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Review Article

A Comprehensive Overview on Pharmacological and Therapeutic Insights of Solanum nigrum Linn

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Solanum nigrum **is a traditional Chinese bush renowned for its dynamic therapeutic activities in the Indian and Chinese systems of medicine. It is a typical, palatable herbal remedy that belongs to the family Solanaceae. This overview assembles the prospective pharmacological and medicinal significance of the last three decades' accomplishments of scholarly reports from internet sources and publications. According to several literature reviews,** ***Solanum nigrum*** **encompasses a variety of phytochemical compounds that could be isolated and identified using various extraction techniques. The major chemical components of this herb are alkaloids, glycoproteins, polysaccharides, and phenolic compounds with a broad spectrum of pharmacological outcomes such as anticancer, immunostimulant, antibacterial, antidiabetic, antiviral, antiinflammatory, antioxidant, antipyretic, antidiarrheal, cardioprotective, anti-hyperlipidemic, anti-ulcerogenic, hepatoprotective, anti-seizure, anti-larvicidal, anti-allergic, anti-asthmatic, and neuropharmacological efficacy. Recently, scientists and researchers have been searching for potentially biologically active plants due to the increasing toxicity and adverse effects of modern synthetic drugs. As every part of** ***Solanum nigrum*** **contains a variety of therapeutically active phytochemicals, it could be a significant source for scientists to conduct further research and discover the proper mechanism for preventing diseases. In conclusion,** ***Solanum nigrum*** **emerges as a valuable resource in the pursuit of alternative therapeutic options. Its multifaceted pharmacological properties and traditional usage underscore its potential significance in modern healthcare.**

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1. Introduction

The use of plants as a source of therapeutic agents has been a cornerstone of traditional medicine for millennia. *Solanum nigrum*, a widely distributed edible medicinal herb, has long held a significant place in traditional medicine, particularly in Southeast Asia [1] [2]. This flowering plant species, a member of the Solanaceae family, encompasses over 2,000 distinct species that are widely distributed across tropical and subtropical regions globally [3]. The species was first mentioned by renowned herbalists and naturalists Pliny the Elder and Pedanius Dioscorides in the first century AD. It grows wild and widely in the open

area [4][5]. It may grow in moist areas in a variety of soil types, including deep, dry, rocky, and shallow soils [6]. It is feasible to cultivate between April and May in tropical and subtropical agro-climatic regions [7]. It can also be used for the reclamation of degraded lands or areas[7]. Relative humidity of 35-40% [8] and an annual rainfall of 50-1200mm are essential for optimal seed germination [9].

1.1. Research methodology

This review, compiled until August 2023, synthesizes research sourced from reputable databases, including Google Scholar, Web of Science, and PubMed, and encompasses articles from peer-reviewed journals and various credible online sources. The literature search involved keywords such as "Solanum nigrum Linn.," "botany," "taxonomy," "phytochemistry," "pharmacology," "biological activity," "traditional applications," "secondary metabolites," "safety," "toxicology," "marketed formulations," "patents," and "clinical trials". Out of the 510 scholarly publications on S. nigrum scrutinized, material deemed irrelevant was omitted, leading to a concentrated examination of 109 key documents. The ChemDraw Ultra 15.0 program facilitated the visual representation of the chemical structures.

1.2. Botanical Description

Solanum nigrum is a perennial, branched, short-lived herb (about 30-120 cm in height) found in forested areas [1][10] and disturbed in Africa, Indonesia, and North American habitats [11]. S. nigrum is recognized for its resilience and is frequently encountered in gardens, fields, waste areas, and disturbed soils. Due to its ability to thrive in diverse ecological niches, it is often categorized as a weed [10].

Parts of plant	Botanical description	References
Leaves	The leaf is ovate, 20.5-10 cm long and 1.5-5.5 cm wide, dull to dark green in colour with smooth surfaces, and the apex is shortly pointed.	[1][10][11]
Flowers	Bell-shaped white, an ovate-shaped calyx, a star-shaped corolla, and featuring five petals that vary in color from white to greenish-white.	
Stems	Round to angular in shape and encircled with small multicellular hairs, erect, branching outward, and 30 to 120 centimeters in height.	
Roots	Having a fibrous texture and a short taproot with a well-developed main root.	
Berries	Small, spherical berry, initially green in color and gradually transitioning to a glossy black as it ripens. Within each berry are numerous diminutive seeds, primarily oval, with an approximate diameter of 1.5-2 mm.	
Seeds	Many, discoid, yellow, minutely.	

Table 1. Botanical Description of *Solanum nigrum* Linn.

Fig. 1. Parts of *Solanum nigrum* (leaf, flower, ripe and unripe berries)

1.3. Taxonomy

Solanum nigrum is the largest species (approximately 3000) of the Solanaceae family [10]. A taxonomical description of Solanum is enlisted in below Table 2.

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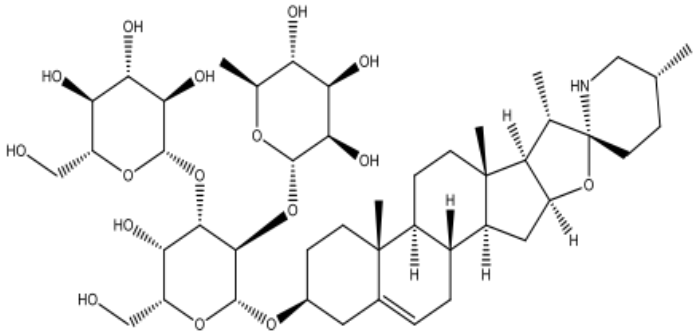
Taxonomy	**Kingdom**	*Plantae*	[12]
	Phylum	*Magnoliophyta*	
	Class	*Magnoliopsida*	
	Order	*Tubeflorae*	
	Family	*Solanaceae*	
	Genus	*Solanum*	
	Species	*Solanum nigrum*	

Table 2. Taxonomy of *Solanum nigrum*

2. Traditional uses and phytochemistry

Solanum nigrum is an integral component of Indian traditional medical practice [13], and humans have used this plant to treat various diseases. Treatments with the juice of the plant include piles, diarrhea, liver cirrhosis, diaphoresis, diuretic, hypnotic, and hydragogue conditions [14][15]. The fruit is used as a diuretic, cathartic, hyper-aspiration, and asthma[16] [8][17]. The leaves were utilized as a poultice to treat gouty or rheumatic joints, skin diseases, nausea, dropsy, and other nervous diseases. These are treatments for bronchitis, pulmonary tuberculosis, asthma, and diuretics[18]. *S. nigrum* comprehends several bioactive phytoconstituents such as glycoalkaloids, glycoproteins, polysaccharides, and polyphenol substances with significant pharmacological properties[19]. The following structures highlight some of the most prevalent and significant phytochemicals.



1. Solasonine

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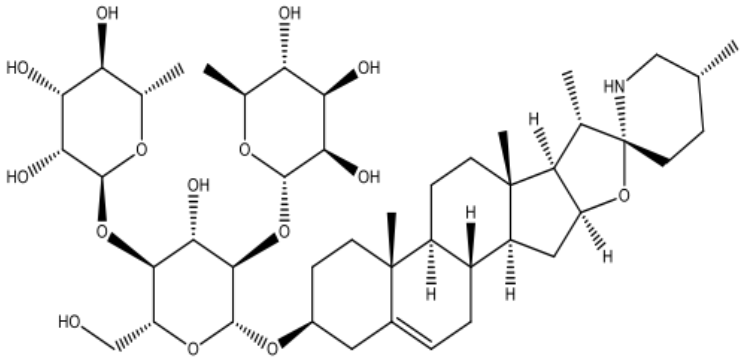

2. Solamargine

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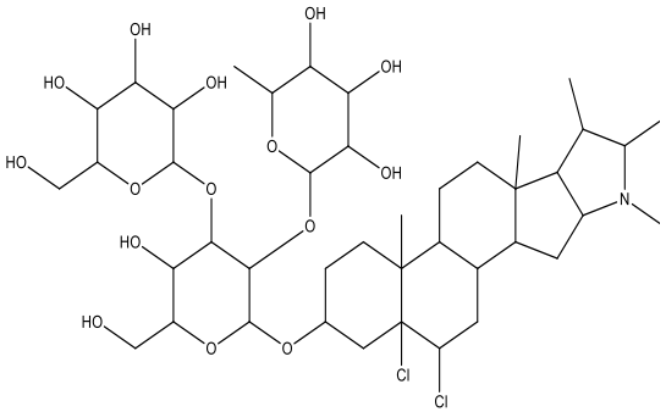

3. Solanine

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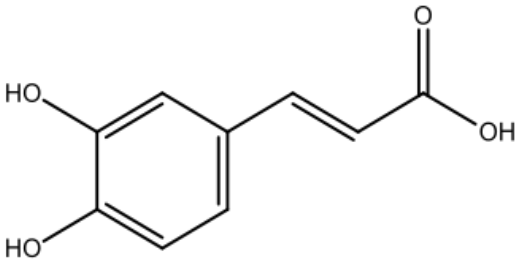

4. Caffeic acid

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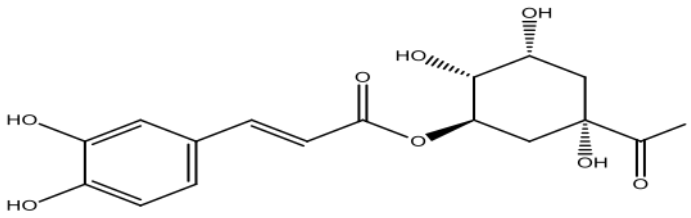

5. Chlorogenic acid

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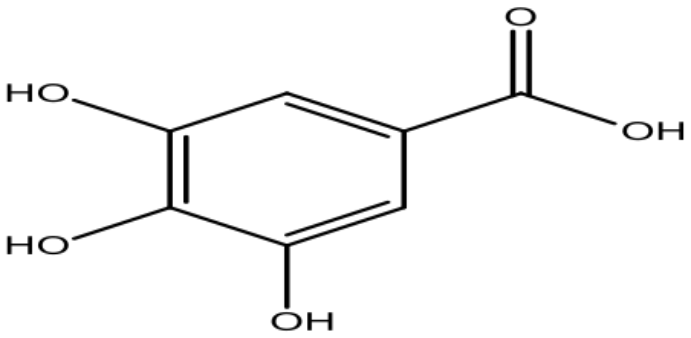

6. Gallic acid

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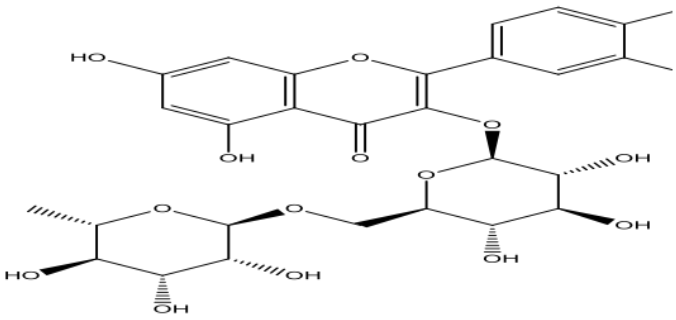

