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Phytochemical characterization and evaluation of the in vitro antimicrobial, antifungal and antioxydant properties of *Solanum elaeagnifolium* methanolic extracts

Doha Naji[1], Fatima Zahrae Moussaid[2], Marouane Aouji[1], Rachid Bengueddour[1]

[1]*Laboratory of Natural Resources and Sustainable Development, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco*
[2]*Life and Health Sciences Team, Faculty of Medicine and Pharmacy-Tangier,Abdelmalek Essaadi University, Morocco*

Solanum elaeagnifolium is a plant of growing interest in ethnopharmacology due to its diverse therapeutic potential. This study aimed to characterize the phytochemical profile and assess the antimicrobial, antifungal, and antioxidant activities of methanolic extracts derived from different plant parts (leaves, fruits, stems, and roots). Total phenolic, flavonoid, and tannin contents were quantified using the Folin–Ciocalteu, aluminum chloride, and vanillin-HCl methods, respectively. Antimicrobial activity was evaluated against four microbial strains: *Staphylococcus aureus* (ATCC 29213), *Escherichia coli* (K12), *Bacillus subtilis* (ATCC 6633), and *Candida albicans* (ATCC 10231). Antimicrobial activity was assessed using the agar well diffusion and broth microdilution methods. In the diffusion assay, 100µL of each methanolic extract was introduced into wells previously made in Mueller-Hinton agar plates, and the inhibition zones were measured after 24h of incubation at 37°C. Antioxidant potential was assessed via the DPPH radical scavenging assay.

The results revealed that fruits exhibited the highest levels of flavonoids and polyphenols, while leaves were richest in tannins. Roots showed the lowest content of phenolic compounds. The fruit extracts demonstrated the strongest antioxidant activity, with an IC_{50} value of 258.42 ± 3.09µg/ml. All extracts exhibited significant antimicrobial effects, suggesting that the identified phenolic compounds, flavonoids, and tannins contribute substantially to the observed bioactivity.

These results underscore the promise of *S. elaeagnifolium* as a reservoir of pharmacologically active compounds, particularly phenolics, with notable antimicrobial and antioxidant effects relevant to drug discovery and botanical therapeutics.

Keywords: Antimicrobial activity, Antioxidant activity, Methanolic extracts, Phenolic content, Phytochemistry, *Solanum elaeagnifolium*.

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CORRESPONDANCE TO:
Doha Naji
Laboratory of Natural Resources and Sustainable Development, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco
Email: naji.doha@uit.ac.ma

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INTRODUCTION

Recently, scientific research has shown increasing interest in plant-derived compounds, particularly for their applications in the phytopharmaceutical field. Natural products obtained from medicinal plants have long served as essential sources of bioactive molecules. So far, more than 119 plant-based compounds are utilized in modern therapeutic formulations, with approximately 74% (88 compounds) exclusively derived from medicinal plants (Tamert et al., 2017). This demonstrates the enduring relevance of plant-based research in the context of global drug discovery and development (Afqir et al., 2024).

Aromatic and medicinal plants have historically played an important role in the prevention and treatment of human diseases, even with the widespread availability of synthetic pharmaceuticals (Aye et al., 2019; Vujanović et al., 2019; Chrysargyris et al., 2024). They remain a central focus of pharmacological investigation due to their broad spectrum of biological activities, relative safety, and richness in secondary metabolites with therapeutic potential (Tamert et al., 2017; Afqir et al., 2024). These effects are largely attributed to their high content of phytochemicals such as polyphenols, flavonoids, alkaloids, terpenoids, and tannins, which exhibit antioxidant, antimicrobial, anti-inflammatory, and anticancer properties (Aye et al., 2019; Chrysargyris et al., 2024).

In particular, polyphenols are known for their ability to modulate oxidative stress and inflammatory responses, thereby contributing to the management of chronic conditions such as cancer, liver disorders, and cardiovascular diseases. Moreover, recent advances in functional nutrition have recognized the role of active molecular peptides (AMPs) from plants as health-promoting agents, further expanding their application beyond traditional medicine (Aye et al., 2019; Chrysargyris et al., 2024).

Traditional African medicine exemplifies the therapeutic potential of herbal remedies. Healers have long utilized indigenous plants to combat parasitic infections, including malaria, and these treatments are still widely regarded as effective by local populations (Usman et al., 2018). Such practices highlight the relevance of ethnopharmacological knowledge as a foundation for the discovery of novel pharmacologically active substances (Kirby et al., 1997). However, despite significant progress in pharmaceutical development, the rise of multidrug-resistant pathogens continues to pose a major global health threat. In this context, the need for alternative sources of antimicrobial agents has become urgent, particularly as bacterial pathogens continue to evolve resistance mechanisms (Usman et al., 2018).

