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Original Article

Antioxidant, Antimicrobial and Antiproliferative Effects of *Serjania racemosa* Schumach Leaves

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ABSTRACT

Background: *Serjania racemosa* Schumach, popularly known in Mexico as bejuco siete corazones (seven-hearted bejuco), is used in traditional medicine for the treatment of a wide variety of conditions, including urinary and prostate conditions, suggesting it may have a positive effect against prostate cancer. **Objectives:** To evaluate the antioxidant, antibacterial, and antiproliferative activities of leaf extracts of *S. racemosa*. **Materials and Methods:** Sequential extraction yielded hexane, ethyl acetate, and methanol extracts of the dried leaves. Secondary metabolite groups were identified using ^{1}H-NMR chemical profiling. Total polyphenol content was determined using the Folin-Ciocalteu method, and antioxidant activity was determined using DPPH and FRAP assays. Antimicrobial activity was evaluated against bacteria and fungi of public health interest using the Kirby-Bauer method, and finally, antiproliferative activity was assessed against the androgen-independent prostate cancer cell line PC-3 using the MTT assay. **Results:** The methanolic extract showed the best antioxidant activity with 91.09% DPPH radical inhibition and 520.39 µmol Fe^{+2}, related to the total phenol content. In addition, it also showed the greatest antibacterial effect inhibiting the growth of *E. coli, P. aeruginosa, S. aureus, K. pneumoniae, P. mirabilis, S. typhi, S. paucimobilis* and *S. saprophyticus* at 10 mg/mL, this activity could be related to the presence of flavonoids. However, ethyl acetate extract was more active than methanolic extract on inhibiting PC-3 cells proliferation, with an IC_{50} of 89.12 µg/mL, this activity could be related to the presence of terpenes. **Conclusion:** This work demonstrates that *S. racemosa* is an important source of compounds that confer antibacterial properties associated with urinary tract infections and antiproliferative properties in prostate cancer cells.

Keywords: Prostate cancer, *Serjania racemosa*, Traditional medicine, Urinary tract infections.

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INTRODUCTION

Cancer is defined as a disease in which damaged cells in the body reproduce despite normal restrictions and can spread to other parts of the body, where they invade and colonize territories normally reserved for other cells (Hausman, 2019). Among the different types of cancer, prostate cancer is the fourth most common neoplasia worldwide, according to statistics from the Global Cancer Observatory in 2020 (Sung *et al.*, 2021). Prostate cancer is diagnosed late, as official figures reveal that 70% of diagnosed cases are in an advanced stage, complicating treatment.

For several years, plants have been considered a primary source for the search for new cancer drugs, since currently around 60% of the drugs used in chemotherapy come from natural sources (Alonso-Castro *et al.*, 2011). For this reason, it is necessary to study those medicinal species that do not have previous scientific reports and that are most frequently used in traditional medicine for the treatment of urinary and prostate conditions, to have new candidates for the search for bioactive components (Sánchez-Aguirre *et al.*, 2021).

The genus *Serjania* belongs to the Sapindaceae family, which includes around 230 species native to tropical and subtropical America (de Freitas *et al.*, 2023). Among them is *Serjania racemosa* Schumach, popularly known in Mexico as the seven-hearted bejuco. It is used for the treatment of diabetes, kidney problems, to reduce kidney inflammation, as a diuretic, kidney stones, urinary problems, and prostate disorders (Del Amo, 1979; Ambrosio and Avendaño, 1999; Burgos, 2009; Cano, 2024).

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Phytochemical and pharmacological information on this species is scarce. It is known that aqueous and methanolic extracts of the leaves of this species possess terpenes and flavonoids, in addition to having inhibitory properties of free radicals such as DPPH with 87.31 and 84.90%, respectively, related to the polyphenol content. These extracts have also been evaluated for their antiproliferative activity against the androgen-independent PC-3 prostate cancer cell line, finding IC_{50} values of 829.3 for the aqueous extract and 642.9 µg/mL for the methanolic extract. In the latter, a cytotoxic effect was observed, while the aqueous extract did not generate evidence of apparent cellular damage (Sánchez-Aguirre *et al.*, 2024).

Due to its increased use in the treatment of urinary and prostate disorders, particularly in the state of Veracruz, Mexico (Cano, 2024), *S. racemosa* is considered to have a positive effect on prostate cancer. Therefore, the objective of this study is to evaluate the antioxidant, antibacterial, and antiproliferative activities of hexane, ethyl acetate, and methanol extracts from *S. racemosa* leaves.

