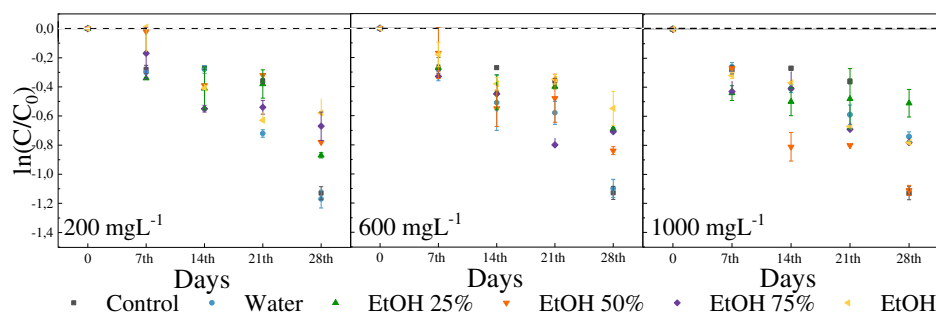


Fig. 7 Effect of treatments with extracts from EBL leaves on the ascorbic acid of tomatoes during 28 days of storage.

Lastly, the SST and TA index was used to determine the half-life of tomatoes (Table 5), where it is possible to note an expressive increase in half-life ($t_{1/2}$) when EtOH 25% and EtOH 50% were the solvents, achieving a $t_{1/2}$ up to 2.45 times longer than the control sample.

Therefore, based on the results obtained, it is possible to affirm that the extracts efficiently preserved the organoleptic characteristics of fresh tomatoes, demonstrating beneficial bioactive properties for prolonging the shelf life of vegetable foods.

Table 5 Effect of treatments on the kinetic parameters of the tomato maturation index.

Treatments	k	R ²	t _{1/2} (days)	Function
Control	0.015	0.82	46.21	y = 0.015x
200mgL⁻¹	Water	0.0095	72.96	y = 0.0095x
	EtOH 25%	0.011	63.01	y = 0.011x
	EtOH 50%	0.0096	72.20	y = 0.0096x
	EtOH 75%	0.016	43.32	y = 0.016x
	EtOH	0.0181	38.29	y = 0.0181x
600mgL⁻¹	Water	0.0083	83.51	y = 0.0083x
	EtOH 25%	0.0088	78.77	y = 0.0088x
	EtOH 50%	0.0062	111.80	y = 0.0062x
	EtOH 75%	0.016	43.32	y = 0.016x
	EtOH	0.0137	50.59	y = 0.0137x
1000mgL⁻¹	Water	0.0082	84.53	y = 0.0082x
	EtOH 25%	0.0061	113.63	y = 0.0061x
	EtOH 50%	0.0064	108.30	y = 0.0064x
	EtOH 75%	0.0145	47.80	y = 0.0145x
	EtOH	0.0097	71.46	y = 0.0097x

Conclusions

Hydroalcoholic extracts from leaves of *Eugenia brasiliensis* Lam. were obtained by a conventional extraction technique. The extracts were evaluated considering their phytochemical characteristics and potential as a natural preservative of fresh tomatoes. The extractions conducted by solvents water and EtOH 25% showed better yields in total phenolic compounds compared with EtOH 50%, EtOH 75%, and EtOH. The same trend was observed in evaluating antioxidant activity in both methods (DPPH and FRAP). In addition, the presence of gallic acid, rutin, and quercetin was identified by HPLC in the five extracts evaluated.

The extracts obtained by solvents water, EtOH 25%, and EtOH 50% stood out concerning the antimicrobial activity of the four bacteria tested when used at a concentration of 100 mg/mL, promoting inhibition halos considered moderately inhibitory by the literature consulted. However, it is suggested that the evaluated extracts present greater action when placed in contact with microbial loads lower than 10⁸ (McFarland), considering that the results of this study can serve to optimize future investigations.

