7 *Solanum nigrum*: Botanical, Phytochemical and Pharmacological Overview

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Abstract

Solanum nigrum (black nightshade or makoi) is gaining growing research interest due to the vast amount of bioactive compounds present in the plant. The bioactive compounds can be used in biomedical and agricultural applications. This review aims to cover Solanum n*i*grum's botanical, phytochemical, and pharmacological properties. Therefore, the review aims to elaborate how this plant can be used as a versatile resource. Solanum n*i*grum has been used in traditional medicinal practices since ancient times. It can be used to treat a variety of diseases, like inflammation, microbial infections, liver diseases, etc. Several modern-day research studies have been conducted to confirm that this plant offers many medicinal and therapeutic advantages. The plant contains a number of bioactive compounds like alkaloids, glycosides, saponins, etc., due to which the plant exhibits many pharmacological activities. The plant is known for its antioxidant, anti-inflammatory, hepatoprotective, antitumor, and antimicrobial properties. Along with these, several studies have highlighted the protective effects of plant extracts on cardiac and nervous systems too. The use of this plant as a source of new therapeutic agents and significant bioactive compounds has been of great interest. The plant has also shown its potential as a natural biocontrol agent. The composition of the bioactive compounds in the plant extracts can be significantly affected by environmental conditions and extraction methods. Phytochemicals of Solanum n*i*grum represent a complex interaction with the biological systems; however, the interactions may vary with the variation in concentration of extracts. Therefore, more systematic studies are required to explore and understand the relation between dosage of extracts and their biological effects.

Keywords: *Solanum nigrum,* Antimicrobial, Botanical, Pharmacological, Phytochemical.

Introduction

Solanum nigrum grows annually and perennially. (Särkinen et al., 2018). The plant is herbaceous in nature. *Solanum nigrum* has been used in therapeutic systems of China, Japan, and India as a remedy for various disorders. It has been used as a cure for infections related to the skin and systems of the body. The plant's extract shows a broad range of medicinal properties. Hence, it is considered a useful plant (Chen et al., 2022).

Botanical Characteristics

- Vernacular name: Kamuni, Makoi (Hin.); Kakki hannu soppu (Kan.); Kaasithazhai (Tam.); Kasi, Kamanchi, Gajju chettu (Tel.); Thutguna (Ori.) (Sankara Rao et al., 2016).
- The plant is widely distributed, with native occurrences in Asia, predominantly in Southeast Asia, Europe, and northern regions of Africa. It was sporadically introduced in Australia, South Africa, and America.
- The distinctive bitter taste and slight toxicity help recognize the plant (Cipollini and Levey, 1997).
- *Solanum nigrum* has found diverse applications in folk remedies.
- Spanning from moderate to tropical climates, the plant can flourish in a wide array of conditions, showcasing its exceptional flexibility.
- The remarkable lifespan of seeds accounts for their potential to become invasive in agricultural systems across the globe.
- The plant has a high degree of phenotypic plasticity, with its general morphology and leaf size changing in response to light and environmental factors (Sankara Rao et al., 2016; Särkinen et al., 2018; Knapp et al., 2023).

Taxonomical Categorization

Table 1: Taxonomical classification of *Solanum nigrum* (POWO, 2026)

KINGDOM	Plantae
DIVISION	Streptophyta
CLASS	Equisetopsida
SUBCLASS	Magnoliidae
ORDER	Solanales
FAMILY	Solanaceae (Potato family)
GENUS	*Solanum* (Nightshade)
SPECIES	*Solanum nigrum*

Source: From IPNI (International plants names index) database.
https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:30048260-2

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Morphology

The plant has a green herbaceous stem. They have green berries when young and are usually toxic to consume. As the fruit ripens, it becomes blackish or dark purplish in color and usually sweet in taste. The flowers are white in color with yellow-colored anthers. The plant has a tap root system, longer in mature plants and shorter in small plants. The leaves are usually oval to heart-shaped and are broad, having uneven wavy edges. (Chen et al., 2022)

Ecology: This plant is found growing along roadsides, in open spaces, and in cultivated lands (Särkinen et al., 2018).

