Original Article
Food Science and Technology
ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)
DOI: https://doi.org/10.5327/fst.00398

Antioxidant capacity and antimicrobial activity of loquat (*Eriobotrya japonica*) extracts from Tenango del Valle, State of Mexico

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Abstract

Nationwide, the State of Mexico is the leading producer of loquat (*Eriobotrya japonica*); however, there are no records about the antioxidant and antimicrobial properties of such fruits from this place. The objective of this research was the evaluation of extracts of different loquat morphological structures (pulp with epidermis, leaves, and seeds) in ethanolic and hydromethanolic solvents. Four methods were used to evaluate the antioxidant capacity: 2,2-Diphenyl-1-Picrylhydrazyl (DPPH), N,N-Dimethyl-p-phenylenediamine Dihydrochloride (DMPD), Folin–Ciocalteu, and ferric-reducing antioxidant power (FRAP). Antimicrobial activity was determined using disk diffusion assays applied to two bacterial strains, *Escherichia coli* and *Salmonella* Typhimurium, and two phytopathogenic fungi strains, *Fusarium oxysporum* and *Rhizoctonia solani.* An analysis of variance and Tukey's test at 5% were performed. There were significant differences between the plant material and the solvent used ($p < 0.05$). The results showed that the ethanol pulp extract presented the highest antioxidant capacity by the DPPH method; in DMPD, the ethanol leaf extract indicated high values of Trolox equivalents and presented the highest values for FRAP, and hydromethanol pulp also had high antioxidant activity; finally, for the Folin–Ciocalteu method, highest values were obtained from the seed extracts with both solvents. The extracts obtained from the pulp with ethanol and hydromethanol showed antibacterial capacity against E. coli and S. typhimurium. Antifungal activity was only present only in the pulp extract obtained with hydromethanol.

Keywords: phenols; trolox; bacteria; fungi.

Practical Application: The practical application of the research lies in the evaluation of the antioxidant and antimicrobial potential of loquat (*Eriobotrya japonica*) extracts using pulp with peel, seeds, and leaves to compare them with each other and report the component with the best values to be used as a natural disinfectant, including its use as a natural fungicide to control phytosanitary problems in fruit and vegetable crops, to extend the shelf life and increase food hygiene.

1 INTRODUCTION

Nowadays, it is known that various bioactive molecules in plant extracts exhibit antioxidant activity capable of stopping oxidative reactions in cells caused by free radicals. Natural compounds with antioxidant capacity used in foods, pharmaceuticals, and supplements have demonstrated the ability to reduce cardiovascular and neurodegenerative diseases due to their anti-inflammatory, antithrombotic, antiallergic, antitumor, and antiasthmatic properties (Vilaplana, 2007). Antioxidant compounds have also shown antimicrobial activity in controlling pests and phytopathogenic diseases, as well as in enteropathogenic bacteria that affect human health, causing foodborne diseases (FBDs) and food poisoning (Thombre et al., 2012).

Organisms identified in FBDs include *Escherichia coli, Salmonella enterica, Staphylococcus aureus,* and *Micrococcus leteus.* The main causative agents in hospitalization cases are *Escherichia coli* O157:H7 and *Salmonella* Typhimurium (OMS-FAO, 2007; Signorini et al., 2006). While FBD is particularly important, the issue of microorganisms causing plant diseases is equally significant. Phytopathogenic fungi directly impact agriculture, destroying one-third of annual crops, leading to significant economic losses due to crop contamination, wilting, color changes, rotting, or inducing vascular necrosis. The main genera of phytopathogenic fungi include *Fusarium, Gibberella, Rhizoctonia, Verticillium, Alternaria,* and *Botrytis*, among others (Kagale et al., 2004).

Currently, there is increasing resistance to bactericides, fungicides, and nematicides in controlling agricultural crop diseases, leading to the use of plant-derived products with antimicrobial activity (Malheiro et al., 2019), and in combating FBDs (Ullah et al., 2020), promoting sustainable microorganism management and reducing environmental contamination (Thombre et al., 2012).

Received: 10 Sept., 2024.
Accepted: 2 Oct., 2024.
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Conflict of interest: nothing to declare.
Funding: COMECyT, project number FICDTEM-2023-15.

