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The Paradox of Black Nightshade: Modern Insights into an Ancient Medicinal Plant

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Abstract
Solanum nigrum, often referred to as black nightshade or "Makoi," is an herbaceous plant valued in traditional medicine for its strong therapeutic effects and diverse pharmacological activities. This review thoroughly investigates the botanical, phytochemical, ethnopharmacological, and pharmacological aspects of M. india, highlighting its potential as a natural option for the management of chronic illnesses. Abundant in glycoalkaloids, flavonoids, saponins, and polyphenols, S. nigrum demonstrates antioxidant, anti-inflammatory, hepatoprotective, and anticancer activities. polysaccharides and alkaloids, in particular, show promising antitumor mechanisms through the induction of apoptosis, enhancement of immune modulation, and reduction of oxidative stress. Traditionally, different parts of the plant such as leaves, roots, and fruits—are employed to address a variety of health issues, including gastric ulcers, skin infections, respiratory problems, fertility, and liver ailments. This review also highlights toxicity assessments, standardization procedures, and regulatory guidelines needed to guarantee its safe use, given solanine's toxic properties. Phytochemical evaluations using HPLC, GC-MS, and spectrophotometry confirmed the integrity and effectiveness of the compounds. Cutting-edge extraction methods, such as ultrasound and microwave-assisted techniques, improve the yield and quality of bioactive materials. Prominent regulatory organizations, As herbal treatments gain popularity worldwide, this review presents S. nigrum not only as a traditional solution but also as a scientifically substantiated medicinal plant with significant therapeutic potential. Further studies examining its bioactive components and clinical validation may reveal the complete range of its pharmacological uses.
Keywords: Solanum nigrum; Black nightshade; Makoi; Phytochemistry; Glycoalkaloids; Solanine; Solamargine; Solasonine; Flavonoids; Saponins; Polysaccharides; Ethnopharmacology; Traditional medicine; Antioxidant activity; Anti-inflammatory activity; Hepatoprotective activity, Toxicity assessment; Standardization; HPLC; GC-MS; Herbal drug regulation.

Introduction

Black nightshade (Solanum nigrum) is a member of the Solanaceae family of plants and is used medicinally. This family includes numerous genera that are well-known for their medicinal properties [1].The tiny white flowers have five widely spaced petals and short pedicella. The principal locations for nigrum include wastelands, abandoned fields, ditches,

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fence rows, boundaries of wooded and farmed areas, and roadsides. It is a widespread plant that grows throughout Africa and Europe. The poisonous amount of solanine, a glycoalkaloid present in various plant sections but with the highest quantities in the unripe berries, is one of the reasons why sulfur is a popular plant [2]. It possesses curative properties, such as cytotoxic, antioxidant, antimicrobial, anti-ulcerogenic, and hepatoprotective activity. It is a possible herbal alternative that possesses anti-cancer properties [3]. Berries are used because of their diuretic, cathartic, and tonic properties. Seeds are also needed for dipsia and giddiness [4]. The erect annual herb Solanum nigrum is 25–100 cm tall and pubescent with simple hairs. The stems are frequently sparsely pubescent and angular. The fruits are globose, dull black, and 8-10 mm across. The ovate leaves have glabrous, coarsely dentate bases that are cuneate, 4–10 cm wide, and an obtuse tip [5].

Figure 1: Solanum Nigrum Plant

The plant has been used to cure several illnesses, such as respiratory, gastrointestinal, skin, and inflammatory diseases. Additionally, it has been used to reduce pain and as a diuretic [6]. Polysaccharides, which are cytoprotective agents that promote mucosal proliferation and regeneration and increase PG production. In a number of experimental models, saponins were found to exhibit anti-ulcer action, maybe by activating protective factors for mucous membranes [7]. Glycoalkaloids such as solanine, solamargine , and solasodine are the main flag chemicals found in S. nigrum, according to phytochemical investigations [8]. Oxidative stress is a pathogen of many human diseases, such as atherosclerosis, ischemia-reperfusion injury, inflammation, cancer, aging, and neurodegenerative diseases [9]. It is well known that eating nightshade plants, such as potatoes, eggplant, and tomatoes, can make joint discomfort worse [10].