MATERIALS AND METHODS

Vegetal material

The leaves of *S. racemosa* were collected on March 10, 2020, from conserved forest areas surrounding the city of Xalapa, Veracruz (latitude 19.507045 and longitude -96.917708). A specimen of the species was deposited in the herbarium of the Institute of Biological Research (CIB) of the University of Veracruz for botanical identification, which was registered with voucher 23296UV.

Extracts

50 g of dried and crushed *S. racemosa* leaves were weighed into a 500 mL Erlenmeyer flask, to which 300 mL of hexane was added. The mixture was left to macerate for four days, protected from light, and then the extract was filtered through Whatman No. 1 filter paper. Then, 300 mL of ethyl acetate was added, leaving the sample to macerate for another four days and filtering it again. Finally, 300 mL of methanol was added to the sample, allowing it to macerate for another four days, and the resulting extract was filtered. To remove excess solvent from the extracts, they were transferred to a rotary evaporator (Büchi R-124) at reduced pressure until dry. The extracts were kept refrigerated until use.

Chemical profile by ^{1}H-NMR

15 mg of each extract was dissolved in 0.5 mL of DMSO-*d6*, which were deposited in a 5 mm nuclear magnetic resonance tube. The analysis was performed on a 500 MHz nuclear magnetic resonance spectrophotometer (BRUKER) type Magnet System 500´54 Ascend ULH with 160 scans of 2 s acquisition time and with a spectral width of 8012.8 Hz. Subsequently, the data was processed in the MestReNova 12.0 software.

Antioxidant activity

Determination of total phenol content

To 50 µL of each extract (1 mg/mL) were added 2.5 mL of a 1:10 solution of the Folin-Ciocalteu reagent, and 2 mL of 7.5% Na_2CO_3. The samples were placed in a water bath at 45°C for 15 min. Subsequently, absorbance readings were taken at 765 nm using a UV-vis spectrophotometer (Metash V-5000). The tests were performed in triplicate and the results were interpolated from a calibration curve at different concentrations of gallic acid (25-1000 µg/mL, R^2=0.997) (Cai and Luo, 2004).

Free radical scavenging by DPPH (1,1-Diphenyl-2-picrylhydrazyl)

To 100 µL of extract (1 mg/mL) were added 2.9 mL of a 9x10-5 M DPPH solution. Subsequently, the samples were placed in a 37°C water bath for 30 min, protected from light. After the time, absorbance readings were taken at 517 nm in a UV-vis spectrophotometer (Metash V-5000). As a positive control, a 5 mM ascorbic acid solution was used (Brand-Williams *et al.*, 1995; Domínguez-Ortiz *et al.*, 2009). The assay was performed in triplicate. The following equation was applied to determine the percentage of DPPH reduction:

$$\% \text{ of DPPH inhibited} = A - A1/A \times 100$$

Where:

A: Absorbance of the DPPH reagent.

A1: Average of the absorbances of the simples.

Iron-reducing power FRAP (Ferric Reducing Antioxidant Power)

The FRAP solution was prepared by dissolving 100 mL of 30 mM sodium acetate buffer solution (pH 3.6), 10 mL of a 10 mM solution of TPTZ (Ferric-2,5,6-tripyridyl-5-triazine complex) dissolved in a 40 mM hydrochloric acid solution was added, and 10 mL of 20 mM ferric chloride dissolved in distilled water was also added.

To 150 µL of the extracts (1 mg/mL) were added 150 µL of distilled water and 2.7 mL of FRAP solution. The samples were placed in a water bath for 4 min and subsequently the absorbance readings of the samples were taken at 593 nm in a UV-vis spectrophotometer. The iron reducing power was measured by interpolation of the samples in a calibration curve with FeSO4.7H2O (6-500 µg/mL, R^2=0.998). The assays were performed in triplicate (Benzie and Strain, 1996; Domínguez-Ortiz *et al.*, 2009).

Ethical statement

The experimental procedures complied with institutional and national guidelines for scientific research. As the study did not involve animal or human subjects, and bacterial strains and cell

lines were obtained from existing laboratory collections, ethical committee approval was not applicable.

Antimicrobial activity

Strains

The bacterial strains used in this study were acquired from the microbiology laboratory of the Regional General Hospital No. 1 of the Mexican Social Security Institute (IMSS) in Orizaba, Veracruz. Various species previously characterized and isolated from patient biological samples were received. The bacterial strains obtained were: *Burkholderia cepacia, Escherichia coli, Klebsiella pneumoniae, Proteus mirabilis, Pseudomonas aeruginosa, Salmonella typhi, Sphingomonas paucimobilis, Staphylococcus aureus, Streptoccocus pneumoniae*, and *Staphylococcus saprophyticus*. The fungal strains obtained were: *Candida albicans, Candida tropicalis*, and *Candida krusei*.

