Pharmacological insights into *Ipomoea staphylina*: Therapeutic activities and the isolated bioactive metabolic compounds

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MINI - REVIEW

Pharmacological insights into *Ipomoea staphylina*: Therapeutic activities and the isolated bioactive metabolic compounds

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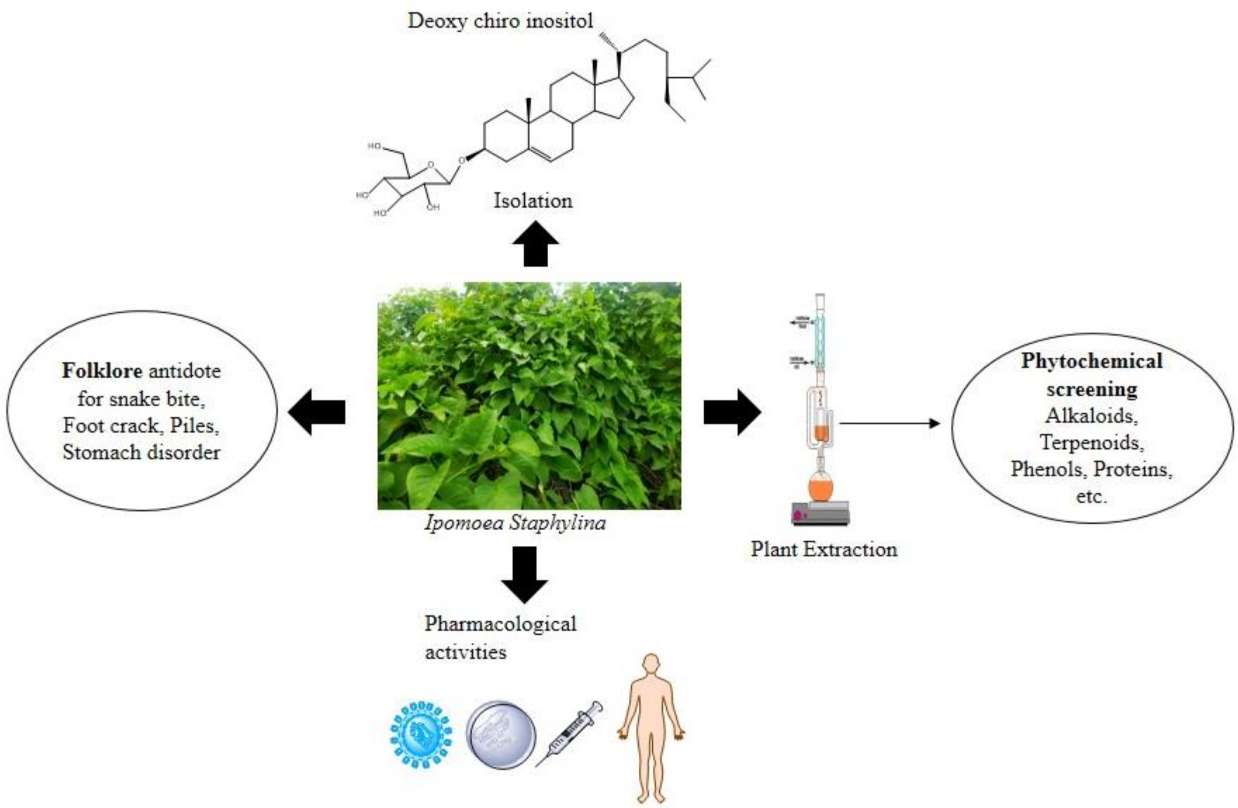
ABSTRACT

This review comprehensively explores *I. staphylina's* traditional uses, diverse applications, and pharmacological activities. Extensively used in traditional medicine, this plant addresses a range of ailments, including stomach disorders, respiratory issues, and rheumatism. Research has highlighted its significant antimicrobial, anti-inflammatory, antioxidant, antidiabetic, anthelmintic, and analgesic properties. Notably, its antiulcer activity highlights its potential as a novel antiulcer agent, while hepatoprotective and nephroprotective effects suggest therapeutic applications in liver and kidney disorders. Studies on its anti-diabetic potential show significant reductions in blood glucose levels and positive impacts on biochemical markers. The plant's anti-mutagenic activity against base-pair mutations expands its potential applications. The review also discusses the isolation and pharmacological applications of pure compounds identified through LC-MS and NMR analyses. This review identifies *I. staphylina* as a promising source of bioactive compounds with therapeutic potential, emphasizing the need for further research to isolate and characterize its active constituents.

Keywords: *Ipomoea staphylina*; Biological activities; Plant extract; Isolation

Graphical abstract



ABBREVIATIONS:

MTT - Microculture Tetrazolium; TNF-α - Tumor necrosis factor; LPS - Lipopolysaccharide; COX - Cyclooxygenase; DPPH - 2,2-Diphenyl-1-picrylhydrazyl; NBT - Nitro Blue Tetrazolium; ABTS- 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid; TBARS - Thiobarbituric acid reactive substance; SGPT- Serum glutamic pyruvic transaminase; SGOT- Serum glutamic oxaloacetic transaminase; GSH- Glutathione; SOD- Superoxide dismutase; GPx - Glutathione peroxidase; LPO - Lipid peroxidase; CAT - Catalase; STZ - Streptozotocin; AST - aspartate aminotransferase; ALT - alanine aminotransferase; ALP - Alkaline phosphatase; NMR - Nuclear magnetic resonance; LCMS - Liquid chromatography - mass spectrometry; HRTEM - High-Resolution Transmission Electron Microscopy;

INTRODUCTION

Plants have long been relied upon by humanity for their medicinal properties and their diverse applications in various aspects of daily life, including food, clothing, flavors, dyes, and more [1]. Traditional herbal medicine, with its roots dating back centuries, forms the basis of modern healthcare systems. Interestingly, even in developed nations such as China, India, and Japan, traditional medicine continues to be practiced [2]. Despite the prevalence of synthetic alternatives in today's digital age, many people remain cautious about the side effects and chemical constituents associated with synthetic medicines. Synthetic drugs, including antibiotics, are known to induce adverse effects such as nausea, vomiting, and photosensitivity [3]. Consequently, there is a growing interest in natural medicines and compounds that offer potential benefits with fewer side effects and a more organic impact on the human body [4]. Natural products, which can be readily integrated into our daily diet, are easily absorbed and often preferred. According to the World Health Organization, approximately 21,000 plant species worldwide have been utilized for medicinal purposes [5]. Remarkably, over 60% to 75% of cancer and infectious disease drugs have been derived from natural sources [6, 7]. Plant-based drugs have therefore gained significant traction in contemporary drug design and development [8, 9].