In this context, loquat has proven to be an important source of bioactive molecules with antioxidant and antimicrobial properties (Gülçin et al., 2011; Parrado Muñoz, 2021; Rivas et al., 2020; Safari & Ahmady, 2019; Turola et al., 2017; Ventura, 2021; SaliHoğlu et al., 2013). The highest loquat production is in the State of Mexico, producing more than 70 tons per year (SIAP, 2019). Chemical studies have shown that fruits contain phenols and carotenoids, which possess anticancer, anti-inflammatory, antioxidant, and hypoglycemic effects (Parrado Muñoz, 2021). Its leaves are used in home remedies for coughs and asthma, and the fruit acts as a sedative and is consumed to stop vomiting and thirst (Mendoza et al., 2004). The leaf extract has been reported to have a free-radical scavenging capacity evaluated by 2,2-Diphenyl-1-Picrylhydrazyl (DPPH) and 2, 2'-azino-bis -3-ethylbenzothiazolin-6-sulfonic acid (ABTS) methods, and it demonstrated 41.68% of Trolox units in the β-carotene bleaching assay (Rosas, 2015).

Regarding antimicrobial activity, Tanaka et al. (2008) demonstrated that the methanol-aqueous extract of loquat leaves inhibited bacterial strains of *Streptococcus mutans* and *Staphylococcus epidermidis*. Regarding antifungal activity, Shen et al. (2021) reported that the loquat leaf extract showed a high degree of inhibition against *Penicillium digitatum* evaluated in postharvest citrus. Although the antioxidant and antimicrobial capacities of loquat have already been described, there are no studies confirming these properties under the climatic and geographical conditions of the State of Mexico, as well as in other experimental conditions (hydromethanol and ethanol solvents) and morphological structures (leaves, pulp, and seeds). Therefore, the objective of this research was to evaluate the antioxidant capacity and antimicrobial activity of extracts obtained from the morphological structures of loquat (*Eriobotrya japonica*) produced in Tenango del Valle, State of Mexico.

2 MATERIALS AND METHODS

This research was conducted in the Food Safety and Food Texture Laboratories of the Faculty of Agricultural Sciences at the Autonomous University of Mexico State.

2.1 Obtaining plant material

Loquat fruits and leaves (*Eriobotrya japonica*) were harvested at physiological maturity during autumn and were acquired in the municipality of Tenango del Valle, State of Mexico, located in the Metropolitan Area of the Valley of Toluca, with coordinates 18°57′38″N 99°34′32″W, at an altitude of 2,560 meters above sea level. This municipality is characterized by temperate and semi-cold subhumid climatic conditions, with maximum average temperatures frequently exceeding 20°C and annual precipitation between 700 and 1,300 mm (Ayuntamiento de Tenango del Valle, 2022; INEGI, 2010).

2.2 Preparation

All plant materials (leaves, pulp, and seeds) were washed with sterilized distilled water and disinfected with 0.05% sodium hypochlorite. The samples were then exposed to UV light in a hood for 20 min for more efficient disinfection. The leaves and seeds were placed in a dehydrator at 55°C for 10–12 h to achieve a moisture content of 8–10% (NOM-116-SSA1-1994). After drying, the samples were ground in a Pulvex 200 mill to reduce their size to a homogeneous state.

The pulp, along with the epicarp, was processed in an Oster® blender. All samples were stored in glass jars with their respective solvents (ethanol and hydromethanol) to begin the maceration process.

2.3 Obtaining the extracts

The samples were classified and labeled according to the type of solvent (ethanol and hydromethanol) and plant material as follows: ethanol pulp (EP), ethanol leaf (EH), ethanol seed (ES), hydromethanol pulp (HP), hydromethanol leaf (HH), and hydromethanol seed (HS).

2.4 Determination of antioxidant capacity

Four methods were used to determine the antioxidant capacity: DPPH, DMPD, FRAP, and Folin–Ciocalteu applied to the six loquat extracts.