A. Plant in natural habitat

B. Flowers

Figure 1: *Solanum nigrum* plants growing at the campus of Bhaskaracharya College of Applied Sciences, University of Delhi, Dwarka, New Delhi.

Source: Photographs captured by the authors.

Phytochemical Composition

The plant's chemical composition usually includes flavonoids, tannins, proteins, carbohydrates, coumarins, phytosterols, steroidal alkaloids, steroidal saponins, glycoproteins, etc. as the main components (Keerthana et al., 2022). Several research studies have suggested that unripe berries of *Solanum nigrum* have a very high content of solanine, a compound that is used as a defense by the plant and is toxic. As the berry ripens and matures to become black or purple, the level of solanine decreases gradually, and it becomes less toxic (Zhang et al., 2023; Heo et al., 2022). It can also be eaten as a food due to its nutritional properties (Akubugwo et al., 2007).

Traditionally, this species has been employed for alleviating hepatotoxic conditions, inflammation, ulcers, and convulsions. Clinical investigations have validated many of these ethnomedicinal properties. Hence, *Solanum nigrum* can be considered a valuable herb with therapeutic significance (Wang et al., 2025; Son and Yen, 2014; Chen et al., 2022).

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Chemical Constituents of *Solanum nigrum*

Phytochemical investigations of this ethnomedicinal herb have shown an enormous number of chemical compounds with pharmacological activities. These chemical compounds majorly include steroidal alkaloids, glycoalkaloids, saponins, flavonoids, phenolic acids, glycoproteins, and peptides.

- **Alkaloids**

Solanine (Glycoalkaloid)

Solanine is a glycoalkaloid distributed throughout several different parts of black nightshadein high concentrations,but the unripe berries of the plant display the most elevated concentration, leading to its toxicity in the unripe stage. The mature fruits are the least toxic and can therefore be consumed. In a similar manner, there is a consistent accumulation of solanine to higher levels in the leaves during growth and maturation. Fractionation of solanine through chromatography gives six distinct components, including α, β, and γ chaconines and α, β, and γ solanines (Cipollini and Levey, 1997; Zhang et al., 2023).

Solanidine and Solasodine

Solanidine is obtained by the hydrolysis of solanine and is less toxic. A structurally steroidal alkaloid called 'solasodine' accumulates at the highest concentration in leaves. Solasodine is one of the major glycoalkaloids of *Solanum* plants and a predominant aglycone. The alkaloidal content of plant parts varies with different development stages (Patel et al., 2013; Chen et al., 2022).

- **Organic Acids**

Variable concentrations pertaining to organic acids across the seedlings and the mature plant of *Solanum nigrum* have been identified, for example, acetic acid, tartaric acid, and malic acid. Tartaric acid, along with citric acid, has been reported to contribute to the physiological adaptation to the stress conditions of the plant (Sridhar et al., 2011).

Seven phenolic hydroxyl-substituted benzoic acids were identified that provide broader pharmaceutical applications, including antioxidant, antimicrobial, and anti-inflammatory activities for disease treatment (Campisi et al., 2019; Francis, 2024).

- **Steroidal Glycoalkaloids (SGAs)**

Steroidal glycoalkaloids operate as chemical defenses with targets that include a wide range of pathogens, pests, and herbivores. Mostly known for their anti-nutritional or toxic effects on humans, the majority of these bioactive constituents have demonstrated a range of pharmacological properties, including antimicrobial, anti-inflammatory, antiviral, and antipyretic (Keerthana et al., 2022). In addition to inhibition of anti-inflammatory responses, both the steroidal glycoalkaloids α-

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solasonine and α-solamargine have also shown their anti-tumor and cell-proliferation-suppression potential (Kaunda and Zhang, 2019).

- **Steroidal Glycosides**

Among higher plants, steroidal saponins are one of the major classes of secondary metabolites as pharmaceutical resources. It is an active pharmacological constituent of *Solanum nigrum.* Seventy-six steroidal saponins have been isolated and their structures elucidated. The newly identified steroidal saponins in 2006 included solanigroside types. Spiro-stanol and furostanol saponins are usually concentrated in the plant's roots and stems (Yuan et al., 2020). Solamargine, β-2-solamargine, and degalactotigonin are the antineoplastic compounds in *Solanum nigrum* (Gabrani et al., 2012). In higher plants, the key classes of secondary bioactive metabolites are steroidal saponins distributed in most of the parts of the plant (Chen et al. 2022).