One notable herb with significant therapeutic potential is *Ipomoea staphylina*, which holds a prominent place in traditional medicine [10, 11]. Traditionally, *I. staphylina* has been employed to address various disorders [10, 11]. Its distribution spans regions in India, China, and Sri Lanka, as well as numerous parts of Asia and South Asia [12]. Recent research has highlighted the antibacterial, anti-diabetic, anti-inflammatory, anti-mutagenic, analgesic, and antioxidant properties of *I. staphylina* [3]. Abundantly found in wastelands and deciduous forests, *I. staphylina* is easily accessible. It possesses a rich composition of phytochemical constituents, including alkaloids, flavonoids, phenolics, proteins, carbohydrates, glycosides, and saponins [3, 13, 14]. In local languages, *I. staphylina* is referred to as "Oonan kodi" or "Onan kodi" in Tamil, "Ugina kodi" or "Unang kodi" in Kannada, and "Sunang kodi" in Irula, while it is known as "Morning clustered glory" in English [9, 14]. Through this literature review, we aim to provide an in-depth exploration of the ethnobotanical and pharmacological properties of *I. staphylina*, shedding light on its potential benefits in healthcare and therapeutic applications. The clear image represents the different plant parts of the *I. staphylina* depicted in Figs. 1 and 2.

Fig. 1. (a, b) Leaves of the *I. Staphylina*, (c) Flower of the *I. staphylina*.

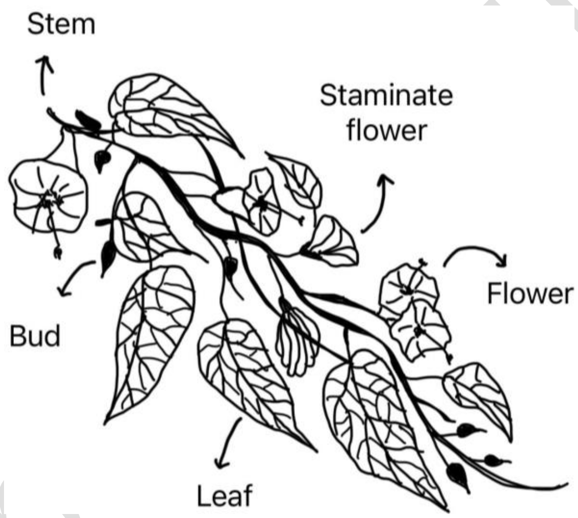


Fig. 2. A formal botanical sketch of *I. staphylina*.

Traditional uses

I. staphylina has been used for many health issues like stomach disorders, inflammation, purgation, pain, and also in rheumatism [15]. Traditionally Dharmapuri (Tamil Nadu) village folk people used stem raw extract for stomach disorders and respiratory disorders. Gingee Hills villagers used leaf latex for foot crack [7]. Tribes of Irulas and Palliyars have used *I. staphylina* roots as an anti-dote (snake bite) [8]. Karandamalai villagers used leave decoction for stomach disorders [16]. Chenchus tribes treated leave extract for piles (Andhra Pradesh) [17].

METHODS

Search strategy

In this review, we systematically compiled data from multiple scientific databases, including Web of Science, Science Direct, Google Scholar, and MEDLINE, focusing on *I. staphylina*. Topics covered include plant extraction, isolation, characterization, biological activity, and nanoparticle synthesis. Our analysis integrates findings from both in vitro and in vivo studies, with data collected from the inception of these databases up to March 2024. Publications in languages other than English, as well as conference abstracts and dissertations, were excluded from the review.

Study selection

Publications in languages other than English, along with conference abstracts and dissertations, were excluded from consideration. The initial search yielded 60 studies, from which duplicate entries were removed. The screening process involved evaluating titles, abstracts, and full texts according to predefined inclusion criteria, resulting in the final inclusion of 44 relevant studies in the review.

Pharmacological activities

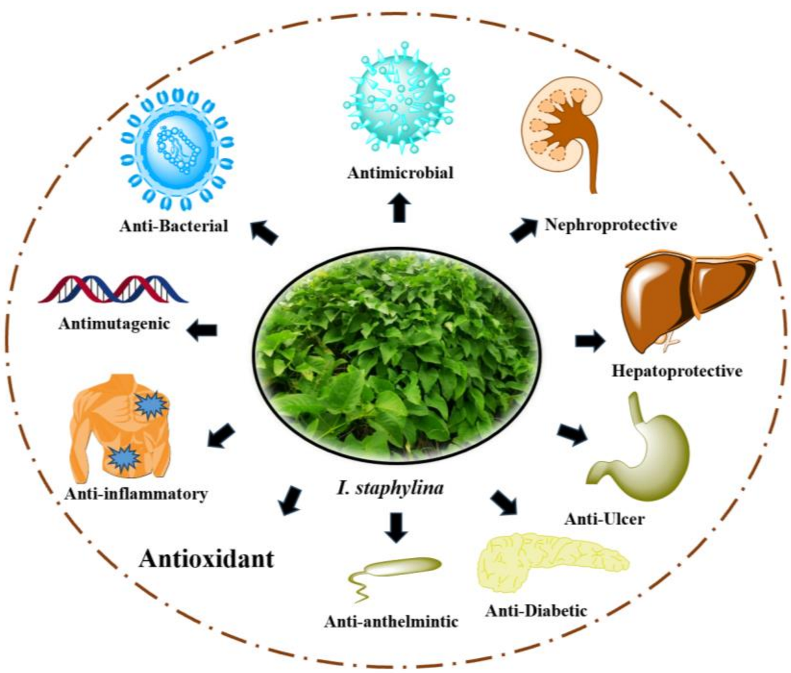


Fig. 3. Pharmacological applications of *I. staphylina*

I.staphylina has been reported for various pharmacological activities in different solvents and methods shown in Table 1 and Fig. 3.