Inoculum preparation

Two to three colonies of each strain were removed and placed in test tubes containing sterile, pharmaceutical-grade saline. They were then homogenized using a vortex mixer (Sciencie MED MX-S). The inoculum absorbance was measured using a UV-vis spectrophotometer at 610 nm until an absorbance of 0.08 to 0.1 was reached, corresponding to the 0.5 McFarland scale containing 1 x 10^8 CFU/mL.

Disk diffusion by the Kirby-Bauer method

Strains were streaked onto the agar surface in 100 x 20 mm Petri dishes containing Mueller-Hinton agar. A sensidisc containing either ceftriaxone or nystatin (20 µg) was then applied as a positive control, followed by a sensidisc impregnated with the solvent used in the extraction (hexane, ethyl acetate, or methanol) as a negative control, and three sensidiscs containing 10 mg/mL of each extract. The samples were incubated at 37°C for 24 hr. The inhibition zones formed were then measured using a Vernier caliper. The antimicrobial activity of the extracts was determined by applying the following equation:

% of inhibition= inhibition of extract (mm) / inhibition of antibiotic (mm) x 100

Antiproliferative activity

A total of 3 mg of the methanolic and ethanolic extracts of *S. racemosa* were weighed and dissolved in 3 mL of RPMI culture medium supplemented with 8% FBS and a 1% mixture of penicillin and streptomycin to obtain a stock solution at 1000 µg/mL. This solution was filtered through a 0.22 µm sterile filtration unit. A series of dilutions was subsequently made to obtain concentrations of 100, 250, 500, 750, and 1000 µg/mL, respectively. The extracts dissolved in the culture medium were stored at -20°C until use.

The PC-3 cell line (bone metastasis prostate cancer) was seeded in a 96-well multi-plate (0.32 cm^2, CORNING) at a density of 12,500 cells/cm^2 in 100 µL of RPMI culture medium supplemented with 8% FBS and 1% penicillin and streptomycin, incubating for 48 hr at 37°C and 5% CO_2.

After this period, the culture conditions were changed, during which the medium was removed and then medium containing the different concentrations of the extracts was added. The cultures were incubated for an additional 48 hr at 37°C and 5% CO_2. At this time, cell viability was determined in the cultures without extract, which was designated T0 (cell viability at the start of treatment) using the MTT assay.

After 48 hr, micrographs were taken with a 25X objective and cell viability was also determined in the cultures treated with the different extract concentrations using the MTT assay. A total of three independent experiments with three replicates each were performed. The absorbance values at 570 nm from the MTT assay were used to develop dose-response curves (nonlinear regression between the percentage of proliferation versus the logarithm of the concentration), following the methodology of the National Cancer Institute of the United State (Monks *et al.*, 1991).

Statistical Analysis

A nonlinear regression analysis was performed using the GraphPad Prism version 8 software, La Jolla, California, USA. The IC_{50} (inhibitory concentration at which cell proliferation is inhibited by 50%), TGI (concentration at which cell proliferation is inhibited by 100%), and LC_{50} (concentration at which 50% of the cell population dies) values were determined from these curves responses-doses.

To develop these curves of antiproliferative activity, the absorbance data were normalized to the percentage of cell proliferation; for this calculation, the following equations were used depending on the absorbance values obtained in the treatment:

If the absorbance value of the sample is greater than T_0, the following is applied:

$$100\ [(T\text{-}T0)/(C\text{-}T0)]$$

If the absorbance value of the sample is less than T0, the following is applied:

$$100\ [T\text{-}T0)/(T0)]$$

Where:

T = Absorbance of the treated sample.

T_0 = Absorbance of the untreated cell culture at the start of the experiment.

C = Absorbance of the untreated cell culture (control).

RESULTS

Identification of secondary metabolite groups by H[1]-NMR

H[1]-NMR analysis allowed us to identify the groups of secondary metabolites found in the hexane, ethyl acetate and methanol extracts of *S. racemosa* leaves by the chemical shifts presented, Figure 1 (see Table 1).

According to the figure above, there is selectivity of the extracted components according to the polarity of the solvents used. In the hexane extract, signals are observed in the aliphatic range from 0.83 to 2.21 ppm. In the ethyl acetate extract, signals are observed in the aliphatic region from 0.5 to 2.25 ppm related to terpenes, followed by 2.5 to 3.5 ppm. Finally, in the methanolic extract from 0.75 to 2.5 ppm, aliphatic signals were identified; the intense signal from 3 to 3.89 ppm represents the characteristic signal of sugars; from 5 to 6 ppm there are double bond signals, and from 6 to 8.08 ppm aromatic signals are observed.

