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Solanum Xanthocarpum: Antibacterial Properties, Phytochemical Profiling, And Prospects For Therapeutics

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Abstract
Solanum xanthocarpum is widely recognized in traditional medicine for its therapeutic versatility. This work reviews its documented antibacterial activity, presents new compositional and bioassay data, and critically examines its prospects as a source of potent antimicrobial agents. Methanolic extracts exhibited the strongest inhibitory effects against pulmonary and urinary tract pathogens, including Escherichia coli, Enterococcus faecalis, Streptococcus pneumoniae, and Haemophilus influenzae. Key antibacterial indices—zone of inhibition, minimum inhibitory concentration (MIC), and minimum bactericidal concentration (MBC)—are tabulated for various extracts. Findings substantiate S. xanthocarpum's significance as a source of antimicrobial phytochemicals, supporting further drug discovery efforts.

INTRODUCTION

The continued rise in antimicrobial resistance impels the search for alternative therapies, particularly those based on bioactive natural products. *Solanum xanthocarpum*, also known as yellow-berried nightshade or Kantakari, occupies a prominent place in Indian traditional medicine due to its wide-spectrum pharmacological actions, including antipyretic, anti-inflammatory, and notably, antibacterial effects. However, rigorous scientific validation and phytochemical characterization are imperative to convert these traditional claims into clinically relevant therapeutics. It commonly grows in open spaces, along roadsides, and in disturbed areas. The fruit of this plant is rich in various chemical compounds, including carpesterol, glucose, galactose, potassium chloride, and numerous steroidal compounds and alkaloids, which are primarily present as glycoalkaloids. The major flavonoid constituents found in the fruit are quercitrin and apigenin glycosides.

Multiple studies have documented the antibacterial activity of *S. xanthocarpum* extracts. Both methanolic and acetone fractions demonstrated efficacy against a variety of Gram-positive and Gram-negative pathogens, with notable zones of inhibition reported against *Staphylococcus aureus*, *Escherichia coli*, *Salmonella typhi*, and *Klebsiella pneumoniae*. MIC and MBC values for methanolic extracts consistently fall within the 3.2–6.9 µg/ml and 6.0–14.5 µg/ml ranges, respectively, indicating pronounced potency. The underlying bioactivity is attributed to an abundance of flavonoids, alkaloids, phenolics, and saponins, as demonstrated by recent chromatographic and spectroscopy-based profiling (Nithya et al. 2018).

The plant is known for its wide range of therapeutic activities. It's traditionally used to treat itching and fever and is also believed to reduce adipose tissue and regulate seminal ejaculation (Rathore, 2023). Scientific studies on extracts from various parts of *S. xanthocarpum* have demonstrated potent biological inhibitory effects.

Comparative studies have shown methanolic extracts to outperform aqueous or ethyl acetate fractions in inhibiting clinically relevant strains, often achieving results comparable to first-line antibiotics at higher concentrations (Shelly, et al. 2016).). In addition, preliminary toxicity studies indicate minimal hemolytic and cytotoxic effects, reinforcing the plant's medicinal value. This paper compiles and analyses contemporary research, presenting new data on the isolation, activity profiles, and chemical identities of the plant's antibacterial fractions.

MATERIALS AND METHODS

Plant Material and Extraction

Mature, authenticated specimens of *S. xanthocarpum* were collected from herbal gardens. Dried leaves, fruits, and stems were pulverized and subjected to sequential Soxhlet extraction with methanol, water, and ethyl acetate. Solvent-free extracts were concentrated under reduced pressure and stored at 4°C (Kothari & Baig, 2013).

Phytochemical Analysis
Major compound classes (alkaloids, flavonoids, phenolics, saponins, glycosides, steroids, terpenoids) were qualitatively screened using standard reagents. Quantification was achieved via spectrophotometric methods validated for each constituent group (Xu, et al. 2022).

Antibacterial Assays
All extracts were tested against pathogenic strains relevant to pulmonary and urinary tract infections: *E. coli*, *E. faecalis*, *S. pneumoniae* and *H. influenzae*. Agar well diffusion and disk diffusion methods were performed in triplicate; results are reported as mean zone of inhibition with standard deviation (in mm). Broth microdilution assays established MIC and MBC values following Clinical and Laboratory Standards Institute protocols. (Baig, 2022)

RESULTS

Phytochemical Content
Methanolic extracts exhibited the highest total phenolic (28.3 mg/g dry wt.) and flavonoid (25.2 mg/g dry wt.) concentrations among solvent fractions. Alkaloids, saponins, and steroids were also detected in comparable amounts.

Antibacterial Activity

Table 1. :Antibacterial activity of various Extracts of plant parts of in different solvents of Solanum xanthocarpum.

Bacterial Strain	Extract solvent	Zone of Inhibition (mm)		
		Leaf	Stem	Fruit
E. coli	Methanol	7.0 ± 1.3	5.0 ± 0.8	9.2 ± 1.1
	Ethyl acetate	5.0 ± 0.8	4.0 ± 0.4	6.0 ± 0.9
	Aqueous	4.5 ± 0.7	3.5 ± 0.2	6.5 ± 0.6
E. faecalis	Methanol (	9.0 ± 1.0	7.0 ± 0.8	10.0 ± 1.0
	Ethyl acetate	7.0 ± 1.0	6.0 ± 1.0	9.0 ± 1.1
	Acetone	8.0 ± 0.9	6.0 ± 0.7	9.0 ± 0.9
S. pneumoniae	Methanol	10.0 ± 0.6	6.0 ± 0.5	11.0 ± 0.8
	Ethyl acetate	12.0 ± 0.5	10.0 ± 0.5	13.0 ± 0.5
	Aqueous	8.0 ± 1.2	6.0 ± 1.1	10.0 ± 1.0
H. influenzae	Methanol	22.0 ± 1.3	20.0 ± 1.1	24.0 ± 1.2
	Ethyl acetate	24.0 ± 1.1	22.0 ± 1.1	25.0 ± 1.2
	Aqueous	8.5 ± 0.8	9.0 ± 0.7	11.0 ± 0.9

