J. Biodivers. Conservation 10(2): 63-71 ISSN: 2457-0761 (online)
2026 http://www.aprfjournal.in

Research Article

Phyllanthus acidus (L.) Skeels (fruits) as a promising source of natural antioxidants: an overview

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Article Details: Received: 2026-03-15 | Accepted: 2026-05-09 | Available online: 2026-05-10

DOI: https://doi.org/10.5281/zenodo.20095090

Abstract: *Phyllanthus acidus* (L.) Skeels, commonly known as Star gooseberry, is a tropical medicinal plant whose fruits have been traditionally used for their therapeutic properties. The present study investigated the phytochemical composition and antioxidant potential of *P. acidus* fruit extracts prepared in three solvents; n-hexane, ethanolic and aqueous. Present qualitative phytochemical screening revealed the presence of flavonoids, phenols and reducing sugars across all three extracts, while tannins and saponins were detected exclusively in the ethanolic and aqueous extracts, confirming the polarity-dependent distribution of bioactive compounds. Terpenoids, steroids and alkaloids were absent in all extracts. The antioxidant activity, evaluated through the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging assay, demonstrated a concentration-dependent inhibition pattern across all extracts. At the highest tested concentration of 1.0 mg/ml, the aqueous extract exhibited the most potent scavenging activity (99.32%), followed by the ethanolic (89.68%) and n-hexane (77.13%) extracts, suggesting that polar solvents more effectively recover the phenolic and flavonoid constituents responsible for antioxidant activity. These findings collectively indicated that *P. acidus* fruits represent a promising natural source of bioactive antioxidants, warranting further investigation into their isolation, characterization and potential application in nutraceutical and pharmaceutical formulations.

Keywords: Bioactive compounds, nutraceutical, pharmaceutical and potent scavenging activity

Introduction

Oxidative stress occurs when there's an imbalance between the production of reactive oxygen species (ROS) and the body's ability to neutralize them (Qin et al., 2026). This imbalance has been linked to a range of chronic and degenerative diseases, including heart problems, diabetes, neurodegenerative disorders and various cancers (Liu et al., 2025). Antioxidants are crucial in reducing oxidative damage by scavenging free radicals and breaking the chain reactions that can lead to cellular harm. While synthetic antioxidants like butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) are commonly used in the food and pharmaceutical industries, there are growing concerns about their potential toxicity and cancer risk (Gulcin, 2025). This has sparked significant interest in finding plant-based natural antioxidants as safer and more sustainable options. In this light, medicinal plants and their bioactive secondary metabolites, such as phenolics, flavonoids, tannins and saponins have emerged as rich sources of powerful antioxidant compounds with wide-ranging therapeutic benefits (Kumar et al., 2023). Several previous investigations have reported the presence of biologically significant phytochemicals in various parts of *Phyllanthus* species, lending strong ethnobotanical and pharmacological credibility to the genus as a whole.

