



Review Article

Phytochemical and Pharmacological investigation of *Solanum nigrum* extract

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Abstract

Solanum nigrum Linn. (*Sn*) also known as Black Nightshade family of Solanaceae. Plant is utilized for treating several pediatric illnesses that are responsible for infant's death especially seizures due to fever, diseases of eyes, phobia of water and severe skin diseases.

Our aim of study *Solanum nigrum* plant review from selected database Journals Scopus, web of science, science direct and PubMed from 2010-2024, phytochemistry and pharmacological activities.

Keywords: *Solanum nigrum*, Pharmacological activity, Anti-inflammatory, Antioxidant, Neuroprotective

Received: 10-08-2025; **Accepted:** 16-09-2025; **Available Online:** 10-11-2025

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1. Introduction

Solanum nigrum Linn. (*Sn*) also known as Black Nightshade having two cotyledons or seed leaves belonging to the Solanaceae family. Including this plant, there are more than 2,000 various species of tropically and sub-tropically grown plants under the genus named as *Solanum*. This plant is also known as Makoi in Hindi and Kachchipandu in Telugu and Black Night Shade in English. This black nightshade which is perennial grows as a shrub and is considered to be a short-lived plant.

The color may vary between purple and green. Whether they are glandular or plain, the prickles are absent on its hairs and non-glandular. *Solanum nigrum* as an Annual branched plant has a height of 90cm, with muted green colored leaves which are dark, juicy, egg shaped or broader below middle, and it may be lacking sharpness to slightly toothed on its ends. Flowers are found to be small and white in color comprising short stem that attaches a single flower to an inflorescence with five broadly wide petals. Fruits are small, black if ripe. It is usually approachable across waste land, old fields, ditches, and across the roads, near fences, or at margins of woods and cultivated land.¹

Along with *S. nigrum*, the family of Solanaceae also consists of fruits and vegetables like potato (*Solanum tuberosum*),

tomato (*solanum lycopersicum*), and peppers, ornamental plants such as petunia, and other plants of medicinal uses such as *Atropa belladonna* L. (deadly nightshade). (Figure 1)



Figure 1: *Solanum nigrum* Linn. plant

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The illnesses like cardalgia can be cured by this plant due to its antimicrobial activity. It is also responsible for various pharmacological activities, like anti-microbial, cytotoxic, anticancer, protection of liver and brain, and antiulcerogenic effects.²

In African, this plant is utilized for treating several pediatric illnesses that are responsible for infant's death

especially seizures due to fever, diseases of eyes, phobia of water and severe skin diseases. *S. nigrum* has traditionally been used to treat discomfort, eczema, hay fever, gastrointestinal infections, dermatitis, asthma, cardiovascular illnesses, type 2 diabetes, and sexually transmitted illnesses.^{3,4}