7. Rutin

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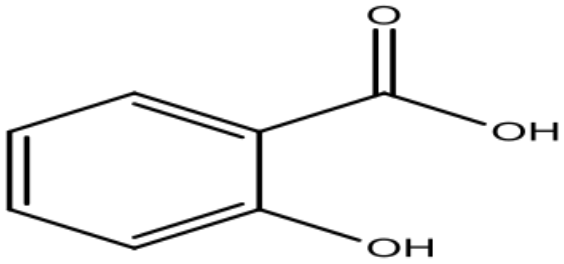

8. Phenolic Acid

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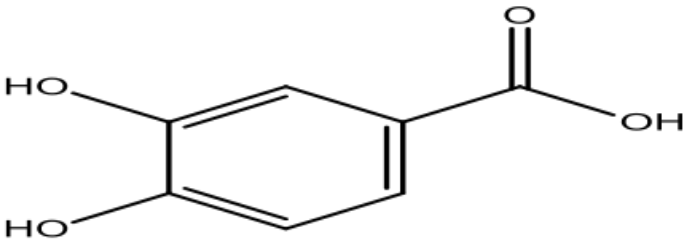

9. Protocatechuic acid

3. Detailed pharmacological and therapeutic potentials

3.1. Anti-diabetic activities

N. S. Aali *et al.*, (2010) investigated the antidiabetic potential of ethanolic extracts. The extracts were tested on albino rats weighing between 150 and 200 grammes at a dosage of 250 milligrammes per kilogramme per day for a period of between five and seven days. The findings point to a noticeable decline in the amount of sugar in the blood [20].

S. Meonah et al., (2012) studied the aq. and hydroalcoholic extracts for antidiabetic efficacy in rats (200 and 400mg/kg b.w.) to assess oral glucose tolerance with conventional Metformin. Results show the stem has no hypoglycemic activity [21].

J. Sugunabai *et al.*, (2014) conducted a study on a group of male patients, aged 35-60, for 90 days to check the efficacy of aq. extract for their hypoglycemic and hyperlipidemic activities. Results showed the level of glucose, LDL, triglyceride, and glycosylated hemoglobin was reduced by 19%, 8%, 17%, and 10%, respectively, and HDL was increased by 2%. Alkaloids possibly increase insulin secretion, and glycoprotein increases the activity of antioxidant enzymes[22].

M. Umamageswari *et al.*, (2017) conducted a study to estimate the hypoglycemic effects of *S. nigrum* berries in alloxan-induced diabetic mice. The animals were treated with AESNB 200 and 400 mg/kg and standard, i.e., 0.1 mg/kg of glimepiride. The results provide clear evidence that the dosage of 400 mg/kg per day formed a substantial drop ($P<0.001$) than 200 mg/kg/day ($P<0.01$) [23].

3.2. Hepatoprotective activities

S. Sultana et al. (1995) investigated the ethanolic leaf extracts for their hepatoprotective activity on mice using a DNA-sugar damage assay. At 25 g/ml, the highest significant inhibition was 29%. According to the study, the herb is hepatoprotective [24].

K. Raju *et al.*, (2003) investigated the ethanolic fruit extract to evaluate its ability to protect against hepatotoxicity caused by CCl_4 in albino male rodents (130-160g). The animals were treated with 250 mg/kg for seven days. The findings showed remarkable hepatoprotective efficacy [25].

H. Lin *et al.*, (2008) studied the *S. nigrum* (SNE) extract on CCl4-induced chronic hepatotoxicity in Sprague-Dawley rats (150-180g). SNE (200, 500, and 100mg/kg b.w.) and CCl_4 (0.5 mL/kg b.w.) were administered orally to rats for 6 weeks. The research findings suggested that SNE has hepatoprotective effects on rats [17].

R. Elhag *et al.*, (2011) evaluated the protective effects of aqueous and methanol extracts on albino rats (80-130g) using a CCl_4-induced hepatotoxicity model. Both extracts were administered dose-dependently to the rats (250 and 500 mg/kg). The findings showed that *S. nigrum* has a hepatoprotective effect. [26].

A. Elshater *et al.*, (2013) used a rat model of CCl4-induced hepatotoxicity at 250 and 500 mg/kg to test the hepatoprotective effects of fruit and plant aq. extracts. There are claims that an extract of the *S. nigrum* fruit is more effective at treating liver damage than the plant itself [27].

R. Ali *et al.*, (2014) tested the efficacy of fruit aq. extracts in protecting albino rat livers from CdCl2-induced damage. According to the findings, its

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hepatoprotective characteristics help prevent liver damage caused by CdCl2 [28].

3.3. Anti-stress activities

S. Zaidi *et al.* (2014) looked into the stress-relieving effects of Solanum leaf extracts as a dietary supplement for reducing oxidative stress in the brain and protecting it from damage caused by stress. Findings suggest that *S. nigrum* might be employed as a safe therapeutic approach for any neurological condition, including physical or psychological stress [29].

3.4 Anti-larvicidal activities

Rawani *et al.* (2010) investigated the effectiveness of several extracts of *S. nigrum* leaf in preventing larvicidal activity in Culex quinquefasciatus. The mortality rate was significantly higher (p less than 0.05) at 50 ppm of ethyl acetate extract. According to the findings, *S. nigrum* exhibited potential as an anti-larvicidal agent [30].

A. Rawani et al. (2013) conducted a study to assess the mosquitocidal effectiveness of several *S. nigrum* berry extracts against Culex quinquesfasticans. Methanol (1/1% v/v) extract has remarkable larvicidal efficacy in crude and chloroform [31].

Rawani *et al.* (2013) evaluated the larvicidal activity of silver nanoparticles (AgNPs) from leaf and fruit extracts of *S. nigrum* against larvae using a larvicidal mosquito bioassay. The results show that the AgNPs of *S. nigrum* can be used to control mosquito larvae in a way that is good for the environment [32].

A. Rawani *et al.*, (2014) exploring the biocontrol potential of an active component (Glucosinolate) produced from *S. nigrum* leaf extracts by conducting this study on Culex quinquefasciatus larvae was the goal of this particular investigation. Out of all the quantities that were examined, the one that had 25 mg/L of the active chemical had the highest fatality rate. The findings suggested that the larvicidal efficacy tested could be effective [33].

A. Rawani et al. (2017) The bioactive components of phytosterol in *S. nigrum* leaf extract (chloroform: methanol, 1:1 v/v) were tested against larvae of the Cx. vishnui group and An. subpictus at a variety of doses. In a bioassay that lasted for 72 hours, the mortality rate was noticeably greater when the concentration was 60 mg/L. It is possible that the isolated phytochemical will prove to be an effective mosquitocidal agent [34].

3.5. Anti-estrogenic activities

S. Jisha *et al.* (2011) experimented on *S. nigrum* fruits methanolic extract for its estrogenic potential. The result of a competitive binding assay using 3H-E2 demonstrates a rise with increasing dosage in MCF cells at a lower concentration (40μg/ml) and progressive cell growth inhibition at a higher concentration (80-320μg/ml) mediated by the estrogen receptor. The finding reveals that methanol extracts demonstrated a characteristic uterotrophic response in mice [35].

3.6. Anti-viral/ HCV activities

T. Javed *et al.* (2011) investigated the anti-HCV action of *Solanum* seeds extract, which suppressed HCV by 37% and 50%, respectively. By transfecting liver cells with a plasmid containing HCV NS3 protease, an attempt was made to study the antiviral impact of the Solanum extract against HCV NS3 protease. In contrast to GAPDH, the chloroform extract was able to reduce the amount of HCV NS3 protease expression as well as its function. The findings suggest that the seeds extract may have antiviral properties that can aid in the battle against HCV, and that using the extracts in conjunction with interferon is a more effective strategy to treat chronic HCV [36].

3.7. Anti-seizure/ anti-convulsant activities

Wannang *et al.* (2008) investigated that intraperitoneal administration of *Solanum* aqueous leaf extract (30-60 mg/kg) effectively stopped seizures in chicks, mice, and rats. The animals were given various proconvulsants in increasing doses after the treatment period of 30 minutes. According to the findings, aqueous leaf extracts significantly prevented electrically induced seizures in rats and chicks and seizures induced by pentylenetetrazole and picrotoxin in mice [37].

K. Ruby *et al.* (2012) evaluated the CNS-depressing action of *S. nigrum* by injecting it intraperitoneally. Isotonic contraction of the rectus abdominis muscle is observed in the solitary toad. The toad heart has a detrimental influence on the chronotropic and inotropic systems. The rat jejunum exhibits isotonic contraction. The cat's BP is reduced [38].

H. Le Son et al. (2014) studied the anticonvulsant effect of *S. nigrum* ethanolic extracts on PTZ-induced

convulsions in mice. At 300 mg/kg, the extract substantially delayed convulsion latency. According to the findings, the ethanolic extract of *Solanum* possesses anticonvulsant activity [39].

3.8. Cytotoxic activities

Y. Son *et al.* (2003) tested the *Solanum nigrum* fruit extract for its ability to suppress DNA synthesis in MCF-7 cells by utilising the MTT and trypan blue exclusion tests. MCF-7 cells displayed a cytotoxic response that ranged from 11 to 16 percent after being treated with SNL extract at a concentration of 50 mg/mL for 12 hours. About seventy percent of the MCF-7 cells exhibited a positive staining response to trypan blue after being treated with the extract at a dose of fifty milligrammes per millilitre. In addition to this, the cytotoxicity that was brought on by the SNL extract manifested itself in a more significant manner as time went on [40].

H. Lin *et al.* (2007) investigated the cytotoxicity of Solanum aqueous extracts on HepG2 cells at 2 and 5 mg/ml; SNE-induced apoptosis. Low doses of SNE (50-1000 g/mL) caused morphological and ultrastructural changes that indicated autophagocytic death. In addition, SNE caused apoptosis and autophagocytosis in hepatoma cells, suggesting it might be used to treat liver cancer [41].

H. Huang *et al.* (2010) tested Solanum extracts on cancer and regular cell lines. The extract was more effective against AU565 breast cancer cells. Higher amounts of SN leaf extract (>100 g/mL) blocked p-Akt and caused autophagy and apoptosis. SN leaf extract enhanced breast cell death through apoptosis and autophagy via two anti-neoplastic actions [42].

3.9. Cytoprotective activities

Prashant Kumar *et al.* (2001) examined the cytoprotective properties of Solanum against gentamicin-induced toxicity in Vero cells. Research findings displayed remarkable hydroxyl radical scavenging activity, indicating a potential strategy of cytoprotection [43].

3.10. Neuropharmacological activities

R. M. Perez *et al.* (1998) studied the neuroprotective effects of *Solanum* ethanolic fruit extracts in Wistar rats. The results demonstrate that *S. nigrum* fruit may have CNS-depressant properties[44].