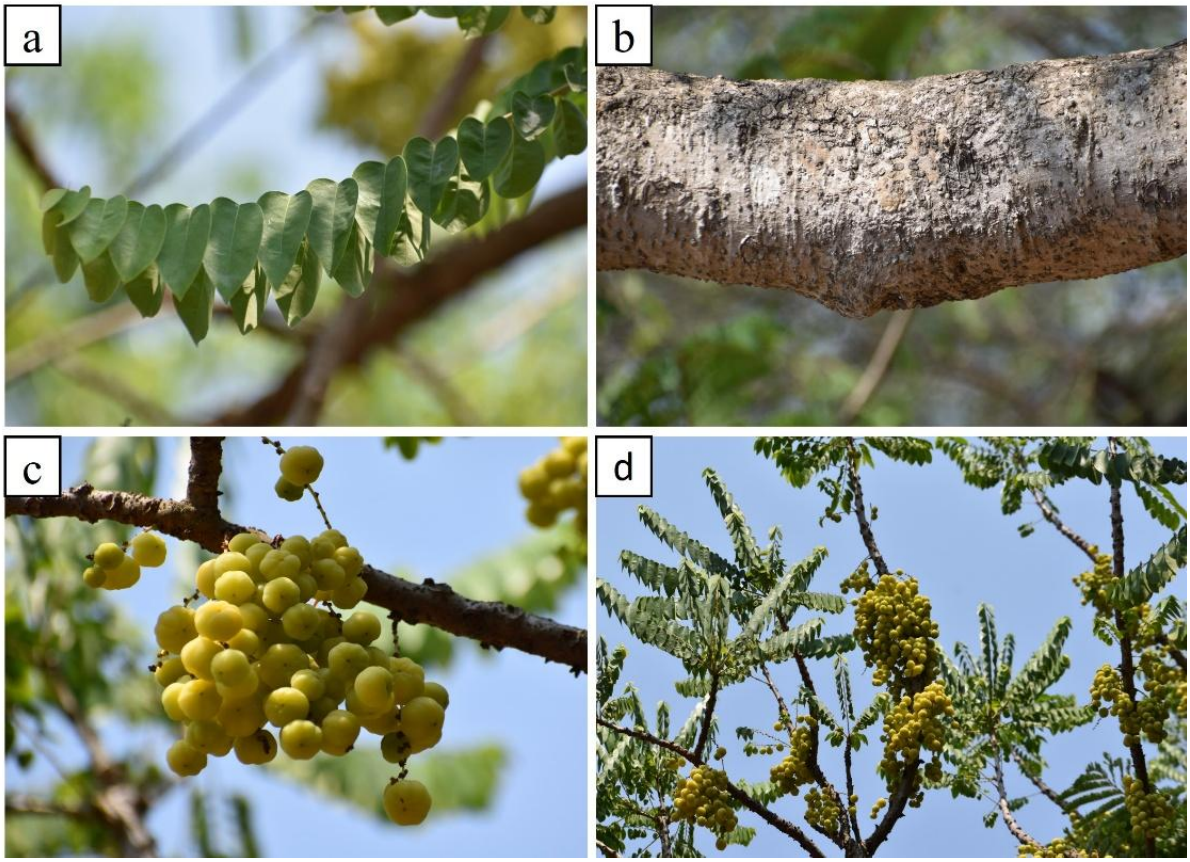

Plate 1: Vegetative parts of *Phyllanthus acidus*; a) leaves, b) Stem, c) fruits and (d) branches

Studies conducted on *Phyllanthus emblica*, *Phyllanthus niruri* and *Phyllanthus urinaria* have documented abundant phenolic acids, flavonoids and tannins as the principal contributors to their remarkable antioxidant, antimicrobial and cytoprotective activities, suggesting that members of this genus are consistently enriched with health-promoting secondary metabolites (Geethangili and Ding, 2018; Prananda et al., 2023). *Phyllanthus acidus* (L.) Skeels, part of the Phyllanthaceae family, is a small tree found in tropical and subtropical regions, particularly in South and Southeast Asia, including countries like India, Bangladesh, Sri Lanka, Thailand and the Philippines known by various names such as Otaheite gooseberry or star gooseberry, this plant has a significant role in traditional medicine systems like Ayurveda and folk remedies (Hazarika et al., 2025; Rupa et al., 2025). Its fruits, leaves, bark and roots (Plate 1) have been used to treat a variety of conditions, including skin issues, liver problems, rheumatism, obesity, bronchitis and asthma (Lima et al., 2026). The fruits of *P. acidus*, which are notably sour and range in color from pale yellow to white, are packed with vitamin C and various phytochemicals that contribute to their well-known health benefits (Tan et al., 2020). In alignment with these reports, the qualitative phytochemical screening of *P. acidus* fruit extracts in the present study confirmed the presence of flavonoids, phenols and reducing sugars across all three solvent extracts while tannins and saponins were additionally detected in the more polar ethanolic and aqueous fractions, a pattern consistent with the known polarity-dependent solubility of these compound classes. This distribution is particularly significant, as phenolics and flavonoids are well-documented to be the primary mediators of free radical scavenging activity in plant-based systems. Present study aims to document the existing knowledge on *P. acidus*, highlighting research gaps and future directions for conservation, sustainable utilization and novel pharmaceutical formulations.