2. Plant Profile (Figure 2)

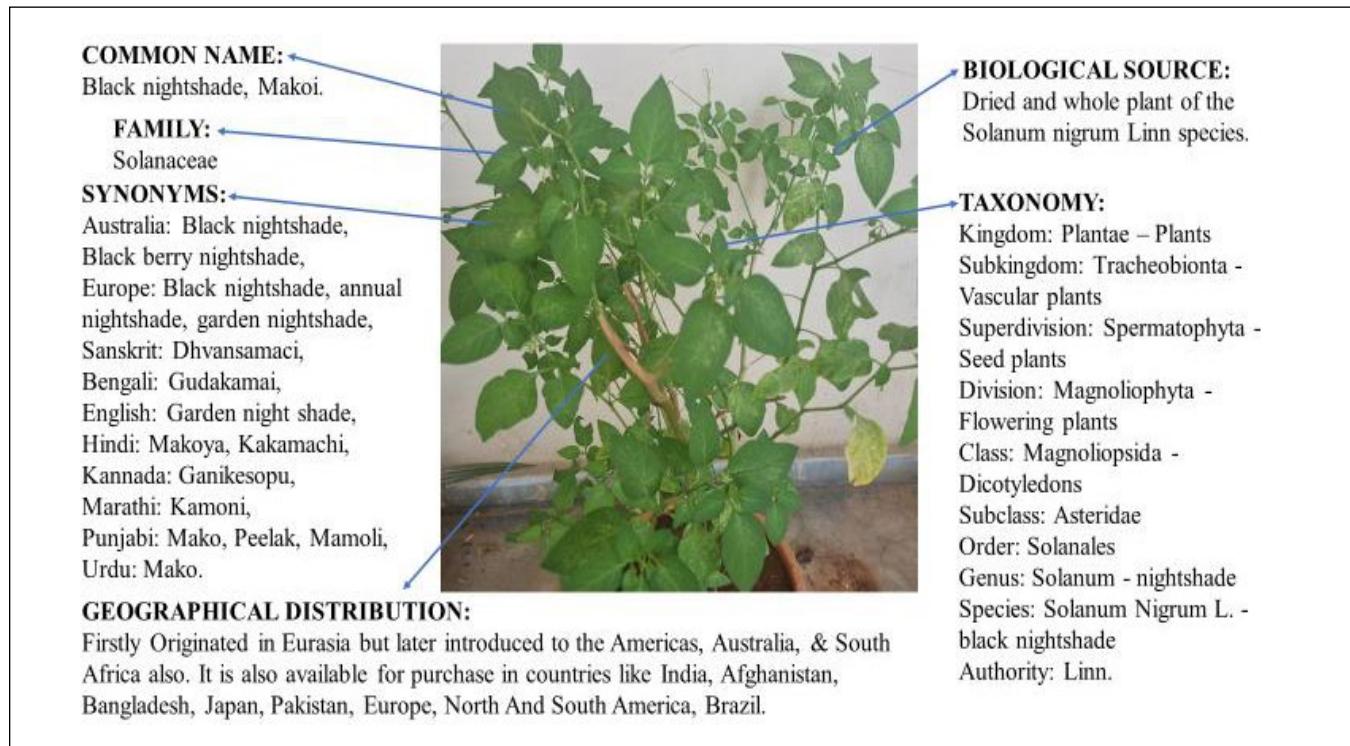


Figure 2: Plant profile of *Solanum nigrum* Linn

3. Morphology (Figure 3)

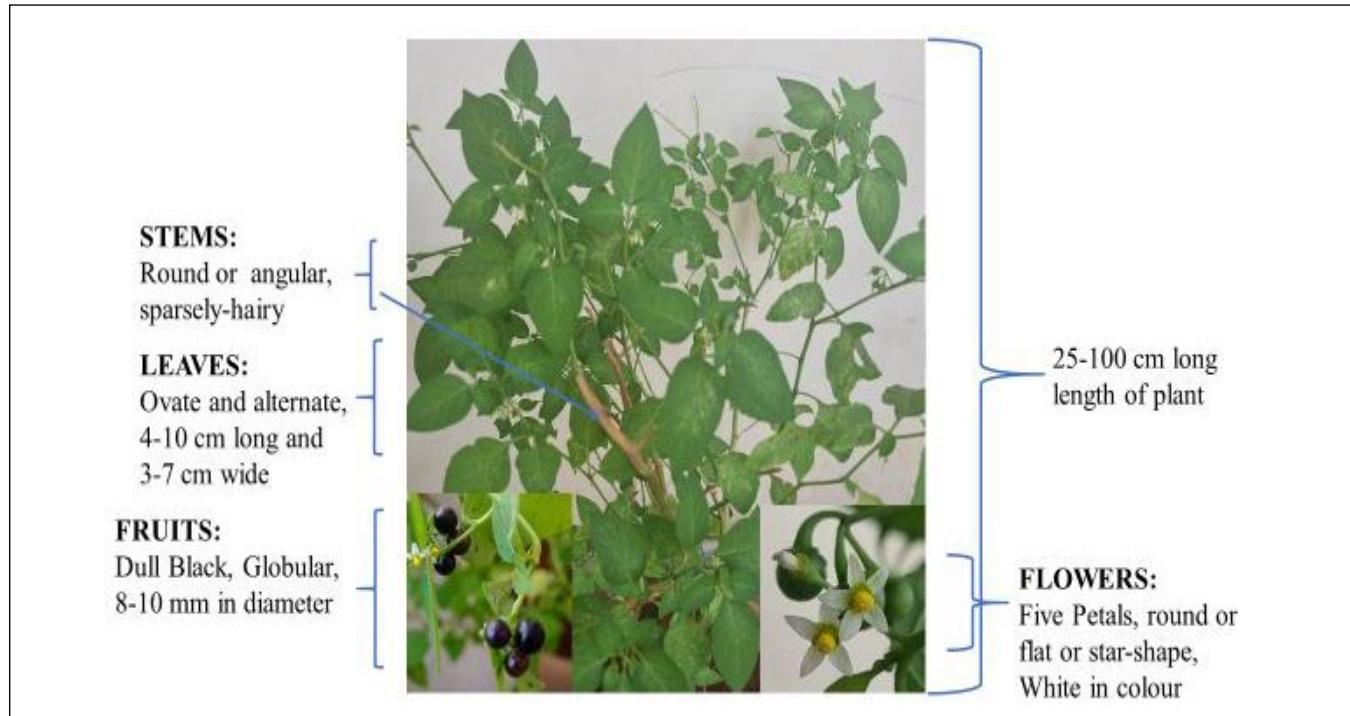


Figure 3: Morphology of *solanum nigrum*

4. Chemical Constituents (Figure 4)

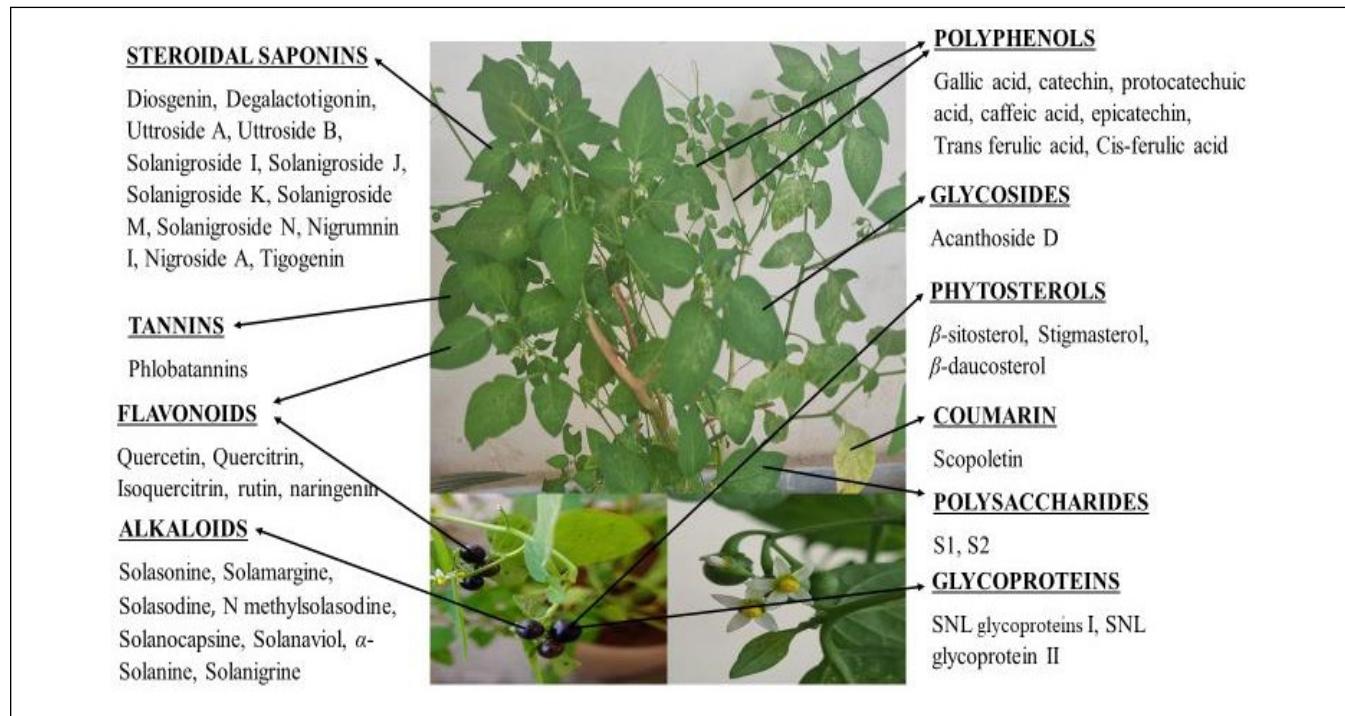


Figure 4: Chemical constituents of *Solanum nigrum*

5. Therapeutic Uses (Figure 5)

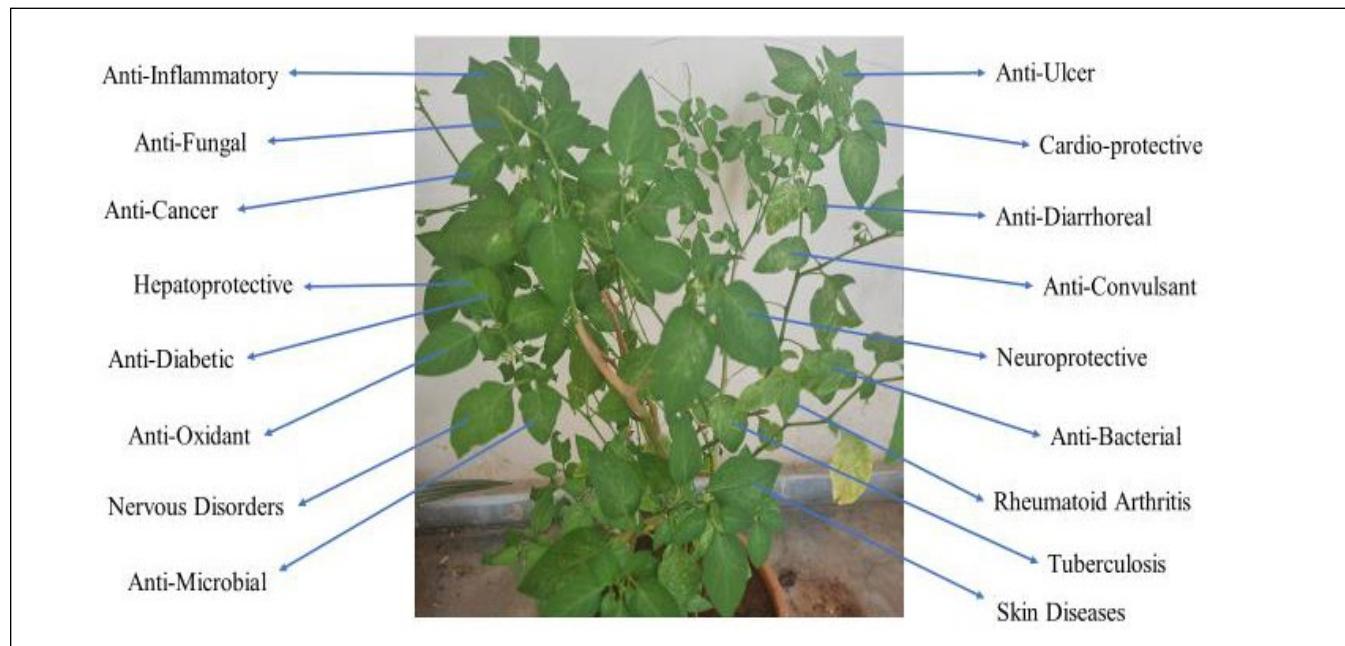


Figure 5: Therapeutic uses of *Solanum nigrum*

6. Pharmacological Activity

6.1. Anti-inflammatory activity

The extract is made from *S. nigrum* by using methanol and its efficacy is determined by administering dose of 375 mg /kg in the animals used in experiments. Thus, the result represents the anti-inflammatory activities of the *S. nigrum*. The same extract obtained from *S. nigrum* on carrageenan induced inflammatory effects significantly reduced local oedema in

rat paws. Therefore, the *S. nigrum* anti-inflammatory activity is determined by this method.