Within this framework, the Solanaceae family has emerged as a particularly important group of plants for both nutritional and medicinal purposes. Ranked as the third most economically significant plant family after Poaceae and Fabaceae (Kirby et al., 1997; Kowalczyk et al., 2022). Solanaceae species are renowned for their ability to produce a diverse array of bioactive secondary metabolites, including solasodine, solamargine, solasonine, glycoalkaloids, sesquiterpenoids, and cytotoxic compounds such as cisplatin, doxorubicin, and docetaxel (Kirby et al., 1997; Usman et al., 2018). These phytochemicals have been reported to exhibit a wide range of biological effects, including antioxidant, antimicrobial, antiepileptic, analgesic, anti-inflammatory, hepatoprotective, anticancer, larvicidal, anti-ulcer, and antifungal activities (Kirby et al., 1997).

Among the less explored members of this family is *Solanum elaeagnifolium*, a perennial herbaceous plant native to the southern United States and northern Mexico, where it is considered a common weed. In regions outside its native habitat, such as the Mediterranean basin and particularly Morocco, *S. elaeagnifolium* has been classified as an invasive species due to its aggressive growth, deep-rooted nature, and competitive behavior against crops for water and nutrients (Abdellah et al., 2017; Balah et al., 2020). Although it is known as a noxious weed, this plant species has shown promising pharmacological potential, largely attributed to its rich phytochemical profile.

While previous studies have recognized its ethnobotanical value, comprehensive analyses of the phytochemical composition and biological activities of different parts of *S. elaeagnifolium* (leaves, stems, roots, fruits) remain limited. So, the present study aims to investigate the phytochemical constituents of methanolic extracts from distinct plant organs and to evaluate their in vitro antioxidant and antimicrobial activities. This work contributes to the valorization of *S. elaeagnifolium* as a potential source of bioactive compounds for future pharmaceutical and biotherapeutic applications. (Thinakaran et al., 2024).

MATERIALS AND METHODS

Collection of the plant

At the beginning of 2022, leaves of *Solanum elaeagnifolium* were randomly collected in the Moroccan town of Ben Guerir, at coordinates 32°13’12.2”N, 7°53’34.4”W. According to the Köppen-Geiger classification, Ben Guerir has a temperate Mediterranean climate characterized by hot, dry summers. The annual average temperature is approximately 19.7°C, with an average annual precipitation of 290.6mm.

The plant organs were hand-harvested and dried in the shade, away from humidity and direct sunlight, in order to preserve their phytochemical integrity. The dried material was then ground using an electric mill and sieved to obtain a fine powder. This powder was carefully stored in clean glass containers under controlled laboratory conditions until further use, thereby maintaining its stability and quality.

Preparation of extracts

Methanol-based extracts from the leaves, stems, roots, fruits of Solanum elaeagnifolium were prepared by maceration. Briefly, a total of 10 grams of powdered material from each part of the plant was mixed with 100ml of methanol. The mixture was mixed for 48h at room temperature in the absence of light. At the end of this period, the mixture is filtered with filter paper. The extracts obtained were stored at 4°C. The extraction yield is calculated on the basis of the weight of the dry plant material. The following equation applies:

$$\mathrm{EY} = \frac{\text{Extract mass obtained}}{\text{Powder initiation mass}} \times 100$$

Total phenol content

Each extract (200µL) is combined with 1000µL of Folin-Ciocalteu reagent (1:10, v/v). After a 5-minute incubation period, 800µL of sodium carbonate (Na_2CO_3) solution (7.5%, w/v) is added to the mixture. The resulting solution is incubated at room temperature for 2h, and the optical density is subsequently measured at a wavelength of 765nm (Zargoosh et al., 2019; Aouji et al., 2023).

Total flavonoid

Flavonoid content composition is determined by the method described by (Aouji et al., 2023). A mixture of 200µL of a 2% $AlCl_3$ solution in methanol and 2000µL of extracts is prepared. After a 10min incubation, the optical density of the solution is subsequently measured at a wavelength of 430nm.

Total tannin

Tannin content composition is determined by the method proposed by (Aouji et al., 2023) using vanillic acid. The extracts were mixed with vanillin reagent and subjected to an incubation period at 30°C for 20min. Absorbance measurements were carried out at 500nm.

Determination of antioxidant activity

The antioxidant capacity of the extracts to scavenge DPPH radicals was assessed using a spectroscopic technique, which relies on the reduction in absorbance of the DPPH radical at its characteristic wavelength. Various concentrations of the extracts (500µL of methanol solutions) were added to 2500µL of 0.2mM DPPH solution in separate tubes. Following thorough mixing, the tubes were incubated at room temperature for 30min. The absorbance of the samples was then measured at 517nm, with a control sample used for comparison. A negative control consisting of 500 µL of methanol and 2500µL of DPPH solution was prepared simultaneously, while methanol served as the blank for absorbance measurements of the samples (Huang et al., 2011; Aouji et al., 2023).