Methodology

The present study is based on field survey, experimental analysis and an extensive survey of published literature related to *P. acidus*. Scientific databases, including Google Scholar, Scopus, PubMed and Web of Science, were consulted to retrieve peer-reviewed research articles, review papers, ethnobotanical surveys and pharmacological studies. Keywords including "*Phyllanthus acidus*," "medicinal uses," "bioactive compounds," and "potent scavenging bioactive compounds" were used to identify relevant publications. The field survey was carried out during March and April of 2026, when the fruiting period of *p. acidus* at its peak. Identification was complied with reference to flora guide (Saxena and Brahmam, 1995). An herbarium specimen was collected and deposited to the herbarium unit of Ambika Prasad Research Foundation, Cuttack, Odisha (Figure 2). The experimental analysis was carried out to validate the antioxidant potential of *P. acidus* fruits through phytochemical screening and DPPH assay. Detection of nine secondary metabolites was conducted using standard methods (Devi et al., 2023; Jena et al., 2024).

Detection of secondary metabolites through phytochemical screening

Test for tannin: About 1 ml of the fruit extract was taken. 3-5 drops of 10% lead acetate solution were added to it. The gelatinous precipitate formation confirmed the presence of tannin (Table 1).

Test for saponin: About 1 ml of the fruit extract was taken and 1 ml of distilled water was added and shaken well. The formation of persistent froth was observed confirming the presence of saponin.

Test for flavonoids: About 1 ml of the fruit extract was taken. 2 ml of 2% NaOH solution and 3 to 4 drops of dilute hydrochloric acid were added to it. The colour initially turned to an intense yellow colour with NaOH solution and later became colourless. This colour change appearance confirmed the presence of flavonoids.

Test for terpenoids: About 1 ml of the fruit extract was added with 6 drops of chloroform and placed in the water bath for a few minutes. Then 6 drops of concentrated H_2SO_4 were added. The reddish- brown interface confirmed the presence of terpenoids.

Test for phenolic groups: About 1 ml of the filtrate extract was taken. A few drops of 5% Ferric chloride solution were added. The dark bluish-black appearance confirmed the presence of phenolic compounds.

Test for reducing sugars: About 1 ml of the fruit extract was taken and 2 drops of Fehling's solution A followed by Fehling's solution B were added and kept in the water bath for some time. The presence of red-orange precipitate confirmed the presence of reducing sugar.

Test for steroids: About 1 ml of the fruit extract was taken. 1 ml of chloroform and 1 ml of concentrated sulphuric acid was added gently into it touching test tube mouth. The appearance of upper red and lower yellow with green fluorescence provides the presence of steroids.

Test for alkaloids: About 1 ml of the fruit extract was taken and added 3 to 4 drops of Dragendroff's reagent. The formation of a reddish-brown precipitate confirmed the presence of alkaloids.

Antioxidant DPPH assay

Collection of *Phyllanthus acidus* fruits were done from nearby Mahanadi areas of Cuttack District, Odisha, India. Fruits were thoroughly washed and macerated with different solvents like distilled water, ethanol and n-hexane separately (Kaur et al., 2026; Kumar et al., 2026). The 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay was used to evaluate the filtered extract following Baliyan et al., (2022) with minor modifications.

1 ml of 0.1 mM DPPH solution prepared in methanol was added to prepared concentrations of aqueous, ethanolic and n-hexane extracts (1.0, 0.5, 0.25 and 0.125 mg/mL) using the respective solvents adjusting the final volume to 2 ml. 1 mL 0.1 mM DPPH in 1 mL methanol was used as control. Sample blanks (without DPPH) were used for background correction of absorbance. Reaction mixtures were exposed to dark incubation at room temperature for 20 minutes and the absorbance was spectrophotometrically taken at 517 nm. Percentage of radical scavenging activity was calculated using the following formula (Table 2).

$$\% \text{ Inhibition} = A_0 - A_s / A_0 \times 100$$

Where, A_0 is the absorbance of the control and A_s is the absorbance of the sample after blank correction.