3.11. Anti-cancer activities

K. Hu *et al.* (1999) investigated the *Solanum nigrum* glycoside (Solamargine) for *in-vitro* cytotoxic effects on various human tumour cell lines (colon and breast). The results of the cytotoxic assay performed on *S. nigrum* demonstrated that solamargine is the primary anti-neoplastic agent [45].

An. Lei *et al.* (2006) evaluated the ethanolic extract of unripe fruits for cytotoxicity on breast and liver cell lines rather than the ethanolic extract of leaves. Fruits had an IC50 value of 12.7 and 16.6 micrograms per millilitre when tested for their ability to kill breast and liver cancer cell lines, respectively. This activity can be attributed to the high levels of steroidal glycoalkaloid concentration in unripe fruit [46].

H. Lin *et al.* (2007) investigated *S. nigrum* extract (SNE) for cytotoxic activity on HepG2 cells. HepG2 cells were made to undergo apoptosis when exposed to SNE at doses of 2 and 5 mg/mL, respectively. According to these findings, SNE was able to cause apoptosis and autophagocytosis in hepatoma cells. These are two distinct anti-cancer activities, and they point to the possibility that it could be effective in the treatment of liver cancer [41].

S. Patel *et al.* (2009) evaluated the anti-cancer effects of *Solanum nigrum* fruit extract on the HeLa cell line. Both the SRB and the MTT tests were performed on HeLa cells in order to evaluate the cytotoxicity of the *Solanum nigrum* extract. In both the SRB and the MTT tests, the presence of 10-0.0196 g/ml of methanolic extract had a substantial effect on the viability of HeLa cell lines. The results showed the potency of *Solanum nigrum* to inhibit cancerous growth [47].

H. Wang *et al.* (2010) reported that the *S. nigrum* water extract (SNWE) was effective in preventing the progression of melanoma. Following treatment with SNWE, an analysis was performed to determine whether B16-F1 cells retained their capacity to migrate and invade. According to the findings, a dose-dependent relationship existed between SNWE's ability to block B16-F1 cell migration and invasion and its ability to treat melanoma [48].

M. Shokrzedah *et al.* (2010) investigated *S. nigrum* extract on cancer cell lines HepG2 and CT26, as well as rat fibroblast and Chinese hamster ovary cells. After conducting a clonogenic experiment, researchers examined the cytotoxic effects of the extracts on several cell lines and determined their IC_{50} values. As

a consequence of this, cytotoxicity against cancer cells has been demonstrated in the *S. nigrum* extract [49].

H. Wang *et al.* (2011) investigated the extract of *Solanum nigrum* and its effect on the development of hepatocarcinoma cells at a concentration of 1 g/ml. The *in-vitro* and *in-vivo* effects on the growth inhibition of HepG2 cells were investigated. According to the findings of this study, the extract is an effective therapeutic therapy for head and neck cancer because it inhibits cell proliferation by inducing G(2)/M arrest and cell death [50].

X. Ding *et al.* (2012) measured the growth inhibition of human hepatoma SMMC-7721 tumour cell lines using the MTT test, as solamargine (SM) is a significant steroidal alkaloid glycoside isolated from SNL. The study's findings demonstrated that solamargine dramatically reduced the proliferation of SMMC-7721 and HepG2 cells, promoted cell death, and exhibited some degree of potential anti-cancer efficacy [51].

N. Akbar *et al.* (2012) conducted a study to evaluate the effects of the SN extract on growth inhibition. *Solanum nigrum* extract has been shown to induce cell cycle arrest and apoptosis in different human prostate cancer cells while having no impact on normal prostate epithelial cells. In prostate cancer cells, the SN extract has the potential to inhibit the proliferation of cells. It could be developed into a potential treatment for prostate cancer as well as a prophylactic agent [52].

Y. Lai *et al.* (2016) demonstrated that the aqueous extract of *Solanum nigrum* (AESN) has considerable anti-cancer and curative properties. Researchers employed the Mitotracker Deep-Red FM stain as a means of determining whether AESN was effective in preventing EMT in MCF-7 breast cancer cells. These findings suggest that AESN may be able to prevent EMT in breast cancer cells via reducing the function of the mitochondria [53].

3.12. Anti-ulcer/ gastritis activities

M. Akhtar *et al.* (1989) investigated three plants to study their antiulcer activity against an aspirin-induced gastric ulcer in rats (male albino rat, 170-200 gm). The methanol extract of *S. nigrum* significantly decreased pepsin levels and gastric pepsin content. The results showed that the acid content was reduced in rats treated with SN methanolic and aqueous extracts. The results suggest that due to its anti-ulcerogenic effect, acid and pepsin outputs decrease, enhancing gastric mucosal strength[54].

M. Jainu *et al.* (2006) has been demonstrated to significantly reduce the severity of stomach lesions in rats caused by cold-resistant stress (76.6 percent), indomethacin (73.8 percent), pyloric ligation (80 percent), ethanol-induced gastric ulcer models (70.6 percent), and acetic acid-induced ulcer models (70%). (85 percent). SNE reduced the volume of gastric secretion, the acidity of the stomach, and the amount of pepsin that was secreted in rats that had gastric ulcers. It does this by inhibiting the activities of H+, K+, and ATPase in ulcers caused by ethanol and by lowering the discharge of the stomach. According to the findings, the fruit of the *S. nigrum* tree has both antiulcerogenic and ulcer-healing properties [55].

M. Rajeswari *et al.* (2013) evaluated the experiments conducted on pylorus-ligated female albino rats with ethanol-induced gastritis and aspirin-induced stomach ulcers to determine the efficacy of extracts from the *Solanum nigrum* leaf and fruit. Stomach ulcers were induced by administering aspirin to the rats (Sprague-Dawley strain, 180-200 gm). The Ulcer Index was drastically reduced after 250 mg/kg of leaf and berry aqueous extracts and 50 mg/kg of fruit extract were orally administered. The results showed that the berry aqueous extract was more effective than the leaf extracts in treating gastritis [56].

F. Razali *et al.* (2016) have confirmed that the ground, dried stem of *Solanum nigrum* contains a non-toxic polysaccharide fraction (SN-PPF3) that inhibits malignancies by boosting the host immune response. Mice with breast tumours were given SN-PPF3 orally at 250 and 500 mg/kg for 10 days, and the tumour volume and body weight were measured. According to the data, there was a discernible decline of 65 percent in the volume of the tumour and a drop of 40 percent in the weight of the tumour. In mice that were given treatment, the tumour tissue was infiltrated by a greater number of T cells, NK cells, and macrophages. In mice that were given treatment, there was an increase in the levels of TNF-alpha, IFN-gamma, and IL-4, but there was a reduction in the levels of IL-6 [57].

3.13. Anti-oxygenic activities

Padmashree *et al.*, (2014) have used a sunflower oil model system to investigate the anti-oxygenic action of *Solanum nigrum* leaves. Refined sunflower oil showed considerable anti-oxygenic activity from both the leaf powder and its methanol/water (80:20) soluble fraction, but the ethyl acetate fraction showed only minimal anti-oxygenic activity. This research

confirmed previous results that leaves contain compounds that stifle oxygen synthesis. Particularly promising as a natural antioxidant that could lessen lipid peroxidation in food was the 80:20 methanol to water extract they created [58].

3.14. Anti-hyperlipidemic activities

Arulmozhi *et al.* (2010) examined the *Solanum nigrum* fruit aqueous extract's (SNF-AE) antioxidant and anti-hyperlipidemic efficacy against ethanol-induced toxicity in adult albino Wistar rats (150-17-gm). Each rat received 250 mg/kg of body weight in 20 percent ethanol once day for 30 days. Thiobarbituric acid reactive compounds were increased in the ethanol-induced rats compared to the control group, and the antioxidant defence system was decreased (GSH, Vit-C, and E). According to these findings, SNF-E is a potent antioxidant and anti-hyperlipidemic agent [59].

Imran Ali *et al.* (2016) carried out research to determine whether or not an ethanolic extract of *Solanum nigrum* (300 mg/kg) was effective in decreasing the cholesterol level in rabbits that had been caused to be hyperlipidemic with lipofundin (20 percent). The elevated levels of total serum cholesterol, triglycerides, high-density lipoprotein, and low-density lipoprotein in the test group dropped towards usual values after being treated with an ethanolic extract of *S. nigrum*. According to the findings, *S. nigrum* exhibited strong anti-hyperlipidemic efficacy in rabbits whose hyperlipidemia was caused by lipofuscin [60].

3.15. Protective activities

P. Chinthana *et al.* (2012) found that an aqueous preparation of the leaves of *Solanum nigrum* offered protection to Swiss albino mice that had been fed lead acetate. After 30 days of oral administration at a dose of 200 mg/kg, the aforementioned extract significantly increased antioxidant levels in mice that had been exposed to lead acetate (SOD, CAT, GPx). Overall lipid peroxidation levels dropped as a result (LPO). These results give conclusive evidence that *S. nigrum* extracts can mitigate lead acetate's neurotoxic effects in albino mouse brains [61].

A. Patel *et al.* (2014) carried out an experiment to investigate the prophylactic effect of an aqueous extract of *Solanum nigrum* leaves (AESN) in two rat models of oral mucositis: one caused by busulfan combined with infrared radiation (chemoradiotherapy), and the other caused by methotrexate (chemotherapy) at doses of 100 and 200 mg/kg. Although AESN was protective in both of the oral mucositis models, the higher dose seemed to have a greater impact on treating chemotherapy-induced oral mucositis. The findings of the study indicate that administration of AESN can protect rats from developing oral mucositis as a consequence of receiving either chemoradiotherapy or chemotherapy [62].

3.16. Anti-spermatogenic and anti-androgenic activities

Meerwal *et al.* (2012) have done on the ethanolic extract of *S. nigrum* at doses of 100, 250, and 500 mg/kg for 60 days orally. The impact on testis weight, blood testosterone, FSH, LH levels, and testis histoarchitecture was studied. According to the research author, the weights of testes, testosterone levels, FSH, and LH levels all decreased significantly in *Solanum nigrum* extract-treated rats. The results suggest that 50% ethanolic extract of the *S. nigrum* fruit has a considerable detrimental impact on sex hormone levels and spermatogenesis[63].

3.17. Immunostimulant activities

M. Haniffa *et al.* (2011) undertook research to identify plant species with immunostimulant potential for use in combating fish diseases. Immunization with 0.2 mL (4 ppm) of five different *Solanum nigrum* extracts and subsequent challenge with heat-killed Aphanomyces invadans was tested in six groups of experimental fish (E. suratensis). The death rate was reduced in the ethanol and methanol extract-treated groups compared to the chloroform, toluene, and water extract-treated groups. The findings suggest that plant extracts can be utilised to treat bacterial infectious illnesses and have great promise as immunostimulants against germs [64].