The percentage of inhibition was calculated using the following equation:

% Activity = ((Abs Cn - Abs Ech) / Abs Cn) × 100

Antimicrobial activities of methanolic extracts of *Solanum elaeagnifolium*
Antimicrobial activities

Preparation of the extracts: 30mg of each extract were dissolved in 5% DMSO (Dimethyl Sulfoxide) and then homogenized using a vortex.

The strains tested: The microbial activity of the extracts tested was evaluated against strains resistant to various classes of antibiotics: three bacterial strains implicated in nosocomial infections were isolated from patients admitted to the intensive care unit at CHU–Fez, as well as one fungal strain.

- *Staphylococcus aureus* ATCC 29213,

- *Escherichia coli* K12,

-*Bacillus subtilis* ATCC 6633

-*Candida albicans* ATCC 1023 asafungalstrain.

Seeding and incubation: The Petri dishes containing the previously prepared MH culture medium were inoculated with the bacterial strains under investigation by the double-layer method via wells (Moussaid et al., 2019; Yan et al., 2020). To this end, 100µl of the bacterial suspension were added to tubes containing 5ml of soft agar (0.5% agar-agar) (Moussaid et al., 2019; Chung et al., 2023). The inoculated tubes were subsequently transferred into Petri dishes containing MH medium. After solidification, wells were made sterilely on the surface of the soft agar using a cork borer.

The extracts thus prepared were then tested against *Staphylococcus aureus* ATCC 29213, *Escherichia coli* K12, *Bacillus subtilis* ATCC 6633, and *Candida albicans* ATCC 1023 on MH medium by pipetting 100µl into the wells. Negative controls were prepared and tested under the same experimental conditions without the addition of extracts. The inoculated Petri dishes were then incubated at 37°C for 24h.

Antimicrobial activity against bacterial strains and *Candida albicans* was assessed after 24h of incubation, as indicated by the formation of inhibition zones around the wells. The diameters of these zones were measured in millimeters. Each sample was tested in triplicate, and the average results were calculated.

Determination of the minimum inhibitory concentration by the microdilution method

The minimum inhibitory concentration (MIC) of the extracts against bacterial pathogens and *C. albicans* was determined by the microdilution method. Microplates were prepared under aseptic conditions, and each sterile 96-well microplate was labeled. Thirty milligrams of each extract were dissolved in 4% DMSO (Dimethyl Sulfoxide) and homogenized using a vortex. In the first column of the plate, 50µl of each extract was introduced using a micropipette. All other wells contained 100µl of sterile MH broth for all pathogens. Serial dilutions were performed to obtain a decreasing concentration range of the dry extract; finally, 40µl of microbial suspension of each strain (10^6 to 10^8 CFU/ml) was added to every well of the plate. After an incubation period of 18–24h for bacteria and 48 hours for *C. albicans* at 37°C, the MIC was determined by a colorimetric method using 0.2% (w/v) 2,3,5-triphenyltetrazolium chloride (TTC).

RESULTS AND DISCUSSION

Extraction yield

The extraction step is crucial for isolating active compounds from plant materials while reducing the presence of interfering substances (Do et al., 2014). Extracts from various parts of *Solanum elaeagnifolium* were prepared using methanol. For each extract, the yield was calculated relative to 10g of dry plant material and expressed as a percentage. The results obtained are shown in Figure 1.

The yields of the fruits, roots, leaves, and stems of *Solanum elaeagnifolium* are 22.05 ± 0.8%, 6.60 ± 0.15%, 5.60 ± 0.35%, and 7.55 ± 0.00%, respectively. The variation in yield may be attributed to the plant organ used and the extraction technique (Marsoul et al., 2020).

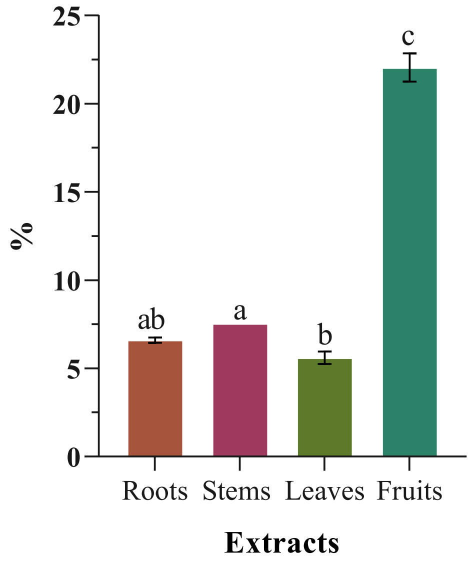

Figure 1. Extraction yield obtained from *Solanum elaeagnifolium*

Total contents of polyphenols flavonoids and tanin

The plant kingdom constitutes a prolific source of bioactive substances with remarkable therapeutic potential. These compounds, which have been used in traditional and modern medicine to treat a multitude of pathologies and counter various pathogens, are the subject of intensive research across the globe. The use of pharmacologically active substances extracted from medicinal plants is attracting growing interest in the pharmaceutical field. Herbal medicines, due to their often high effectiveness, generally low cost, non-narcotic nature, and typically benign side effect profile, are employed by 80% of the world's population, reflecting the importance of this natural source of active ingredients (Marsoul et al., 2020). The key factor in determining the antioxidant capacity of samples is the concentration of phenolic compounds. Figure 2 presents the measurement results.