2.5 Determination of antioxidant capacity by the DPPH method (2,2-diphenyl-1-picrylhydrazyl)

The method developed by Brand-Williams et al. (1995) with modifications was used. The DPPH 3 mM reagent (Sigma) was prepared by dissolving 0.0266 g in 200 mL of methanol. Subsequently, 400 µL of each extract sample and 200 µL of distilled water were added to a 2.0-mL cell and reacted with 1,400 µL of DPPH reagent and left to react for 30 min, and absorbance was read at 517 nm in a spectrophotometer (UV Thermo Genesys 10-S, Rochester, NY, USA) after adding the sample.

Based on the obtained absorbances, a calibration curve was created using ascorbic acid (Sigma-Aldrich), allowing the determination of the inhibition percentage and the antioxidant capacity of each extract, expressing the results in mM Trolox equivalent/gps.

2.6 Determination of antioxidant capacity by the DMPD Method (N, N-dimethyl-p-phenylenediamine dihydrochloride)

Antioxidant activity was determined using the DMPD method proposed by Fogliano et al. (1999). The DMPD reagent (Aldrich) was added along with a 0.1 M acetate buffer at a pH of 5.25 (Merck) and 0.05 M ferric chloride hexahydrate (Sigma-Aldrich). Then, 1,000 µL was placed in a 1.5-mL cell, and 50 µL of each extracted sample was added, left to rest for 10 min, and absorbance was read at 505 nm in a spectrophotometer for each extract. The inhibition percentage was obtained using a calibration curve based on Trolox. The results were expressed in mM Trolox equivalent/gps.

2.7 Determination of antioxidant capacity by the Folin–Ciocalteu method

Total polyphenols were quantified using the colorimetric Folin–Ciocalteu method reported by Singleton et al. (1999), with modifications. In a 1.5-mL cell, 75 µL of Folin–Ciocalteu reagent and 120 µL of each extract sample were added. After 5 minutes, 300 µL of 15% sodium carbonate (Na_2CO_3) (Sigma-Aldrich) and

300 µL of distilled water were added. The solution was left to rest for 2 h, and absorbance was read at 760 nm in a spectrophotometer. The calibration curve was obtained using a gallic acid solution (MEYER). The polyphenol content of the samples was reported in mg of gallic acid equivalent/mL of extract.

2.8 Determination of antioxidant capacity by the FRAP method (ferric-reducing antioxidant power assay)

The FRAP method (Benzie & Strain, 1996; Pulido et al., 2000) was performed with modifications. The FRAP reagent was prepared with a 300-mM acetate buffer (Merck) at a pH of 3.6; a 10 mM Tris (2-pyridyI)-s-triazine (TPTZ) solution (Sigma-Aldrich) in 40 mM HCl (EMSURE); and 20 mM FeCl3 (Sigma-Aldrich) in 10 mL of water. The solution was heated to 37°C for 30 min. Subsequently, in a 1.5-mL cell, 30 µL of each extract sample, 90 µL of water, and 900 µL of FRAP reagent were added. Absorbances were determined at 595 nm in a spectrophotometer. Finally, a calibration curve was created using 25-mM $FeSO_4$ (Sigma-Aldrich), and the results were expressed in mM Trolox equivalent/gps of loquat extract.

2.9 Determination of antimicrobial activity

To determine the antimicrobial activity of the six loquat extracts, their inhibitory effect on two bacterial strains, *Salmonella* Typhimurium and *Escherichia coli* O157:H7, and two phytopathogenic fungal strains, *Fusarium oxysporum* and *Rhizoctonia solani*, was evaluated.

2.10 Reactivation of bacterial strains

Two Gram-negative bacterial strains, *Escherichia coli* O157:H7 and *Salmonella* Typhimurium, stored in a water–glycerol solution (50:50) at -20°C were used. The bacteria were reactivated in Tryptic Soy Broth (CST) (DIBICO®) and then grown in differential and selective media, MacConkey agar (DIBICO®), Salmonella Shigella agar (BD BIOXON®), and Chromogenic E. coli O157:H7 agar (DIBICO®) for 24 h at 37°C. They were identified by biochemical reactivity tests (IMViC): indole, mobility, Voges-Proskauer, sulfide, complemented by methyl red, Simmon's citrate, and ornithine decarboxylation (Koneman & Allen, 2008). Gram staining tests were also conducted. After confirming the strains, they were streaked on MacConkey agar (BD BIOXON) using the cross-streak technique, incubated at 35°C for 24 hours, and then stored at 4°C until use.