Table 1. Biological activities of *I. staphylina*

Pharmacological effects	**Plant part(s)**	**Solvent of the crude extract**	**References**
Antioxidant, cytotoxic	Whole plant	Ethanol	Padmashree M.S *et al*., (2018)
Hepatoprotective and antioxidant (in vivo)	Leaves	Aqueous	Jayadevi R *et al*., (2019)
Hepatoprotective and nephroprotective	Leaves	Hydroalcoholic	Bag A.K *et al*., (2013)
Cytotoxic, Antimicrobial and anti-inflammatory	Stems, Crude latex	Water Ethanol n-Butanol	Narra P *et al*., (2014)
Anti-mutagenic	Leaves	Hydroalcoholic	Banerjee A *et al*., (2020)
Anti-ulcer	Whole plant	Hydroalcoholic	Banerjee A *et al*., (2014)
Anti-anthelmintic	Leaves	Aqueous	Gosh S *et al*., (2013)
Adulticidal Larvicidal	Leaves	Hexane Ethyl acetate Acetone Methanol	Santhoskumar T *et al*., (2011)
Anti-inflammatory	Leaves	Ethanol	Firdous *et al*., (2012)
Anti-diabetic	Leaves	Ethanol	Firdous *et al*., (2014)
Anti-diabetic type 2	Leaves	Ethanol	Firdous *et al*., (2016)
Anti-diabetic	Whole plant & leaf	Ethanol	Shobana D *et al*., (2021)
Antioxidant, Superoxide Anti-diabetic Anti-inflammatory (LOX-5)	Whole plant	Hydroalcoholic	Reddy D.P *et al*., (2012)
Analgesic	Leaves	Hydroalcoholic	Gosh S *et al*., (2014)

Antimicrobial activity

In a research study conducted by Narra *et al*, the antimicrobial potential of the crude latex obtained from the stems of *I. staphylina* was investigated. The study aimed to evaluate its activity against *Staphylococcus aureus* and *E. coli* bacteria, two common pathogens known to cause various infections. Different concentrations of the extract were utilized to determine its efficacy in inhibiting the growth of these bacteria [13]. The study demonstrated that the ethanol extract of *I. staphylina* exhibited significant inhibitory activity against *S. aureus* and *E. coli*, indicating its potential as a source of novel antimicrobial agents. To evaluate the safety profile of the extract, an MTT assay was conducted using J774.2 cells, a standard model for assessing cell viability and cytotoxicity of test compounds. The assay results offered crucial insights into the extract's effects on cell viability, supporting its potential therapeutic application. Overall, the study by Narra *et al* sheds light on the antimicrobial activity of the crude latex from *Ipomoea staphylina* stems and highlights its potential as a source of natural compounds with antimicrobial properties [13]. Given its excellent antimicrobial activity, formulations such as antimicrobial ointment or cream could be developed from this plant.

Anti-inflammatory activity

Firdous *et al*. (2012) investigated the anti-inflammatory properties of the ethanolic leaf extract of *I. staphylina*. The study evaluated both the ethanolic extract and its ethyl acetate and n-butanol fractions through in vivo and in vitro models. The fractions displayed significant anti-inflammatory activity in carrageenan-induced paw edema. Additionally, when administered orally at a dose of 200 mg/kg, the extract and its fractions significantly reduced granuloma formation in the cotton pellet-induced granuloma model ($P > 0.001$). The study also examined the inhibition of TNF-α in LPS-activated RAW 264.7 cells, where the ethanol, n-butanol, and ethyl acetate fractions showed notable inhibitory effects. Cell viability across different concentrations was further assessed using the MTT assay [15].

Narra *et al*. (2014) focused on the stem ethanol extract of *I. staphylina* to evaluate its anti-inflammatory properties through COX activity assay. The COX assay was performed using a specific chemiluminescent substrate to measure the activity. The latex sample (approximately 20 µl) was added and incubated for 2 hours, followed by the addition of 50 µl of the chemiluminescent substrate to determine the activity. The ethanolic extract demonstrated potent inhibitory activity against COX [13].

In a study by Reddy *et al*. (2012), the entire plant of *I. staphylina* was evaluated for its anti-inflammatory activities using a modified version of the techniques. The methanolic and hydroalcoholic extracts of *I.staphylina* were assessed for their ability to inhibit LOX-5 enzyme. The percentage of inhibition was determined, and the extracts of *I. staphylina* exhibited 50% lower inhibitory percentages compared to standard drugs [14]. The reported anti-inflammatory properties of *I. staphylina*, both in vivo and in vitro, highlight its importance in inflammation management in medical situations. Its potent activity against important inflammatory enzymes such as COX and LOX-5 makes it an attractive candidate for formulations targeting inflammatory disorders [13-15]. Given its shown efficacy and minimal toxicity profile, *I. staphylina* is a promising candidate for the development of anti-inflammatory formulations, such as gel or tablet formulations. These compositions with significant anti-inflammatory activities have the potential to provide effective treatment while minimizing side effects, addressing a critical demand in inflammatory therapy.

Anti-oxidant and free radical scavenging activity

Reddy *et al.* (2012) conducted a study to investigate the antioxidant activity of methanolic and hydroalcoholic extracts derived from the entire plant of *I. staphylina*. The DPPH radical scavenging method was employed to assess the free radical activity. Various concentrations (25, 50, 75, and 100 μg/ml) of the fractions were prepared, and their absorbance at 517 nm was measured to determine the activity. The results revealed that the hydroalcoholic stem extract and methanolic leaf extract exhibited noteworthy antioxidant activity compared to other extracts [14].

The superoxide radical scavenging activity of the methanolic leaf extract of *I. staphylina* was investigated using the Nitro Blue Tetrazolium (NBT) riboflavin photoreduction method, following the methodology established by Mccord and Fridovich. Reddy *et al*., testified that the hydroalcoholic extract derived from the stem (IC_{50} = 15.54 μg/ml) and leaf (IC_{50} = 16.02 μg/ml) of *I. staphylina* demonstrated remarkable efficacy compared to other extracts evaluated in the study [14].

