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Original Article

Phytochemical Screening of Some Medicinal Plants and Antibacterial Activity against Bacteria Isolated from Clinical Specimens - Dhamar City – Yemen

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Abstract

Medicinal plants continue to play an important role in traditional healthcare systems, particularly in regions where access to modern medicine is limited. Many of these plants are known to contain bioactive compounds with antimicrobial properties. This study aimed to investigate the phytochemical composition and antibacterial activity of aqueous extracts from *Solanum incanum* (leaves and fruits), *Dodonaea viscosa* (leaves), and *Argemone mexicana* (leaves) against selected bacterial pathogens isolated from clinical specimens in Dhamar City, Yemen. Qualitative phytochemical screening was carried out using standard methods to detect major secondary metabolites, while antibacterial activity was evaluated using the agar well diffusion technique. The tested bacterial species included *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella* spp., and *Salmonella* spp. The screening results revealed the presence of several bioactive compounds, including alkaloids, phenols, tannins, flavonoids, steroids, terpenoids, saponins, and glycosides, although their distribution varied among the extracts. Alkaloids, phenols, and tannins were consistently detected in all tested samples. Among the evaluated extracts, the aqueous fruit extract of *S. incanum* showed the strongest antibacterial activity, particularly at a concentration of 100 mg/mL. The largest zones of inhibition were observed against *E. coli* (22 ± 1.6 mm), followed by *Salmonella* spp. (18.6 ± 1.7 mm), *Klebsiella* spp. (17.7 ± 1.2 mm), and *S. aureus* (15 ± 0.8 mm). Overall, the findings highlight the antibacterial potential of *S. incanum*, especially its fruit extract, and support its traditional use as a medicinal plant. Further studies are recommended to isolate and characterize the active compounds and to evaluate their potential as alternative antimicrobial agents.

Keywords: Phytochemical screening; Antibacterial activity; Medicinal plants; *Solanum incanum*; Yemen

1. Introduction

Yemen is known for its rich plant biodiversity, with many species traditionally used for medicinal purposes. For generations, these plants have played an essential role in healthcare, particularly in rural communities where access to modern medical facilities remains limited. In such settings, traditional medicine continues to be the primary source of treatment for a wide range of illnesses, relying on local knowledge passed down through generations [1, 2]. This reliance on medicinal plants reflects both cultural practices and practical necessity.

Medicinal plants have long attracted scientific interest because they contain phytochemicals—naturally occurring bioactive compounds that contribute to their therapeutic properties. According to the World Health Organization, nearly 80% of the global population uses herbal remedies as part of primary healthcare, largely due to their accessibility, affordability, and perceived safety [3]. These phytochemicals include alkaloids, flavonoids, phenols, terpenoids, tannins, sterols, and glycosides, many of which exhibit antimicrobial, anti-inflammatory, and antioxidant activities [4, 5].

Among the medicinal plants widely used in traditional medicine, species belonging to the genus *Solanum* have received considerable attention for their antimicrobial potential. *Solanum incanum* L. (family Solanaceae) is one such species and is commonly used in folk medicine. Previous studies have reported that this plant contains solanine and other steroidal alkaloids that show activity against several pathogenic microorganisms [6, 7]. Similarly, *Dodonaea viscosa* L. (family Sapindaceae) has been investigated for its antibacterial properties, with reports indicating its effectiveness against *Staphylococcus aureus* and other Gram-positive bacteria, particularly in the treatment of skin infections [8-11].

Another plant of interest is *Argemone mexicana* L. (family Papaveraceae), commonly known as Ghamoya. Although native to South

America, it is now widely distributed in tropical and subtropical regions and has become well established in parts of Yemen. Traditionally, different parts of the plant—especially the leaves—have been used to treat wounds, skin infections, ulcers, cough, and itching. Because of its availability and ethnomedicinal importance, *A. mexicana* has been the subject of several studies exploring its antimicrobial and antifungal activities [12-14].