The toxicity evaluation indicated that the extracts obtained from water, EtOH 75%, and pure EtOH have low or no toxicity.

In addition, the feasibility of the proposed treatments was demonstrated to preserve fresh tomatoes. The results showed that the immersion treatments of the fruits, in solutions with the extracts of water, EtOH 25%, and EtOH 50%, in concentrations higher than 600 mg L⁻¹, were responsible for preserving organoleptic properties determinants in the acceptance of consumer's by-products of vegetable origin.

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Author Contributions

All authors contributed to the study's conception and design. Material preparation, data collection, analysis, and the first draft of the manuscript were performed by PGS. AT conducted further investigations. Supervision and funding acquisition performed by MRM and LIM. Reviewing was performed by FOF and LIM. PGS wrote it, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data Availability

The data supporting this study's funding are available on request from the corresponding author.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

References

1. Fischer, D.C.H., Limberger, R.P., Henriques, A.T., Moreno, P.R.H.: Essential oils from leaves of two eugenia brasiliensis specimens from southeastern Brazil. *J. Essent. Oil Res.* 17, 499–500 (2005). <https://doi.org/10.1080/10412905.2005.9698977>
2. Dametto, A.C., Agustoni, D., Moreira, T.F., Plaza, C. V., Prieto, A.M., Silva, T.G.A., Souza, F.O., Boralle, N., Maria Sorbo, J., Silva, D.H.S., Soares, C.P.: Chemical composition and in vitro chemoprevention assessment of *Eugenia jambolana* Lam. (Myrtaceae) fruits and leaves. *J. Funct. Foods.* 36, 490–502 (2017). <https://doi.org/10.1016/j.jff.2017.07.013>
3. Lima, N.P., Cerqueira, S.H.F., Fávero, O.A., Romoff, P., Lago, J.H.G.: Composition and chemical variation of the essential oil from leaves of eugenia brasiliensis lam. And Eugenia sp. (Myrtaceae). *J. Essent. Oil Res.* 20, 223–225 (2008). <https://doi.org/10.1080/10412905.2008.9699997>
4. Infante, J., Rosalen, P.L., Lazarini, J.G., Franchin, M., De Alencar, S.M.: Antioxidant and anti-inflammatory activities of unexplored Brazilian native fruits. *PLoS One.* 11, (2016). <https://doi.org/10.1371/journal.pone.0152974>
5. Siebert, D.A., Bastos, J., Spudeit, D.A., Micke, G.A., Alberton, M.D.: Determination of phenolic profile by HPLC-ESI-MS/MS and anti-inflammatory activity of crude hydroalcoholic extract and