Furthermore, the antioxidant potential of the ethanolic leaf extract of *I. staphylina* was assessed using a comprehensive range of assays. These included measurements of superoxide radical scavenging, hydroxyl radical scavenging, DPPH assay, ABTS assay, and metal chelating assay. The extract was subjected to various concentrations, and the IC_{50} values were determined employing standard protocols. Furthermore, the study conducted by Shobana D *et al*., in 2021 investigated the antioxidant activity of the ethanolic leaf extract and whole plant extract of *I. staphylina* on streptozotocin-induced rats, yielding excellent results [14, 18]. The findings from the above-mentioned studies provided valuable insights into the antioxidant properties of *I. staphylina*, further enhancing its potential therapeutic applications [14]. The biochemical measurements in the rats were performed using the methods outlined in Table 2. These reported antioxidant activities suggest that extracts from *I. staphylina* can be formulated into antioxidant drugs.

Table 2. Methods used for biochemical measurements in diabetic-induced rats

Experiment	References
Thiobarbituric acid reactive substance (TBARS) and lipid peroxide (HP)	Jean *et al.,* (1992)
The measurement of glutathione in the tissue (GSH)	Beutler, (1984)
Superoxide dismutase (SOD)	Kakkar *et al*., (1984)
Glutathione peroxidase (GPx)	Rotruck *et al*.,(1984)
Anti-oxidant (Vitamin C and Vitamin E)	Bakers *et al*., (1980)

Anti-diabetic activity

In a study conducted by Shobana D *et al*. (2021), the ethanolic leaf extract and whole plant extract of *I. staphylina* were investigated for their antioxidant, peroxide, and anti-diabetic activities. Male Wistar rats were used, and administration of Streptozotocin and diabetes was induced through intraperitoneal. The assessment of biochemical parameters was performed using established methods. The results demonstrated that *I. staphylina* extracts pointedly reduced glucose levels in diabetic-induced rats and increased antioxidant levels compared to normal rats. Moreover, the extracts exhibited notable reductions in glutathione peroxidase, hyperoxide, and TBARS levels in diabetic rat tissues. Among the extracts, the ethanolic leaf extract of *I. staphylina* showed the most promising results in diabetic-induced rats [18].

Firdous *et al*., (2014) conducted a study to investigate the anti-diabetic activity of the ethanolic extract of *I. staphylina* in Swiss albino mice induced with Streptozotocin. The extract was orally administered, and no acute toxicity or signs of toxicity were observed. The ethanolic extract notably reduced blood glucose levels. Biochemical analysis revealed significant decreases in serum creatinine blood urea, and blood urea nitrogen, levels upon treatment with the extract. Additionally, the ethanolic extract led to reductions in serum total protein and liver glycogen levels in streptozotocin-induced diabetic mice. The ethanol, n-butanol, and ethyl acetate extract fractions exhibited decreases in SGOT, ALP, and SGPT activities in diabetic mice. Furthermore, the ethanol extract and ethyl acetate fraction demonstrated enhancements in GPx, CAT, and SOD levels [19]. Biochemical analysis, as outlined in Table 3.

Table 3. *In vivo* biochemical measurements and methods [19].

Biochemicals	Assay and Methods
Serum glucose	Glucometer (Accu-Chek Active, India)
Serum total cholesterol, total triglyceride, LDL-c, VLDL-c and HDL-c	Standard enzymatic (Span Diagnostic, India)

SGOT, SGPT, serum ALP, total protein, serum urea, and creatinine	Standard enzymatic (span diagnostic, India
Glycogen content in the liver	Spectrophotometric determination of glycogen with o-toluidine reagent
Lipid peroxidase (LPO), Superoxide dismutase (SOD), Catalase (CAT) and glutathione peroxidase (GPx).	10% ice-chilled potassium chloride solution

In a study by Firdous *et al*. (2016), the ethanol, n-butanol, and ethyl acetate extract fractions of *I. staphylina* were assessed for their anti-diabetic property. Alloxan-induced diabetic rats were used in the study, and the extracts were administered orally. The extracts significantly reduced the blood glucose levels.

Moreover, Firdous *et al*. (2016) examined the anti-diabetic effects of the ethanol, n-butanol, and ethyl acetate leaf extract fractions of *I. staphylina* against nicotinamide-streptozotocin-induced type 2 diabetes. Wistar rats were employed in this study. The findings indicated a significant reduction in blood glucose levels following treatment with the leaf extracts. Additionally, the extracts led to reductions in biochemical markers such as SGOT, SGPT, and ALP. Histological analysis of the liver, kidney, and pancreas, revealed improvements at the cellular level after 21 days of oral administration of *I. staphylina* extract and its fractions in nicotinamide-streptozotocin induced type 2 diabetic rats [20]. According to the studies mentioned above, various parts of the *I. staphylina* plant demonstrate remarkable antidiabetic activities effective against both type 1 and type 2 diabetes [18-20]. Through oral administration, these plant parts effectively reduce blood glucose levels. Consequently, the therapeutic potential of *I. staphylina* in the management of diabetes is evident, suggesting its utility in the development of diabetic medications. This could include the formulation of oral tablets or syrups tailored to regulate blood sugar levels and alleviate symptoms associated with diabetes.

Anthelmitic activity

In research conducted by Gosh S *et al*. (2013), the distilled water extract of *I. staphylina* was evaluated for its anthelmitic ability. The extract was tested against Perionyx excavates earthworm at three different concentrations (25, 50, and 100 mg/ml). A standard drug, Piperazine citrate, was used for comparison. The findings indicated that the *I. staphylina* plant extract did not exhibit any anthelmintic activity on earthworms, as evidenced by the results obtained [21].

Anti-ulcer activity

Banerjee A *et al*. (2015) conducted a scientific investigation to estimate the anti-ulcer activity of a water and ethanolic (3:7) extract derived from *I. staphylina*. The study employed dried powdered samples of the entire plant to assess its efficacy. Two well-established experimental models, namely pyloric ligation and ethanol-induced gastric ulcer methods, were employed to simulate ulcer conditions. Oral administration of the *I. staphylina* plant extract was carried out in rats, and the acid index, a key indicator of ulcer severity, was determined using the standard drug Omeprazole for reference. The findings of the study revealed that the *I. staphylina* extract exhibited significant anti-ulcer properties, as evidenced by a remarkable reduction in acid pH levels. This indicates the plant's potential as a promising candidate for the development of novel anti-ulcer agents [22].