- **Phenylpropanoids**

Isolation and chemical identification of phenylpropanoids, phenylpropionic acid, coumarin, and lignans from the entire plant was done. The tumor-inhibiting, anti-inflammatory, hypoglycemic, anti-hypertensive, and neuroprotective effects were shown by scopoletin (Chen et al. 2022).

- **Flavonoids**

This contributes to about 50% of the phenolics (Moyo et al., 2020) that is responsible for the antioxidant and anti-inflammatory activities (Arunachalam et al., 2009; Berardi et al., 2016).

- **Polysaccharideds**

Around 12 kinds of polysaccharides have been reported in black nightshade that are necessary for the immune-regulating, anti-fatigue, antioxidative, anti-radiative, blood sugar-lowering, antiviral, antitumor, and liver-protective effects (Keerthana et al., 2022). are

Pharmacological Activities

Solanum nigrum has been recognized for the various medicinal properties present in it due to the wide array of phytochemical constituents present in different plant sections. The leaf tissues and berry extracts, for example, are used primarily in the treatment of illnesses, like skin conditions and joint problems, and also for the tuberculosis medication formulation (Perez et al., 1998; Elias et al., 2013; Knapp and Särkinen, 2018; Kaunda and Zhang, 2019; Mani et al., 2022; Chen et al., 2022; Knapp et al., 2023; Mandal et al., 2023; Wang et al., 2025).

- **Antitumor (Anti-Cancer)**

Polysaccharides isolated from *Solanum nigrum* significantly inhibit tumor growth in animal models through programmed cell death and block the progression of

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the cell cycle (Zhang et al., 2023). Apoptosis in cancer cell linings has been reported to be induced by the phytochemicals of the plant, like solanine. The *Solanum nigrum* extract acts as a multi-target anticancer agent with dual dose-dependent mechanisms. Autophagy results with a low dosage, and programmed cell death results with a high dosage (Francis, 2024).

- **Anti-Inflammatory and Anti-Ulcerogenic**

The black nightshade plant exhibits notable anti-inflammatory activity by transcription factor modulation that leads to suppressed inflammatory signaling molecules' expression, such as inducible nitric oxide synthase (iNOS) as well as cyclooxygenase-2 (COX-2) (Kalam et al., 2021).

Through various experimental ulcer models, like stress, ethyl alcohol, and drug-associated stomach ulcers, the anti-ulcerogenic property of this medicinal herb was validated. The plant extract was seen to significantly reduce gastric lesions due to ulceration by lowering gastric acid secretion, pepsin activity, and gastric volume. Its gastroprotective effects are primarily due to hydrogen–potassium ATPase of the gastric proton pump (Jainu and Devi, 2006) inhibition coupled with suppressing secretion of the stomach's G-cells (gastrin), which is crucial for stimulating gastric acid (hydrochloric acid) synthesis.

- **Antioxidant**

The high levels or concentrations of phenolics (Moyo SM et al., 2020), flavonoids, and antioxidant enzymes contribute to the strong antioxidant property of *Solanum nigrum.* The free radicals like hydroxyl radicals, superoxide anions, and 2,2-diphenyl-1-picrylhydrazyl radicals are inhibited effectively due to these phytochemicals. The antioxidant potential of the plant varies and is influenced by processing methods, like cooking and pre-treatment, that affect the bioactive compound stability (Campisi et al., 2019; Ghosh et al., 2012; Knapp and Särkinen, 2018; Perez et al., 1998).

- **Antimicrobial and Larvicidal**

Antimicrobial activity against various bacteria, fungi, parasites, and insect larvae has been explored in *Solanum nigrum*.

Antibacterial

Solanum nigrum, which is a medicinal plant, is widely used in traditional systems like Ayurveda due to its medicinal properties. It is known to have a very broad range of antibacterial activity. Phytochemicals are present in various parts of the plant, including leaves, berries, and roots, and are associated with some prominent antibacterial effects. Methanol extracts of plants have proven to be active against Gram-positive and Gram-negative bacteria, including *Escherichia coli, Staphylococcus aureus, Bacillus subtilis,* and *Pseudomonas aeruginosa* (Upadhyay

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et al., 2015). Overall, Gram-positive bacteria are more likely to be sensitive to bioactive compounds of the plant. (Košćak et al., 2023).