S. nigrum being an anti-inflammatory agent, has also been used in the traditional Indian system of medicine for treating the swelling which is due to building up of fluids

in the body tissues and for inflammation in the breast tissue (mastitis). Lipid mediators such as LTC4 which are leukotrienes are present in higher concentration during inflammatory responses. Different inflammatory conditions such as asthma and atopic rhinitis can be managed using anti-leukotrienes. *S. nigrum*, possesses maximum inhibition for leukotrienes and this was examined by using (E)-ethyl caffeate, a component extracted from *S. nigrum*, hence *S. nigrum* can be considered as therapeutic compound showing potential inhibition of inflammation.

At the doses like 100 and 200 mg/kg of body weight, potential anti-inflammatory activity in carrageenan and egg white induced hind paw oedema of rats is seen by using *S. nigrum* extract made by methanol.⁵

Using Ethanolic extracts of *S. nigrum* which was administered orally at different doses of 100, 250 and 500 mg/kg, the anti-inflammatory effect was observed on Carrageenan-induced rat paw oedema. Among all these doses, at dose 500 mg/kg anti-inflammatory effect was observed as compared by using standard drug namely Diclofenac sodium at the dose of 50 mg/kg.⁵

6.2. Anti-cancer activity

HeLa cell line were used for determining anti-cancer properties in *S. nigrum* fruits. These lines were employed to examine the inhibitory effects of *Solanum nigrum* fruits. The possibility of the cell line was evaluated by using the Trypan blue dye exclusion method. The cell damaging effects of *S. nigrum* on immortalized cells (HeLa) were assessed using the sulforhodamine B (SRB) assay and MTT assay that measures cell viability, proliferation and cytotoxicity. The methanolic extract of *S. nigrum* shows notable cytotoxic effects on the immortalized Cell Line (HeLa) within a concentration, ranging from 10 mg/ml to 0.0196 mg/ml, as determined using the sulforhodamine B assay.⁶

S. nigrum's extract using chloroform and its separated constituents both shows antiproliferative properties on many cancer cells lines. The liver, colon, breast and cervical tumour cell lines were used for examining anti-proliferative properties through the raw organic material and separated components.

Dried fruits of *S. nigrum* can also be used to produce crude extract along with the complete plant. The toxicity of the isolate on cells upon examination shows antimutagenic activity (DNA fragmentation) of these fractions. The cervical carcinoma growth is prevented using hydrophilic plant extracts which comprise anticancer effect. This is comparable to the mechanism of action of isolated polysaccharides (SNL-P) and aqueous extracts.

The active components like polysaccharides have antioxidant activities and also shows anti-cancer potential. The U14 bioreactors produced from cancer has no cytotoxic effect which was demonstrated by SNL-P.

The variation of host immune response is due to immunomodulatory traits having anti-cancer activity. Research has shown that crude extracts of *Solanum nigrum* elicit variation in cellular responses in vitro at both high and low concentrations, supporting the observation that treating hepatic tumor cell lines (HepG2) by increased levels of the extracted compound activates an enzyme that regulates many cellular processes, including cell survival, proliferation, and differentiation (JNK) which further promotes to the upregulation of proteins that signal a cell to die through apoptosis (pro-apoptotic factors) like proteins that regulates programmed cell death (Bax), which subsequently causes cytochrome c to be released from the mitochondria, activating caspases and initiating the process of apoptosis.⁷

Solanine, a steroidal alkaloid derived from *S. nigrum* is assessed for its anti-tumour effect by using MTT assay, using three tumour cell lines of the digestive system. It exhibits a level-dependent IC (50) score for these three cancerous cell lines named as, human liver cancer cell (HepG 2), human gastric cancer cell line (SGC-7901), and human colorectal adenocarcinoma cell line (LS-174) with their respective concentrations and indications of apoptosis were also observed. Consequently, the role of solanine in promoting cell death in human liver cancer cells appears in facilitation by the suppression of B cell lymphoma-2 protein enhancement.

Glycoprotein isolate of *S. nigrum* which are rich in proline and glycine has different effects on nuclear Factor-kappa B and Activator Protein-1 and iNO, these are transcriptional factors which causes nitric oxide production in human breast cancer (MCF-7) cells (Heo et al., 2004; Son et al., 2003; Lim, 2005). This witnesses the stimulation of a protein in mitochondria that regulates cell life and death, known as cytochrome c by this glycoprotein that interferes in the activation of enzymes involved in cell death and inflammation (caspase activation) leading to necrosis of tumor cell.

The anticancer properties of *Solanum nigrum* are merged to its capability to destroy the cancerous cell membrane by interrupting DNA and RNA formation, modifies distribution of cell cycle restricting pathway that counteracts the signals that promote cell death of transcriptional factor like Nuclear Factor-kappa B, trigger caspase enzyme cascades, and increased NO production.

A study of cytosolic form of the protein microtubule associated protein 1 light chain (LC3-I) and protein associated with autophagosomes (LC3-II) in Human liver cancer cells is helpful in determining the role of programmed cell death in the cancer curing mechanisms shown by *S. nigrum*.

Research indicate the role of *S. nigrum* in autophagy and vacuolization within cells which is concentration dependent. This may be useful for treating hepatic cancer.

S. nigrum has protease inhibitors that can promote oesophagi growth and oncogenesis.

6.3. Anti-diabetic activity

The *Solanum nigrum* was examined for lowering blood glucose levels using test that shows the inhibition of amylase which was executed. For this activity single combination of few litres (500L) of the extract of known concentration and α -amylase were employed for 10 mins at a temperature of 25°C. 500 litres of a 1% solution of starch along with 0.02 M Na_3PO_4 (sodium phosphate) buffer, were also incubated at 25°C.