Antioxidant activity

The antioxidant activity results shown in Table 1 shows that the methanolic extract of *S. racemosa* has the greatest capacity to inhibit free radicals and reduce ferric ion. This was compared with ascorbic acid and was found to have strong antioxidant activity, which is related to the total phenol content.

Antimicrobial activity

Figure 2 shows the percentage of inhibition values of *S. racemosa* extracts against bacterial and fungal strains. Inhibition was presented as follows: methanol>ethyl acetate>hexane extract, where the methanolic extract (Figure 2C) showed the greatest activity, inhibiting mainly Gram-positive bacteria at 10 mg/mL, with *E. coli* and *K. pneumoniae* being the most susceptible to treatment; while the ethyl acetate (Figure 2B) and hexane extracts (Figure 2A) showed greater inhibition against *P. mirabilis*. In all cases, *B. cepacia* and *Candida* strains were negative compared to nystatin.

Antiproliferative activity

The antiproliferative activity of hexane, ethyl acetate and methanol extracts of *S. racemosa* leaves were evaluated against the androgen-independent prostate cancer cell line PC-3 shown in Figure 3.

Figure 3a shows the dose-response curve in which the decrease in cell proliferation can be seen as a function of the concentration of each of the extracts. The extract with the highest activity was the ethyl acetate extract, which showed IC_{50} values of 89.12 µg/mL, TGI of 223.87 µg/mL and an LC_{50} of 446.68 µg/mL. According to the micrographs of the cultures for this extract (Figure 3c), from 100 µg/mL significant morphological changes were observed, among them the cells appeared rounded and with a break in the cell-cell junction compared to the control culture without treatment (0 µg/mL). At a concentration of 250 µg/mL, fewer cells were observed, as well as the presence of vacuolization and cellular debris; while at concentrations of 500 to 1000 µg/mL the cells were seen to be destroyed. The next extract that showed activity was the methanolic one, which presented IC_{50} values of 123.02 µg/mL, TGI of 288.40 µg/mL and LC_{50} of 575.43 µg/mL, respectively. Figure 2d shows the micrographs of the cultures for the methanolic extract. Cultures incubated at a concentration of 100 µg/mL did not present morphological alterations; while cultures treated with 250 and 500 µg/mL of the extracts showed a lower cell density, elongation and cytoplasmic vacuolization. At 750 and 1000 µg/mL the cultures were lysed compared to the control culture without treatment (0 µg/mL). Finally, the hexane extract was the least active, with IC_{50} values of 169.82 µg/mL, TGI of 354.81 µg/mL, and LC_{50} of 602.55 µg/mL. Micrographs of cultures incubated with the hexane extract showed that concentrations of 100 and 200 µg/mL (Figure 3b) did not show morphological changes, while in those incubated from 500 µg/mL the cells separated, rounded, and vacuolated; while those from 700 to 1000 µg/mL were completely cytotoxic. These results demonstrate that the ethyl acetate extract of *S. racemosa* has a strong effect on the proliferation of PC-3 prostate cancer cells through a cytotoxic mechanism.

DISCUSSION

[1]H-NMR analysis detected signals from the main groups of secondary metabolites that make up *S. racemosa* extracts. Terpenes (0.5-2.25 ppm) were detected in the hexane and ethyl acetate extract, while signals of aliphatic compounds (0.75-2.25 ppm), sugars (5-6 ppm), and phenols (6-8.08 ppm) were identified in the methanolic extract, related to the presence of saponins, flavonoids, and glycosylated flavonoids, with terpenes and flavonoids being the most abundant in this species. A wide variety of secondary metabolites have been identified in the genus *Serjania*, such as isoprenoids, diterpenes, triterpenes, saponins,

Table 1: Antioxidant activity of *S. racemosa* extracts.

Extract	mg of gallic acid/g of sample	% DPPH inhibited	µmol Fe^{+2}
Hexane	0.0734±0.001	22.10±0.80	59.40±0.05
Ethyl acetate	0.0752±0.012	34.07±0.32	190.02±0.03
Methanol	0.244±0.003	91.09±0.75	520.39±0.05
Ascorbic acid	---	100	---

The table shows the average of three replicates±the standard deviation.