The main active phytochemicals in this plant that mainly contribute to its antibacterial activity include alkaloids (solanine and solamargine), flavonoids, saponins, tannins, and phenolic compounds.

Antifungal

The root and leaf extracts hold the potent antifungal effect, predominantly arising due to the saponins reported in these parts of the plant. Flavonoids, alkaloids, tannins, phenolic compounds, saponins, terpenoids, and glycosides are all linked with *Solanum nigrum's* antifungal properties. *Solanum nigrum* can target a wide range of fungi, which may cause diseases. The antifungal effects might be related to disrupting fungal cell structures or interfering with essential metabolic processes. The antifungal properties are usually shown by the methanolic extracts. (Shakir et al., 2023; Atanu et al., 2011; Sridhar et al., 2011; Sankara Rao et al., 2013).

The aqueous extracts show less antifungal activity compared to the organic solvents. In some studies, ethanolic seed extract showed the least minimum inhibitory concentration (MIC) values when it was used against *Penicillium notatum* and *Aspergillus nige*r. Therefore, ethanol is the best solvent for producing antifungal effects. (Masih, 2025; Sridhar et al., 2011), whereas aqueous extracts are less selective and show lower antifungal activity. Aqueous extracts of leaves have inhibitory effects on *Aspergillus carbonarius* and *Penicillium expansum* but no effects on *Aspergillus flavus, Fusarium graminearum,* and *Fusarium verticillioides* (Musto, 2015).

Larvicidal

The *Solanum nigrum* demonstrated larvicidal effects against mosquito species through extracts from leaves and berry extracts in a silver nanoparticle-based study (Sankara Rao et al., 2013). This indicates a potential use in vector control applications of this plant (Ghosh et al., 2012).

This species of *Solanum* has been documented to contain molluscicidal and cercaricidal activity. Further, it has been reported to be a potential mosquito biocontrol extract against specific species of *Culex* and *Anopheles* (Rawani et al., 2017; Knapp et al., 2004; Chowański et al., 2018).

- **Neuroprotective**

Studies have indicated that extracts made of the fruits and the leaves of this plant have neuroprotective effects as well as anticonvulsant properties. It causes CNS depressant effects, prolonging sedative-induced sleep and reducing locomotor and exploratory behavior. These effects are mediated through acetylcholine-like activity, influencing neurotransmission.

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The plant also helps control seizures, hence highlighting its anticonvulsant property (Noel et al., 2008; Perez et al., 1998; Son and Yen, 2014).

- **Hepatoprotective**

Solanum nigrum, upon recent studies, has been shown to have hepatoprotective activity using chemically induced liver injury models. The plant significantly reduces liver enzyme levels, oxidative stress markers, and histopathological damage. Additionally, this plant inhibits hepatocarcinogenesis and enhances antioxidant enzyme activity. **(**Knapp and Särkinen 2018; Knapp et al., 2023; Kuppuswamy et al., 2003).

- **Antidiabetic**

The black nightshade also shows hypoglycemic activity (like treating type 2 diabetes). Long-term treatment using crude extract of *Solanum nigrum* resulted in the reduction of the level of blood glucose in the rats fed on a high-fat diet (Nderitu et al., 2023).

- **Anti-Obesity**

Rats in the high-fat diet control group had significant increases in body mass index (BMI), whereas those in *Solanum nigrum* leaf extracts showed a decrease in BMI, which demonstrated their anti-obesity properties (Nderitu et al., 2023).

- **Cardioprotective**

The extracts of *Solanum nigrum* have reported various cardioprotective activities through animal models (Bhatia et al., 2011).