1 ml of 3,5-DNS (Dinitro salicylic acid) was then used along with this combination by warming it in a boiling water bath for approximately 5 mins and diluting with 10 ml of double-purified water, and then leaving the mixture to cool at room temperature. Using spectrophotometer, the absorbance was checked using wavelength of 540 nm. Subsequently the inhibitory property of the enzyme alpha-amylase was measured and noted.⁸

Solanum nigrum hydro-alcoholic with aqueous extracts from various parts like leaf, stem and fruits were used for determining anti-diabetic activity in Sprague Dawley rats.

The oral glucose tolerance was examined using various doses of the extract and comparing with standard Metformin. The water-based and hydroalcoholic extracts made from leaf and fruit possess significant anti-diabetic effect based on the doses.

The result indicates the effect of the crude *Solanum nigrum*'s extract made by using ethanol on the blood glucose levels of albino rats was assessed after routinely administration of doses at 250mg/kg for five to seven days, respectively.

It was observed that long-term dosing may result in a marked reduction in blood glucose levels in comparison with the control group. Therefore, *Solanum nigrum* has hypoglycaemic activity.⁹

6.4. Anti-ulcer activity

The plant *Solanum nigrum* in Ayurveda, has been used for treating gastric ulcer. Therefore, it is necessary to know the mechanism of anti-ulcer effect. The different categories of tension like cold restraint tension, indomethacin, shay method, ethanol & acetic acid were applied on rats for inducing stress ulcers.

Different concentrations of *Solanum nigrum* fruit extract were used for inhibiting the gastric lesions 76.6, 73.8, 80.1 and 70.6%, when compared to omeprazole. The acidity, pepsin secretion and gastric secretory volume of ulcerated rats concomitant attenuated by *S. nigrum* extract. In addition, *Solanum nigrum* extract in the doses of 200, 400 milligrams/kilogram figure mass speeds up curing of ulcers caused by Acetic acid post 7 days treatment.¹⁰

In ethanol induced ulcer model *S. nigrum* extract notably hinders hydrogen-potassium adenosine triphosphatase action and reduces the discharge of gastrin. The studies at tissue level shows a decrease in ulcer size which is due to *S. nigrum* extract. The current information represents the *S. nigrum* analgesic & anti-inflammatory activities.

In Recent studies, the glycoprotein 150 kDa which is obtained from *S. nigrum* shows higher efficacy in averting DSS-triggered colitis in A/J mice. *Solanum nigrum* lowers the levels of NO formation, discharge of LDH, & TBARS were noted. These occurs due to transcription factors like nuclear factor-kappaB (p50) & activator protein-1(c-Jun). *S. nigrum* produces variations in expressions of inducible nitric oxide synthase & cyclooxygenase-2, as an enzyme plays crucial part of inflammatory reaction pathways.

Solanum nigrum fruits methanolic extract were evaluated & aimed at its against ulcerogenic effects in acetylsalicylic acid caused ulcer in rats, stressing on free radical scavenger effect in mucous membrane lining of the stomach. Acute gastric mucosal damaged rats show increased concentration of lipid peroxides which is used for the measurement of oxidative stress.

Aspirin upon oral administration, reduces the actions of free radical scavenger defence enzymes. Reduced amount in free radical scavenger enzymes with enhance mucosa damage was normalise after pre-treatment with *S. nigrum* fruits in comparison with ulceration in rats. Further research on *S. nigrum* fruits concludes that it possesses gastroprotective effect through their capability to destroy free radicals and helps in managing gastric conditions.¹¹

6.5. Anti-oxidant activity

The *Solanum nigrum* Linn. extract was examined for its anti-oxidant activity by employing a stable radical known as 2,2-diphenyl-1-picrylhydrazyl (DPPH) due to formation of strong absorption band at a wavelength of 517nm. The pairing of one electron with other electron will decolourize it and subsequently increases the electrons in numbers used due to presence of single free radical scavenger. DPPH in 86 micromilligrams along with the different additional concentrations of every extract is present in the final product.¹²

Various conditions including both communicable and non-communicable diseases participate in causing oxidative stress.

Over all major difference reported in the contents of carotenoids, phenolics, flavonoids and tannins represent fragility of anti-oxidants found in *S. nigrum*. The glycoprotein in *Solanum nigrum* Linn. shows radical scavenging activity on radicals which is dose dependent. These includes radicals like DPPH, OH radical, and superoxide anion. the inhibition of NF- κ B activation is responsible for inducing apoptosis through oxidative stress in colorectal cancer cells. The ethanol extract in 50% obtained from the complete plant

of *Solanum nigrum* shows hydroxyl group radical scavenging activity, also said as cell protecting mechanism. Post-restraint treatment proves *S. nigrum* with better antioxidant activity when compared with prerestraint administration. This was suggested by the evaluation of the antioxidant activity of *Solanum nigrum* leaves upon application of increased oxidative stress for 6 hours.

S. nigrum Methanolic extracts inhibits the DPPH by 92 percent; whereas, the radical scavenger activities of *S. nigrum* aqueous extracts is less effective.

The biochemical anti-oxidant profile of tissue was employed to demonstrate this activity present in the *S. nigrum* fruit extract made by using methanol. This antioxidant activity can also be known using biochemical antioxidant profile of tissue of heart and it is done dose independently.