- ethyl acetate fraction from leaves of *Eugenia brasiliensis*. *Brazilian J. Pharmacogn.* 27, 459–465 (2017). <https://doi.org/10.1016/j.bjp.2017.01.008>
6. Lima, A.B., Delwing-de Lima, D., Vieira, M.R., Poletto, M.Z., Delwing-Dal Magro, D., Barauna, S.C., Alberton, M.D., Pereira, E.M., Pereira, N.R., Salamaia, E.M., Siebert, D.A.: Hypolipemiant and antioxidant effects of *Eugenia brasiliensis* in an animal model of coconut oil-induced hypertriglyceridemia. *Biomed. Pharmacother.* 96, 642–649 (2017). <https://doi.org/10.1016/j.biopha.2017.10.047>
 7. Simões, R.R., Kraus, S.I., Coelho, I.S., Dal-Secco, D., Siebert, D.A., Micke, G.A., Alberton, M.D., Santos, A.R.S.: *Eugenia brasiliensis* leaves extract attenuates visceral and somatic inflammatory pain in mice. *J. Ethnopharmacol.* 217, 178–186 (2018). <https://doi.org/10.1016/j.jep.2018.02.026>
 8. Colla, A.R.S., MacHado, D.G., Bettio, L.E.B., Colla, G., Magina, M.D.A., Brighente, I.M.C., Rodrigues, A.L.S.: Involvement of monoaminergic systems in the antidepressant-like effect of *Eugenia brasiliensis* Lam. (Myrtaceae) in the tail suspension test in mice. *J. Ethnopharmacol.* 143, 720–731 (2012). <https://doi.org/10.1016/j.jep.2012.07.038>
 9. Sardi, J. de C.O., Freires, I.A., Lazarini, J.G., Infante, J., de Alencar, S.M., Rosalen, P.L.: Unexplored endemic fruit species from Brazil: Antibiofilm properties, insights into mode of action, and systemic toxicity of four *Eugenia* spp. *Microb. Pathog.* 105, 280–287 (2017). <https://doi.org/10.1016/j.micpath.2017.02.044>
 10. Benfatti, C.S., Cordova, S.M. de, Guedes, A., Magina, M.D.A., Cordova, C.M.M. de: Atividade antibacteriana in vitro de extratos brutos de espécies de *Eugenia* sp frente a cepas de mollicutes. *Rev. Pan-Amazônica Saúde.* 3, 33–39 (2010). <https://doi.org/10.5123/S2176-62232010000200003>
 11. Martillanes, S., Rocha-Pimienta, J., Cabrera-Bañegil, M., Martín-Vertedor, D., Delgado-Adámez, J.: Application of Phenolic Compounds for Food Preservation: Food Additive and Active Packaging. In: *Phenolic Compounds - Biological Activity*. pp. 116–124. InTech (2017)
 12. Banu A, T., Ramani P, S., Murugan, A.: Effect of seaweed coating on quality characteristics and shelf life of tomato (*Lycopersicon esculentum* mill). *Food Sci. Hum. Wellness.* 9, 176–183 (2020). <https://doi.org/10.1016/j.fshw.2020.03.002>
 13. Fan, X.J., Zhang, B., Yan, H., Feng, J.T., Ma, Z.Q., Zhang, X.: Effect of lotus leaf extract incorporated composite coating on the postharvest quality of fresh goji (*Lycium barbarum* L.) fruit. *Postharvest Biol. Technol.* 148, 132–140 (2019). <https://doi.org/10.1016/j.postharvbio.2018.10.020>
 14. Islam, T., Afrin, N., Parvin, S., Dana, N.H., Rahman, K.S., Zzaman, W., Islam, M.N.: The impact of chitosan and guava leaf extract as preservative to extend the shelf-life of fruits. *Int. Food Res. J.* 25, 2056–2062 (2018)
 15. Khaliq, G., Ramzan, M., Baloch, A.H.: Effect of Aloe vera gel coating enriched with *Fagonia indica* plant extract on physicochemical and antioxidant activity of sapodilla fruit during postharvest storage. *Food Chem.* 286, 346–353 (2019). <https://doi.org/10.1016/j.foodchem.2019.01.135>