Botanical Description and Phytovhemistry

Table 1: Plant Profile

PLANT PROFILE [3] [11] [12]
Biological Source

Solanum nigrum commonly known as Black Nightshade is a plant species belonging to the solanaceae family.
Common Name
Black nightshade, Makoi
Prioritized Scientific Name
Solanum nigrum L.
Alternative Scientific Name
Solanum retroflexum Dunal
International common name
English: blackberry nightshade Spanish: hierba mora French: creve-chien; morelle noire Arabic: uyyoub Portuguese: era moira
Geographical Source
Chennai, Tamil Nadu, India
Species In India
S. americanum, S. nigrum, S. villosum

Synonyms

Language	Synonyms
Sanskrit	Dhvansamaci
Bengali	Gudakamai
English	Garden night shade
Hindi	Makoya, kakamachi, kali makoy
Kannada	Ganikesopu
Malayalam	Manatakkali
Marathi	Kamoni
Punjabi	Mako, Peelak, Mamoli
Urdu	Mako

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Taxonomical name
Kingdom Plantae – Plants
Subkingdom Tracheobionta - Vascular Plant
Superdivision Spermatophyta - Seed Plants
Division Magnoliophyta - Flowering Plant
Class Magnoliopsida – Dicotyledons
Family Solanaceae - Potato
Order Solanales
Genus Solanum - Nightshade
Species Solanum Nigrum L – Black Night Shade Author Linn

Habitat

Species related to black nightshade are distributed in various habitats, such as croplands, road edges, riverbanks, forest garden weeds, and neglected lands, particularly in areas ranging from sea level to an altitude of 3000 m.

Growth Pattern	Required Conditions	Plant Type
• Colder temperature; summer • Tropical and subtropical region; Rainy season	• Colling, fertile soil • Nitrogen and phosphorus rich soil • Warm condition • Adequate daylight	• weeds type • Reproduce by seeds

Botanical Description

Black nightshade is an herbaceous plant or tiny shrub with a short lifespan. Plants stand between 0.25 and 1 m tall [14]. and Solanum nigrum L. has been found to have two distinct varieties: orange and black-fruited. Both of the Solanum nigrum varieties [15].

Leaves

The ovate leaves have cuneate bases that are 4–10 and 3–7 cm wide, glabrous, and coarsely dentate, with an obtuse and short-pointed apex. The leaves have a drab, dark green colour, and the edges are toothless to slightly toothed. The petiole length ranged from 1 to 2 cm. With five to six veins on each side and uneven, wavy, coarse teeth throughout or on each side, the leaf's cuneate is a base wedge that is broad and descends to the petiole. It is also smooth, soft, and hairy on both sides [14].

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Figure 2 : Solanum nigrum leaves

Flowers

The petals of Solanum nigrum blooms range from green to white. The extra-axillary inflorescence consists of three to six blooms. The entire length of the pedicel is between 1 and 2.5 cm and the pubescent, roughly 5 mm long. The corolla is white, and the calyx is tiny, shallow, cup-shaped, and measures approximately 1.5 to 2 mm in diameter. The lobes were approximately 2 mm in length and were ovoid and oblong. The anthers are yellow, roughly 1.2 mm long (four times the length of the filaments) and the apical hole is inward. The filaments were short. The style was approximately 1.5 mm long, and the ovary was oval with a diameter of 0.5 mm. There is not much stigma involved [14].

Figure 3 : Solanum nigrum flower

Fruits

Berries are typically 6–10 mm wide, roughly oval, yellowish-green ,dull purple to blackish and when ripe, they fall from calyces or remain on plants [13]. Arranging fruits in an umbelliform pattern [16]. The black-fruited variety has large, black-coloured fruits, whereas the orange-fruited variety has tiny, orange fruits [15].

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Figure 4: Solanum nigrum fruit

Seeds

The seeds are discoid and are largely ovoid. It is compressed on both sides, with a diameter of approximately 1.5-2 mm. The seeds are yellow, silky, and slightly pitted [14]. Orange-fruited seeds are minutely scaly, whereas black-fruited seeds are discoid, minutely pitted, and yellow in colour [15].