S. nigrum alcoholic extract also represents antioxidant activity which is evaluated by performing various tests, including the assumption of the overall phenolic content present in the plant extract. The *S. nigrum* methanolic extracts shows high potency in radical scavenging ability when compared with the aqueous extracts by inhibiting the DPPH by 92%. The glycoproteins Isolated from *S. nigrum* also have antioxidant properties in addition to methanolic extract.^{11,13}

6.6. Hepatoprotective activity

Solanum nigrum Aqueous and methanolic extracts were utilised for testing hepatoprotective effects by using Sprague-Dawley (SD) rats which were administered 0.2 ml CCL4/kg of body weight for about ten days. The main goal for testing this is to evaluate these extracts. *S. nigrum* aqueous extract were also instilled to the rats at the dose range about 250-500 mg/kg weight after treatment with carbon tetrachloride for the duration of about ten to eleven days. The results obtained by using aqueous extracts of *S. nigrum* shows that the plant extract possesses hepatoprotective activity against the hepatic damage which was produced via CCl4. It also determines that decrement of RBC levels of the enzymes like alkaline phenyl phosphatase, serum glutamic-oxaloacetic transaminase, and serum glutamic pyruvic transaminase.¹⁴

The medications used in this experiment also decreases the elevation in liver biomarkers (Glutamic oxaloacetic transaminase, Glutamic pyruvic transaminase, and measurement of amount of bilirubin) caused by CCl4 & diminished the production of reactive oxygen species in comparison with set treated with CCl4.

The study of liver also interprets that *Solanum nigrum* extract decreases the chances of causing liver damage such as swelling of hepatic cells, infiltration of lymphocytes, hepatic necrosis, and proliferation of fibrous connective tissue in rats which is due to the usage of carbon tetrachloride.

S. nigrum L., an herbal plant is considered to have an anti-inflammatory activity along with hepatoprotective activity in

traditional Chinese system of medicine. Different research involving various hepatotoxic agents like thioacetamide (TAA), which induces liver fibrosis, showed that a 12-days treatment with extraction of *Solanum nigrum* at dose of 0.2 or 1.0 grams/kilogram through tube feeding reduces the effects throughout the duration of study.

Solanum nigrum suppressed hepatocarcinogenesis, aligning with the elevated appearance of GST- α & μ , along with levels of sequence-specific DNA-binding factor nuclear factor erythroid 2-related factor 2, GPx, SOD1 superoxide dismutase-1, & catalase.

Histological and pathological studies on Liver also provide evidence that *S. nigrum* decreases the chances of liver lesions occurrence. In addition to this, different study indicates that the alcoholic extract of *S. nigrum* fruits administered at a dose of 0.25 g/kg exhibits hepatoprotective activity in rat model of Carbon tetrachloride caused hepatic damage. Thioacetamide-caused hepatic fibrotic scarring in mouse was also assessed using *Solanum nigrum* extract. Histological analysis verified that entire herbal extract of *Solanum nigrum* diminished the extent of fibrosis induced by TAA treatment by lowering hydroxyproline levels, thereby reducing collagen. Consequently, these findings indicate that *S. nigrum* may safeguard the liver from oxidative damage caused by CCl4 and TAA in rats.

Till now, clinical trials are not done on *S. nigrum* and its phytoconstituents. Nonetheless, these are explored from clinical trials involving formulations like Liv 60054, 90 and 93, which include *S. nigrum* among their ingredients and have been utilized as liver-protective agents.¹⁵

6.7. Anti-fungal activity

Solanum nigrum plant extraction is made to evaluate the anti-fungal activity using a method called as agar diffusion method and by utilizing three different fungal strains namely: *P. notatum*, along with fungi belonging to the class of eurotiomycetes (*aspergillus niger*) and nectriaceae (*fusarium oxysporum*).

The ethanolic extract made by using seeds shows highest potential ranging from 6.0-16.8 mm for fungi strains utilized, in comparison to leaf and root extract. The resistance developed by *P. notatum* using ethyl acetate root extracts is less nearly 4-4.5 mm when compared to other strains.¹⁶

Solanum nigrum L. was examined for its anti-fungal effect and the result shown the new observation by introducing solamargine, an alkaloid.

The antifungal potential of *Solanum nigrum* was investigated and showed that solamargine obtained at higher yield by several microbes for microbial epiphytic fungus culture.

Solamargine production can be improved by more research including medium tuning, 1 strain, numerous compounds, and genomic change.¹⁷

6.8. Anti-microbial activity

Solanum nigrum root extract were evaluated for its anti-microbial activity using different isolates of *Alternaria brassicicola* (ABA-31 and ABA-104). This fungal necrotrophic plant pathogen causes black leaf spot disease on Napa cabbage. using *Solanum nigrum* dried root tissues extract which was made by using methanol shows anti-microbial activity for this fungal pathogen. Different fractions made by using ethyl acetate, 1-butanol and aqueous fractions of root extracts were used for fractionation and anti-microbial screening. Among these fractions, 1-butanol extracts has the highest potential. The Saponins in *Solanum nigrum* Linn were considered as the main phytoconstituent showing antimicrobial activity.