3.18. Anti-tumor activities

Jian Li *et al.* (2007) analysed the effect on tumour development of SNL-P, a crude polysaccharide extracted from the plant *Solanum nigrum* Linn. The growth of cervical cancer (U14) in tumor-bearing mice was also dramatically delayed by SNL-P. After 12 days of oral administration of SNL-P, further examination into the tumour inhibition mechanism indicated an increase in the number of apoptotic tumour cells, an increase in Bax expression, and a

drastic reduction in the expression of Bcl-2 and mutant p53 in cervical cancer sections [65].

Y.B. Ji *et al.* (2008) have shown that solanine, extracted from the *Solanum nigrum*, inhibits the growth of tumour cells in three different cell lines derived from the digestive tract using an MTT experiment to determine the IC50. Flow cytometry was used to evaluate cell proliferation, apoptosis, and cell cycle phase (FCM). Western blot analysis confirmed the level of Bcl-2 protein expression. HepG2 cells were induced to undergo programmed cell death by solanine at a rate of 6.0%, 14.4%, 17.4%, 18.9%, and 32.2%, respectively. Western blotting revealed that solanine inhibited Bcl-2 protein expression. This suggests that solanine induces apoptosis in HepG2 cells by blocking their ability to produce Bcl-2 protein [66].

Jian Li *et al.* (2008) tested mice that had been genetically engineered to carry tumours with a *Solanum nigrum* aqueous extract (SNL-AE), and a FACScan flow cytometer was utilised to assess whether or not the extract decreased the growth of the tumours. Both the number of CD4+ T lymphocyte subsets and the CD4+/CD8+ T lymphocyte ratio rose as a result of treatment with SNL-AE, which prevented the proliferation of U-14 cervical cancer cells. Based on these findings, it appears as though SNL-AE might be able to reduce the risk of developing cervical cancer by modifying the immune responses of tumor-bearing mice, causing tumour cell cycle arrest in the G0/G1 phase, and causing apoptosis with only very mildly detrimental effects on the animals [4].

Jain Li *et al.* (2009) examined the effects of crude polysaccharides derived from *Solanum nigrum* Linn. (SNL-P) on U-14 cervical cancer cells. At dosages of 1 mg/ml, SNL-P did not exhibit any antiproliferative effects when tested in vitro. In-vivo therapy of U14 cervical cancer-bearing mice with SNL-P (90, 180, or 360 mg/kg bw, orally) resulted in a reduction in the amount of tumour cells found in the ascites and an increase in the mice's lifespan. The SNL-P therapy made use of the ELISA method, which led to a remarkable decrease in the amount of II-4 while simultaneously producing a notable rise in the amount of IFN-g. In mice with U-14 cervical carcinoma, the research demonstrated that SNL-P has a significant anti-cancer effect and may exhibit anti-tumor action by stimulating a variety of host immune responses rather than directly eliminating cancer cells [67].

Jian Li *et al.* (2010) have investigated the polysaccharide component from *Solanum nigrum* Linn that has anti-tumor properties (SNL-P). This chemical has been utilised to investigate the protective effects of the active component on the thymus, and it has been shown to have anti-cervical cancer and modifying characteristics. Injections of ascites U14 cells into animal models allowed researchers to assess SNL-P's ability to prevent cervical cancer. Histological and TUNEL labelling were used to assess SNL-P fraction 1a's (SNL-P1a) ability to protect thymus tissue against tumours in tumor-bearing animals. The growth of U14 cervical carcinoma is considerably slowed by SNL-P1a, as has been demonstrated [68].

R. Gabrani *et al.* (2012) conducted research on leukemic, Jurkat, and HL60 cell lines to investigate the antiproliferative efficacy of organic solvent and aqueous extracts produced from *Solanum nigrum* berries. The MTT test was used to determine cell viability after treatment with *Solanum nigrum* extract. According to the observations, higher extract concentrations increased cytotoxicity[69].

H. Chen *et al.* (2013) examined the antitumor activity of polysaccharides derived from *Solanum nigrum* Linn. (SNL-P) in Kunming mice that had been surgically implanted with tumours. The MTT test was utilised in order to investigate how various dosages of SNL-P affected the rate of lymphocyte proliferation in animals that had tumours. The growth of mouse H22 solid was substantially inhibited by additional doses of SNL-P, which also promoted lymphocyte proliferation, elevated IL-2 levels, increased the concentration of calcium ions in lymphocytes, and improved the survival time of mice that carried tumours [70].

Z. Zhao *et al.* (2018) explored the anti-cancer properties of the compound known as degalactotigonin (DGT), which was isolated from the *Solanum nigrum* plant. DGT can prevent osteosarcoma from developing and spreading throughout the body. Using the MTT, colony formation, and apoptosis assays, researchers looked at the effects that DGT had on the viability of osteosarcoma cells in vitro. In this study, animal models were used to investigate the role of DGT in osteosarcoma tumour growth and metastasis. DGT inhibited osteosarcoma cell growth, induced apoptosis, and lowered both migration and invasion of osteosarcoma cells. According to the findings of the study, DGT is able to inhibit human osteosarcoma development and metastasis through

modifying the GSK3b inactivation–mediated control of the Hedgehog/Gli1 pathway [71].

Y. Huang *et al.* (2018) conducted experiments in mice with H22 hepatocarcinoma cells to determine whether polysaccharides (SNPs) from the *Solanum nigrum* Linn. plant have an effect on the formation of tumour cells. After administering SNP to experimental animals at dosages of 30, 60, and 120 mg/kg, the tumour inhibition rate as well as the spleen and thymus indexes were computed. The dose of SNP that was administered resulted in a dose-dependent reduction in the average tumour weight, with respective tumour inhibition rates of 37.73, 38.24, and 42.60 percent. The findings demonstrated that mice carrying H22 had less tumour growth and better immune function when SNP was administered [72].

J. Li *et al.* (2021) identified a treatment for HGG; the anti-tumor effects of SN extract were investigated utilising both in-vitro and in-vivo rat C6 glioma models. C6 cells had a dose-dependent drop in their viability, as well as a reduction in their capacity to clone and migrate when treated with extract from *S. nigrum*, which also caused a decrease in their ability to proliferate. The presence of the active ingredient in *S. nigrum* caused a reduction in the rate of both the growth of C6 HGG (high-grade glioma) and its invasion into surrounding tissue [73].

Razali et al. (2021) performed a preclinical study that assessed the acute toxicity of a crude polysaccharide extracted from Solanum nigrum stem. The key findings indicate that when orally administered at a concentration of 2,000 mg/kg/bw, the polysaccharide exhibited a very mild acute toxicity effect, with an estimated LD50 ranging from 2,500 to 5,000 mg/kg/bw. This suggests that the polysaccharide has a relatively low toxicity profile, making it a promising candidate for further investigation as a potential immunomodulatory and anti-tumor agent [74]

3.19. Anti-asthmatic activities

S. Nirmal *et al.* (2012) demonstrated using guinea pig ileum to test the anti-asthmatic potential of extracts of *Solanum nigrum* berries prepared using petroleum ether, ethanol, and aqueous medium at doses of 50, 100, and 200 mg/kg, administered intraperitoneally. According to the findings, the catalepsy brought on by clonidine was greatly alleviated by the petroleum ether extract, but none of the extracts was able to stop the catalepsy brought on by haloperidol. When compared to other extracts, the histamine-induced relaxation in the guinea pig ileum was shown to be greater in the ileum produced by the petroleum extract. According to the findings of HPTLC, the petroleum extract has a B-sitosterol component, which is the active ingredient in the anti-asthmatic activity [75].

3.20. Anti-apoptotic activities

S. Lee *et al.* (2004) used HCT-116 cells that had been subjected to chemically generated tumour promotion to test the anti-cancer effects of a glycoprotein derived from *Solanum nigrum* L. (SNL glycoprotein) with a 150-kDa molecular weight. Powerful cytotoxic and dose-dependent apoptosis-inducing capabilities were demonstrated by the SNL glycoprotein. HCT-116 cells triggered with TPA (61.68 g/ml) showed inhibition of NF-jB DNA binding activity, NF-jB protein activity, and NO production at doses as low as 10 g/ml. These results suggest that the SNL glycoprotein can induce apoptosis by regulating signal mediators [76].

X. Zhang *et al.* (2018) investigated the impact that solamargine has on human cholangiocarcinoma QBC939 cells. Solamargine lowered the viability of QBC939 cells in a dose-dependent way. According to the findings of this study, solamargine possesses the ability to trigger apoptosis in human cholangiocarcinoma QBC939 cells by way of the mitochondrial pathway and to change the levels of proteins linked with apoptosis [77].

3.21. Anti-proliferation activities

Y. Son *et al.* (2003) investigated the impact on human breast cancer cell proliferation of an ethanol extract of *Solanum nigrum* ripe fruits. Also, unlike superoxide anions, the hydroxyl and DPPH radicals were neutralised by the SNL extract, making it a potential scavenger. The results of the trials suggest that the fruit extract has potential as an anti-cancer antioxidant and chemopreventive agent [40].

X. Ding *et al.* (2012) discovered that solamargine (SM), a major steroidal alkaloid glycoside generated from SNL, inhibits the growth of the human hepatoma SMMC-7721 cell line. The IC_{50} for tumour cell lines was determined using the MTT assay, which led to this discovery. Both SMMC-7721 and HepG2 cell growth was significantly suppressed, and both cell types were induced to undergo apoptosis in the presence of SM. The results of this study show that SM is able to induce apoptosis and suppress the growth of hepatoma cells in vitro by targeting malignant

SMMC-7721 cells through activation of caspase-3 and regulation of the cell cycle [51].

3.22. Cardioprotective activities

Bhatia Nitish *et al.* (2011) evaluated the preventive properties of a methanol extract of *Solanum nigrum* berries against a worldwide in-vitro ischemia-reperfusion injury model in rats. Individuals were given either 2.5 or 5.0 mg/kg over the course of thirty days, with therapy occurring six days per week during the whole period. The extract had a cardioprotective effect against global ischemia-reperfusion damage that was statistically significant ($p \leq 0.001$) [78].

P. Varshney *et al.* (2016) tested *S. nigrum* aqueous extract for its potential to protect against doxorubicin-induced cardiotoxicity in mature Wistar albino rats (150-200 gm). Experiments were conducted with 100 mg/kg daily for 20, 30, and 40 days. Cardioprotection was shown by a significant (p0.001) reduction in the time-dependent increase of these parameters in the *Solanum nigrum* pretreatment group. Rats given SN extract showed a dose-dependent increase in cardioprotective effects [79].

S. Shaik *et al.* (2016) performed an investigation on the hydroalcoholic (ethanolic) extract of *Solanum nigrum* (SNL) for its cardioprotective activity in isoproterenol-induced myocardial infarction in male Wistar albino rats (200-250g). The study was carried out using 75, 150, and 300 mg/kg SNL for 21 days. SNL extract-treated rats showed an increase in SOD, CAT, and GSH levels. The treatment group significantly reduced the effects of isoproterenol-induced myocardial infarction. The rats treated with the ethanolic extract showed dose-dependent cardioprotective action [80].