2.11 Subculturing the fungi

F. oxysporum and *R. solani* were placed on potato dextrose agar medium (PDA) (BD BIOXON), and samples were transferred to the prepared medium using the cork borer technique and incubated for 5–10 days at 25°C. Once fungal growth was observed, identification was carried out by observing macroscopic and microscopic morphological characteristics. The microscopic description of the colonies grown on the medium was done by preparing semipermanent slides stained with cotton blue, and their reproductive structures were identified using a Leica Binocular CME, ML23 microscope, confirming their identity.

2.12 Evaluation of extracts for inhibition of Salmonella *Typhimurium and* Escherichia coli *O157:H7*

The extracts were diluted in 10% dimethyl sulfoxide at a proportion of 25:75 (Pinkee et al., 2011). To evaluate antibacterial activity, a disk diffusion assay was performed according to the methodology proposed by Bauer et al. (1966). Filter paper disks (8 µm pore size, 5 mm diameter) were sterilized in an autoclave at 120 lb pressure for 15 min. Under aseptic conditions, a massive seeding of pure bacteria with a sterile swab on a Petri dish with 20 mL of Mueller–Hinton agar (BD BIOXON) was performed. The filter paper disks were immersed in 100 µL of each extract for 30 min; for the control, the disks were impregnated with sterilized distilled water. The dishes were incubated at 35 ± 2°C for 24 h, the test was interpreted as positive when zones of inhibition were present, and the inhibition halos were measured using a digital vernier caliper (Thomas Scientific).

2.13 Evaluation of extracts for inhibition of Fusarium oxysporum *and* Rhizoctonia solani

To evaluate the antifungal effect, Petri dishes with PDA medium (BD BIOXON) were prepared. In the center of each dish, a sensi-disc was placed, replicating the previously mentioned immersion method. Around this, four agar discs with mycelium were placed equidistant from the extract-impregnated disc. For the control, the same procedure was followed, impregnating the sensi-disc with sterile distilled water. These assays were conducted in triplicate for each extract and fungus. The dishes were incubated at 25°C for 7 days, and the perimeter of mycelial growth inhibition was measured. Finally, the percentage of growth inhibition caused by each treatment compared to the control was calculated using the formula reported by Corzo (2012) (Equation 1):

$$\%Inhibition = \frac{extract\ halo\ diameter - white\ halo\ diameter}{halo\ diameter\ positive\ control - white\ diameter}\ x\ 100 \qquad (1)$$

2.14 Experimental design and statistical analysis

A completely randomized design with a multifactorial arrangement was used for the treatment analysis. Six treatments (extracts) and one control were applied across four methods for determining antioxidant capacity, and the same treatments were applied to assess antimicrobial activity through inhibition halos in *Salmonella* Typhimurium and *Escherichia coli* O157:H7. The obtained data were subjected to an analysis of variance. When significant differences were found, a Tukey test at 5% was applied. Only descriptive statistics were applied to the inhibition halos of *F. oxysporum* and *R. solani*.

3 RESULTS AND DISCUSSION

3.1 Determination of antioxidant capacity

3.1.1 Determination of antioxidant capacity by the DPPH method

The results obtained for the antioxidant capacity in loquat by the DPPH method were expressed in mM Trolox equivalent/