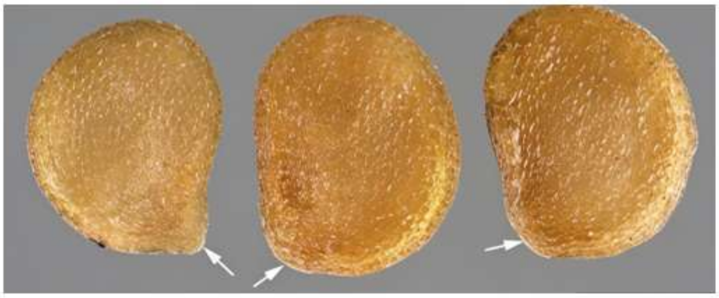

Figure 5: Solanum nigrum seed

Pharmacognostic Characters [17]. Pharmacogenetic traits such as organoleptic, physicochemical, and phytochemical features are crucial to identify, authenticate, and detect adulteration in medicinal plants. Plant identity was verified using organoleptic characteristics. While phytochemical profiling confirms the existence of specific bioactive components, physicochemical features guarantee consistency and quality. Inconsistencies in these attributes may signify adulteration or substitution, guaranteeing safety and authenticity.

Whole plant powder's organoleptic properties Physicochemical Properties

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Table 2: Physicochemical properties of solanum nigrum

Parameter	Results n=3 %w/w
	Average ±
Loss on drying	17.62 ± 0.01
Total Ash	14.38 ± 0.10
Acid Insoluble Ash	0.00 ± 0.00
Water Soluble Ash	7.47 ± 0.23
Alcohol soluble extractive value	4.41 ± 0.00
Water soluble extractive value	20.90 ± 0.005

Phytochemical Constituents

Table 3 : Phytochemical Constituents of Solanum nigrum (Black Nightshade)

Sr.no	Phytochemical Class / Compound(s)	Plant Part(s)
1	Glycoalkaloids: Solanine, Solamargine, Solasodine, Soladulcine	Leaves, berries, whole plant [9].
2	Steroidal Saponins	Leaves, stems, berries [9].
3	Flavonoids: Quercetin, Kaempferol glycosides	Leaves, berries [9,18].
4	Phenolic acids: Caffeic, Chlorogenic, Ferulic acids	Leaves, fruits [18].
5	Tannins	Leaves, stems [18].

Comparison To Other Species

S. nigrum is one of several related species (S. nigrum) that often coexist and act as weeds in comparable environments. There are many of them in various regions of the world. S. americanum is a common weed with glossy immature and mature fruits and translucent, lighter green leaves. S. luteum, occurring in the Middle East, has yellow fruit. The widespread weed S. retroflexum is similar to S. nigrum in appearance, but it is more common and has shallow to deeply lobed leaves that are paler below than above. S. sarrachoides, a plant that grows all over the world, is identified by its fine hairs on the stems and leaves and its greenish fruit, which is encased in an expanded persistent calyx.

Ethnopharmacology Uses In India

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Table 4 : uses of S. nigrum

Plant part	Conditions	Preparation
a) Leaf	Stomach ache	Fresh Leaves cooked with onion bulbs and cumin seeds
	Gastric ulcers	Leaves juice can be taken orally
	Used as a liver tonic and in cases of indigestion	Tonic
	Treatment of skin conditions and rheumatoid and gouty arthritis, and used as anti-tuberculosis.	Used usually as a poultice
	Wound healing	Extracts
	Fungal Infections	Make smooth paste of clean and dry Leaves
	Indigestion	Leaves juice can be taken orally
	Dysentery	decoction
	Rabies	Grind the Leaves to make a paste and apply it with extract on the infected area
b) Roots	Increase fertility in women	Roots are boiled with a little sugar
	Asthma and whooping cough	Juice of roots is extracted
c)Whole plant	Cough	Taken as meal Oral decoction
	Against fever and alleviating pain	Fresh juice
	Wounds	Topically apply paste of green Leaves

d) Fruits	Treatment of cough and diarrhea. inflammations and skin diseases	Decoction of berries
	Laxative, and for treating asthma Used as an appetite stimulant and excessive thirst.	Tonic
	Used for toothache	Fruits
	Remedy for cough and erysipelas	Juice prepared as a decoction of fresh fruits and flowers
	Hemorrhoids	Consume fruits

Pharmacological Activities

Antioxidant Activity

Mechanism of Action: Free Radical Scavenging: Quercetin and kaempferol, two phenolic substances found in S. nigrum, provide free radical electrons, neutralizing them and halting cellular damage. According to molecular docking studies, these substances attach to oxidative enzymes efficiently, preventing their activity and lowering the generation of ROS

Enhancement of Antioxidant Defense Systems: S. nigrum extracts increase intracellular glutathione levels, a vital antioxidant that supports the body's defense against oxidative damage.