Solanum nigrum leaves for its antibacterial properties of methanolic, water extracts, and for identifying the compounds responsible for these effects a phytochemical screening was performed.¹⁸

The gram negative bacterias like *E. coli*, *Klebsiella aerogenes*, and *P. aeruginosa*, and the gram-positive bacteria like *Staphylococcus aureus*, were used for anti-microbial effect using aqueous and methanolic extracts of *S. nigrum*. The area of media where microorganisms are unable to grow determines its sensitivity towards the *S. nigrum*, which is dependent of microorganism type and the solvent used for extractions. The extract made by using methanol shows increased efficacy in comparison with water-based extract. hence, leading to its use as an anti-microbial agent in the study of individuals suffering from opportunistic infections in diabetes.¹⁸

Laboratory evaluation is done for analyzing antimicrobial activity using Methanolic extracts obtained from the leaves and seeds of different varieties (black and red) of *Solanum nigrum*. Six bacterias including gram negative and gram positive namely *E. coli*, *Citrobacter*, *Shigella flexneri*, *S. aureus*, *Klebsiella aeruginosa*, and *Yersinia albovæ*, an anti-bacterial examination was conducted, which revealed that *S. nigrum* shows strong activity against all microbial strains. The extracts show both moderate and significant effect towards various fungal strains.

The different alcoholic and ethyl acetate extracts of leaves, seeds, and roots of *S. nigrum* were used for the evaluation of antifungal effects against different fungal strains like *P. notatum*, *Aspergillus niger*, and *Trichoderma viride*. The area of growth inhibition was considered for comparison with the standard antibiotics. The antifungal activity is seen in ethyl acetate seed extracts which is used antagonistically shows strong antifungal activity (8.0-16.0 mm zone of inhibition) for all the fungal strains tested, in comparison to leaf and root extracts, while the lowest Minimum Inhibitory Concentration value was found with ethanol seed extracts and the values ranges from (2.0-6.0 µg/ml).¹⁹

The gram-negative bacterium *E. coli* (NCIM: 2065) and *Staphylococcus aureus* which is gram positive (NCIM: 2079)

were used to perform preliminary phytochemical screening, and then it is compared with the results obtained from the standard drug of penicillin at various concentrations by the Kirby-Bauer method. *S. nigrum* shows the highest zone of inhibition for *Escherichia coli* at approximately 30.1 mm, whereas the standard drug of penicillin shows decreased activity when compared to *S. nigrum* extract.

On using ethanolic extracts of *S. nigrum*, antimicrobial evaluation was performed. This results in inhibition of *S. aureus* and *B. subtilis* (Gram +ve) by the extract of plant at all tested concentrations of 100, 75, 50, and 25 milligrams per ml in comparison with the standard drug of Ciprofloxacin dose of 20 microgram per ml, but the extract shows a notable inhibition effect for *C. albicans* at all concentration excluding 25 milligram per ml when compared to Amphotericin B (100 µg/ml) which acts as standard drug.²⁰

The tests were performed to identify the chemicals responsible for these effects and for the verification of antibacterial activity of methyl ester and the aqueous extracts from *S. nigrum* leaves.

6.9. Analgesic activity

Analgesic activity in mice was seen by using *S. nigrum* ethanolic extract. Test animals were administered of 0.5 milliliters from one of four different potencies, for a duration of 30 days. Increased analgesic effect was seen in female rats using the hot plate method or the tail flick method by aqueous extract obtained from the leaves and methanolic extract obtained from the seeds of *S. nigrum*.²¹

Analgesiometer and writhing due to acetic acid were used for analyzing analgesic effects of the *S. nigrum* for peripheral & central pharmacological activities.

Using doses given through enteral route of 100, 250, and 500 milligram/kilogram the research was done. Standard medication Diclofenac sodium (50 mg/kg) is used for comparing the analgesic effect of the dose demonstrated at 500 mg/kg.²⁰

6.10. Cardio-protective activity

The assessment finished by global in vitro ischemia reperfusion injury on extraction made from *S. nigrum* fruits using methanol for cardio-protective activity using different doses 2.5 and 5.0 milligram/kilogram for six days/every week for thirty days.²²

According to given data by global in-vitro ischemia-reperfusion injury that extraction shows effective considerable ($p < 0.001$) cardioprotective activity. The activity shown is dose independent. Thus, cardio protective action was seen using m methanolic extract of *Solanum nigrum* fruits.

Global in situ ischaemia perfusion injury paradigm has evaluated ethyl acetate component obtained from *S. nigrum* fruits for cardio protective activity.

Another benefit of *S. nigrum* is it can also be used a dietary supplement using leaf tincture or isolated ingredients which also helps in eliminating free radicals that are produced due to neurological stress or any neurological disorder.²²

6.11. Anti-convulsant activity

S. nigrum was intraperitoneally administered for measuring of Central nervous system-depressant action considering several neuropharmacological parameters. *S. nigrum* fruit extracts increases the duration of time that pentobarbital-induced sleep lasted, changed the overall behavior pattern, decreased the known functioning, inhibited hostile nature, altered locomotory action, and decreased spontaneous motion which may support its acetylcholine-like action and supports its use as an anti-convulsant. According to African pediatrics, the effectiveness of *S. nigrum* may also be used to prevent infant convulsions. The anti-seizure properties of *S. nigrum* greeneries is present in rats, mouse, & chicks.