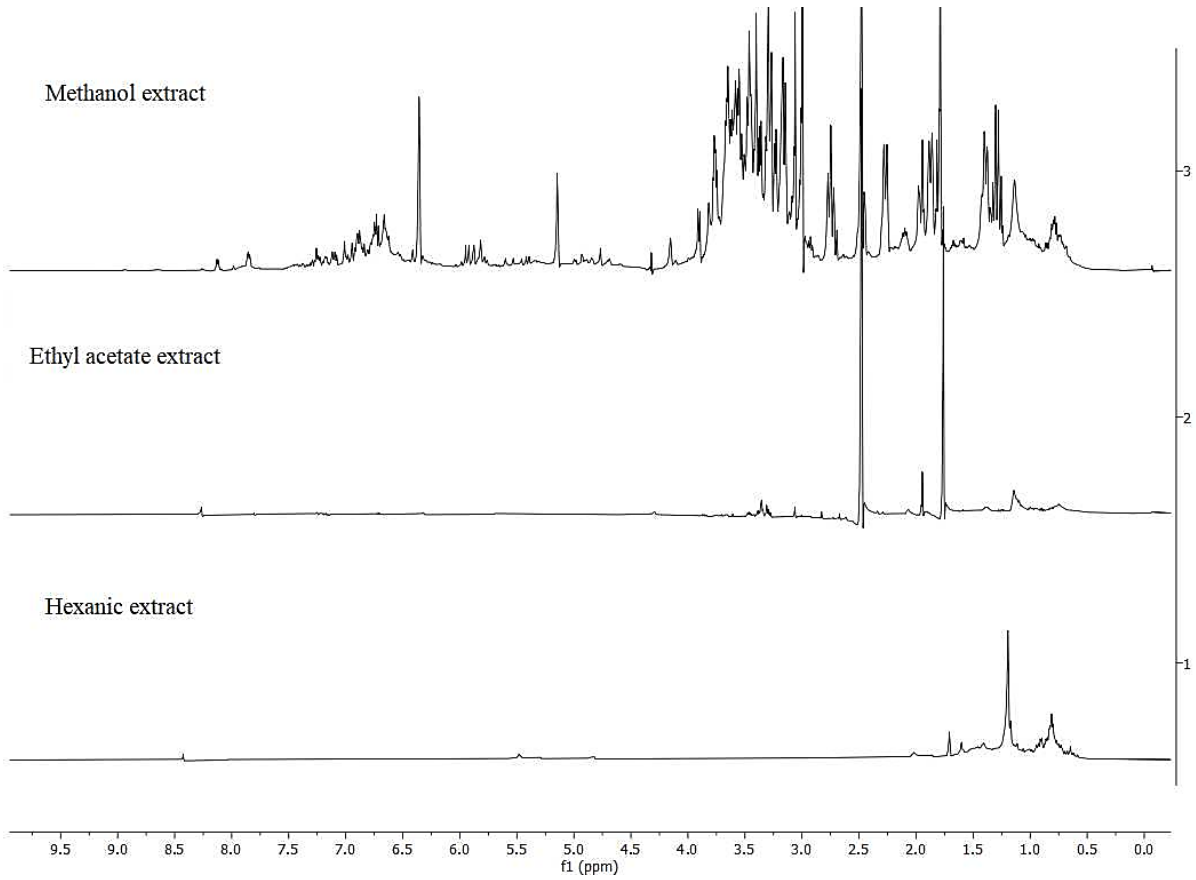

Figure 1: H1-NMR of hexane, ethyl acetate and methanol extracts of *S. racemosa* leaves (500 MHz, DMSO d6).

polyphenols, flavonols, flavones, tannins, and catechins (Gomig *et al.*, 2008).The methanolic extract of *S. racemosa* showed a strong antioxidant activity (91.09% DPPH radical inhibition and 520.39 µmol Fe^{+2}) compared to the others, which could be related to the total phenol content. In species of the same genus, Heredia-Vieira *et al.*, (2014) reported that proanthocyanidins are the main compounds responsible for the antioxidant activity in *S. marginata* due to their strong free radical scavenging properties.

Lima *et al.*, (2013) isolated the flavonoids kaempferol, kaempferol-3,7-di-*O*-α-L-rhamnopyranoside, (-)-epicatechin, apigenin-6-C-*β*-D-glucopyranoside from the ethanolic extract of *S. erecta* leaves, while the isolation of kaempferol-3-*O*-α-l-rhamnopyranoside and kaempferol-3-*O*-α-L-rhamnopyranosyl- (1→6)-*β*-D-glucopyranoside was reported from the ethanolic extract of *S. erecta* roots. Retaking the ^{1}H-NMR spectrum of the ethanolic extract of *S. racemosa*, signals of flavonoids and glycosides were detected, so this type of compounds may be related to the antioxidant activity of this species and is a characteristic of the genus.Antioxidants can act primarily by delaying, preventing, or eliminating damage to a target molecule. Flavonoids act as antioxidants through free radical scavenging, metal chelation, suppression of enzymes associated with free radical generation, and stimulation of internal antioxidant enzymes. Flavonoids primarily act by directly scavenging Reactive Oxygen Species (ROS). This is due to the hydroxyl groups, ortho hydroxy position in the B ring, the C2-C3 unsaturated bond combined with the C-4 carbonyl group in the C backbone, and the O-methylation they contain in their chemical structure (Banjarnahor and Artanti, 2014).