The Folin-Ciocalteu, vanillin, and aluminium chloride methods were employed to determine the total phenolic content, tannin content, and total flavonoid content, respectively. The flavonoid content of *Solanum elaeagnifolium* extracts is expressed as micrograms of quercitrin equivalent per gram of dry matter (µg EQ/g). Based on the results (Figure 2), the flavonoid contents of the methanolic extracts of the fruits, roots, leaves, and stems of *Solanum elaeagnifolium* were, respectively, in the following order 46.31 ± 1.22µg EQ /g, 34.30 ± 0.04µg EQ /g and 31.24 ± 1.22µg EQ/g and 11.19 ± 0.03µg EQ/g. Flavonoids have several properties, but their ability to trap free radicals and act as antioxidants is undoubtedly the most relevant. In comparison with other studies, these results are lower than those found by Ouerghemmi et al. (2017), who reported: 304.71mg EC/g DM and 298.54 mg EC/g DM for stages 1 and 2, respectively (Ouerghemmi, et al., 2017).

The polyphenol contents of the extracts studied were expressed in milligrams of gallic acid equivalent per gram of dry matter (mg GAE/g). The results (Figure 2) indicate that the average total polyphenol content in fruits, stems, leaves, and roots is, respectively: 0.46 ± 0.01mg GAE/g, 0.13±0.03mg GAE/g, 0.11±0.01mg GAE/g and 0.08±0.00mg GAE/g, respectively. The results indicated that the fruits contain twice as many polyphenols as the stem and root extracts, with the difference being statistically significant ($P< 0.05$) compared to the other findings. However, these results remain lower than those reported by Ouerghemmi et al. (2017). (367.60 mg EAG/g DM and 384.51mg EAG/g DM for stage 1 and stage 2, respectively). Indeed, the roots showed the lowest levels of total polyphenols, as also reported by Ouerghemmi et al. (2017).

Tannin content was determined at 430nm using the acidic vanillin reagent method, and the results were calculated as milligrams of catechin equivalent per gram of dry matter (mg EC/g). Figure 2 indicates that the tannin content in the leaves, fruits, stems, and roots is as follows: (0.10 ±0.02mg QE /g and 0.09 ±0.01mg QE/g, 0.06 ±0.01mg QE/g and 0.01±0.00mg QE/g), respectively.

The difference in tannin content between the four parts of *Solanum elaeagnifolium* is not statistically significant ($P> 0.05$). These results are lower than those reported by Ouerghemmi et al. (2017), whose findings showed values of 434 and 342.9mg EC/g DM for mature and immature fruits, respectively.

Thus, the results clearly demonstrate variation in the contents of total polyphenols (PPT), flavonoids (FT), and condensed tannins (TC) depending on the plant organ tested—leaves, fruits, stems, and roots. These differences can be attributed to factors such as geographical location, climate, the solvent and extraction technique used, the type of sample analyzed, and the stage of maturation (Ouerghemmi et al., 2017).

According to Do et al. (2014), the variability of plant metabolites can be influenced by environmental factors (such as geographical location, cultivar genotype, and soil type) as well as experimental variables (including the harvest period, the specific plant part used, the polarity of the solvent, and the extraction method applied).

Similarly, the variability in total phenolic content and total flavonoid content may be attributed to several factors, including climatic conditions, geographical origin, soil fertility, the plant's genetic background, and experimental parameters such as the organ analyzed, harvest timing, extraction technique, solvent polarity, and extraction duration (Ghatak et al., 2017).