In recent years, the growing problem of antibiotic resistance has intensified the search for new antimicrobial agents. The misuse and overuse of antibiotics in both clinical practice and agriculture have contributed significantly to the emergence of multidrug-resistant bacteria [15, 16]. These resistant pathogens are increasingly responsible for both hospital-acquired and community-acquired infections [17, 18]. Common bacterial species such as *Escherichia coli*, *Klebsiella pneumoniae*, *Salmonella* spp., *Staphylococcus aureus*, and *Pseudomonas aeruginosa* have developed resistance to many commonly used antibiotics, posing serious challenges to public health worldwide [17, 19]. Recent estimates suggest that antibiotic-resistant infections are responsible for millions of illnesses and tens of thousands of deaths each year [20, 21].

Despite Yemen's long history of traditional medicine and its wide variety of medicinal plants, scientific studies evaluating the antimicrobial potential of native plant species remain limited. In particular, there is a lack of laboratory-based evidence supporting the use of commonly used plants against clinically relevant bacterial pathogens. Therefore, the present study aimed to evaluate the phytochemical composition and antibacterial activity of aqueous extracts from the leaves of *S. incanum*, *D. viscosa*, and *A. mexicana*, as well as the fruits of *S. incanum*. The antibacterial activity of these extracts was assessed against selected bacterial isolates (*E. coli*, *S. aureus*, *Klebsiella* spp., and *Salmonella* spp.) obtained from clinical specimens in Dhamar City, Yemen, with the goal of identifying potential plant-based alternatives for antimicrobial therapy.

2. Materials and Methods

2.1 Plant Collection

Leaves of *Solanum incanum*, *Dodonaea viscosa*, and *Argemone mexicana*, as well as fruits of *S. incanum* (Figure 1), were collected from different locations within Dhamar City, Yemen, between August and September 2024. Fresh plant materials were selected to avoid contamination or degradation. Botanical identification was carried out by specialists from Thamar University, and voucher specimens were authenticated to ensure correct species identification before laboratory analysis.

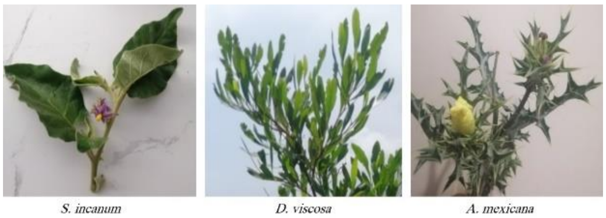

Figure 1: Medicinal plants used in the study collected from Dhamar City, Yemen: *Solanum incanum* (leaves and fruits), *Dodonaea viscosa* (leaves), and *Argemone mexicana* (leaves).

2.2 Preparation of Extracts

Fresh plant materials were washed, air-dried in the shade, and then pulverized using a laboratory blender. Approximately 10 grams of the dried and powdered plant material were extracted twice by maceration in 100 mL of distilled water. The mixtures were agitated continuously for three days using an orbital shaker. After maceration, the solutions were filtered through Whatman No. 1 filter paper. The resulting crude aqueous extracts were concentrated by evaporation in a water bath at 50°C, then weighed and stored in sterile, airtight containers at 4 °C for subsequent use within two weeks [22]. Three concentrations of plant extracts were used, each at 100 mg/ml, 50 mg/ml, and 25 mg/ml. These extracts were subsequently subjected to phytochemical screening [23].

2.3 Phytochemical Screening

Standard qualitative methods were used to detect the presence of major phytochemicals, including alkaloids, flavonoids, phenols, tannins, saponins, terpenoids, steroids, and glycosides. Procedures were adapted from established protocols [24, 25] as described in Table 1.

Table 1: Qualitative phytochemical screening tests used for the detection of major secondary metabolites in aqueous plant extracts.

Phytoconstituents	Test	Observation
Alkaloids	Mayer's test	Creamy or white precipitate
Phenols	Ferric chloride test	Blue-black coloration
Flavonoids	Alkaline reagent test	Yellow color and colorless on the addition of 3 drops of HCl
Tannin	Braymer's Test	Green precipitate
Glycosides	Killer Killiani test	Reddish brown at the junction
Saponins	Froth test	Layer of foam
Steroids	Liebermann-Burchard test	Brown ring at the junction
Terpenoids	Salhowski test	Reddish brown coloration

2.4 Antibacterial Activity

2.4.1 Sample Collection

Clinical bacterial isolates were obtained from patients at Taiba Hospital and Al-Dubai Specialized Laboratories between September and November 2024. Samples were transported to microbiology laboratories at Thamar University and Al-Hikma University (Dhamar) for analysis. Isolates were cultured on nutrient agar and incubated at 37°C for 24 hours. Identification of bacterial strains—*Escherichia coli*, *Klebsiella* spp., *Salmonella* spp., and *Staphylococcus aureus*—was performed using standard biochemical techniques [26].