16. Moshari-Nasirkandi, A., Alirezalu, A., Hachesu, M.A.: Effect of lemon verbena bio-extract on phytochemical and antioxidant capacity of strawberry (*Fragaria x ananassa* Duch. cv. Sabrina) fruit during cold storage. *Biocatal. Agric. Biotechnol.* 25, 101613 (2020).
<https://doi.org/10.1016/j.bcab.2020.101613>
17. Zhang, Q.W., Lin, L.G., Ye, W.C.: Techniques for extraction and isolation of natural products: A comprehensive review. *Chinese Med. (United Kingdom)*. 13, 1–26 (2018).
<https://doi.org/10.1186/s13020-018-0177-x>
18. Chemat, Abert Vian, Ravi, Khadhraoui, Hilali, Perino, Tixier: Review of Alternative Solvents for Green Extraction of Food and Natural Products: Panorama, Principles, Applications and Prospects. *Molecules*. 24, 3007 (2019). <https://doi.org/10.3390/molecules24163007>
19. Singleton, V.L., Rossi, J.A.J.: Colorimetry to total phenolics with phosphomolybdic acid reagents. *Am. J. Enol. Vinic.* 16, 144–58 (1965)
20. Prommuak, C., De-Eknamkul, W., Shotipruk, A.: Extraction of flavonoids and carotenoids from Thai silk waste and antioxidant activity of extracts. *Sep. Purif. Technol.* 62, 444–448 (2008).
<https://doi.org/10.1016/j.seppur.2008.02.020>
21. Brand-Williams, W., Cuvelier, M.E., Berset, C.: Use of a free radical method to evaluate antioxidant activity. *LWT - Food Sci. Technol.* 28, 25–30 (1995). [https://doi.org/10.1016/S0023-6438\(95\)80008-5](https://doi.org/10.1016/S0023-6438(95)80008-5)
22. Rufino, M. do S.M., Alves, R.E., Sousa De Brito, E., Maia De Moraes, S., De Goes Sampaio, C., Pérez-Jiménez, J., Saura-Calixto, F.D., Maria, F., Rufino, S.M.: Metodologia Científica: determinação da atividade antioxidantes total em frutas pelo método de redução do ferro (FRAP), (2006)
23. Belmiro, T.M.C., Pereira, C.F., Paim, A.P.S.: Red wines from South America: Content of phenolic compounds and chemometric distinction by origin. *Microchem. J.* 133, 114–120 (2017).
<https://doi.org/10.1016/j.microc.2017.03.018>
24. Bauer, A.W., Kirby, W.M.M., Sherris, J.C., Turck, A.M., Graevenitz, A. Von: Antibiotic Susceptibility Testing by a Standardized Single Disk Method. *Am. J. Clin. Pathol.* 45, 493–496 (1966). [https://doi.org/10.1016/S0305-4179\(78\)80006-0](https://doi.org/10.1016/S0305-4179(78)80006-0)
25. Fonseca, R.C., de Souza, N.A., Correa, T.C.L., Garcia, L.F., dos Reis, L.G.V., Rodriguez, A.G.: Assessment of toxic potential of cerrado fruit seeds using *Artemia salina* bioassay. *Food Sci. Technol.* 33, 251–256 (2013). <https://doi.org/10.1590/S0101-20612013005000032>
26. Lutz, I.A.: 1ª Edição Digital. In: *Métodos físicos-químicos para análise de Alimentos*. pp. 83–158 (2008)
27. Kamel, H.M.: Impact of Garlic Oil, Seaweed Extract and Imazalil on Keeping Quality of Valencia Orange Fruits During Cold Storage. *J. Hortic. Sci. Ornam. Plants*. 6, 116–125 (2014).
<https://doi.org/10.5829/idosi.jhsop.2014.6.3.1145>
28. Rahmanzadeh Ishkeh, S., Asghari, M., Shirzad, H., Alirezalu, A., Ghasemi, G.: Lemon verbena (*Lippia citrodora*) essential oil effects on antioxidant capacity and phytochemical content of raspberry (*Rubus ulmifolius* subsp. *sanctus*). *Sci. Hortic. (Amsterdam)*. 248, 297–304 (2019).
<https://doi.org/10.1016/j.scienta.2018.12.040>