3.23. Antioxidant activities

K. Heo *et al.* (2004) conducted a study on the glycoprotein isolated from *Solanum nigrum L.* for antioxidative properties against oxygen free radicals using a DPPH assay. In cell cultures (NIH/3T3), SNL glycoprotein was more efficient against hydroxyl radicals. It has a catalase activity of 0.1μg/ml, which can scavenge hydroxyl radicals. The results indicate that SNL glycoprotein possesses antioxidative properties [5].

M. Devi *et al.* (2004) research was carried out on the biochemical antioxidant profile of the tissue, and the antioxidant potential of a methanolic fruit extract of *Solanum nigrum* was evaluated. According to the findings of the cardiac tissue biochemical antioxidant profile, the extract possessed a considerable (p 0.001) level of antioxidant capacity. Based on the findings, one can draw the conclusion that an extract of *Solanum nigrum* berries made with methanol had antioxidant activity [81].

U. Karmakar *et al.* (2010) looked into the potential of an ethanolic extract of the dried fruit of *Solanum nigrum* Linn for a variety of medical uses, including pain relief, preventing diarrhoea, killing bacteria, and killing cancer cells. An investigation into the qualitative antioxidant properties of an extract utilising a DPPH test revealed that the extract possessed free radical scavenging capabilities. Based on the findings, one can draw the conclusion that the antioxidant potential of *Solanum nigrum* extract can be utilized [14].

J. Jeong *et al.* (2010) explored whether the antioxidant lunasin, which was isolated from *Solanum nigrum* L., might prevent oxidative damage to DNA. It has been demonstrated that lunasin can protect DNA from the oxidative damage that is generated by the hydroxyl radical and the Fe2+ ion. It was shown that consumption of lunasin protects DNA from oxidation via chelation of Fe2+, which suggests that lunasin may play a significant role in the chemoprevention of oxidative carcinogenesis [82].

Bhatia Nitish *et al.*, (2011) investigated the fact that an experiment was carried out in order to assess the level of antioxidant activity that the methanolic extract of *Solanum nigrum* berries contained in comparison to the tissue biochemical antioxidant profile. Berries from the Solanum genus were used in the experiment. During the course of the study, doses of 2.5 and 5.0 mg/kg were given to the participants on six days out of every week for a total of thirty days. The data showed that the methanolic extract had a significant amount of antioxidant potential ($p \leq 0.001$), which was able to be deduced from the heart tissue biochemical antioxidant profile [78].

U. Akula *et al.* (2013) explored the anti-inflammatory effects, total phenolic content, and free radical scavenging activity of aqueous and methanolic extracts of 18 South African leafy vegetables. These extracts were examined (*Solanum nigrum* is one of these). In tests of radical scavenging, methanolic extracts from six different plants were able to minimise DPPH absorption. It is possible that the high quantities of phenolic compounds found in the plants that were analysed contribute to their antioxidant and anti-inflammatory benefits [83].

A. Campisi *et al.* (2019) compared the antioxidant activities of methanolic:water (80:20) and water extracts of *Solanum nigrum* plant leaves. These extracts significantly reduced the cell-damaging effects of glutamate by blocking both glutamate uptake and glutamate excitotoxicity [82].

3.24. Analgesic activities

D. Kaushik *et al.* (2009) explored whether an extract of *Solanum nigrum* fruit that had been processed with ethanol had any effect on reducing pain. Using Eddy's hot plate and acetic acid-induced writhing, the analgesic efficacy was assessed for both central and peripheral pharmacological activity. At a dose of 500 mg/kg, the extract demonstrated substantial analgesic effectiveness [84].

U. Karmakar *et al.* (2010) explored whether an ethanolic extract of the dried fruit of *Solanum nigrum* could have a possible analgesic effect. The writhing reflex in mice was induced by the administration of acetic acid; the ethanolic extract, at doses of 250 and 500 mg/kg, was found to inhibit the writhing reflex by 51.39 and 66.67 percent, respectively. According to research, ethanolic extracts possess characteristics that make them analgesic [14].

3.25. Anti-diarrheal activities

Karmakar *et al.* (2010) investigated the efficacy of a treatment for diarrhoea that was derived from an ethanolic extract of the dried fruit of the *Solanum nigrum* Linn plant. At dosages of 250 mg/kg and 500 mg/kg, the extract demonstrated strong anti-diarrheal efficacy against castor oil-induced diarrhoea in mice [14].

Gbadamosi *et al.* (2015) investigated the efficacy of ethanol extracts of the *Solanum nigrum* plant in combating the pathogenic organisms that are the root cause of diarrheal diseases. The agar well diffusion method was used as the screening technique while testing antibacterial agents for indicator organisms. This method was utilised in the testing process. During the course of this investigation, it was found out that the extracts of *S. nigrum* have the potential to be used in the treatment of diarrhoea [85].

3.26. Anti-microbial activities

D. Kaushik *et al.* (2009) conducted an investigation of the antibacterial properties of an ethanolic extract of *Solanum nigrum* fruit in this work. At each of the tested concentrations (100, 75, 50, and 25 mg/ml), the extract from the plant was able to significantly inhibit the growth of S. aureus and B. subtilis. According to the findings, ethanolic extracts exhibited antimicrobial action [84].

U. Karmakar *et al.* (2010) tested the antibacterial properties of an ethanolic extract of *Solanum nigrum* fruits. Both gram-positive and gram-negative bacteria were resistant to the ethanolic extract's lack of antibacterial activity. The results suggest that *Solanum nigrum* extract's anti-microbial characteristics can be put to good use [14].

G. Ravishankar *et al.* (2011) investigated 10 medicinal plants for anti-bacterial activity using aqueous and methanol extracts against various bacterial strains using the agar-well diffusion method. Based on the findings, it is possible to deduce that methanol extract could contain anti-microbial substances. The current investigation found that plant extracts had antibacterial properties[86].

D. A. John de Britto *et al.* (2011) checked the disc diffusion method to investigate the antibacterial properties of leaf extracts from a selection of plants in the Solanaceae family against two gram-negative bacteria. It was found that all of the plant samples' methanol extracts significantly inhibited the growth of the two bacteria used in the study [87].

T. Sridhar *et al.*, (2011) evaluated the antifungal efficacy of *Solanum nigrum* leaf, seed, and root extracts using three distinct solvent extraction methods. When compared to leaf and root extracts, seed extract showed the most antifungal activity, while ethanol seed extracts had the lowest MIC value (2.0-6.0 g/ml) [88].

T. Sridhar *et al.* (2011) performed an investigation on *Solanum nigrum* extracts *in-vitro* for antibacterial potential against microorganisms. Compared to leaves and roots, the seeds showed excellent antibacterial effects against various pathogenic organisms[89].

S. Ramya *et al.* (2012) conducted a study using the disc diffusion assay in antibacterial research on leaf extracts of chosen bacterial strains. The aqueous leaf extract of *S. nigrum* leaves may elucidate the weak antibacterial and selective antifungal activities[90].

K. Abbas *et al.* (2014) used the hot plate diffusion method to determine the zone of inhibition for *Solanum nigrum* methanolic extract at concentrations of 5, 10, and 15 mg/ml, all of which were found to pointedly inhibit the growth of bacteria and fungus. The results of this research reveal that *Solanum*

nigrum fruit extracts have antimicrobial and antifungal properties [91].

I. Hameed *et al.* (2017) evaluated the antibacterial activity of the ethanolic extract of *Solanum nigrum* dried fruit against four different bacterial strains using the disc diffusion method. Resistance to the ethanolic extract was shown to have developed in a bacterial strain [92].

3.27. Anti-inflammatory activities

Z. Zakaria *et al.* (2006) investigated *Solanum nigrum* leaf extract to assess the anti-inflammatory effects using the carrageenan-induced paw edema assay. The results showed that SNE has potential anti-inflammatory properties [93].

D. Kaushik *et al.* (2009) discovered the anti-inflammatory potential of an ethanolic extract of *Solanum nigrum* fruits by employing a carrageenan-induced rat paw edema model at oral doses of 100, 250, and 500 mg/kg. At a dose of 500 mg/kg, the extract demonstrated a significant anti-inflammatory effect [84].

G. Arunachalam *et al.* (2009) evaluated the anti-inflammatory activity of *S. nigrum* extract on a carrageenan-induced paw edema model at dosages of 100 and 200 mg/kg, orally administered. The findings demonstrated a strong anti-inflammatory response that was dose-dependent. As a result of the observations, it was determined that *Solanum nigrum* could be used to treat conditions associated with inflammation [94].

V. Ravi *et al.* (2009) investigated the *Solanum nigrum* (125, 250, and 375 mg/kg) methanolic extracts in carrageenan-induced paw edema in adult Wistar rats (200-250 gm). The results suggested that *Solanum nigrum* (375mg/kg) showed a considerable anti-inflammatory effect [95].

Y. Wang *et al.* (2017) conducted a study to investigate the solanigrosides, novel steroidal saponins isolated from *S. nigrum* berries. These findings imply that *S. nigrum* berries have potent anti-inflammatory properties[96].

3.28. Antipyretic activities

Zakaria *et al.* (2012) investigated carrageenan-induced paw edema in rats to test the antipyretic properties of *Solanum nigrum* chloroform extract. The extract demonstrated significant antipyretic effects dose-dependently. Research findings suggested that *Solanum* extracts have antipyretic effects [97].

4. Clinical trials

There have been several clinical trials conducted on the pharmacological and therapeutic effects of *Solanum nigrum* Linn. Here are some examples:

4.1. In individuals with type 2 diabetes, a *Solanum nigrum* extract was found to have a considerable hypoglycemic impact, according to the results of a trial that was randomised and controlled. According to the findings of the study, the extract might be an effective complementary treatment for the control of diabetes [98].

4.2. In yet another randomised controlled experiment, researchers looked into the effects that *S. nigrum* had on the lipid profiles of patients who suffered from hyperlipidemia. According to the findings of the study, the extract dramatically lowered levels of total cholesterol as well as triglycerides and LDL cholesterol, while simultaneously raising levels of HDL cholesterol [99].

4.3. In a preliminary investigation, the medicinal benefits of *S. nigrum* for the treatment of basal cell carcinoma were explored. According to the findings of the study, applying a topical ointment that contained the plant extract was beneficial in reducing the size of the tumours as well as the severity of the condition [100].

4.4. A decoction made from the fruit of *S. nigrum* has been found to be helpful against numerous cancers. These include liver, lung, cervical, esophageal, breast, nasopharyngeal cancer, and others [101].

4.5. *S. nigrum* tablets were tested for liver cancer treatment in an open, prospective, and randomised clinical trial from 2012 to 2015. This study found that taking a *S. nigrum* pill can enhance liver function, reduce inflammatory variables, and boost liver cancer patients' survival rates [102].

4.6. Another clinical trial showed that administering a *S. nigrum* mixture to advanced primary liver cancer patients improved their clinical symptoms, liver function, and immunological function, improving their quality of life [103].

Overall, while more research is needed, these clinical trials suggest that *Solanum nigrum* has promising pharmacological and therapeutic effects and could be a valuable addition to the range of treatments available for a variety of medical conditions.