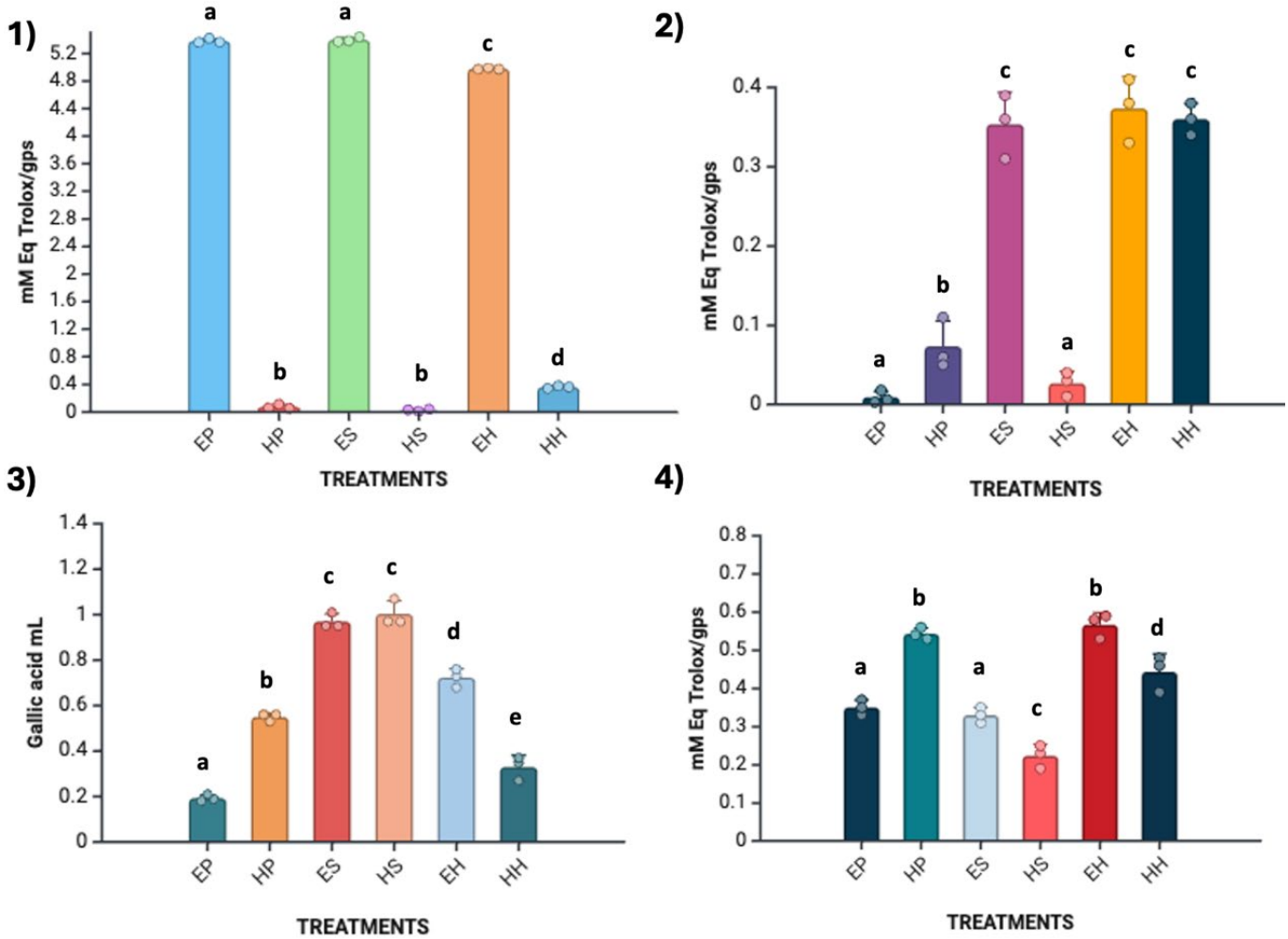
gps, which are shown in Figure 1. The extraction of antioxidant compounds with the ethanol solvent showed higher effectiveness than with hydromethanol; in consequence, the results showed statistically significant differences ($p < 0.05$) according to the solvent used in the different extracts (leaves, seeds, and pulp). There were no significant differences ($p < 0.05$) between the HP and HS treatments, as well as in EP and ES. This study shows that the ES extract obtained the most effective inhibition of the DPPH radical with 5.38 mM Eq Trolox/gps, followed by EP (5.37 mM Eq Trolox/gps) and EH (4.97 mM Eq Trolox/gps). According to Rivas et al. (2020), in a study conducted on several fruits, the highest antioxidant activity in the aqueous and lyophilized loquat extract obtained a value of 7.56 mM Eq Trolox/gps, while in the present study, the EP extract showed 5.38 mM Eq Trolox/gps. These results indicate that the solvent can determine the amount of antioxidants by this method.

On the contrary, Cevallos and Bravo (2021) conducted a study on dried loquat leaves (*Achras zapota*) with hydroethanol (80:20 %v/v) as a solvent in which a value of 0.0217 mM Eq Trolox/gps was obtained, which contrasts with the results obtained in this study, where the EH (0.38 mM Eq Trolox/gps) and HH (0.36 mM Eq Trolox/gps) extracts showed a higher amount.