2.4.2 Inoculum Preparation

Three to four well-isolated colonies of each bacterial strain were selected and inoculated into peptone water, followed by incubation at 35°C for three hours. The resulting turbidity was adjusted to match the 0.5 McFarland standard, ensuring a uniform bacterial concentration suitable for sensitivity testing.

2.4.3 Assessment of Antibacterial Activity

Antibacterial efficacy of the plant extracts was evaluated using the agar well diffusion method, as described by [27]. A standardized bacterial suspension (10^8 CFU/mL) was spread evenly across sterile Mueller-Hinton Agar (MHA) plates using sterile cotton swabs. After allowing the surface to dry, wells of 6 mm diameter were created using a sterile cork borer. Each well was filled with 20 µL of the respective plant extract using a sterile syringe, and a positive control (Amoxicillin 10 mcg) was added. Plates were incubated at 37 ± 2°C for 24 hours. Following incubation, zones of inhibition were measured in millimeters using a digital caliper. All experiments were conducted in triplicate to ensure reliability and reproducibility.

2.5 Data Analysis

All data were expressed as mean ± standard deviation. Statistical analysis was performed using one-way analysis of variance (ANOVA) via SPSS software (version 21, 2006). Differences among means were analyzed using the Student–Newman–Keuls post hoc test, with statistical significance accepted at $p < 0.05$.

3. Results and Discussion

3.1 Phytochemical Screening

Qualitative phytochemical screening revealed the presence of several secondary metabolites across the tested plant extracts, although their distribution varied among species and plant parts (Table 2). Alkaloids, phenols, and tannins were consistently detected in all extracts, suggesting that these compounds are common constituents of the selected medicinal plants. Flavonoids were present in most extracts but were not detected in the leaves of *Solanum incanum*. Saponins were absent in *Dodonaea viscosa*, while steroids and terpenoids were mainly confined to the fruit extract of *S. incanum*.

These findings are in agreement with previous studies. For instance, Karanja et al. (2021)[28] Reported that *S. incanum* fruits contain alkaloids, glycosides, steroids, tannins, flavonoids, phenols, saponins, and terpenoids. Similar results were found by Akanmu et al. (2019) [29], who observed the presence of cardiac glycosides, flavonoids, terpenoids, and steroids in *S. incanum* extracts. Jepkoech and Gakunga (2017) [21] also identified alkaloids as dominant compounds, followed by saponins and steroid glycosides, with terpenoids, flavonoids, and cardiac glycosides detected in lesser amounts.

Table 2: Phytochemical constituents detected in aqueous extracts of *Solanum incanum* (leaves and fruits), *Dodonaea viscosa* (leaves), and *Argemone mexicana* (leaves).

Phyto \ Plants	*Solanum incanum* leaves	*Solanum incanum* fruit	*Dodonaea viscosa*	*Argemone mexicana*
Alkaloids	+ve	+ ve	+ ve	+ ve
Phenols	+ ve	+ ve	+ ve	+ ve
Flavonoids	- ve	+ ve	+ ve	+ ve
Tannin	+ ve	+ ve	+ ve	+ ve
Glycosides	+ ve	+ ve	- ve	- ve
Saponins	+ ve	+ ve	- ve	+ ve
Steroids	- ve	+ ve	- ve	- ve
Terpenoids	- ve	+ ve	- ve	- ve

(+ve indicates presence; −ve indicates absence)

The presence of glycosides and saponins in several extracts is pharmacologically significant, as these compounds are known for their ability to combat microbial infections [24]. Their identification in this study further supports the medicinal value of these plants and their potential application in the development of novel antibacterial formulations.

3.2 Susceptibility of Bacterial Isolates to Plant Extracts

The antibacterial activity of each plant extract was assessed against three isolates of each bacterial species using the well-diffusion method. These species are known pathogens commonly implicated in human infections. Results indicated that all tested plant extracts exhibited antibacterial activity, though to varying degrees. This supports the concept that medicinal plants are rich reservoirs of bioactive compounds with antimicrobial potential [30].