Hepatoprotectivity and Nephroprotectivity

Bag A.K *et al*. (2013) conducted a study to assess the hepatoprotective and nephroprotective properties of a hydroalcoholic leaf extract from *I. staphylina*. To assess the nephroprotective and hepatoprotective activity, Wistar albino rats were induced with gentamicin and CCl4, respectively. The administration of the plant extract was done orally, and no signs of toxicity were observed.

For the evaluation of hepatoprotective activity induced by CCl_4, the levels of AST, ALP, ALT, and total bilirubin were measured. The *I. staphylina* plant extract demonstrated a significant decrease in the levels of AST, ALP, ALT, and total bilirubin, indicating its potential hepatoprotective effects [23].

Furthermore, Jayadevi *et al*. (2019) reported the hepatoprotective activity of an aqueous leaf extract from *I. staphylina*. In a study conducted on CCl_4-induced Wistar rats, the extract showed a reduction in liver enzymes such as SGOT, SGPT, ALP, and bilirubin. It is important to note that both studies highlight the protective properties of *I. staphylina* extracts on liver and kidney functions, suggesting their potential therapeutic applications in the treatment of hepatic and renal disorders [24].

Analgesic activity

Ghosh *et al*., (2014) conducted a study to assess the analgesic activity of the hydroalcoholic extract of *I. staphylina*. The evaluation was performed using established methods including abdominal writhing, formalin-induced paw licking, and the Eddy's hot plate test in Swiss albino mice. As reference standards, Acetylsalicylic acid, Pentazocine, and Diclofenac were utilized. The administration of the hydroalcoholic extract of *I. staphylina* at a dose of 200 mg/kg resulted in a significant analgesic effect. The observed activity suggests the potential of the extract as an analgesic agent, comparable to the standard drugs used in the study [25]. This research approach provides valuable insights into the analgesic properties of the hydroalcoholic extract of *I. staphylina*, indicating its potential for further exploration and development as a natural analgesic alternative

Adulticidal activity and Larvicidal activity

In research conducted by Santoshkumar *et al*. (2011), the inhibitory properties of dried leaf extracts of *I. staphylina* were investigated. Various solvents such as ethyl acetate, hexane, methanol, and acetone were utilized for the extraction process. The evaluation focused on the inhibition of adults of *H. bispinosa*, the hematophagous fly *H. maculata*, and the *instar larvae* of the malaria vector *A. subpictus* [26].

The results demonstrated that the leaf extracts of *I. staphylina* exhibited significant inhibitory activity against these targeted organisms. This suggests the presence of bioactive compounds within the plant that have the potential to act as effective agents against these medically important vectors.

The findings from this scientific investigation provide valuable insights into the potential of *I. staphylina* as a natural source for developing novel insecticidal agents. Further research and exploration of the specific bioactive constituents responsible for the observed inhibitory effects are warranted for the development of effective vector control strategies.

Anti-mutagenic activity

Banerjee *et al*. (2020) performed research to investigate the anti-mutagenic activity of the hydroalcoholic (ethanol 7:3 distilled water) leaf extract of *I. staphylina* against base-pair mutations induced by 2-Nitrofluorene. Two nonvirulent strains of *S. typhi* were used to evaluate this activity, namely TA1535 & TA1538. Two different concentrations of the plant extract (250 and 500 µg/ml) were employed along with Cyclophosphamide (50 µg/ml) as a reference.

The assessment of anti-mutagenic activity was carried out using the Ames method. The results obtained from the study indicated that *I. staphylina* exhibits anti-mutagenic activity, and the extent of this activity depends on the dosage of the plant extract [27]. These findings shed light on the potential of *I. staphylina* as a source of anti-mutagenic compounds. Further research is warranted to identify and isolate the specific constituents responsible for this activity, and to explore their potential for therapeutic applications in mutagenesis-related disorders.

Phytochemical profile

Secondary metabolites are chemical compounds responsible for the biological properties of plants or herbs [31-33]. Various parts of *I. staphylina* have been reported to contain important phytochemicals, including alkaloids, terpenoids, tannins, flavonoids, carbohydrates, sterols, saponins, and phenols [13-14,18-24]. These secondary metabolites contribute significantly to enhancing the medicinal properties of *I. staphylina* [13-18]. Also, these phytochemicals exert crucial roles in human health, functioning as antioxidants, antibacterial, antifungal, anti-inflammatory, anti-allergic, antispasmodic, chemopreventive, hepatoprotective, hypolipidemic, neuroprotective, hypotensive agents. They contribute to preventing aging, diabetes, osteoporosis, cancer, and heart diseases [31-36], while inducing apoptosis, acting as diuretics and CNS stimulants, and providing analgesic effects. Furthermore, they shield against UVB-induced carcinogenesis, modulate the immune system, and possess carminative properties [31-36].

Isolated compounds

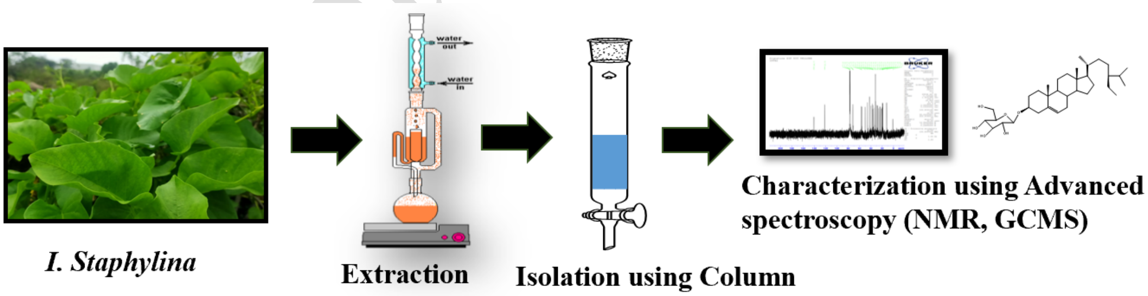


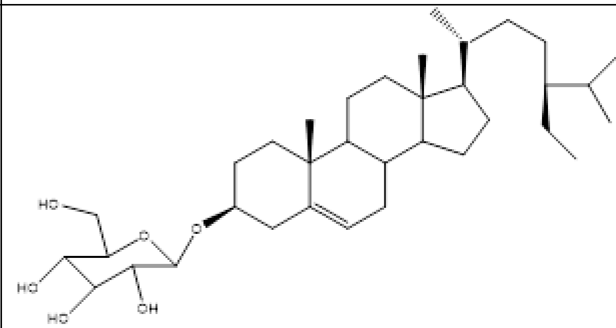
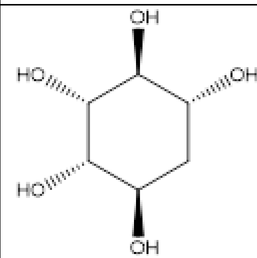
Fig. 4. Isolation of chemical compound from plant extracts