Safari and Ahmady (2019) reported a result of 69.43% inhibition of the DPPH radical in their study about the antioxidant activity of methanolic extracts on loquat leaves, which coincides with the HH extract of 69%, unlike that found with the EH extract of 32%, both obtained in this study.

3.1.2 Determination of the antioxidant capacity by DMPD method

The results of the DMPD method are shown in Figure 1, where significant differences ($p < 0.05$) in DMPD radical inhibition are observed as a function of the solvent used for EP and HP extracts, as well as between ES and HS. While EH and HH did not present significant differences, it is worth highlighting there is a higher inhibition obtained in both leaf extracts: EH (0.38 mM Eq Trolox/gps) and HH (0.36 mM Eq Trolox/gps), followed by ES (0.35 mM Eq Trolox/gps). The remaining three extracts (EP, HS, and HP) showed lower inhibition than the others.



EP: ethanol pulp, HP: hydromethanol pulp, ES: ethanol seed, HS: hydromethanol seed, EH: ethanol leaf, HH: hydromethanol leaf; **(1)** Free radical inhibition, DPPH method. **(2)** Free radical inhibition, DMPD method. **(3)** Phenolic compounds, Folin–Ciocalteu method. **(4)** Reduction capacity of Fe^{3+} al Fe^{2+}, FRAP method; Means followed by the same letters indicate the absence of significant differences by Tukey's test ($p < 0.05$).

Figure 1. Results of the antioxidant capacity of loquat extracts.

Gülçin et al. (2011) reported that the aqueous and freeze--dried extract of common loquat (*Mespilus germanica*) fruits contains 1.88x10-5 mM Eq Trolox/gps, as compared to what was obtained in the present study where EP obtained 0.01 mM Eq Trolox/gps and HP obtained 0.07 mM Eq Trolox/gps; we can attribute these differences to the solvent and loquat species used.

SaliHoğlu et al. (2013) assessed the aqueous leaf extract of common loquat (*Mespilus germanica*) and found it to have lower antioxidant capacity when compared to other aqueous extracts of *Smilax excelsa, Laurocerasus officinalis,* and *Urtica dioica*.

3.1.3 Determination of the antioxidant capacity by the Folin–Ciocalteu method

The determination of the antioxidant capacity by the Folin–Ciocalteu method showed statistically significant differences in the phenolic compounds' contents in leaf, pulp, and seed extracts ($p < 0.05$), as well as hydromethanol and ethanol solvents in pulp and leaves. However, there were no significant differences between the seed extracts evaluated ($p < 0.05$). The HS extract contains a higher amount of phenolic compounds (1.00 mg gallic acid/mL of extract), while EP with 0.19 mg gallic acid/mL, presented a lower content of these compounds.

A study focused on the seed starch extract obtained from the loquat (*Eriobotrya japonica*) fruit was conducted by Turola et al. (2017) where they found 0.112 mg/g of phenolic content, while, in the present study, the seed extracts obtained higher contents of mg gallic acid/mL, than those reported in the seed starch. Suggesting that the differences between results may have happened due to the use of the whole seed.

The results obtained in EH were lower compared with Ventura (2021), who obtained a total phenol content of 1.627 mg gallic acid/mL in the ethanolic extract of dried loquat leaves. Nevertheless, SaliHoğlu et al. (2013) obtained 0.055 mg of gallic acid/mL in the aqueous extract of the loquat species *Mespilus germanica,* which is lower than EP and HP extracts (0.55 mg gallic acid/mL).

Based on the results obtained in the present study regarding the amount of phenols (HS: 1.0 mg gallic acid/mL), it can be concluded that loquat seeds have the highest antioxidant capacity, in agreement with Rivas et al. (2020) who mentioned that there is a positive correlation between the content of total phenols, flavonoids, and antioxidant capacity, indicating that phenolic compounds are key contributors to determine the antioxidant activity.

3.1.4 Determination of antioxidant capacity by FRAP method

When determining the antioxidant activity by the FRAP method, which indicates the reduction of Fe^{3+} al Fe^{2+}, the results showed that there are statistically significant differences ($p < 0.05$) between the solvents and the vegetable samples. The HP and EH extracts and EP and ES extracts did not present statistically significant differences ($p < 0.05$), as shown in Figure 1.