Notably, the fruit extract of *S. incanum* displayed the strongest antibacterial effect across all bacterial isolates at a concentration of 100 mg/mL (Table 3), followed by its leaf extract. In contrast, the aqueous leaf extract of *D. viscosa* exhibited comparatively lower antibacterial efficacy. The enhanced activity of *S. incanum* extracts may be attributed to the higher concentration and diversity of phytochemicals present in its tissues [28]. As highlighted by Femi-Adepoju (2023) [31], the antimicrobial activity of plant-derived extracts is closely linked to the nature and abundance of their phytochemical constituents.

3.3 Antibacterial Activity Assessed by the Well Diffusion Method

This study evaluated the antibacterial properties of aqueous extracts from *S. incanum* (leaves and fruits), *D. viscosa* (leaves), and *Argemone mexicana* (leaves) against four clinically significant bacterial species: *Escherichia coli*, *Salmonella* spp., *Klebsiella* spp., and *Staphylococcus aureus*. Antibacterial activity was determined by measuring the zones of inhibition around the wells.

Among all extracts tested, the aqueous fruit extract of *S. incanum* exhibited the highest antibacterial activity. This can be attributed to its diverse range of phytochemical constituents—including alkaloids, glycosides, steroids, tannins, flavonoids, phenols, saponins, and terpenoids—which are known for their antimicrobial mechanisms [32, 33]. The solubility of these secondary metabolites in water may further enhance their bioactivity in aqueous extracts.

Each major class of phytochemicals contributes to antibacterial activity via specific mechanisms: Alkaloids act through various pathways, including inhibiting bacterial DNA replication, interfering with respiratory enzymes, disrupting membrane integrity, and modulating virulence gene expression. Phenolic compounds, including flavonoids and simple phenols, exhibit antimicrobial effects by forming stable complexes with bacterial proteins, inhibiting essential enzymes, and disrupting microbial membranes [34, 35].

Flavonoids contribute via direct interaction with bacterial membranes and oxidative disruption. Their activity is influenced by molecular structure; some studies report greater activity with increased hydroxylation [36], while others suggest higher membrane permeability in flavonoids lacking hydroxyl groups on the B-ring [37].

Overall, the extracts demonstrated differential efficacy against the bacterial strains, with *E. coli* showing the most significant susceptibility, followed by *Klebsiella* spp., *Salmonella* spp., and *S. aureus*.

In Tables 4 and 5, significant differences were observed between the plant extract and the bacteria used, except for *S.aureus* bacteria with Solanum leaves.

Previous studies support these findings. For instance, methanolic extracts of *A. mexicana* showed significant inhibition against *E. coli* and *Klebsiella* spp. at 100 mg/mL[38]. However, Sbhatu and Abraha (2020) [39] reported that *S. incanum* fruit extracts showed particularly high activity against Salmonella typhi. Similarly, Al-Haj et al. (2019)[40] found that methanolic extracts of *D. viscosa* produced inhibition zones of 8–9 mm against *S. aureus*. Importantly, our findings support a dose-dependent relationship, as greater inhibition was observed with higher extract concentrations—a trend consistent with other studies [41-43].

Table 3: Susceptibility of clinical bacterial isolates to different concentrations of aqueous plant extracts, expressed as number and percentage of responsive isolates.

Plants	Concentration of the plant extract	Bacteria							
		E. coli No = 3		*Salmonella* spp. No = 3		*Klebsiella* spp. No = 3		S. aureus No = 3	
		No.	%	No.	%	No.	%	No.	%
***Solanum incanum* leaves**	25 mg	1	33.3	0	0	0	0	1	33.3
	50 mg	2	66.7	2	66.7	1	33.3	1	33.3
	100 mg	3	100	2	66.7	2	66.7	2	66.7
***Solanum incanum* Fruit**	25 mg	3	100	2	66.7	3	100	2	66.7
	50 mg	3	100	3	100	3	100	3	100
	100 mg	3	100	3	100	3	100	3	100
***Dodonaea viscosa* leaves**	25 mg	0	0	0	0	0	0	0	0
	50 mg	1	33.3	1	33.3	2	66.7	1	33.3
	100 mg	2	66.7	2	66.7	2	66.7	2	66.7
***Argemone mexicana* leaves**	25 mg	0	0	0	0	0	0	0	0
	50 mg	1	33.3	2	66.7	2	66.7	1	33.3
	100 mg	2	66.7	2	66.7	3	100	2	66.7

Table 4: Antibacterial activity of aqueous plant extracts against selected bacterial species, measured as zones of inhibition (mm) using the agar well diffusion method.