Inhibition of Oxidative Enzymes: Enzymes involved in the synthesis of pro-oxidant compounds, such as lipoxygenase and cyclooxygenase, can be inhibited by specific steroidal alkaloids found in S. nigrum. The plant lessens the production of ROS and related oxidative stress by inhibiting these enzymes[19].

Anti-Inflammatory

Black nightshade (Solanum nigrum) has long been utilized for its anti-inflammatory properties. According to research, its capacity to prevent the synthesis of proinflammatory mediators is the main cause of its anti-inflammatory properties. In particular, it has been demonstrated that substances extracted from S. nigrum inhibit the release of leukotriene C4, a chemical implicated in inflammatory reactions. To reduce inflammation, this suppression is accomplished by blocking the enzymes that produce leukotrienes [20]. Furthermore, S. nigrum contains polyphenols and polysaccharides that block the actions of cyclooxygenase-2 (COX-2) and inducible nitric oxide synthase (iNOS), two enzymes that are important in the inflammatory process. S. nigrum further contributes to its anti-inflammatory properties by lowering the synthesis of prostaglandins and nitric oxide by blocking the enzymes. extract activates c-Jun N-terminal kinase (JNK), which in turn activates pro-apoptotic proteins such as Bax in liver cancer cell lines (HepG2). Additionally, it causes mitochondria to release cytochrome c, which activates caspases and initiates apoptosis. In contrast to apoptosis, autophagy was induced when the same cell lines were exposed to low amounts of the extracts. Autophagy is a lysosomal degradation process that helps cells adapt to stressful conditions by repairing damaged organelles or malfunctioning pathways. This could be the reason autophagy results from the low concentration [1].

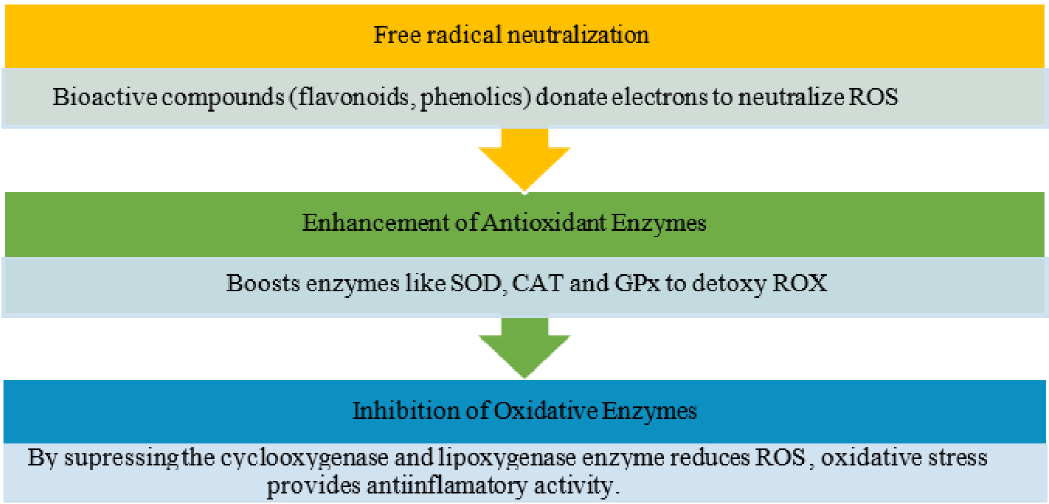

Figure 7 : Mechanism Showing Antioxidant and anti-inflammatory activity Of Solanum Nigrum

Hepatoprotective Activity

Hepatoprotective effects of ethanol extract of Solanum nigrum Linn. The fruit was administered orally to male albino rats at a concentration of 250 mg/kg. It offers a strong defence against the majority of the metabolic changes induced by carbon tetrachloride (CCl_4). When CCL_4 was administered, there was a considerable increase in the activities of serum aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase, and total bilirubin [3]. Additionally, CCl_4 lowers the concentrations of antioxidant enzymes, such as superoxide dismutase (SOD) and glutathione (GSH) [1]. The water extracts demonstrated a hepatoprotective effect against CCl_4-induced liver damage, as evidenced by a decrease in serum levels of bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphates (ALP) activities, as well as mild histopathological lesions. The reduced levels of SOD and GSH were restored by the higher dosage of S. nigrum aqueous extract (0.5 and 1.0 g kg^{-1}), suggesting that the hepatic tissue damage caused by CCl_4 had been repaired. The methanolic extracts of S. nigrum (250-500 mg/kg) also had hepatoprotective effects, with levels of serum AST, ALT, ALP, and bilirubin decreasing significantly in animals treated with S. nigrum methanolic extract compared to the untreated group [21]. In rats with CCl_4-induced liver damage, the study evaluated the effects of these extracts on serum enzymes and oxidative stress markers. The findings showed that the extracts had strong hepatoprotective effects, which could be explained by their antioxidant qualities [22].