The results showed that a higher reduction of Fe^{3+} was obtained in the EH extract containing 0.57 Eq Trolox/gps, followed by HP with 0.54 mM Eq Trolox/gps and HH with 0.44 mM Eq Trolox/gps.

Parrado Muñoz (2021) conducted a study on freeze-dried loquat pulp *Eriobotrya japonica* and reported values of 0.0202 and 0.0225 mM Eq Trolox/g. These values differ from those reported in the present investigation since higher values were found in all the extracts. This author also mentioned the factors that can determine these differences in antioxidant content are agronomic management, climatic conditions, and genotypes. In addition, the solvent influences the results, as observed in this study.

Gülçin et al. (2011) demonstrated that extracts of loquat fruit *Mespilus germanica* obtained by aqueous extraction and subsequently lyophilized contained $3.6x10^{-7}$ Trolox equivalents/g, with a lower amount than the present study. Likewise, these authors pointed out that the extraction conditions also influence the Fe^{2+} reduction capacity.

3.2 Morphological description

The macroscopic description of the bacteria grown in the differential and selective media corresponds to what is reported in their technical data sheets; for *E. coli* O157:H7 on MacConkey agar, the growth of lactose-fermenting bacteria was obtained, reddish-pink colonies with observation of a bile precipitation halo and a characteristic and specific growth of blue–green color in the *E. coli* O157:H7 chromogenic agar; for *Salmonella*, the growth of colorless colonies in MacConkey agar; in the specified agar, there were changes in the color of the medium that goes from red to yellow, besides generating sulfuric acid developing colonies with a black center. The results of the biochemical tests agree with those reported by Koneman and Allen (2008), thus confirming the identity of both microbial groups.

The isolates of *F. oxysporum* and *R. solani* had macro- and micro-morphological characteristics of the species: *F. oxysporum* showed growth of cottony aerial mycelium, with the presence of a filamentous border of faint violet coloration; microscopically, nonseptate microconidia and crescent-shaped, hyaline, and septate macroconidia were found. Regarding *R. solani*, it showed white mycelium.

3.3 Determination of antibacterial activity

3.3.1 Evaluation of extracts for the inhibition of Salmonella Typhimurium *and* Escherichia coli *O157:H7*

The results of the antimicrobial activity of loquat extracts were obtained from the diameter of the halos, and the average percentage of inhibition was determined. In this context, of the six extracts obtained, only three of them (HP, EP, and ES) had an effect. In the case of *E. coli*, HP presented a percentage of 28% higher inhibition than EP; likewise, the HP effect against Salmonella Typhimurium was 8% and 35% higher, respectively, than EP and ES.

For *Escherichia coli*, *Salmonella* Typhimurium, *F. oxysporum,* and *R. solani*, the inhibition values are shown in Table 1.

Table 1. Evaluation of antimicrobial activity in loquat.

Treatment	Inhibition halo (mm.)			
	Escherichia coli **($\bar{x} \pm$ DS)**	***Salmonella*** **Typhimurium** **($\bar{x} \pm$ DS)**	***Fusarium oxysporum*** **($\bar{x} \pm$ DS)**	***Rhizoctonia solani*** **($\bar{x} \pm$ DS)**
EP	1.26 ± 1.15 **a**	19.83 ± 0.50 **a**	NP	NP
HP	2.20 ± 1.01 **b**	21.66 ± 0.64 **a**	9.025 ± 1.37	3.9 ± 1.46
ES	NP	13.93 ± 1.43 **b**	NP	NP
HS	NP	NP	NP	NP
EH	NP	NP	NP	NP
HH	NP	NP	NP	NP

EP: ethanol pulp, HP: hydromethanol pulp, ES: ethanol seed, HS: hydromethanol seed, EH: ethanol leaf, HH: hydromethanol leaf. NP: did not present inhibition; Means followed by the same letters indicate the absence of significant differences by Tukey's test ($p < 0.05$).