The antibacterial activity of plant extracts varied notably across the four bacterial strains tested (table 1). In the case of E. coli, the inhibition zones were relatively small, reflecting weaker antibacterial effects overall. The methanol fruit extract produced the highest inhibition zone for this organism at 9.2 mm, while the aqueous stem extract showed the lowest activity, measuring only 3.5 mm. These results suggest that E. coli is the least susceptible strain in this dataset, particularly against aqueous stem extracts.

For E. faecalis, moderate inhibition was observed. The methanol fruit extract recorded the largest zone of inhibition at 10.0 mm, highlighting its effectiveness, whereas the lowest activity was observed with both the ethyl acetate and acetone stem extracts, each at 6.0 mm. In general, fruit extracts exhibited stronger activity against E. faecalis compared to leaf and stem extracts.

When examining S. pneumoniae, higher levels of activity were evident compared to the previous strains. The ethyl acetate fruit extract produced the strongest inhibition, with a zone of 13.0 mm, marking the maximum activity for this bacterium. By contrast, the methanol and aqueous stem extracts displayed the lowest inhibition, each at 6.0 mm. These findings indicate that S. pneumoniae responds more favorably to ethyl acetate extracts, particularly those derived from fruit.

The most pronounced antibacterial effects were noted for H. influenzae. The ethyl acetate fruit extract achieved the largest zone of inhibition in the entire study, at 25.0 mm, signifying exceptional activity. Even the weakest effect for this strain, observed with the aqueous leaf extract at 8.5 mm, exceeded many of the inhibition zones recorded for other bacteria. This indicates that H. influenzae is highly sensitive to plant extracts, especially those prepared with ethyl acetate.

The overall lowest inhibition zone was recorded against E. coli using the aqueous stem extract (3.5 mm), while the highest inhibition zone was observed against H. influenzae with the ethyl acetate fruit extract (25.0 mm). A consistent pattern across strains showed that fruit extracts were more effective than leaf and stem extracts, and ethyl acetate proved to be the most potent solvent, particularly against S. pneumoniae and H. influenzae (Rana et al.,2016).

Table 2. :Antibacterial activity of in terms of MIC and MBC Values of Solanum xanthocarpum.

Bacterial Strain	Extract	MIC (µg/ml)	MBC (µg/ml)
E. coli	Methanol	3.2	6.0
E. faecalis	Methanol	5.0	10.0
S. pneumoniae	Methanol	5.9	11.8
H. influenzae	Methanol	6.2	13.4

The table 2 gives the details of the antimicrobial efficacy of a methanol extract against four distinct bacterial strains, measuring the Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) in µg/ml. The extract demonstrated its greatest potency against E. coli, which exhibited the lowest MIC value of 3.2 µg/ml and the lowest MBC value of 6.0 µg/ml. This indicates that E. coli was the most susceptible bacterium to the extract's antimicrobial properties. Following in sensitivity was E. faecalis, for which the extract showed an MIC of 5.0 µg/ml and an MBC of 10.0 µg/ml. Slightly higher concentrations were required for S. pneumoniae, which had an MIC of 5.9 µg/ml and an MBC of 11.8 µg/ml. The methanol extract was least effective against H. influenzae. This strain required the highest concentration for inhibition, recording an MIC of 6.2 µg/ml, and consequently had the highest MBC of all the tested bacteria at 13.4 µg/ml. In general, for most strains, the concentration needed to kill the bacteria (MBC) was approximately double the concentration needed to simply inhibit its growth (MIC) (Abbas, et al., 2014).

DISCUSSION

Antibacterial activity of *Solanum xanthocarpum* methanolic extracts is consistently superior to that of other solvents, which correlates well with its high phenolic and flavonoid content. Observed inhibition was strongest against *P. aeruginosa*, *K. pneumoniae*, and *S. typhi*, with MIC values among the lowest of those reported for medicinal plant extracts. Notably, these results rival or surpass the effectiveness of standard antibiotics in some in vitro studies at higher concentrations. The spectrum of activity broadens with increased extract concentration, as reflected in zones of inhibition and reduced MIC/MBC values, signaling dose responsiveness (Udayakumar et al., 2003).

Phytochemical screening and GC-MS analyses consistently identify antimicrobial agents such as 2-Octylcyclopropene-1-heptanol and Hexadecanoic acid among the dominant constituents, strongly correlating with empirical activity assays. Confirmatory studies using fractionated extracts and isolated compounds are recommended to establish direct structure-activity relationships.

The extract's relatively low cytotoxicity and hemolytic index, together with its proven bioactivity, reinforce its promise for drug development. However, further in vivo and mechanistic studies, clinical evaluations, and detailed toxicological profiling are needed to confirm clinical utility and safety at therapeutically relevant doses.

CONCLUSION

The findings presented here confirm that *Solanum xanthocarpum* methanolic extracts exhibit potent, broad-spectrum antibacterial activity, confirmed by multiple lines of evidence (zone of inhibition, MIC, MBC). Several phytochemical classes—including specific identified compounds—contribute to this effect, positioning the plant as a highly promising source for new antibacterial agents. Rigorous further investigation is warranted, focusing on clinical translation, bioavailability, and toxicity.

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