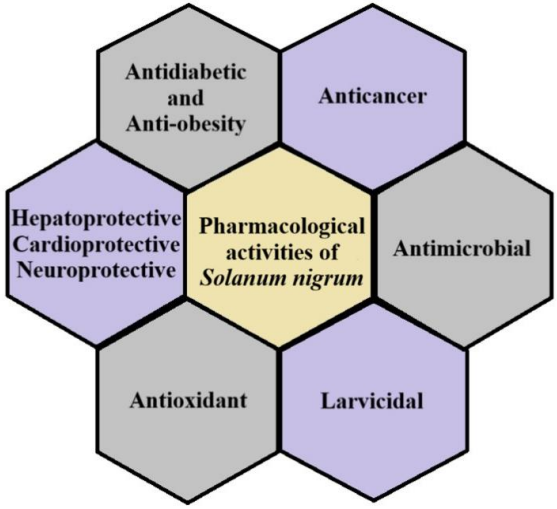

Figure 2: *Solanum nigrum* pharmacological activities

Source: Illustration prepared by authors based on various published botanical literature (Chen et al., 2022; Bhatia et al., 2011; Nderitu et al., 2023; Masih, 2025; Musto, 2015; Shakir et al., 2023).

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Microbial Growth-Stimulating Effects of *Solanum nigrum*

Although *Solanum nigrum* is reported as having antimicrobial activity, some studies have indicated that, under specific environmental and nutritional conditions, the plant extracts may have an promoting effect on the growth of certain microorganisms. *Solanum nigrum* has abundant bioactive compounds, such as alkaloids, flavonoids, and phenolics, which may affect microbial growth, depending on the experimental conditions (Gębarowska et al., 2022).

- **Nutrient Provision vs. Bioactive Compound Extraction**

The extraction solvent plays a crucial role in determining the biological activity of *Solanum nigrum* extracts, influencing whether they promote or inhibit microbial growth, since it determines which phytochemicals are extracted. Water is very good at extracting polar primary metabolites such as sugars, amino acids, and organic acids, which can be used as sources of nutrition by the fungi. Ethanol is less polar, and as such, it is better at producing secondary metabolites, which have potential bioactivity (Kalwar, 2015).

- **Context-Dependent Variability**

There may also be differences in plant materials, such as geographical source, plant part, stage of development, microbial source specificity, etc., and experimental conditions that are responsible for variation in the biological effects of the extracts in *Solanum nigrum*. Thus, the antimicrobial effect of the extracts of *Solanum nigrum* is strongly affected by plant parts and the microorganisms' strains used in the experiment (Gębarowska et al., 2022).

***Solanum nigrum*: Indian Knowledge System Perspective**

Solanum nigrum, locally also known as Kali makoi, is a plant of significant Ayurvedic importance because of its use as a folk medicine. It has been described in *Charaka Samhita* for the management of liver related disorders (Jagtap et al., 2013) and antidiabetic potential (Nand Lal and Sharma, n.d.). The whole plant (Panchang) extract of *Solanum nigrum* has been shown to have many medicinal properties like hepatoprotective activity (Elshater et al., 2013).

Conclusion and Future Prospects

Solanum nigrum grows abundantly as a weed and is highly adaptable to the abiotic stresses. Therefore, this plant can be explored for its medicinal, biomedical, and therapeutic aspects very easily without disturbing the natural flora.

A number of studies on the medicinal properties of *Solanum nigrum* and its clinical significance have been conducted; however, the phytochemicals may vary with the variation in geographical location. Moreover, there are limited studies conducted on the pharmacokinetics and toxicity studies of the plant extract.

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Therefore, more studies are required to cover these research gaps so that the *Solanum nigrum* can be used to its full potential.

Panchang extract is an Indian knowledge system concept where we use all five parts of the plant, namely, leaves, stems, roots, flowers, and seeds. The studies conducted till now has been focused on individual and specified plant parts, therefore, more studies are required to be conducted to bridge the gap between Indian knowledge systems and modern sciences.

Even though *Solanum nigrum* contains toxic compounds, if the extraction procedures are controlled and the dosage is optimal, the plant shows many medicinal benefits. Some of the plant's medicinal benefits, like antitumor, anti-inflammatory and neuroprotective activities, etc., (Arunachalam et al., 2009), can be explored if proper dosage and modern extraction procedures are followed. Therefore, advanced research studies on *Solanum nigrum*'s phytoconstituents can be done to check its vast pharmacological potential.

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