29. Rothwell, J.A., Day, A.J., Morgan, M.R.A.: Experimental determination of octanol-water partition coefficients of quercetin and related flavonoids. *J. Agric. Food Chem.* 53, 4355–4360 (2005). <https://doi.org/10.1021/jf0483669>
30. Pedriali, C.A., Fernandes, A.U., Bernusso, L.D.C., Polakiewicz, B.: The synthesis of a water-soluble derivative of rutin as an antiradical agent. *Quim. Nova.* 31, 2147–2151 (2008). <https://doi.org/10.1590/S0100-40422008000800039>
31. Rotili, M.C.C., Villa, F., Braga, G.C., de França, D.L.B., Rosanelli, S., Laureth, J.C.U., da Silva, D.F.: Compostos bioativos, atioxidante e características físico-químicas de frutos de doviális. *Acta Sci. - Agron.* 40, (2018). <https://doi.org/10.4025/actasciagron.v40i2.35465>
32. Oliveira, F.C. de, Marques, T.R., Machado, G.H.A., Carvalho, T.C.L. de, Caetano, A.A., Batista, L.R., Corrêa, A.D.: Jabuticaba skin extracts: phenolic compounds and antibacterial activity. *Brazilian J. Food Technol.* 21, 1–11 (2018). <https://doi.org/10.1590/1981-6723.10817>
33. Rabêlo, S.V., Da Costa, M.M., Libório, R.C., Almeida, J.R.G.D.S.: Antioxidant and antimicrobial activity of extracts from atemoia (*Annona cherimola* Mill. x *A. squamosa* L.). *Rev. Bras. Frutic.* 36, 265–271 (2014). <https://doi.org/10.1590/S0100-29452014000500031>
34. Al-Habib, A., Al-Saleh, E., Safer, A.M., Afzal, M.: Bactericidal effect of grape seed extract on methicillin-resistant *Staphylococcus aureus* (MRSA). *J. Toxicol. Sci.* 35, 357–364 (2010). <https://doi.org/10.2131/jts.35.357>
35. Narayani, M., Subanthini, A., Jayakumar, M.: Antimicrobial Activity and Phytochemical Analysis of Citrus Fruit Peels -Utilization of Fruit Waste. 3, 5414–5421 (2011)
36. Bouarab-Chibane, L., Forquet, V., Lantéri, P., Clément, Y., Léonard-Akkari, L., Oulahal, N., Degraeve, P., Bordes, C.: Antibacterial properties of polyphenols: Characterization and QSAR (Quantitative structure-activity relationship) models. *Front. Microbiol.* 10, (2019). <https://doi.org/10.3389/fmicb.2019.00829>
37. Das, Q., Lepp, D., Yin, X., Ross, K., McCallum, J.L., Warriner, K., Marcone, M.F., Diarra, M.S.: Transcriptional profiling of *Salmonella enterica* serovar Enteritidis exposed to ethanolic extract of organic cranberry pomace. *PLoS One.* 14, 1–20 (2019). <https://doi.org/10.1371/journal.pone.0219163>
38. Braguini, W.L., Pires, N.V., Alves, B.B.: Phytochemical analysis, antioxidant properties and Brine Shrimp lethality of unripe fruits of *Solanum viarum*. *J. Young Pharm.* 10, 159–163 (2018). <https://doi.org/10.5530/jyp.2018.10.36>
39. Clarkson, C., Maharaj, V.J., Crouch, N.R., Grace, O.M., Pillay, P., Matsabisa, M.G., Bhagwandin, N., Smith, P.J., Folb, P.I.: In vitro antiplasmodial activity of medicinal plants native to or naturalised in South Africa. *J. Ethnopharmacol.* 92, 177–191 (2004). <https://doi.org/10.1016/j.jep.2004.02.011>
40. Luengwilai, K., Fiehn, O.E., Beckles, D.M.: Comparison of leaf and fruit metabolism in two tomato (*Solanum lycopersicum* L.) genotypes varying in total soluble solids. *J. Agric. Food Chem.* 58, 11790–11800 (2010). <https://doi.org/10.1021/jf102562n>
41. Nair, M.S., Saxena, A., Kaur, C.: Effect of chitosan and alginate based coatings enriched with pomegranate peel extract to extend the postharvest quality of guava (*Psidium guajava* L.). *Food*

Chem. 240, 245–252 (2018). <https://doi.org/10.1016/j.foodchem.2017.07.122>

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