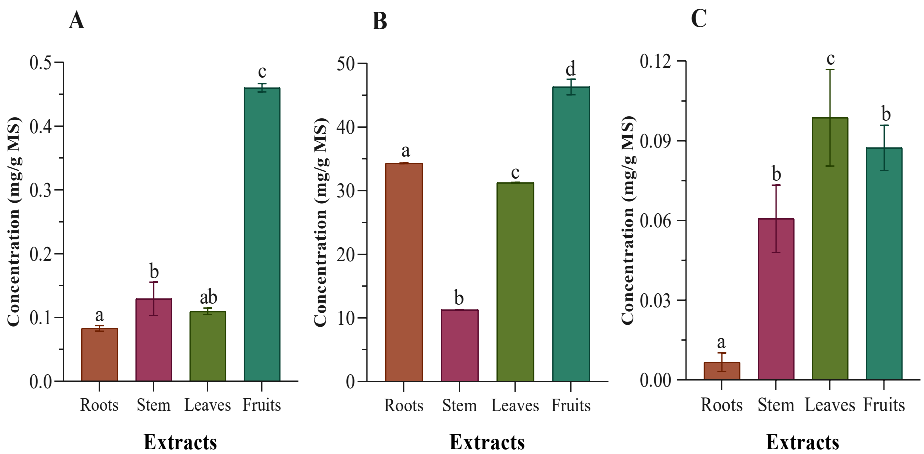

Figure 2. Evaluation of the total content of phenolic compounds, flavonoids and tannins [A: Polyphenols; B: Flavonoids; C: Tannins. Distinct letters indicate significant differences between the means ($P<0.05$)]

Determination of antioxidant activity by scavenging DPPH free radical

The antioxidant power of the four parts of *Solanum elaeagnifolium* extracts was evaluated by measuring their scavenging capacity against DPPH free radicals. The results from the IC_{50} measurement test are presented in Figure 3. The IC_{50} value represents the effective concentration required to achieve a 50% reduction in the initial DPPH concentration. A lower IC_{50} value indicates a stronger antioxidant activity and a more effective protective effect.

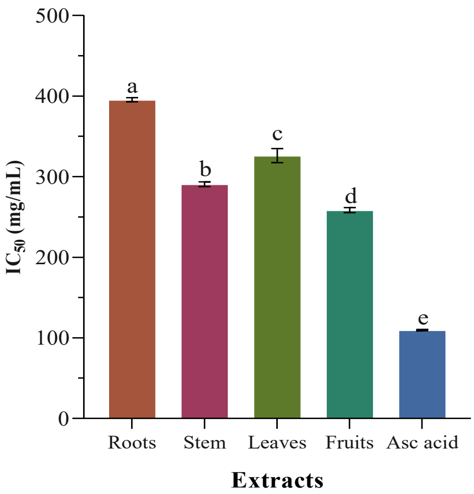

Figure 3. Anti-radical activity (IC_{50}) of extracts of *Solanum elaeagnifolium* a, b, c and d, values showing a statistically significant difference

The IC_{50} of fruits, stems, leaves and roots of this plantare 258.42±3.09µg/mL, 290.69± 2.97µg/mL, 326.02±8.77 µg/mL and 395.48± 2.61µg/mL, respectively. Compared to the antioxidantactivity of the reference substance (ascorbicacid), which is 109.63±0.83µg/ml; The antioxidant power of the four parts of *Solanum elaeagnifolium* is relatively low.

The difference in IC_{50} values between the extracts of the four plant parts is statistically significant ($P< 0.05$). The results are in agreement with those of Rajalakshmi & Pugalenthi (2016). Indeed, the methanolic extracts of the different parts of *Solanum elaeagnifolium* exhibit strong anti-radical activity, particularly the fruits, which surpass the other parts of the plant. This effectiveness is attributed to their high content of polyphenols, which are responsible for their ability to significantly neutralize free radicals.

According to Rajalakshmi & Pugalenthi (2016), the antioxidant activity of silver nanoparticles synthesized from the leaves of *Solanum elaeagnifolium* is higher than that of the leaf extract itself, with IC_{50} values of 2.30mg/ mL, demonstrating their powerful antioxidant properties.

Similarly, Xavier et al. (2022) reported significant antioxidant activity of *Solanum elaeagnifolium* leaves in DPPH, SO, FRAP, MCA, and PHM assays, suggesting their potential as effective antioxidant agents.

Antimicrobial activities

The antimicrobial activity of methanolic extracts of *Solanum elaeagnifolium*—namely FMeOH (fruits), RMeOH (roots), TMeOH (stems), and FEMeOH (leaves)—was assessed in vitro against *Staphylococcus aureus* ATCC 29213, *Escherichia coli* K12, *Bacillus subtilis* ATCC 6633, and *Candida albicans* ATCC 10231. The diameters of the inhibition zones (measured in millimeters) represent the average of three replicates and are shown in Figures 4 and 5. These inhibition zones reflect the effectiveness of the methanolic extracts—FMeOH, RMeOH, TMeOH, FEMeOH—against the tested microorganisms. The results demonstrate that the methanolic extracts of *Solanum elaeagnifolium* exhibit a very significant antimicrobial effect.

For *Candida albicans*, the methanolic extracts FRMéOH (fruits), FEMéOH (leaves), and RMéOH (roots) of *Solanum elaeagnifolium* showed the most significant inhibitions with the widest inhibition zones: $\Phi = 15.5 \pm 0.28$mm, $\Phi = 10\pm0.57$mm, and $\Phi = 7.5 \pm 0.29$mm, respectively. These results reveal significant antifungal activity.