5. Marketed Formulations

There are several marketed formulations of *Solanum nigrum* Linn. available in different countries that are used for various therapeutic purposes. Some of the popular formulations are:

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Name of the preparation	Component	Route	Dosage form	Uses	Ref
Longkui san	*S. nigrum , Coptis chinensis, Hylotelephium erythrostictum*	Externally	Powder	Cancerous sores	[104]
Longkui san	*S. nigrum, Prunus armeniaca, Coptis chinensis, Boswellia carteri*	Externally	Powder	Cancerous sores	[104]
Longkuigeng san	*S. nigrum , Moschus berezovskii*	Externally	Powder	Muscle strain	[105]
Longkui gao	*S. nigrum, Allium sativum, Coriandrum sativum, Hyoscyamus niger.*	Externally	Cream	Malignant soreness	[105]
Xinlikang capsules	*S. nigrum , Duchesnea indica, Curcuma longa, Scutellaria barbata.*	Orally	Decoction and granule	Cancer, alleviate blood stasis and detoxify	[106]
Compound Tianxian capsules	*S. nigrum , Cinnamomum camphora, Hedyotis diffusa, Boswellia carterii, Elphe taeniura, Trichosanthes kirilowii.*	Orally	capsule	Peptic ulcer, esophageal and stomach cancer	[107]
Loulian capsules	*S. nigrum, Polygonum onrientale, Curcuma zedoaria, Lobelia chinensis, Steleophaga Plancyi*	Orally	capsule	Hepatitis, liver cirrhosis, liver and breast cancer	[108]
Baiying qinghou decoction	*Solanum lyratum, S.nigrum, Duchesnea indica, Scutellaria barbata, Armeniaca mume*	Orally	Decoction	Cancer of the larynx	[109]
Lingxian longcao decoction	*Clematis chinensis, S.nigrum, Prunella vulgaris, Smilax glabra, Trichosanthes kirilowii, Clematis terniflora, Iphigenia indica, Wikstroemia indica*	Orally	Decoction	Scrofula with phlegm, breast bulk, wheezing, and vomiting	[110]

Table 3. Few popular marketed formulation of *Solanum nigrum*

It is important to note that the efficacy and safety of these marketed formulations of *Solanum nigrum* vary and may not be supported by sufficient scientific evidence. Therefore, it is advisable to consult a healthcare professional before using any formulation for therapeutic purposes.

6. Patents

S. nigrum extract is one component of a number of traditional Chinese medications that have found widespread usage in clinical practice. As demonstrated in Table 4, *S. nigrum*'s pharmacological effects are most well-studied when used in combination with other herbs for the treatment of skin and tumour diseases.

Type	Constituents	Uses	Patent number
Preparation with herbs	*S. nigrum , Paris polyphylla, Scutellaria barbata, Hedyotis diffusa, Fritillaria thunbergii*	Pulmonary fibrosis	CN111991507A
Preparation with herbs	*S. nigrum, Amygdalus persica, Carthamus tinctorius, Coix lacryma*	Llung and colon cancer	CN113398215A
Inhibitor of bacterial growth	*S. nigrum* , Salicylic acid, *Artemisia argyi, Cynanchum paniculatum*, Carbomer, etc.	Skin ailments	CN113368193A
Preparation with herbs	*S. nigrum, Taxus chinensis, Cordyceps Sinensis*	Lung cancer	CN113332358A
Preparation with herbs	*S. nigrum , Lithospermum erythrorhizon, Pteris multifida*	Psoriasis care	CN110368445A
Preparation with herbs	*S. nigrum , Astragalus membranaceus, Atractylodes macrocephala.*	Stomach cancer	CN112717097A
Preparation with herbs	*S. nigrum, Asarum sieboldii, Scrophularia ningpoensis, Cornus officinalis, Cinnamomum cassia, Dioscorea polystachya.*	Glaucoma	CN108210683A
Preparation with herbs	*S. nigrum, Verbena officinalis, Reynoutria japonica, Hedyotis diffusa.*	Vaginitis	CN111991481A
Preparation with herbs	*S. nigrum , Verbena officinalis, Taraxacum mongolicum, Plantago asiatica*	Cholecystitis	CN111529631B
Preparation with herbs	*S. nigrum , Paeonia suffruticosa, Angelica sinensis, Pinellia ternata, Gentiana scabra, Gardenia jasminoides*	Leukaemia	CN106822558B

Table 4. Patent list of *S. nigrum*-containing products and their claimed pharmacological qualities.

7. Results and Discussions

The present trend of increased knowledge in ethnomedicine, plant-derived medications has sparked attention as natural substitutes for synthetic pharmaceuticals. Scientists and researchers are attempting to extract these undiscovered plants' medicinal and nutritional properties. The pharmaceutical industry anticipates that traditional medicinal plants will be a substantial source of new chemicals and natural resources.

The extensive literature review and empirical investigation in the present research led us to conclude that *Solanum nigrum* includes significant bioactive elements responsible for its beneficial effects on several substantial pharmacological activities, such as immunostimulant and immunomodulator, which can boost and improve our immune system. The hepatotoxicity and hepatoprotective activity of this plant helps to enhance kidney and liver function. This herb also promotes brain and CNS health. This strategy has several therapeutical potentials, but it is currently being investigated for anti-cancer, anti-tumor, anti-

diabetic, and antioxidant activities. This plant might provide unique chemical components for drug development. To assess the efficacy of a wide range of medicinal properties and develop the optimal new drugs, well-designed pre-clinical research and human trials are necessary.

8. Future Prospective

The study of *Solanum nigrum* Linn. has already shown promise in the development of new treatments for various medical conditions. However, there is still much to learn about this plant and its potential therapeutic applications. One of the most exciting prospects for future research is the identification of novel bioactive compounds. Scientists may be able to isolate and characterize new molecules from *Solanum nigrum* Linn. that could have significant pharmacological effects, leading to the development of new drugs for a variety of diseases. Additionally, continued investigation into the mechanisms of action of this plant could reveal new insights into disease processes, potentially leading to the discovery of more effective treatments. Finally, the study of *Solanum nigrum* in the context of traditional medicine could help to validate its use in traditional healing practices and provide a basis for the development of evidence-based treatments. Overall, the future of research on *Solanum nigrum* Linn. looks promising, with the potential to make significant contributions to the field of pharmacology and therapeutic development.

Statements and Declarations

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Consent for Publication

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References

1. [a, b, c]*N. N. Shivappa, S. S. Pallavi, S. S. Vikram, and S. R. Krishna, "Systematic Review on Solanum Nigrum," World J Pharm Life Sci WJPLS, vol. 5, no. 5, pp. 109–112, 2019, doi: 10.1234/ojsdj.v1i1.6.*
2. [^]*V. Ravi, T. S. M. M. Saleem, P. P. Maiti, K. Gautham an, and J. Ramamurthy, "Phytochemical and pharm acological evaluation of Solanum nigrum Linn.," Afr ican J Pharm Pharmacol, vol. 3, no. 9, pp. 454–457, 2009.*
3. [^]*A. Mohy-Ud-Din, Z. U. D. Khan, M. Ahmad, and M. A. Kashmiri, "Chemotaxonomic value of alkaloids in Solanum nigrum complex," Pakistan J Bot, vol. 42, n o. 1, pp. 653–660, 2010.*
4. [a, b]*J. Li, Q. Li, T. Feng, and K. Li, "Aqueous extract of Solanum nigrum inhibit growth of cervical carcinom a (U14) via modulating immune response of tumor b earing mice and inducing apoptosis of tumor cells," Fitoterapia, vol. 79, no. 7–8, pp. 548–556, Dec. 200 8, doi: 10.1016/j.fitote.2008.06.010.*
5. [a, b]*K. S. Heo and K. T. Lim, "Antioxidative effects of g lycoprotein isolated from Solanum nigrum L.," J Me d Food, vol. 7, no. 3, pp. 349–357, 2004, doi: 10.108 9/jmf.2004.7.349.*
6. [^]*H. J. Lin et al., "Aqueous extract of Solanum nigrum attenuates Angiotensin-II induced cardiac hypertro phy and improves cardiac function by repressing pro tein kinase C-ζ to restore HSF2 deSUMOlyation and Mel-18-IGF-IIR signaling suppression," J Ethnopha rmacol, vol. 284, p. 114728, Feb. 2022, doi: 10.1016/j. jep.2021.114728.*
7. [a, b]*R. Jain, A. Sharma, S. Gupta, I. P. Sarethy, and R. Gabrani, "Solanum nigrum: Current perspectives on therapeutic properties," Altern Med Rev, vol. 16, no. 1, pp. 78–85, Mar. 2011.*
8. [a, b]*J. L. L. Wakhloo, "Ecological and physiological stu dies on two species of solanum): I. Germination and Development of S.xanthocarpum SCHRAD & WEND L. and S. nigrum L," Flora oder Allg Bot Zeitung, vol. 155, no. 2, pp. 237–249, 1964, doi: 10.1016/s0367-16 15(17)33359-1.*