In a study conducted by Reddy *et al*. (2012), two pure compounds were isolated from the methanolic leaf extract of *I. staphylina*. The pictural illustration of the isolation is represented in Fig. 4. The identification and confirmation of these compounds were carried out using LC-MS and NMR analysis. Detailed information and characteristics of these isolated compounds are provided in Table 4. The utilization of analytical techniques such as LC-MS and NMR ensures the accurate identification and structural elucidation of the compounds, providing valuable insights into their chemical composition and potential biological activities [14]. The isolation of these pure compounds from *I. staphylina* adds to the knowledge of its phytochemical profile, and further investigation is warranted to determine their specific biological properties and potential applications in various fields, such as medicine, and pharmacology. The isolated compound **1**, sitosteryl-3-O-β-D-glucoside, has been reported to exhibit various biological activities, including analgesic and anti-inflammatory effects [28]. The parent moiety of sitosteryl-3-O-β-D-glucoside, beta-sitosterol, possesses a wide range of biological activities, such as antimicrobial, anticancer, antidiabetic, antioxidant, angiogenic, immunomodulatory, anti-inflammatory, and antinociceptive properties, without significant toxicity [29, 30].

In 2018, Padmashree *et al*. analyzed the ethanolic extract derived from *I. staphylina* using GC-MS. This analysis revealed the presence of several significant bioactive compounds. Among these compounds were 2-furanmethanol, 1,2-benzenediol, 2-methoxy-4-vinylphenol, tocopherol, beta-sitosterol, 4H-pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-, and 4-((1E)-3-hydroxy-1-propenyl)-2-methoxyphenol, alongside 2,6,10,14,18,22-tetracosahexaene, 2,6,10,15,19,23-hexamethyl-, (all-E), and hexadecanoic acid. Notably, these compounds are known for their remarkable antioxidant activities [36]. This research underscores the potential of *I. staphylina* as a valuable source of bioactive compounds with antioxidant properties [36]. Additionally, minor percentages of compounds such as 3-(4-hydroxyphenyl)-, vitamin E, 9,12,15-octadecatrienoic acid, methyl ester, (Z,Z,Z)-,3,7,11,15-tetramethyl-2-hexadecen1-ol; 4-((1E)-3-hydroxy-1-propenyl)-2-methoxyphenol, caryophyllene, 4H-pyran-4-one, 2,3-dihydro-3,5-dihydroxy6-methyl-, cyclopentane, 1-acetyl-1,2-epoxy-,2-propenoic acid, γ-tocopherol, phytol, α-caryophyllene, and 2-methoxy-4-vinylphenol have been identified [36].

The plant species harbors numerous active compounds, predominantly phenols, carbohydrates, and sterol-like constituents within the extract of *I. staphylina* [36, 37]. These compounds, acting synergistically, contribute significantly to the plant's medicinal properties, such as antioxidant, anthelmintic, anti-inflammatory, anti-diabetic, antimicrobial, and analgesic activities [31, 32, 36, 37]. Additionally, the isolated compound **2**, deoxychiro-inositol, has been reported to exhibit insulin-like actions [38].

Table 4. Isolated compounds of *I. staphylina* [14].

Compounds	**Extract**	**Structure**
Sitosteryl-3-O-β-D-glucoside	Ethanol extract of *I. staphylina*	
Deoxy chiro inositol	Ethanol extract of *I. staphylina*	

Nanoparticle synthesis

Over the last few decades, there has been a rise in the fabrication of therapeutic and diagnostic agents based on nanoparticles for various medical uses, with plants and herbs emerging as promising sources for nanoparticle synthesis [39, 40]. Various biological sources harbour the potential to yield a wide array of nanoparticles, each characterized by unique properties, shapes, and sizes [41, 42]. In the past few years, much research has been done in the Nanomaterials field using the *I. staphylina* plant [39-42]. In 2020, Pugazhendhi synthesized silver nanoparticles utilizing *I. staphylina* leaf extract, employing green chemistry techniques [43]. The synthesized nanoparticles underwent characterization via UV–Vis spectroscopy, FTIR, HRTEM, and XRD. The average particle size of the synthesized silver nanoparticles, determined using Scherrer's formula, was found to be approximately 20 nm, a value corroborated by HRTEM analysis (22 nm) [43].

In a recent study by Lakshmanan N *et al.* in 2024, silver and CuO nanoparticles were synthesized using the ethanolic extract of *I. staphylina* for larvicidal activity [44]. Employing environmentally sustainable green chemistry methodologies, the researchers validated the nanoparticle structure and size through XRD analysis, while field-emission scanning electron microscopy (FE-SEM) revealed precise nanostructures. Elemental composition was elucidated via energy-dispersive X-ray (EDX) analysis, and UV-vis spectroscopy provided bandgap energy values (3.15 eV for silver, 1.2 eV for CuO nanoparticles). These nanoparticles displayed potential larvicidal activity, with CuO nanoparticles demonstrating superior LC_{50} and LC_{90} values compared to silver nanoparticles. Furthermore, the developmental toxicity of CuO and Ag NPs was assessed in zebrafish embryos as part of non-target eco-toxicological investigations conducted in a standard laboratory setting. These findings highlight the potential of these nanoparticles as highly effective and ecologically friendly natural insecticides, providing cost-effectiveness and ecological benefits [44].