For *Escherichia coli*, the methanolic extracts TMéOH (stems), RMéOH, and FEMéOH did not show any inhibition, except for the FRMéOH extract, which showed sensitivity with an inhibition zone of $\Phi = 2 \pm 0.57$mm.

For *Bacillus subtilis*, the methanolic extracts FRMéOH, FEMéOH, and TMéOH were the only active extracts against the pathogenic strains studied, with significant antibacterial activity of $\Phi = 11\pm0.57$mm and $\Phi = 8.5\pm0.28$mm for FRMéOH and FEMéOH, respectively.

For *Staphylococcus aureus*, the methanolic extracts FRMéOH and FEMéOH also showed significant effectiveness with inhibition zones of $\Phi = 11\pm0.57$mm and $\Phi = 9\pm0.57$mm, respectively.

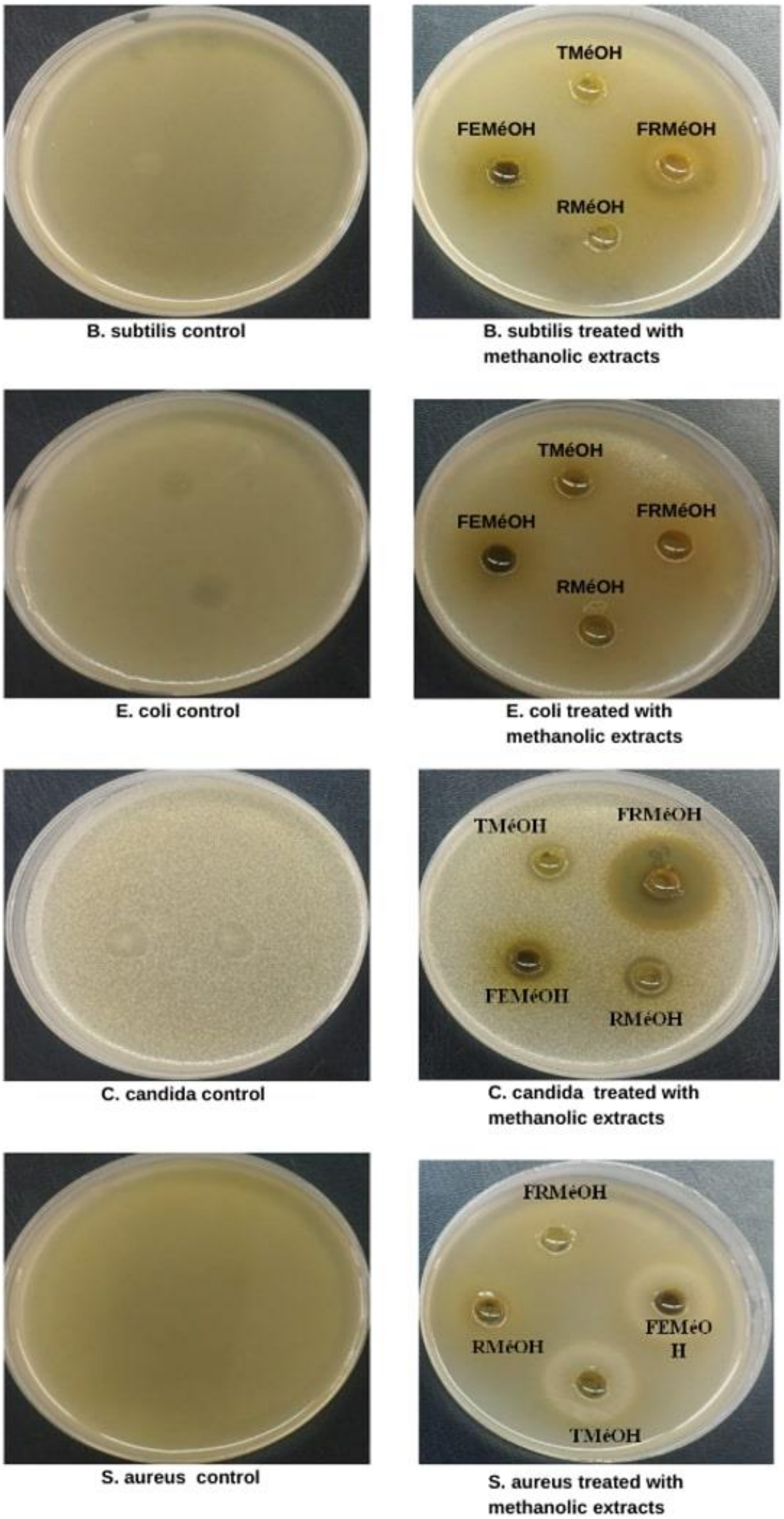

Figure 4. The antimicrobial effects of *Solanum elaeagnifolium* extracts studied on the pathogens tested (FRMéOH, RMéOH, and FEMéOH: methanolic extracts)