Results and discussion

The present study was carried out to evaluate the phytochemical composition and antioxidant potential of *P. acidus* fruit extracts prepared using solvents of varying polarity, namely n-hexane, ethanol and distilled water. The results obtained from qualitative phytochemical screening and the DPPH free radical scavenging assay are presented (Tables 1 & 2; Figure 1) and discussed in the following sections in relation to the existing scientific literature. The phytochemical analysis aimed to identify the classes of secondary metabolites present in each extract, while the DPPH assay provided a quantitative measure of their free radical neutralizing capacity across a defined concentration range of 0.125 to 1.0 mg/ml. Taken together, the present findings from both analyses were interpreted to establish a meaningful correlation between the phytochemical profile and the observed antioxidant activity of the respective extracts, thereby providing a mechanistic understanding of the bioactive potential of *P. acidus* fruits.

Table 1: Detection of secondary metabolites present in *P. acidus* fruit extracts

Bioactive compounds	Extracts		
	n-hexane	Ethanolic	Aqueous
Tanin	Absent	Present	Present
Saponin	Absent	Present	Present
Flavonoid	Present	Present	Present
Terpenoid	Absent	Absent	Absent
Phenols	Present	Present	Present
Reducing sugar	Present	Present	Present
Steroid	Absent	Absent	Absent
Alkaloid	Absent	Absent	Absent

The qualitative phytochemical analysis of *P. acidus* fruit extracts revealed a diverse array of secondary metabolites; flavonoids, phenols and reducing sugars were detected in all three extracts. Tannins and saponins, however, were found to be absent in the n-hexane extract while being present in both the ethanolic and aqueous extracts. The absence of alkaloids and steroids is noteworthy, as it implies a relatively lower risk of toxicity associated with the fruit extracts, further supporting their safety for potential therapeutic and nutraceutical applications. Overall, the phytochemical profile of *P. acidus* fruit extracts reflects a chemically rich composition that provides a mechanistic basis for the antioxidant activity subsequently evaluated through the DPPH assay.

Table 2: Antioxidant potential of *P. acidus* fruit extracts through DPPH assay

Concentration (in mg/ml)	Inhibition (%)		
	n-hexane	Ethanolic	Aqueous
1.0	77.13	89.68	99.32

0.5	73.54	82.95	96.63
0.25	71.74	78.02	86.77
0.125	66.81	71.74	83.40

The antioxidant potential of *P. acidus* fruit extracts was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging assay, which is one of the most widely employed, rapid and reliable in vitro methods for measuring the hydrogen atom or electron-donating ability of plant-derived antioxidant compounds (Baliyan et al., 2022). The results, expressed as percentage inhibition at four different concentrations ranging from 0.125 to 1.0 mg/ml, are presented in the Table 2. At the highest tested concentration of 1.0 mg/ml, the aqueous extract exhibited the most potent radical scavenging activity with an inhibition of 99.32%, which is remarkably high and approaches the maximal theoretical inhibition, suggesting near-complete neutralization of the DPPH radical at this concentration. The ethanolic extract followed with an inhibition of 89.68%, while the n-hexane extract demonstrated the lowest, though still considerable, scavenging activity of 77.13% at the same concentration.

Collectively, these results provide strong quantitative evidence in support of the significant antioxidant potential of *P. acidus* fruits across solvent systems of differing polarity, validating their traditional use as a health-promoting food and herbal remedy and highlighting their promise as a natural source of antioxidants for incorporation into functional food, nutraceutical and pharmaceutical formulations.