The antioxidant activity and this type of compound is related to the antibacterial activity found since the methanolic extract of *S. racemosa* also showed the highest activity, with Gram (-) bacteria being the most susceptible, among them, *E. coli, S. typhi* and *K. neumoniae*, the three associated with urinary tract infections. Inhibition was also presented in the growth of *P. aeruginosa, S. aureus, P. mirabilis* and *S. paucimobilis*. On the other hand, the growth of *S. saprophyticus*, related to urinary tract infections, was inhibited only by the methanolic extract. In the case of *S. pneumoniae*, this bacteria showed inhibition in its growth only with the ethyl acetate extract, while the growth of *B. cepacia* was not inhibited by any of the extracts. In the case of *Candida* strains, they were not sensitive to any of the *S. racemosa* extracts.

Although the inhibition zones were not high compared to the positive control, the antibiotic ceftriaxone, the results are of great interest because crude extracts of *S. racemosa* leaves were tested, not pure plant components. This is especially true considering that *E. coli* is the Gram-positive bacterium responsible for 95% of urinary tract infections and was the most susceptible to the methanolic leaf extract. These results reveal the antibacterial

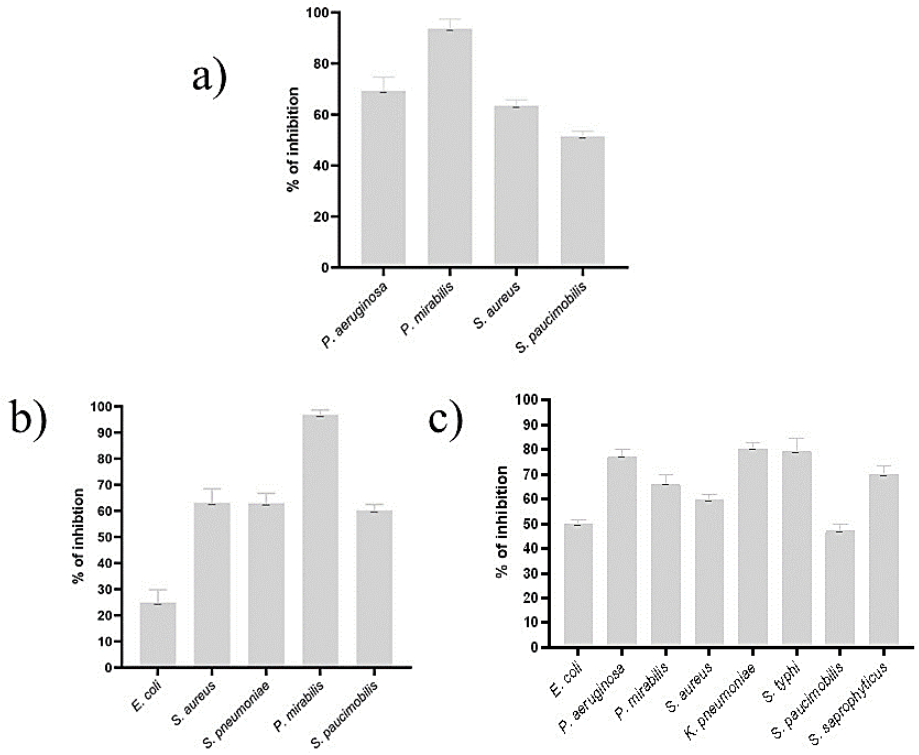

Figure 2: Antimicrobial activity of *S. racemosa* extracts. a) Hexanic extract, b) Ethyl acetate extract and c) methanol extract.

potential of this species against urinary tract infections, justifying its use in traditional Mexican medicine.

Other *Serjania* species have been shown to exert an antibacterial effect against *E. coli*, this is the case of the aqueous extracts of leaves and stems of *S. marginata*, the ethanolic extract of leaves and stems of *S. lethalis* and *S. erecta* (Falcao *et al*., 2024; Lima *et al*., 2006; Cardoso *et al*., 2013). After *E. coli, Proteus mirabilis* is the second most important bacterium in urinary tract infections in humans. Its growth was inhibited by hexane and ethyl acetate extracts obtained from *S. racemosa*, by 31 and 33% inhibition, in relation to the effect of ceftriaxone. It is important to highlight this result since *P. mirabilis* is one of the most studied bacteria, causing serious infections in hospitals and with strong resistance to various antibiotics (Alqurashi *et al*., 2022).