The *S. nigrum* leaf extract is administered through intraperitoneal injection for duration of 30 minutes provides shield for the animals from various categories & the drugs which produces convulsions. Water based extraction from leaves showed that notable ($p < 0.05$) dosage reliant on defense in contrast to electrical devices caused seizures in chicks and rats, along with seizures caused by pentylenetetrazole & picrotoxin in mouse and rats. Initial researchers to give practical evidence keeping the assertions behind for ach similar action of *S. nigrum*. Their conclusion was founded in the observation of these effects like 1) Muscle contractility in separated rectus abdominis of a toad; 2) Decreased heart rate & the force which affects muscle contractions on separated heart of a toad; 3) Muscle contractility of ileum from an separated isolated guinea pig; 4) Muscle contractility of separated middle part of small intestine from a rat; 5) decrease in arterial blood pressure of a cat; 6) Secretory actions observed in the submaxillary gland of a rat. The acetylcholine-active compounds were also found in the fruits of Sn reaching 250 $\mu\text{g}/\text{gram}$ of berry.²³

It has been shown that administering leaf extract intraperitoneally to mice and rats has an anticonvulsant effect on the animals. Amphetamine use may result in an increase in the anticonvulsant's effectiveness. Improving the properties that act as an anticonvulsant is beneficial. A study by Km. Anticonvulsant properties of water-based *S. nigrum* leaves extracts administered intraperitoneally to rats, mice, and chicks. The extract's ability to prevent seizures was enhanced by amphetamine.²³

S. nigrum utilized in traditional medicine has demonstrated anticonvulsant effects in animal studies and could serve as a potential source for new antiepileptic medications.²⁴

6.12. Immuno-stimulant activity

Using five distinct extracts of *S. nigrum* for immunization in 6 groups of experimental fish (*E. Suratensis*) through

intra-peritoneal injection at the dose of 0.2ml (4ppm) and tested with *Aphanomyces invadans* killed by heat. The RBC samples were withdrawn from both immunized and normal fish by employing different methods which includes methods for quantifying the concentration of specific antigen in the sample, immunoglobulin determination, test of nitro-blue-tetrazolium, Immunoglobulin G concentration evaluation, & assessment of resistance developed by host cells. The greatest immunoglobulin response in both the experimental and control groups was seen on 21st day post-immunization & decreased on 28th day. For fishes treated with methanolic content prepared by using sn, the antibody response showed a notable increase on days 14 and 21. The highest immunoglobulin G level is seen on 21st day and diminished by 28th day.²⁵

For the fishes treated with Chloroform and toluene extract, the activity of neutrophil in increased on 6th day. Groups treated with alcoholic extracts like methanol and ethanol exhibited a lower mortality rate compared to the group treated with chloroform, toluene, and water extracts. Plant extracts hold significant promise as immunostimulants against microorganisms and may be utilized in treating infectious diseases caused by these pathogens.

6.13. Anti-bacterial activity

Based on pharmacological report the anti-fungal activity of *S. nigrum* leaf extract which is obtained using 4 solvents ethanol, chloroform, volatile liquid, & purified water, these are effective in contrast to 5 mycological rinsing like black mould, *Aspergillus* ear rot, baker's yeast, black spot, & *F. oxysporum*. Minimum inhibitory concentration ranging from concentration 250 to 1,000 microgram/millimeter, having the area of growth inhibition of 9.3 mm for the extraction made by using stem made with purified water is used in contrast to *Aspergillus* ear rot & fruit extract was made with chloroform towards black mould. Highest area of growth inhibition was seen with ethanolic extract of *S. nigrum* which are 16.88, 11.33, & 19.25 micrometer for *S. aureus*, *E. coli*, and *Aeromonas sobria* at conc. of 200 milligram/milliliter, individually.

Solasodine-3-O- β -d-glucopyranoside and isolated compound exhibits strong fungicidal effects for both strains of *Candida albicans* in spider medium, these strains are azole-sensitive and azole-resistant. The glucosyl functional group which may be the reason of its minimum inhibitory concentration range of 32 milligram/millilitre. Research on pharmacological mechanism revealed that this isolated compound has raised the pH of intracellular vacuole and enhanced its permeability resulting in necrosis. It may also reduce virulence of *Candida albicans* by preventing attachment and morphological conversion from yeast to hyphal. Results from XTT reduction assay shows that it could inhibit biofilm formation at higher level or for conc. of 16 milligrams/liter.²⁶

6.14. Neuroprotective activity

Advancement in contemporary medicine has led to a rising number of studies aimed at elucidating the mechanisms of

action of phytoconstituents obtained from *S. nigrum* has led to the discovery of clinical applications in return. Central nervous system was taken into consideration for examination of neuro protective effect of Sn using rat model of cognitive impairment induced by scopolamine²⁷

These were treated using 10% *S. nigrum* extract which is helpful in restoring impairment of memory, lower in acetylcholinesterase action, Malondialdehyde levels, and Butyrylcholinesterase action, & enhancement of Glutathione levels in brain.

For the year 2019, Using *Drosophila melanogaster*, the study on neuro protective activity was continued by Ogunsuyi et al. and concluded that the reduced physiology of behaviour & enzymatic action (GST, MAO, chE) was found in the flies which were treated initially and routinely treated with pulverized vegetables for duration of a week .

For the year 2021, Decrement of survival rate at the level of reactive oxygen species with increment of total thiol content is seen due to 1% dietary inclusions of *S. nigrum* and this was proved.²⁸

7. Source of Funding

None.

8. Conflict of Interest

None.

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Cite this article: Tazneem B, Begum T, Sultana Y, Ali MM, Ilyas S, Affari OBS. Phytochemical and Pharmacological investigation of *Solanum Nigrum* extract. *Int J Pharm Chem Anal*. 2025;12(3):157–165.