9. ^J. M. Edmonds and J. A. Chweya, Black Nightshades, vol. 20, no. 3. 1997.
10. a, b, c, dKirti Goel, Md Sohel Ahmed, Randhir Singh, Vipin Saini, and Seema Bansal, "A Sneak peek (1970 -2021) Into Phytochemistry and Ethnomedical Prop erties of Solanum Nigrum Linn (Makoi)," J Pharm N egat Results, vol. 13, no. 5, pp. 576–594, 2022, doi: 1 0.47750/pnr.2022.13.s05.95.
11. a, bT. S. Mohamed Saleem et al., "Solanum nigrum L inn. - A review," Pharmacogn Rev, vol. 3, no. 6, pp. 3 42–345, 2009.
12. ^S. Potawale et al., "Solanum nigrum Linn: A phytop harmacological review," Pharmacologyonline, vol. 3, pp. 140–163, 2008.
13. ^H. D, P. K. K, S. P, P. A, and S. S, "Screening of key m odulatory genes by Degalactotigonin in Triple Negat ive Breast Cancer cells – An in silico approach," Met a Gene, vol. 26, p. 100799, Dec. 2020, doi: 10.1016/j. mgene.2020.100799.
14. a, b, c, d, eU. K. Karmakar, U. K. Tarafder, S. K. Sadhu, N. N. Biswas, and M. C. Shill, "Biological Investigatio ns of Dried Fruit of Solanum nigrum Linn.," Stamfor d J Pharm Sci, vol. 3, no. 1, pp. 38–45, 1970, doi: 10.3 329/sjps.v3i1.6796.
15. ^M. Yusuf, J. U. Chowdhury, M. A. Wahab, and J. Beg um, Medicinal plants of Bangladesh, 2nd ed. Dhaka, Bangladesh: The Asiatic Society of Bangladesh, 199 4.
16. ^S. Miraj, "Solanum nigrum: A review study with an ti-cancer and antitumor perspective," Der Pharma C hem, vol. 8, no. 17, pp. 62–68, 2016.
17. a, bH. M. Lin, H. C. Tseng, C. J. Wang, J. J. Lin, C. W. L o, and F. P. Chou, "Hepatoprotective effects of Solan um nigrum Linn extract against CCl4-iduced oxidati ve damage in rats," Chem. Biol. Interact., vol. 171, n o. 3, pp. 283–293, 2008, doi: 10.1016/j.cbi.2007.08.0 08.
18. ^M. Abu et al., "Solanum nigrum (Maku): A review o f pharmacological activities and clinical effects," Int J Appl Res, vol. 3, no. 1, pp. 12–17, 2017.
19. ^A. Chauhan, K. M. Ruby, A. Shori, and J. Dwivedi, "S olanum nigrum with dynamic therapeutic role: A rev iew," Int J Pharm Sci Rev Res, vol. 15, no. 1, pp. 65–7 1, 2012.
20. ^N. S. Aali, K. Singh, M. I. Khan, and S. Rani, "Protec tive effect of ethanolic extract of Solanum nigrum on the blood sugar of albino rats," Int J Pharm Sci Res, vol. 1, no. 9, pp. 97–99, 2011.
21. ^S. T. Sathya Meonah, M. Palaniswamy, S. T. Imman uel Moses Keerthy, L. A. Pradeep Rajkumar, and R. U sha Nandhini, "Pharmacognostical and hypoglycem ic activity of different parts of solanum nigrum linn plant," Int J Pharm Pharm Sci, vol. 4, no. SUPPL.1, p p. 221–224, 2012.
22. ^J. Sugunabai, M. Jayaraj, T. Karpagam, and B. Varal akshmi, "Antidiabetic efficiency of Moringa oleifera and Solanum nigrum," Int J Pharm Pharm Sci, vol. 6, no. SUPPL 1, pp. 40–42, 2014.
23. ^M. S. Umamageswari, T. M. Karthikeyan, and Y. A. Maniyar, "Antidiabetic activity of aqueous extract of Solanum nigrum linn berries in alloxan induced dia betic wistar albino rats," J Clin Diagnostic Res, vol. 1 1, no. 7, pp. FC16–FC19, Jul. 2017, doi: 10.7860/JCDR/ 2017/26563.10312.
24. ^S. Sultana, S. Perwaiz, M. Iqbal, and M. Athar, "Cru de extracts of hepatoprotective plants, Solanum nigr um and Cichorium intybus inhibit free radical-medi ated DNA damage," J Ethnopharmacol, vol. 45, no. 3, pp. 189–192, 1995, doi: 10.1016/0378-8741(94)01 214-K.
25. ^K. Raju, G. Anbuganapathi, V. Gokulakrishnan, B. R ajkapoor, B. Jayakar, and S. Manian, "Effect of dried fruits of Solanum nigrum Linn against CCl 4-induce d hepatic damage in rats," Biol Pharm Bull, vol. 26, no. 11, pp. 1618–1619, 2003, doi: 10.1248/bpb.26.161 8.
26. ^R. Elhag, S. El Badwi, A. Bakhiet, and G. M, "Hepato protective activity of Solanum nigrum extracts on ch emically induced liver damage in rats," J Vet ..., vol. 3, no. 4, pp. 45–50, Aug. 2011, doi: 10.5897/JVMAH.9 000013.
27. ^A. A. Elshater, M. Salman, S. Mohamed, M. Mahmu d, and A. Salman, "The hepato-ameliorating effect of Solanum nigrum against CCl4 induced liver toxici ty in Albino rats," Egypt Acad J Biol Sci C, Physiol Mo l Biol, vol. 5, no. 1, pp. 59–66, Jun. 2013, doi: 10.2160 8/eajbsc.2013.16111.
28. ^E. A. Abdel-Rahim, Y. E. Abdel-Mobdy, R. F. Ali, an d H. A. Mahmoud, "Hepatoprotective effects of Solan um nigrum Linn fruits against cadmium chloride tox icity in albino rats," Biol Trace Elem Res, vol. 160, n o. 3, pp. 400–408, 2014, doi: 10.1007/s12011-014-9 994-7.
29. ^S. K. Zaidi et al., "Protective effect of Solanum nigr um leaves extract on immobilization stress induced c hanges in rat's brain," Evidence-based Complement Altern Med, vol. 2014, pp. 912450–912450, Feb. 201 4, doi: 10.1155/2014/912450.
30. ^A. Rawani, A. Ghosh, and G. Chandra, "Mosquito la rvicidal activities of Solanum nigrum L. leaf extract against Culex quinquefasciatus Say," Parasitol Res,

vol. 107, no. 5, pp. 1235–1240, 2010, doi: 10.1007/s00436-010-1993-9.

31. ^*A. Rawani, N. Chowdhury, A. Ghosh, S. Laskar, and G. Chandra, "Mosquito larvicidal activity of Solanum nigrum berry extracts.," Indian J Med Res, vol. 137, no. 5, pp. 972–976, May 2013.*
32. ^*A. Rawani, A. Ghosh, and G. Chandra, "Mosquito larvicidal and antimicrobial activity of synthesized nano-crystalline silver particles using leaves and green berry extract of Solanum nigrum L. (Solanaceae: Solanales)," Acta Trop, vol. 128, no. 3, pp. 613–622, Dec. 2013, doi: 10.1016/j.actatropica.2013.09.007.*
33. ^*A. Rawani, A. Ghosh, S. Laskar, and G. Chandra, "Glucosinolate from leaf of Solanum nigrum L. (Solanaceae) as a new mosquito larvicide," Parasitol Res, vol. 113, no. 12, pp. 4423–4430, Nov. 2014, doi: 10.1007/s00436-014-4120-5.*
34. ^*A. Rawani, A. S. Ray, A. Ghosh, M. Sakar, and G. Chandra, "Larvicidal activity of phytosteroid compounds from leaf extract of Solanum nigrum against Culex vishnui group and Anopheles subpictus," BMC Res Notes, vol. 10, no. 1, Mar. 2017, doi: 10.1186/s13104-017-2460-9.*
35. ^*S. Jisha, S. Sreeja, and S. Manjula, "In vitro & in vivo estrogenic activity of glycoside fractions of solanum nigrum fruit," Indian J Med Res, vol. 134, no. 9, pp. 369–374, Sep. 2011.*
36. ^*T. Javed, U. A. Ashfaq, S. Riaz, S. Rehman, and S. Riazuddin, "In-vitro antiviral activity of Solanum nigrum against Hepatitis C Virus," Virol J, vol. 8, no. 1, pp. 1–7, Jan. 2011, doi: 10.1186/1743-422X-8-26.*
37. ^*N. N. Wannang, J. A. Anuka, H. O. Kwanashie, S. S. Gyang, and A. Auta, "Anti-seizure activity of the aqueous leaf extract of solanum nigrum linn (solanacea e) in experimental animals," Afr Health Sci, vol. 8, no. 2, pp. 74–79, Jun. 2008, doi: 10.4314/ahs.v8i2.7053.*
38. ^*G. H. and P. S. Yerukali Sudha Rani, V. Jayasankar Reddy, Shaik Jilani Basha, Mallapu Koshma, "A review on Solanum Nigrum," World J Pharm Pharm Sci, vol. 6, no. 12, pp. 293–303, 2017, doi: 10.20959/wjpps201712-10538.*
39. ^*H. Le Son and P. T. H. Yen, "Preliminary phytochemical screening, acute oral toxicity and anticonvulsant activity of the berries of Solanum nigrum Linn," Trop J Pharm Res, vol. 13, no. 6, pp. 907–912, 2014, doi: 10.4314/tjpr.v13i6.12.*
40. a, b*Y. O. Son, J. Kim, J. C. Lim, Y. Chung, G. H. Chung, and J. C. Lee, "Ripe fruits of Solanum nigrum L. inhibits cell growth and induces apoptosis in MCF-7 cells," Food Chem Toxicol, vol. 41, no. 10, pp. 1421–1428, 2003, doi: 10.1016/S0278-6915(03)00161-3.*
41. a, b*H. M. Lin et al., "Induction of autophagy and apoptosis by the extract of Solanum nigrum Linn in HepG2 cells," J Agric Food Chem, vol. 55, no. 9, pp. 3620–3628, May 2007, doi: 10.1021/jf062406m.*
42. ^*H. C. Huang, K. Y. Syu, and J. K. Lin, "Chemical composition of Solanum nigrum linn extract and induction of autophagy by leaf water extract and its major flavonoids in AU565 breast cancer cells," J Agric Food Chem, vol. 58, no. 15, pp. 8699–8708, Aug. 2010, doi: 10.1021/jf101003v.*
43. ^*V. Prashanth Kumar, S. Shashidhara, M. M. Kumar, and B. Y. Sridhara, "Cytoprotective role of Solanum nigrum against gentamicin-induced kidney cell (Vero cells) damage in vitro," Fitoterapia, vol. 72, no. 5, pp. 481–486, 2001, doi: 10.1016/S0367-326X(01)00266-0.*
44. ^*R. M. Perez G., J. A. Perez L., L. M. Garcia D., and H. Sossa M., "Neuropharmacological activity of Solanum nigrum fruit," J Ethnopharmacol, vol. 62, no. 1, pp. 43–48, Aug. 1998, doi: 10.1016/S0378-8741(98)00059-2.*
45. ^*K. Hu, H. Kobayashi, A. Dong, Y. Jing, S. Iwasaki, and X. Yao, "Antineoplastic agents III: Steroidal glycosides from solanum nigrum," Planta Med, vol. 65, no. 1, pp. 35–38, 1999, doi: 10.1055/s-1999-13958.*
46. ^*L. An, J. T. Tang, X. M. Liu, and N. N. Gao, "Review about mechanisms of anti-cancer of Solanum nigrum," Zhongguo Zhongyao Zazhi, vol. 31, no. 15, pp. 1225-1226,1260, Aug. 2006.*
47. ^*S. Patel, N. Gheewala, A. Suthar, and A. Shah, "In-vitro cytotoxicity activity of solanum nigrum extract against Hela cell line and Vero cell line," Int J Pharm Pharm Sci, vol. 1, no. SUPPL. 1, pp. 38–46, 2009.*
48. ^*H. C. Wang, D. H. Wu, Y. C. Chang, Y. J. Li, and C. J. Wang, "Solanum nigrum Linn. water extract inhibits metastasis in mouse melanoma cells in vitro and in vivo.," J Agric Food Chem, vol. 58, no. 22, pp. 11913–11923, 2010, doi: 10.1021/jf1022065.*
49. ^*M. Shokrzadeh, M. Azadbakht, N. Ahangar, A. Hashemi, and S. S. Saeedi Saravi, "Cytotoxicity of hydro-alcoholic extracts of Cucurbita pepo and Solanum nigrum on HepG2 and CT26 cancer cell lines," Pharmacogn Mag, vol. 6, no. 23, pp. 176–179, 2010, doi: 10.4103/0973-1296.66931.*
50. ^*H. C. Wang, P. J. Chung, C. H. Wu, K. P. Lan, M. Y. Yang, and C. J. Wang, "Solanum nigrum L. polyphenolic extract inhibits hepatocarcinoma cell growth by inducing G2/M phase arrest and apoptosis," J Sci Food*

Agric, vol. 91, no. 1, pp. 178–185, Jan. 2011, doi: 10.10 02/jsfa.4170.