Plants	Bacteria	Inhibition Zone (mm) (mean ± SD of 3 isolates			Control positive
		25 mg	50 mg	100 mg	
***Solanum incanum* leaves**	*S. aureus*	10.3 ± 1.2	11.3 ± 1.7	13.3 ± 1.2	10 ± 0.8
	E. coli	7.3 ± 0.46	10.7 ± 0.46	14.3 ± 1.2	23.6 ± 1.2
	Salmonella spp.	0	10 ± 1.6	14.6 ± 0.46	22 ± 1.4
	Klebsiella spp.	0	8.7 ± 0.46	10.7 ± 0.94	11 ± 0.8
***Solanum incanum* Fruit**	*S. aureus*	11 ± 1.6	13.3 ± 0.46	15 ± 0.8	10 ± 0.8
	E. coli	15.3 ± 1.2	18.6 ± 1.2	22 ± 1.6	23.6 ± 1.2
	Salmonella spp.	14.3 ± 1.7	16.3 ± 1.2	18.6 ± 1.7	22 ± 1.4
	Klebsiella spp.	8 ± 0.8	13.6 ± 1.2	17.7 ± 1.2	11 ± 0.8
***Dodonaea viscosa* leaves**	*S. aureus*	0	7.3 ± 0.46	9.6 ± 0.46	10 ± 0.8
	E. coli	0	8.3 ± 1.2	12.3 ± 1.2	23.6 ± 1.2
	Salmonella spp.	0	7	8.3 ± 1.2	22 ± 1.4
	Klebsiella spp.	0	8 ± 0.8	10.3 ± 0.46	11 ± 0.8
***Argemone mexicana* leaves**	*S. aureus*	0	9.6 ± 1.2	12 ± 0.8	10 ± 0.8
	E. coli	0	7.3 ± 0.46	8.3 ± 0.46	23.6 ± 1.2
	Salmonella spp.	0	8.6 ± 0.9	9	22 ± 1.4
	Klebsiella spp.	0	10 ±1.6	12.3 ± 1.2	11 ± 0.8

Values are presented as mean ± standard deviation (n = 3). Amoxicillin (10 µg) was used as a positive control.

Table 5: Statistical significance (p-values) of antibacterial activity between plant extracts and tested bacterial species.

Plants ex. / Bacteria sp.	*Solanum incanum* leaves	*Solanum incanum* fruit	*Dodonaea viscosa*	*Argemone mexicana*
S. aureus	0.23^{ns}	0.0029**	<0.0001***	<0.0001***
E. coli	<0.0001***	<0.0001***	<0.0001***	<0.0001***
***Salmonella* spp.**	<0.0001***	0.0011**	<0.0001***	<0.0001***
***Klebsiella* spp.**	<0.0001***	<0.0001***	<0.0001***	<0.0001***

Significance levels: ns = not significant (p > 0.05), ** = significant (p < 0.01), *** = highly significant (p < 0.001).

4. Conclusion

This study demonstrated that aqueous extracts from selected medicinal plants commonly used in Yemen possess measurable antibacterial activity against clinically relevant bacterial pathogens. Among the tested plants, the fruit extract of *Solanum incanum* showed the strongest and most consistent antibacterial effect, which may be attributed to its rich and diverse phytochemical composition. The observed dose-dependent inhibition supports the role of plant-derived secondary metabolites as contributors to antimicrobial activity. These findings provide scientific support for the traditional use of *S. incanum*, *Dodonaea viscosa*, and *Argemone mexicana* in the treatment of infectious diseases. Although the results are limited to in vitro conditions, they highlight the potential of these plants—particularly *S. incanum*—as accessible sources of antibacterial agents. Further studies are warranted to isolate active compounds, evaluate their mechanisms of action, and assess safety and efficacy in vivo, with the aim of developing cost-effective alternatives to conventional antibiotics.

Data Availability

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

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