The results obtained coincide with those of Grande et al. (2020) who reported that there are types of *E. coli* within the category of microorganisms with resistance mechanisms since inhibition is affected by the concentration and the solution used in the extract. Several authors point out that there is a greater antimicrobial activity in Gram-positive bacteria such as *S. aureus*, compared to Gram-negative bacteria such as *E. coli* and *Salmonella*, due to the composition of the cell wall, which has a thick layer of lipopolysaccharides that acts as a hydrophobic barrier, which prevents the penetration of compounds, together with the presence of enzymes in the periplasmic space that limits the entry of substances from outside (Safari & Ahmady, 2019; Sotelo et al., 2010).

Likewise, Safari and Ahmady (2019) evaluated the antibacterial activity in the methanolic extract of loquat leaves on various bacteria; in the case of *E. coli,* they used an extract concentration of 62.5 mg/mL which obtained an inhibition of 8.34 mm. This contrasts with the findings of the present study since there was no inhibition when the leaf extract was used.

Cornejal et al. (2023) reported that the ethanolic extract obtained from dried leaves and stems of *E. japonica* showed significant inhibition of bacterial growth of *E. coli* and *S. epidermidis* using a spectrophotometric method that monitored bacterial growth over time.

Zhou et al. (2019) found that the *E. japonica* leaf extract with 96% ethanol showed no inhibition against the following bacterial strains: *E. coli* XL1-Blue MRF′, *Acinetobacter bohemicus, Kocuria kristinae, Micrococcus luteus, Staphylococcus auricularis*, and *Bacillus megaterium*. Even though the leaf extract was evaluated in different bacteria, these results correspond to a similar behavior obtained in this research. However, it would be important to explore other experimental conditions in terms of concentrations, solvents, and species because these results contrast with the findings of Safari and Ahmady (2019) in methanol extracts obtained from the leaf of *Mespilus germanica* species which presented inhibition against *Salmonella* Typhimurium and *Salmonella* Paratyphi, so these results indicate that this species has important antibacterial properties.

Similarly, extracts have been evaluated on phytopathogenic microorganisms; a study by Hamdy et al. (2023) demonstrated the effect of *Eriobotrya japonica* leaf extract against phytopathogenic bacteria such as *Ralstonia solanacearum*, which showed a zone of inhibition of 23.00 mm, followed by *Pectobacterium atrosepticum* with 21.67 mm and *Pectobacterium carotovorum* with 17.00 mm.

Respecting antifungal activity, this study showed that HP was able to inhibit both *R. solani* and *F. oxysporum*, the latter being superior to *R. solani* with 57%.

According to other studies, plant extracts that have shown antimicrobial capacity against phytopathogenic fungi are those obtained from *Cowanai plicata, Flourensia microphylla, Flourensia cernua, Annona cherimola,* and *Cinnamomum zeylanicum*, which inhibited different species of *Fusarium* (Balanta et al., 2013; Contreras et al., 2011; Kumar et al., 2014; Ochoa et al., 2012; Rodríguez et al., 2007; Zhao et al., 2013). Regarding *R. solani* inhibition, the extracts that have been used with favorable results are *Oryza sativa, Larrea tridentata, Rosmarinus officinalis, Allium sativum, Agave lechuguilla, Solanum lycopersicum, Mentha piperita, Boehmeria nivea,* and *Opuntia ficus* (Castillo et al., 2015; Centurión et al., 2013; Dania et al., 2014; López et al., 2005; Rodríguez et al., 2020).

The results of this study showed that the extracts of *Eriobotrya japonica*, particularly those obtained with ethanol, present antioxidant capacity by the DPPH method; particularly, EP presented antibacterial activity against *E. coli*; ES only presented inhibition for *Salmonella* Typhimurium, while the HP extract exhibited the capacity to antibacterial and antifungal activity and had inhibition halos for *Salmonella* and *F. oxysporum* as well as the highest antioxidant capacity by the FRAP method.

4 CONCLUSIONS

The present study demonstrated that both ethanol and hydromethanol extracts of loquat (*Eriobotrya japonica*) showed antioxidant and antimicrobial activity. It is important to consider that the plant material, the solvent, and the method of analysis influence the extraction of the antioxidant content, which allows the inhibition of free radicals and enhances the antimicrobial effectiveness.

ACKNOWLEDGMENTS

This research was supported by COMECyT, project number FICDTEM-2023-15.

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