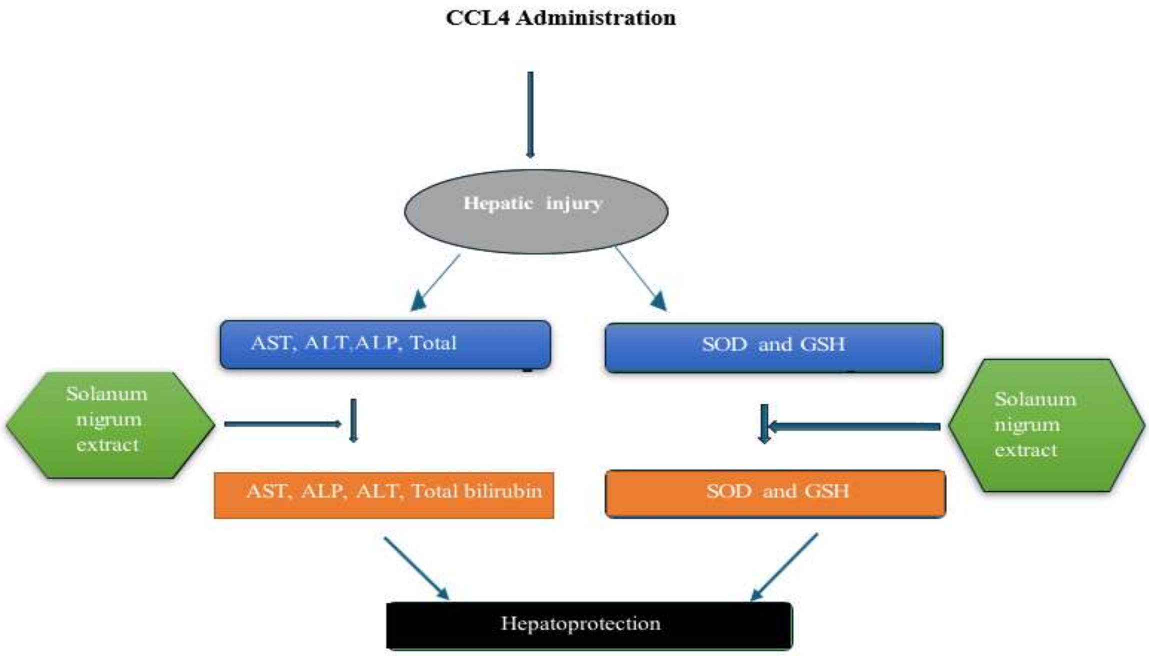

Figure 9 : Mechanism of Action of Solanum Nigrum Showing Hepatoprotective Activity

Safety,Toxicity,And Adverse Effects

Toxicity Studies:

The experiment had ten treatments, each performed duplicate. The following groups were established a blank group (CK without LDPE and Cd), a single LDPE group with varying amounts, a Cd group with a fixed concentration (20.00 mg·kg−1), and an LDPE group with varying concentrations. The height and length of the main roots of Solanum nigrum L. were measured using vernier calipers, as illustrated in Figure 1. The roots were then cleaned with tap water, any excess water was removed using absorbent paper, and the fresh weight of the roots was calculated. A chlorophyll meter was used to measure the chlorophyll of fresh Solanum nigrum L. leaves, and a weight-weighing method was used to determine the leaf area of the plant [23].