Perico *et al*., (2015) confirmed the antimicrobial activity of a hydroalcoholic extract of *S. marginata* leaves against *Helycobacter pylori* (MIC 125 µg/mL), a bacterium that proliferates in the human gastric mucosa, affecting more than 50% of the world's population, causing peptic ulcers, gastritis and stomach cancer (Cervantez-García, 2016). Considering the results of the present work in which Gram (-) bacteria were the most susceptible to the extracts, it is likely that *S. racemosa*, and other *Serjania* species can exert an antibacterial effect against *Helycobacter pylori*.Medicinal plants are one of the main natural resources as they offer enormous potential for the search for new bioactive compounds that can combat resistant pathogenic microorganisms. Chemical components from medicinal plants are a broad group of compounds found naturally in plants. These can restore the clinical application of older antibiotics by increasing their potency and thus preventing the emergence of resistance (Vaou *et al*., 2021).

The methanolic extract of *S. racemosa* can contain a wide variety of secondary metabolites, which can exert synergy, increasing the activity displayed. This synergy occurs because the interactive effects of the extract's chemical matrix, characterized by the plurality and diversity of its constituents, are greater than the effects of any individual compound. This synergy modulates biochemical pathways and changes membrane potentials, as well as receptor selectivity and protein modifications (Vaou *et al*., 2022).

Lima *et al*., (2013) evaluated the antimicrobial activity of *S. erecta* leaves and roots, finding activity against *S. aureus, P. aeruginosa, C. albicans, S. setubal, S. cerevisiae*, and *E. coli* strains with MIC (minimum inhibitory concentration) values between 5 and 25 µg/mL and M. tuberculosis between 128 and 256 µg/mL. This activity was related to flavonoids. On the other hand, Ekabo and Farnsworth (1996) found that the saponins hederagenin-3-*O*-α-L-arabinopyranoside, salzmannianoside A, and salzmannianoside B isolated from the methanolic extract of *S. salzmanniana* stems have antifungal properties against *C. albicans, C. neoformans*, and *A. fumigatus* strains. These investigations suggest that in the case of *S. racemosa* the compounds responsible for the observed activity may be flavonoids.Ethyl acetate extract showed the best antiproliferative activity against prostate cancer

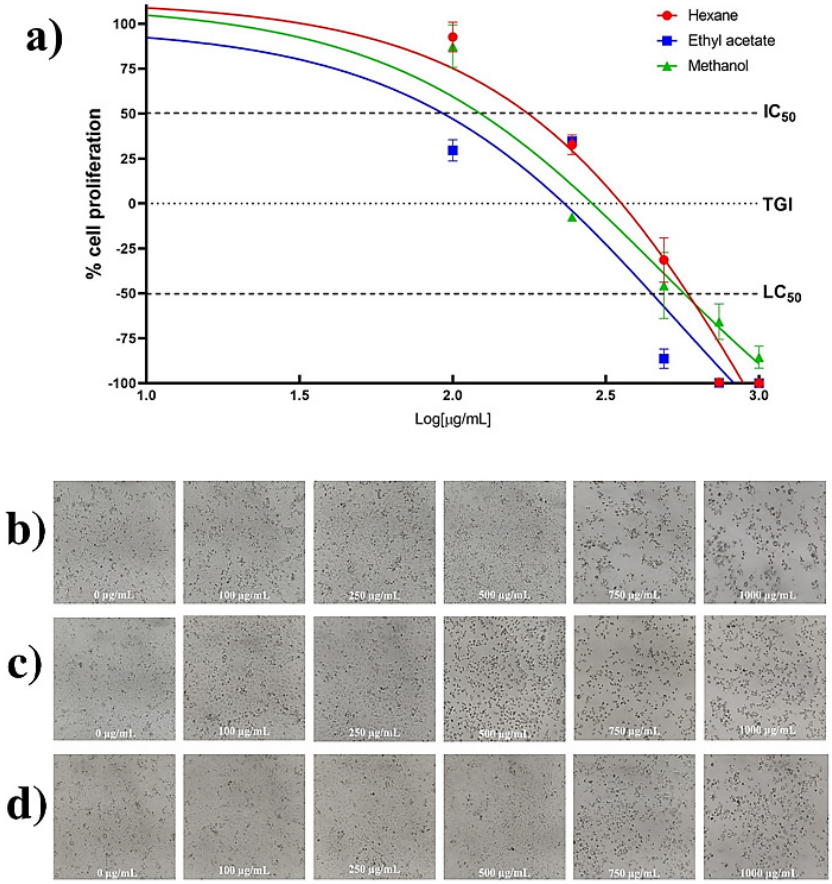

Figure 3: Antiproliferative activity of *S. racemosa* leaf extracts against the PC-3 cell line. a) Dose-response curve of *S. racemosa* extracts after 48 hr of treatment, the graph shows the mean of three independent experiments±standard error of the mean, b) Micrographs of cultures treated with different concentrations of the hexane extract of *S. racemosa*, c) Micrographs of cultures treated with different concentrations of the ethyl acetate extract of *S. racemosa* and d) Micrographs of cultures treated with different concentrations of the methanolic extract of *S. racemosa*.