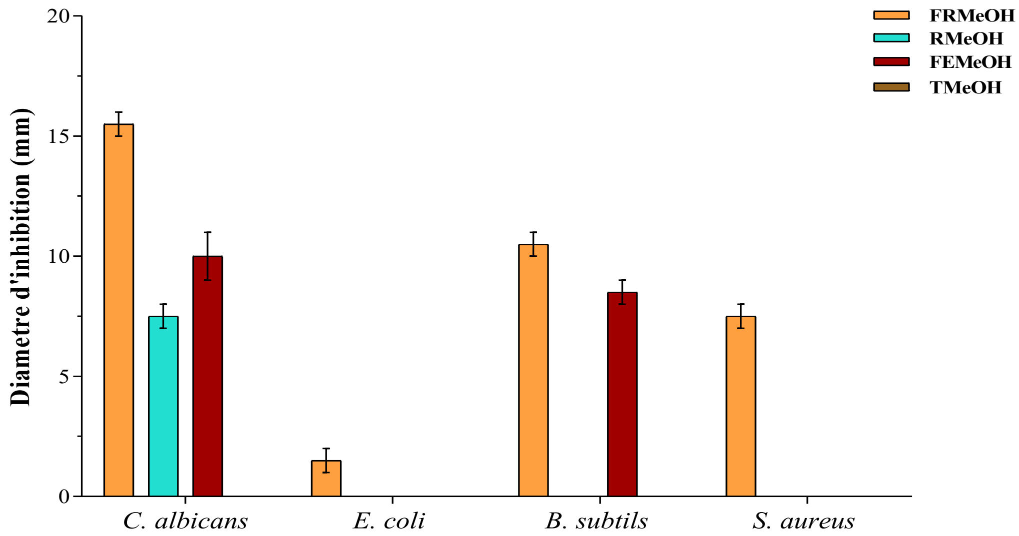

Figure 5. The antimicrobial activity of methanolic extracts of *Solanum elaeagnifolium*

The FRMéOH methanolic extract of *Solanum elaeagnifolium* presents the most interesting antimicrobial activity compared to the other extracts. This extract demonstrated the highest inhibitory activity against *Candida albicans* ATCC 10231, with an inhibition zone diameter of Φ= 15.5 ± 0.28mm.

The differences in the inhibition zone diameters might be mainly due to the chemical composition of the methanolic extracts of *Solanum elaeagnifolium*. The antibacterial activity could primarily be attributed to the functional compounds present in these extracts.

These results show that the extracts studied have notable effectiveness, indicating their potential in the treatment of microbial infections. The methanolic extracts of *Solanum elaeagnifolium* (FRMéOH, RMéOH, FEMéOH) showed very significant antibacterial and antifungal activity. This suggests that the bioactive compounds present in the extracts are better solubilized or more concentrated in methanol, which is crucial for their effectiveness.

These methanolic extracts may prove especially effective in the treatment of fungal infections, particularly candidiasis caused by the pathogenic yeast *Candida albicans*, as well as in the treatment of bacterial infections caused by pathogenic Gram-positive bacteria, notably *Bacillus subtilis* and *Staphylococcus aureus*.

Regarding the *Escherichia coli* strain, a Gram-negative bacterium, it showed relative resistance to all extracts tested, which might require either higher concentrations or combinations of extracts for optimal and significant effectiveness.

Determination of the minimum inhibitory concentration by the microdilution method MICs

The results of the MICs of the extracts studied against the different pathogenic strains are presented in Table 1. These results clearly show that the MIC values generally correspond with the inhibition diameters obtained during the antimicrobial activity tests on solid medium. Indeed, extracts that induced significant zones of inhibition present low MICs on the corresponding strains. It is evident that the MICs of the TMéOH, RMéOH, FRMéOH, and FEMéOH extracts are low.

Table 1. Results of the minimum inhibitory concentration of plant extracts

Extracts (µg/ml)	Microorganisms			
	C. albicans	***S. aureus***	***E. coli***	***B. subtilis***
TMeOH	187±0.00	187±0.00	187±0.00	187±0.00
RMeOH	187±0.00	187±0.00	375±0.00	187±0.00
FRMeOH	187±0.00	187±0.00	187±0.00	187±0.00
FEMeOH	187±0.00	187±0.00	187±0.00	187±0.00

For *Candida albicans*, all methanolic extracts — TMéOH, RMéOH, and FRMeOH — have a minimum inhibitory concentration (MIC) of 187µg/ml. For *Staphylococcus aureus*, all methanolic extracts — TMéOH, RMéOH, FRMeOH, and FEMéOH — also have an MIC of 187µg/ml. For *Bacillus subtilis*, all methanolic extracts — TMéOH, RMéOH, FRMeOH, and FEMéOH — have an MIC of 187µg/ml.