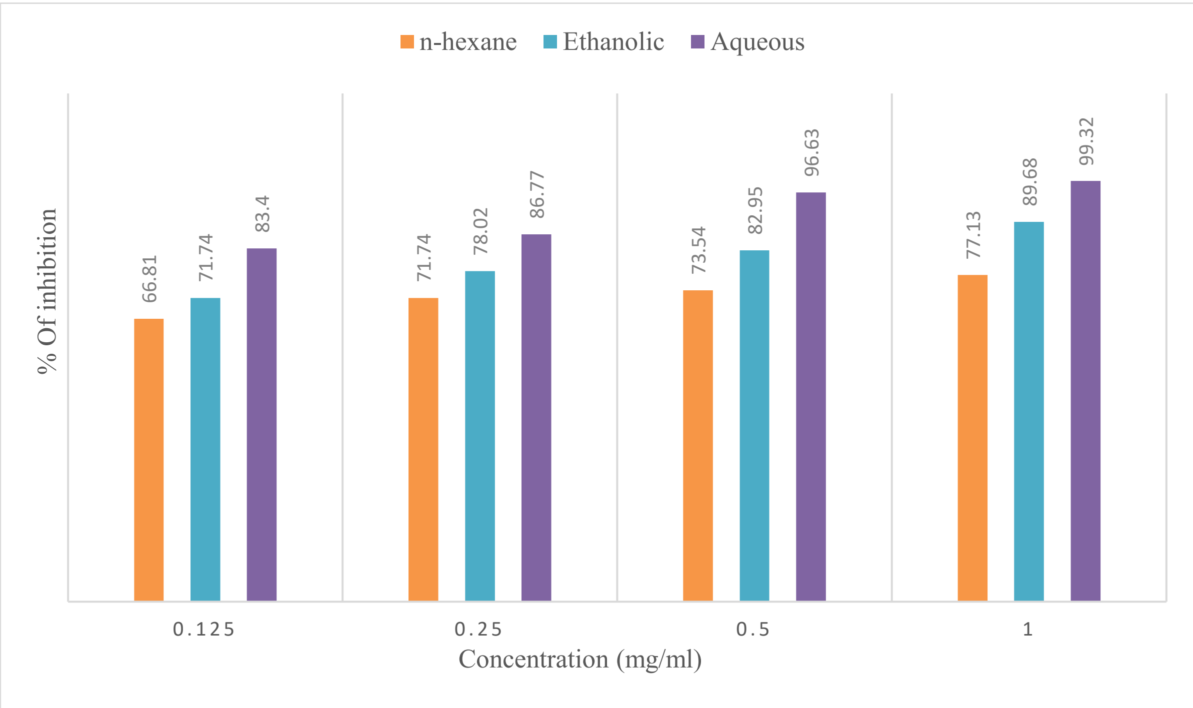

Figure 1: The hierarchy of antioxidant activity of *P. acidus* fruit extracts

Research gaps and Future aspects

While the *P. acidus* fruit extracts showed great promise with their antioxidant properties and impressive phytochemical profile, we still need to dive deeper into the quantitative analysis of individual bioactive compounds. In addition, complementary antioxidant tests like ABTS [2,2′-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid)] and FRAP (Ferric Reducing Antioxidant Power) haven't been explored yet. To accurately identify these compounds, we should definitely consider using advanced chromatographic techniques such as HPLC (High-Performance Liquid Chromatography) and GC-MS (Gas Chromatography–Mass Spectrometry). Additionally, it's crucial to conduct in vivo studies, assess bioavailability and perform toxicological evaluations to back up these initial findings. By addressing these gaps, we could really position *P. acidus* fruits as a powerful, safe and commercially viable natural source of antioxidants for both nutraceutical and pharmaceutical uses.

Figure 2: Herbarium specimen of *P. acidus* (APRFH- 247)

Conclusion

The present study conclusively demonstrated that *P. acidus* fruits are a rich source of phenolics, flavonoids and tannins, exhibiting significant concentration-dependent antioxidant activity, with the aqueous extract showing the highest DPPH scavenging potential (99.32% at 1.0 mg/ml). These findings strongly validate the traditional therapeutic use of *P. acidus* and highlight its considerable promise as a potent natural antioxidant for nutraceutical and pharmaceutical applications.

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