cell line PC-3 with an IC_{50} of 89.12 µg/mL. Atjanasuppat *et al.*, (2009) classified the antiproliferative and cytotoxic activity of plant extracts into four categories according to their IC_{50} values: ≤ 20 µg/mL is active, 20-100 µg/mL is moderately active, 100-1000 µg/mL is weakly active, and > 1000 µg/mL is inactive. Taking these categories into account, the ethyl acetate extract of *S. racemosa* is considered moderately active. This result is important because, according to the micrographs of the cultures for this extract at 100 µg/mL, no apparent cell damage is observed, indicating that the extract is not cytotoxic at this concentration. It is also a good indication that the components comprising this extract do not generate adverse effects like conventional anticancer agents, which destroy more than just tumor cells. Therefore, it is important to search for the compounds that confer this activity.

In the ethyl acetate extract of *S. racemosa*, terpene signatures were identified, suggesting that compounds of this nature are responsible for the activity. Consulting the literature, we found that the sesterterpene goniocarpic acid was isolated from the hexane fraction of the methanolic extract of *S. goniocarpa* leaves. This compound has shown significant activity against cancer cell proliferation, inhibiting the proliferation of HeLa, Hep-2, MCF-7, KB, PC-3, and Hek-293 cell lines with IC_{50} values of 16.1, 8.7, 7.8, 3.4, 45.5, and 15.3 µg/mL, respectively. It has also generated cytotoxic effects on these same cells (Quintal-Novelo *et al.*, 2015). This is evidence that the active compounds responsible for the antiproliferative activity in *S. racemosa* against PC-3 prostate cancer cells may be terpenes or medium polarity in nature.

CONCLUSION

The results of this study on *S. racemosa* are promising in terms of its antibacterial and antiproliferative activity, which is linked to its use in traditional Mexican medicine for the treatment of urinary and prostate conditions. However, future studies are needed to identify the secondary metabolites responsible for these activities and to evaluate the toxicity of the extracts to ensure their safety and efficacy. This study also includes understanding the mechanisms of action involved.

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ABBREVIATIONS

CFU: Colony-Forming Units; **CIB:** Institute of Biological Research; **DMSO:** Dimethylsulfoxide; **DPPH:** 2,2-Diphenyl-picrylhydrazyl; **FBS:** Fetal Bovine Serum; **FRAP:** Ferric Reducing Antioxidant Power; **IC_{50}:** inhibitory concentration at which cell proliferation is inhibited by 50%; **IMSS:** Mexican Social Security Institute; **TGI:** concentration at which cell proliferation is inhibited by 100%; **LC_{50}:** concentration at which 50% of the cell population dies; **MTT:** 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide; **NMR:** Nuclear Magnetic Resonance; **P/S:** Penicillin-Streptomycin; **RPMI:** Roswell Park Memorial Institute; **TPTZ:** Ferric Complex-2,5,6-tripyridy l-5-triazine; **UV-vis:** Ultraviolet-visible.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

FUNDING

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AUTHOR CONTRIBUTIONS

Oscar Antonio Sánchez-Aguirre: conceptualization, methodology, investigation, writing original draft. Daniel Salazar-Vela: methodology, investigation. Marina Guevara Valencia: methodology, investigation. Enrique Juárez-Aguilar: methodology, investigation, writing original draft. Omar Germán Malagón-Aviles: methodology, investigation, writing original draft. Leticia Margarita Cano-Asseleih: Conceptualization, Resources, Supervision, Writing -original draft, Writing-review and editing.

SUMMARY

Serjania racemosa (seven-hearted vine) is used in traditional Mexican medicine against urinary and prostate conditions. In this study, hexane, ethyl acetate, and methanol extracts of *S. racemosa* leaves displayed antioxidant, antibacterial, and antiproliferative activities. The methanolic extract presented the highest antioxidant capacity (91.09% DPPH inhibition and 520.39 µmol Fe^{+2}) and antibacterial activity (*E. coli, P. aeruginosa, P. mirabilis, S. aureus, K. pneumoniae, S. typhi, S. paucimobilis, S. saprophyticus*), whereas the ethyl acetate extract most effectively inhibited the proliferation of PC-3 prostate cancer cells (IC_{50}=89.12 µg/mL). These findings support the pharmacological potential of *S. racemosa* in the treatment of urinary tract infections and prostate cancer.

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