CONCLUSION

The documented pharmacological properties of *I. staphylina* substantiate its medicinal uses, further validating its traditional significance based on ethnobotanical knowledge. This plant has been reported to possess a range of biological activities, including antibacterial, anti-inflammatory, anti-mutagenic, hepatoprotective, nephroprotective, antioxidant, anti-ulcer, and anti-diabetic, anthelmintic, and analgesic effects. These diverse therapeutic applications can be attributed to the presence of various bioactive phytoconstituents within the plant. The findings from reported studies on *I. staphylina* underscore the importance of this botanical resource in healthcare. This article aims to provide comprehensive pharmacological and ethnobotanical information about *I. staphylina*, thereby facilitating further exploration and understanding of the plant's potential benefits. By shedding light on its pharmacological attributes and traditional uses, this research contributes to the holistic appreciation and utilization of *I. staphylina* as a valuable resource in the field of medicine.

Declaration of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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AUTHOR CONTRIBUTIONS

Mr. Lakshmanan Narayanan collected the plant details and wrote the paper. This review paper was supervised and edited by Dr. Suseem S.R. All authors read and approved the final manuscript.

REFERENCES

1. Dias D.A., Urban S., Roessner U. (2012). A historical overview of natural products in drug discovery. *Metabolites*, ***2***(2), 303-336. https://doi.org/10.3390/metabo2020303
2. Dar R.A., Shahnawaz M., Rasoo, S., Qazi P.H. (2017). Natural product medicines: A literature update. *J. Phytopharmacol.*, ***6***(6), 349-351. https://doi.org/10.31254/phyto.2017.6608
3. Capasso R., Izzo A.A., Pinto L., Bifulco T., Vitobello C., *et al*., (2000). Phytotherapy and quality of herbal medicines. *Fitoterapia*, ***71***, S58-S65. https://doi.org/10.1016/S0367-326X(00)00173-8
4. Calixto J.B. (2000). Efficacy, safety, quality control, marketing and regulatory guidelines for herbal medicines (phytotherapeutic agents). *Braz. J. Med. Biol. Res.*, ***33***, 179-189. https://doi.org/10.1590/S0100-879X2000000200004
5. Rizvi S.I., Mishra N. (2013) Traditional Indian medicines used for the management of diabetes mellitus. *J. Diabetes Res.*, **2013**(1). https://doi.org/10.1155/2013/712092
6. Harvey A.L. (2008). Natural products in drug discovery. *Drug Discov. Today*, ***13***(19-20), 894-901. https://doi.org/10.1016/j.drudis.2008.07.004
7. Atanasov A.G., Zotchev S.B., Dirsch V.M., Supuran C.T. (2021). Natural products in drug discovery: Advances and opportunities. *Nat. Rev. Drug Discov.*, ***20***(3), 200-216. https://doi.org/10.1038/s41573-020-00114-z
8. Balandrin M.F., Kinghorn A.D., Farnsworth N.R. (1993) Plant-derived natural products in drug discovery and development. In: *Human Medicinal Agents from Plants*. *ACS Pubs.,* **534**, 2-12. https://doi.org/10.1021/bk-1993-0534.ch001
9. Ulrich-Merzenich G., Panek D., Zeitler H., Vetter H., Wagner H. (2010) Drug development from natural products: Exploiting synergistic effects. *Indian J. Exp. Biol.*, **48**(3), 208-219.
10. Muralidharan R., Narasimhan D. (2013) Plants used for topical application from Gingee hills, Tamil Nadu, India. *Current Botany*, **3**(4), 49-52.
11. Sarvalingam A., Rajendran A., Sivalingam R. (2014) Wild edible plant resources used by the Irulas of the Maruthamalai Hills, Southern Western Ghats, Coimbatore, Tamil Nadu. *Indian J. Nat. Prod. R*esour., **5**(2), 198-201.
12. Staples G.W. (1996) The identity of *Ipomoea staphylina* (Convolvulaceae) in Asia. *Taiwania*, **41**(3), 185-196. https://doi.org/10.6165/tai.1996.41.185

13. Narra P., Kandavara P. (2014) Evaluation of cytotoxic, antimicrobial, and anti-inflammatory properties from the latex of *Ipomea staphylina*. *J. Microbiol. Biotech. Food Sci.*, ***3***(5), 350-352. https://office2.jmbfs.org/index.php/JMBFS/article/view/6993.
14. Reddy D.P., Kota R., Anarthe S.J., Raghavendra M. (2013) Isolation, characterization of phytoconstituents and pharmacological screening of *Ipomoea staphylina*. *Asian J. Pharm. Clin. Res.*, ***6***(1), 30-33.
15. Firdous S.M., Koneri R. (2012) *In vivo* and *in vitro* antiinflammatory activity of leaves of *Ipomoea staphylina. Int. J. Pharm. Pharm. Sci*., **4**(5) 339-343.
16. Kottaimuthu R. (2008) Ethnobotany of the Valaiyans of Karandamalai, Dindigul District, Tamil Nadu, India. *Ethnobototanical Leaflets* **1,** 195-203. Available at: https://opensiuc.lib.siu.edu/ebl/vol2008/iss1/24
17. Kumar T.D., Pullaiah T. (1999) Ethno-Medico-Botany of Chenchus of Mahaboobnagar District, Andhra Pradesh. *Anc. Sci. Life*, **19**(1-2), 31.
18. Shobana P. Devi, Begum M. Shabana (2021) Antioxidant and antiperoxidative effects of *Ipomoea staphylina* in Streptozotocin-induced diabetic rats. Res. *J. Agril. Sci.,* **12**(1), 374-379.
19. Firdous S.M., Koneri R. (2014) Antidiabetic and antioxidant activities of *Ipomoea staphylina* Leaves in Streptozotocin (STZ) induced diabetic mice. *J. PharmaSciTech,* **3**(2). http://www.pharmascitech.in
20. Firdous S.M., Singh A. (2016) Effect of *Ipomoea staphylina* leaves on streptozotocin-nicotinamide induced type-II diabetes in Wistar rats. *Asian Pac. J. Health Sci.*, ***3***, 30-44. https://doi.org/10.21276/apjhs.2016.3.3.6
21. Ghosh S., Firdous S.M. (2014) Effect of aqueous extract of *Ipomoea staphylina* on Indian earthworm. *Evaluation*, **12**, 13.
22. Banerjee A., Firdous S.M. (2015) Antiulcer activity of hydroalcoholic extract of *Ipomoea staphylina* plant in rats. *Bangladesh J. Pharmacol.,* **10**(3), 652-653. https://doi.org/10.3329/bjp.v10i3.24034.
23. Bag A.K., Mumtaz S.F. (2013) Hepatoprotective and nephroprotective activity of hydroalcoholic extract of *Ipomoea staphylina* leaves. *Bangladesh J. Pharmacol.*, ***8***(3), 263-268. https://doi.org/10.3329/bjp.v8i3.14845.
24. Jeyadevi R., Ananth D.A., Sivasudha T. (2019) Hepatoprotective and antioxidant activity of *Ipomoea staphylina* Linn. *Clin. Phytosci.*, **5**(1), 1-11.