Acute Oral Toxicity Studies

Groups of six mixed-sex mice that had fasted overnight were housed in a laboratory setting with unrestricted access to water. Using a gastric catheter, the aqueous extract was administered orally at concentrations of 500, 1000, 1500, and 2000 mg/kg after being dissolved in distilled water [24]. The LD50 values of Sn and metal ion-conjugated (Sn/glycoalkaloids) and metal ion-depleted glycoalkaloids of Sn (Sn/glycoalkaloids/excluded) were determined by dividing Swiss albino mice of both sexes and approximately equal weights into ten groups, each comprising six animals. Following the delivery of the test substance for 24 h, the number of dead animals in each group was noted. Mortality was used to evaluate the toxicological effect, which was represented by an LD50 number [25]. Rats, mice, hamsters, and rabbits have been the subjects of most toxicological investigations into the glycoalkaloids of Solanaceae members. The intraperitoneal LD50 values for solanine, chaconine, and tomatine in mice were 27, 30, and 34 mg/kg bw, respectively. The LD50 of the different glycoalkaloids was between 30 and 60 mg/kg bw for most animals. According to toxicological research, solanidanes are more hazardous than comparable spirosolanes, including solamargine, solasonine, and solasodine [26].

Subacute Toxicity Studies

On days 7, 14, and 21 of the trial, the animals' weights decreased. Following the animals' 21-day sacrifice, histological analyses of the liver and measurements of glycogen levels in the kidney and liver were performed. The total RBC count, total WBC count, %Hb, clotting time, and differential count were among the haematological analyses (Ghai, 1998). ASAT, ALAT, ALP, TB, DB, albumin, total protein, and globulin levels were determined are other biochemical/serum profile analyses. Lipid profile analyses included TC, TG, HDL, LDL, and VLDL [24]. Albino rats weighing 200–250 g were divided into ten groups of six animals each for subacute oral toxicity testing.

Group 1: Received purified water (control group)

Groups 2–4: Administered whole plant extract of *S. nigrum* at 1 g/kg, 2 g/kg, and 4 g/kg body weight, respectively

Groups 5–7: Administered Sn glycoalkaloid-rich fraction at 100, 200, and 400 mg/kg body weight, respectively

Groups 8–10: Administered glycoalkaloid-depleted fraction of Sn extract at 100, 200, and 400 mg/kg body weight of Sn/glycoalkaloids/excluded [25].

Quality Control, And Standardization

Quality Control

Phytochemical Evaluation

1. Phytochemical ⟹ Test Performed ⟹ Observation ⟹ Result
2. Alkaloids ⟹ Drangendorff's Test ⟹ orange-red ppt ⟹ Positive
3. Flavonoids ⟹ Shinoda Test ⟹ pink/reddish pink ⟹ Positive
4. Glycosides ⟹ Legal's Test ⟹ pink-red colour ⟹ Positive
5. Saponins ⟹ Foam Test ⟹ 1 cm foam layer ⟹ Positive
6. Steroids ⟹ Liebermann-Burchard Test ⟹ bluish green colour Positive
7. Tannins ⟹ Ferric Chloride Test ⟹ dark blue/greenish black ⟹ Positive [27].

Advanced Techniques for detailed phytochemical analysis

HPLC: The purpose of this method is identification, quantification, and separation of substances such as alkaloids, flavonoids, and phenolic acids.

GC-MS: The purpose of this method is to profile terpenoids and volatile substances.

FTIR Spectroscopy: Purpose of this method to detect of chemical bonds and functional groups via vibration modes. [28].

TLC: The purpose of this method is the preliminary screening of phytoconstituents.

NMR Spectroscopy: Purpose of this method is Structural elucidation of unknown compounds [29].

Analysis of contaminants

Heavy Metal Analysis: Heavy metals such as lead, cadmium, arsenic, mercury, and chromium are commonly detected in Solanum nigrum plants. These heavy metals were detected using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Atomic Absorption Spectroscopy (AAS) [30]. Pesticides and Herbicides: Pesticide residues in plants are analyzed using high-performance liquid chromatography (HPLC) and Gas Chromatography-Mass Spectrometry (GC-MS). Microbial Contaminants: The Solanum nigrum plant typically contains microorganisms, which are detected by Microbial Culture Methods (for example, *Pseudomonas aeruginosa*, *Aspergillus niger*), Polymerase Chain Reaction (for example, *Salmonella and E. coli*) and Enzyme- Linked Immunosorbent Assay (eg. *ochratoxins or aflatoxins*). [31].

Standardization

Physicochemical Standards

Moisture Content: To moisture level of plant material should be maintained to stop microbial development and the breakdown of bioactive substances, In general, dried plant material should have a moisture level of no more than 10–12%.

Test Method: For more accurate measures, the moisture content can be determined by Karl Fischer titration or oven drying (at 105°C).

Ash composition:

Total Ash: Indicates the inorganic composition of the plant, such as minerals. An excessive amount of ash could indicate of adulteration or pollution.