These methanolic extracts showed strong effectiveness against *S. aureus* and *C. albicans* with an MIC of 187µg/ml. This suggests that the bioactive compounds in the methanolic extracts are very effective against these microorganisms. This effectiveness may be attributed to the presence of bioactive compounds, including flavonoids, phenolic compounds, and other secondary metabolites soluble in methanol, which are known for their antimicrobial properties.

For *Escherichia coli*, the methanolic extracts TMéOH and FRMeOH have an MIC of 187µg/ml, while FEMéOH and RMéOH have an MIC of 37µg/ml. These results indicate less effectiveness against *E. coli*, known as the most resistant Gram-negative pathogen.

The results show that the *Solanum elaeagnifolium* methanolic extracts studied have strong antifungal and antibacterial activity, particularly against *Candida albicans* and the Gram-positive bacteria *Bacillus subtilis* and *Staphylococcus aureus*. These extracts could be further explored for the development of natural antifungal and antibacterial treatments. The antifungal activity of methanolic extracts is especially relevant.

The results of this investigation are consistent with those reported by (Gębarowska et al., 2022), who demonstrated that methanolic extracts of the aerial parts of *Solanum nigrum* exhibit higher antibacterial efficacy than those derived from the root system. Specifically, their data revealed MIC values ranging between 125 and 250µg/mL for extracts from aerial parts, while the corresponding MIC values for root extracts exceeded 500µg/mL.

Additionally, (Do et al., 2014) recorded pronounced antibacterial activity against *Pectobacterium carotovorum* and Gram-positive cocci, with minimum bactericidal concentrations (MBCs) being twice the MICs. Conversely, root extracts showed negligible activity against specific strains such as *Staphylococcus aureus*, *Bacillus* spp., *Escherichia coli*, *Pseudomonas aeruginosa*, and *Candida albicans*. This confirms previous research indicating the limited effectiveness of root extracts against these pathogens.

Additionally, the antimicrobial efficacy of *Solanum incanum* leaf against *Staphylococcus aureus* is remarkable, with a minimum inhibitory concentration (MIC) of 1g/mL, highlighting its potential as a potent agent against this particular pathogen (Obat et al., 2023). Along similar lines, *Solanum aculeastrum* fruit extracts exhibited significant antimicrobial properties against *Staphylococcus aureus* and *Candida albicans*, emphasizing the contribution of plant-derived substances in the search for natural antimicrobial pharmaceuticals, especially within the context of traditional African medicine (Xavier et al., 2022).

In another study, *Solanum* seeds, as documented by (Aye et al., 2019), showed antimicrobial activity against *Streptococcus mutans* and *Aggregatibacter actinomycetemcomitans*, with precise MIC and minimum bactericidal concentration (MBC) values defined (Xavier et al., 2022).

These results reinforce the contention that *Solanum nigrum* extracts have considerable potential as natural antimicrobial agents, particularly against Gram-positive cocci, *Pectobacterium* species, and some fungal pathogens (Gębarowska et al., 2022). Additionally, recent research on *Solanum anguivi* revealed substantial antifungal activity against *Candida albicans*, with a clear dose-response relationship, thus validating the effectiveness of this extract under specific conditions (Sitapha et al., 2023).

Acetone extracts of *Solanum dolichosepalum* have also demonstrated antioxidant effects on *Candida albicans* and *Fusarium oxysporum*, attributable to the presence of phenolic compounds likely responsible for these antifungal properties (Slighoua et al., 2023). Furthermore, *Solanum hispidum* leaves exhibited moderate antifungal activity against *Candida albicans*, *Aspergillus brasilensis*, and *Trichophyton mentagrophytes*, showing significant zones of inhibition and low MIC values, as documented by (Mendoza-León et al., 2022).

In conclusion, these various studies confirm that phytochemicals such as phenols, tannins, and flavonoids, present in plant extracts, play a central role in their antifungal and antimicrobial capacities (Kengne et al., 2023). These findings lay the groundwork for innovative approaches that utilize plant extracts as natural alternatives in the fight against bacterial and fungal infections.

CONCLUSION

This study provides a comprehensive analysis of Solanum elaeagnifolium extracts, highlighting their richness in bioactive compounds. Through detailed phytochemical profiling, including the identification of phenolic compounds, flavonoids, tannins, and alkaloids, we support the plant's traditional medicinal applications. The results demonstrate notable differences in phytochemical content across various plant parts, suggesting that the distribution of these compounds plays a key role in the species' biological activities. Considering the high bioactivity observed in Moroccan Solanaceae and related native species, further investigation into their biochemical pathways is essential to fully harness their potential in phytotherapy.

Conflict of interest: The authors declare no conflict of interest.

Authors' contributions: Naji Doha: Drafting, data analysis, experimental execution, visualization of tables and figures, confirmation of results and revision; Moussaid Fatima Zahrae: Confirmation of results and revision; Aouji Marouane: Confirmation of results and revision; Bengueddour Rachid: Study design, choice of scientific methods.

Ethical approval: Not applicable.

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