https://doi.org/10.1186/s40816-019-0112-4

25. Ghosh S., Firdous S.M. (2014) Evaluation of analgesic activity of hydroalcoholic extract of *Ipomoea staphylina*. *TJPS*, **38**(2), 57-60. https://doi.org/10.56808/3027-7922.1971
26. Santhoshkumar T., Rahuman A.A., Bagavan A., Kirthi A.V., Marimuthu S., *et al*. (2012) Efficacy of adulticidal and larvicidal properties of botanical extracts against *Haemaphysalis bispinosa*, *Hippobosca maculata*, and *Anopheles subpictus*. *Parasitol. Res.*, **111**, 1833-1840. https://doi.org/10.1007/s00436-011-2608-9
27. Banerjee A., Firdous S.M. (2020) *In vitro* antimutagenic activity of *Ipomoea staphylina*. *Bangladesh J. Pharmacol.,* **15**(1), 41-43. https://doi.org/10.3329/bjp.v15i1.43446
28. Villaseñor I.M., Angelada J., Canlas A.P., Echegoyen D. (2002) Bioactivity studies on β-sitosterol and its glucoside. *Phytother. Res.,* **16**(5), 417-421. https://doi.org/10.1002/ptr.910
29. Rashed K. (2020) Beta-sitosterol medicinal properties: a review. *J. Sci. Innov. Technol.*, **9**, 208-212. 226313318
30. Ambavade S.D., Misar A.V., Ambavade P.D. (2014) Pharmacological, nutritional, and analytical aspects of β-sitosterol: a review. *Orient. Pharm. Exp. Med.*, **14**, 193-211. https://doi.org/10.1007/s13596-014-0151-9
31. Prakash D., Gupta C., Sharma G. (2012) Importance of phytochemicals in nutraceuticals. *J. Chin. Med. Res. Dev.*, **1**(3), 70-78.
32. Nwozo O.S., Effiong E.M., Aja P.M., Awuchi C.G. (2023) Antioxidant, phytochemical, and therapeutic properties of medicinal plants: A review. *Int. J. Food Prop.*, **26**(1), 359-388. https://doi.org/10.1080/10942912.2022.2157425
33. Luo B., Wen Y., Ye F., Wu Y., Li N., *et al.*, (2023) Bioactive phytochemicals and their potential roles in modulating gut microbiota. *J. Agric. Food Res.*, **12**, 100583. https://doi.org/10.1016/j.jafr.2023.100583
34. Kawatra A., Gupta S., Dhankha, R., Singh P., Gulati P. (2023) Application of phytochemicals in therapeutic, food, flavor, and cosmetic industries. In: Swamy M.K., Kumar A. (eds) Phytochemical Genomics. Springer, Singapore, 85-108. https://doi.org/10.1007/978-981-19-5779-6_4

35. Luo Y., Zeng Y., Peng J., Zhang K., Wang L., *et al*., (2023) Phytochemicals for the treatment of metabolic diseases: Evidence from clinical studies. *Biomed. Pharmacother*, **165**, 115274. https://doi.org/10.1016/j.biopha.2023.115274
36. Padmashree M.S., Ashwathanarayana R., Raja Naika R.B. (2018) Antioxidant, cytotoxic and nutritive properties of *Ipomoea staphylina* Roem & Schult. plant extracts with preliminary phytochemical and GC-MS analysis. *A. J. Pharm. Parmacol.*, **4**(4), 473-92. https://doi.org/10.31024/ajpp.2018.4.4.16
37. Tucker J.M., Townsend D.M. (2005) Alpha-tocopherol: Roles in prevention and therapy of human disease. *Biomed. Pharmacother.*, **59**(7), 380-387. https://doi.org/10.1016/j.biopha.2005.06.005
38. Rendle P.M., Kassibawi F., Johnston K.A., Hart J.B., Cameron S.A., *et al*., (2016) Synthesis and biological activities of d-chiro-inositol analogues with insulin-like actions. *Eur. J. Med. Chem.*, **122**, 442-451. https://doi.org/10.1016/j.ejmech.2016.06.047
39. Xiong R., Sauvage F., Fraire J.C., Huang C., De Smed S.C., *et al*., (2023) Photothermal nanomaterial-mediated photoporation. *Acc. Chem. Res.*, **56**(6), 631-643. https://doi.org/10.1021/acs.accounts.2c00770
40. Zhang L., Gu F.X., Chan J.M., Wang A.Z., Langer R.S., *et al*., (2007) Nanoparticles in medicine: Therapeutic applications and developments. *Clin. Pharmacol. Ther.*, **83**(5), 761-769. https://doi.org/10.1038/sj.clpt.6100400
41. Yildiz I., Shukla S., Steinmetz N.F. (2011) Applications of viral nanoparticles in medicine. *Curr. Opinion Biotech.,* **22**(6), 901-908. https://doi.org/10.1016/j.copbio.2011.04.020
42. Van Rijt S.H., Bein T., Meiners S. (2014) Medical nanoparticles for next generation drug delivery to the lungs. *Eur. Respir. J.,* **44**(3), 765-774. https://doi.org/10.1183/09031936.00212813
43. Pugazhendhi S. (2020) Synthesis of *Ipomoea staphylina* plant extract mediated silver nanoparticles. *Materials Today: Proceedings*, **33**, 4626-4629. https://doi.org/10.1016/j.matpr.2020.08.287
44. Narayanan L., Suseem S.R., Kamara C. (2024) An investigation into the larvicidal activity of biologically synthesized silver and copper oxide nanoparticles against Mosquito larvae. *Chemistry and Biodiversity* **21**(4), e202301774. https://doi.org/10.1002/cbdv.202301774