Acid Insoluble Ash: The amount of ash that is insoluble in diluted hydrochloric acid is known as acid-insoluble ash. This helps determine whether soil or other pollutants are present.

Test Method: The sample was burned at a high temperature (approximately 550°C) in a furnace, and the remaining residue was measured to determine the amount of ash present.

Extractive Value: The amount of soluble components in the plant material is estimated by the extractive value. This is a crucial indicator of the plant's capacity to produce bioactive substances. Method of Testing:

Water Extractive Value: Determined by using water to extract the plant material.

Ethanol Extractive Value: By ethanol extractive value was determined by using ethanol or other solvents, This measurement method helps evaluate the quality of the plant and the possible yield of active ingredients.

Quantification of Marker Compounds

Solanine:

Importance: Solanum nigrum contains solanine, a poisonous alkaloid, particularly in unripe fruits. Quantifying it ensures plant safety.

Approach: High-Performance Liquid Chromatography (HPLC) is the most accurate technique for measuring solanine. UV-Visible Spectrophotometry A more straightforward estimation based on the absorbance at a particular wavelength can be made using UV-visible spectrophotometry.

Standard: To prevent toxicity, solanine levels should be maintained below safe limits, which are normally less than 0.2% in dried plant materials.

Flavonoids:

Importance: The antioxidant and anti-inflammatory properties of Solanum nigrum are attributed to flavonoids such as quercetin and kaempferol.

Approach: UV-Visible Spectrophotometry: This method. which is usually based on absorption at 415 nm, measures the total flavonoid concentration. HPLC was used To detect and measure certain flavonoids, such as kaempferol and quercetin.

Standard: The Amount of flavonoids should be measured using accepted reference standards, such as 2–5% in dried leaves.

Methods of Extraction Maceration Extraction

Technique: With occasional stirring, the plant material is soaked in the selected solvent for a long time (several hours to days).

Benefits: Easy, affordable, and efficient removal of a variety of substances.

Validation: HPLC or UV spectrophotometry is used to assess the extraction yield, purity, and concentration of bioactive compounds.

Soxhlet Extraction

Technique: Using a solvent in a specialized Soxhlet apparatus, the plant material is continually extracted over an extended period to enable a more thorough extraction.

Benefits: Offers excellent extraction efficiency, particularly for substances that are poorly soluble in the selected solvent.

Validation: Conduct HPLC quantification, yield analysis, and purity tests on marker chemicals such as flavonoids and solanine.

Extraction Assisted by Ultrasound (UAE)

Technique: By creating cavitation, which promotes the release of bioactive chemicals from plant cells, ultrasound waves are employed to improve the extraction process.

Benefits: Quick, effective, and could use less solvent.

Validation: Determine the solanine concentration, compound purity, and extraction yield. When compared to conventional approaches, this methodology can provide improved extraction efficiency and reproducibility.

Extraction Assisted by Microwaves (MAE) Technique: The solvent is heated using microwave energy to improve the release of bioactive chemicals from the plant material.

Benefits: include less solvent usage, increased efficiency, and quicker extraction.

Validation: Use spectrophotometric and chromatographic techniques to assess purity, yield, and efficiency. SFE, or supercritical fluid extraction

Method: Bioactive chemicals are extracted using supercritical CO_2, which provides an environmentally friendly, solvent-free alternative.

Benefits: include the capacity to isolate particular chemicals, high selectivity, and the absence of solvent residues.

Validation: The method's solvent purity, target compound yield, and concentration should all be confirmed [32].

Conclusion

Black nightshade, or Solanum nigrum, is a plant with considerable therapeutic efficacy that has been acknowledged in contemporary pharmacological research and has strong roots in traditional medical systems. This thorough analysis focuses on its extensive phytochemical profile, which includes alkaloids, flavonoids, saponins, and glycoalkaloids. These compounds support its various biological actions, including hepatoprotective, anti-inflammatory, antioxidant, and antiproliferative properties. Its historic application for respiratory, gastrointestinal, hepatic, and dermatological conditions is supported by ethnopharmacological evidence. Advanced extraction and standardization techniques have also addressed safety issues, especially those related to solanine toxicity, while reinforcing its medicinal promise. Even if its bioactivities appear promising, more investigation and clinical validation are required to guarantee a safe transition into standard treatments. In phytomedicine and drug development, S. nigrum has the potential to become a valuable resource with strict quality control, regulatory oversight, and further research into its molecular mechanisms.

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