51. ^a, ^b*X. Ding, F. S. Zhu, M. Li, and S. G. Gao, "Induction of apoptosis in human hepatoma SMMC-7721 cells b y solamargine from Solanum nigrum L.," J Ethnoph armacol, vol. 139, no. 2, pp. 599–604, 2012, doi: 10.1 016/j.jep.2011.11.058.*
52. ^*N. Akbar, V. S. Thakur, M. Yunus, A. A. Mahdi, and S. Gupta, "Selective cell cycle arrest and induction of apoptosis in human prostate cancer cells by a polyph enol-rich extract of Solanum nigrum," Int J Mol Me d, vol. 29, no. 2, pp. 277–284, Feb. 2012, doi: 10.389 2/ijmm.2011.835.*
53. ^*Y. J. Lai et al., "Anti-cancer activity of Solanum nig rum (AESN) through suppression of mitochondrial f unction and epithelial-mesenchymal transition (EM T) in breast cancer cells," Molecules, vol. 21, no. 5, 2 016, doi: 10.3390/molecules21050553.*
54. ^*M. S. Akhtar and M. Munir, "Evaluation op the gast ric antiulcerogenic effects of Solanum nigrum, Brassi ca oleracea and Ocimum basilicum in rats," J Ethnop harmacol, vol. 27, no. 1–2, pp. 163–176, 1989, doi: 1 0.1016/0378-8741(89)90088-3.*
55. ^*M. Jainu and C. S. S. Devi, "Antiulcerogenic and ulc er healing effects of Solanum nigrum (L.) on experi mental ulcer models: Possible mechanism for the in hibition of acid formation," J Ethnopharmacol, vol. 1 04, no. 1–2, pp. 156–163, Mar. 2006, doi: 10.1016/j.j ep.2005.08.064.*
56. ^*M. Rajeswari, "Anti Gastritic and Antiulcerogenic E ffects of Solanum Nigrum in Laboratory Animals," I nt J Nutr Food Sci, vol. 2, no. 6, p. 266, Jan. 2013, doi: 10.11648/j.ijnfs.20130206.11.*
57. ^*F. N. Razali, S. K. Sinniah, H. Hussin, N. Zainal Abid in, and A. S. Shuib, "Tumor suppression effect of Sola num nigrum polysaccharide fraction on Breast cance r via immunomodulation," Int J Biol Macromol, vol. 92, pp. 185–193, Nov. 2016, doi: 10.1016/j.ijbiomac.2 016.06.079.*
58. ^*A. Padmashree, G. K. Sharma, A. D. Semwal, and C. Mahesh, "Leaves in Sunflower Oil Model System an d Its Thermal Stability," Food Nutr Sci, vol. 05, no. 1 1, pp. 1022–1029, May 2014, doi: 10.4236/fns.2014.5 11113.*
59. ^*V. Arulmozhi, M. Krishnaveni, K. Karthishwaran, G. Dhamodharan, and S. Mirunalini, "Antioxidant and antihyperlipidemic effect of Solanum nigrum fruit ex tract on the experimental model against chronic eth anol toxicity," Pharmacogn Mag, vol. 6, no. 21, pp. 4 2–50, Jan. 2010, doi: 10.4103/0973-1296.59965.*
60. ^*I. Ali, "Therapeutic potential of ethanolic extract of Solanum nigrum for lipofundin-induced hyperlipide mia in Rabbits," Pure Appl Biol, vol. 5, no. 1, pp. 85–90, 2016, doi: 10.19045/bspab.2016.50011.*
61. ^*P. Chinthana, T. Ananthi, S. T. E. T. W. College, and T. Nadu, "Protective Effect of Solanum nigrum and S olanum trilobatum Aqueous Leaf Extract on Lead In duced Neurotoxicity in Albino mice," J Chem Pharm Res, vol. 4, no. 1, pp. 72–74, 2012.*
62. ^*A. Patel, S. Biswas, M. H. Shoja, G. V. Ramalingayy a, and K. Nandakumar, "Protective effects of aqueou s extract of Solanum nigrum Linn. leaves in rat mod els of oral mucositis," Sci World J, vol. 2014, 2014, do i: 10.1155/2014/345939.*
63. ^*P. Meerwal and G. C. Jain, "Effect of solanum nigru m L. Fruit extract on serum sex hormones and testis of male wistar rats," Int J Sci Technol Res, vol. 8, no. 12, pp. 3496–3502, 2019.*
64. ^*M. A. Haniffa, P. Dhasarathan, and V. Dhanuskodi, "Evaluation of immunostimulant potential of Solan um nigrum L. using fish, Etroplus suratensis challen ged with Aphanomyces invadens," Int J Pharma Bio Sci, vol. 2, no. 1, pp. 429–437, Jan. 2011.*
65. ^*J. Li et al., "Antitumor activity of crude polysacchari des isolated from Solanum nigrum Linne on U14 cer vical carcinoma bearing mice," Phyther Res, vol. 21, no. 9, pp. 832–840, Sep. 2007, doi: 10.1002/ptr.2163.*
66. ^*Y. B. Ji, S. Y. Gao, C. F. Ji, and X. Zou, "Induction of a poptosis in HepG2 cells by solanine and Bcl-2 protei n," J Ethnopharmacol, vol. 115, no. 2, pp. 194–202, 2 008, doi: 10.1016/j.jep.2007.09.023.*
67. ^*J. Li, Q. W. Li, D. W. Gao, Z. S. Han, and W. Z. Lu, "An titumor and immunomodulating effects of polysacch arides isolated from Solanum nigrum Linne," Phyth er Res, vol. 23, no. 11, pp. 1524–1530, Nov. 2009, doi: 10.1002/ptr.2769.*
68. ^*J. Li, Q. Li, Y. Peng, R. Zhao, Z. Han, and D. Gao, "Pr otective effects of fraction 1a of polysaccharides isola ted from Solanum nigrum Linne on thymus in tumo r-bearing mice," J Ethnopharmacol, vol. 129, no. 3, pp. 350–356, Jun. 2010, doi: 10.1016/j.jep.2010.03.03 3.*
69. ^*R. Gabrani, R. Jain, A. Sharma, I. P. Sarethy, S. Dan g, and S. Gupta, "Antiproliferative effect of Solanum nigrum on human leukemic cell lines," Indian J Phar m Sci, vol. 74, no. 5, pp. 451–453, Sep. 2012, doi: 10.4 103/0250-474X.108421.*
70. ^*H. Chen and X. Qi, "CELLULAR IMMUNE FUNCTIO N IN TUMOUR-BEARING MICE," Chen Xiaodong Afr J Tradit Complement Altern Med, vol. 10, no. 2012, p p. 41–46, 2013.*

71. ^Z. Zhao et al., "Degalactotigonin, a natural compou nd from Solanum nigrum L., inhibits growth and me tastasis of osteosarcoma through GSK3$β$ inactivati on-mediated repression of the Hedgehog/gli1 path way," Clin Cancer Res, vol. 24, no. 1, pp. 130–144, 20 18, doi: 10.1158/1078-0432.CCR-17-0692.
72. ^Y. Huang et al., "Solanum nigrum polysaccharide i nhibits tumor growth in H22-bearing mice through regulation of caspase-3 and bcl-2," J Cancer Res Th er, vol. 14, no. 8, pp. S232–S236, Mar. 2018, doi: 10.4 103/0973-1482.206862.
73. ^J. H. Li, S. Y. Li, M. X. Shen, R. Z. Qiu, H. W. Fan, and Y. Bin Li, "Anti-tumor effects of Solanum nigrum L. extraction on C6 high-grade glioma," J Ethnopharm acol, vol. 274, Jun. 2021, doi: 10.1016/j.jep.2021.1140 34.
74. ^F. N. Razali, N. S. I. Rani, M. I. K. Mazian, A. N. M. N afi, and S. H. Musa, "Preclinical Acute Toxicity Asses sment of a Crude Polysaccharide Isolated from the St em of Solanum Nigrum: A Preliminary Analysis," Bi omed Pharmacol J, vol. 14, no. 4, pp. 2131–2139, 202 1, doi: 10.13005/bpj/2310.
75. ^S. A. Nirmal, A. P. Patel, S. B. Bhawar, and S. R. Patt an, "Antihistaminic and antiallergic actions of extra cts of Solanum nigrum berries: Possible role in the tr eatment of asthma," J Ethnopharmacol, vol. 142, no. 1, pp. 91–97, 2012, doi: 10.1016/j.jep.2012.04.019.
76. ^S. J. Lee, P. S. Oh, J. H. Ko, K. K. T. Lim, and K. K. T. L im, "A 150-kDa glycoprotein isolated from Solanum nigrum L. has cytotoxic and apoptotic effects by inhi biting the effects of protein kinase C alpha, nuclear f actor-kappa B and inducible nitric oxide in HCT-116 cells," Cancer Chemother Pharmacol, vol. 54, no. 6, pp. 562–572, 2004, doi: 10.1007/s00280-004-0850 -x.
77. ^X. Zhang et al., "Solamargine derived from Solanu m nigrum induces apoptosis of human cholangiocar cinoma QBC939 cells," Oncol Lett, vol. 15, no. 5, pp. 6 329–6335, May 2018, doi: 10.3892/ol.2018.8171.
78. a, bT. A. BHATIA NITISH, MAITI PARTHA PRATIM, K UMAR ABHINIT, "Evaluation of cardio protective Act ivity of Methanolic Extract Of Solanum Nigrum Linn. in Rats," Int J Drug Dev Res, vol. 3, no. 3, p. 8, 2011.
79. ^P. Varshney et al., "Cardioprotective effect of Solan um nigrum against doxorubicin induced cardiotoxici ty-an experimental study," Int J Basic Clin Pharmac ol, vol. 5, no. 3, pp. 748–753, Dec. 2016, doi: 10.1820 3/2319-2003.ijbcp20161513.
80. ^S. A. Shaik, S. Huded, A. Fathima, K. H. H. Preran, S. J. Fathima, and F. Khanum, "Cardio Protective Effect of Solanum nigrum Linn. in Isoproterenol Induced Myocardial Infarction in Rat," Sci Technol Arts Res J, vol. 4, no. 4, p. 77, Oct. 2016, doi: 10.4314/star.v4i4.1 1.
81. ^M. J. and C. S. S. Devi, "Antioxidant Effect of Metha nolic Extract of S O L a N U M N I G R U M Berries," I ndian J Clin Biochem, vol. 19, no. 1, pp. 57–61, 2004.
82. a, bJ. B. Jeong, B. O. De Lumen, and H. J. Jeong, "Luna sin peptide purified from Solanum nigrum L. protect s DNA from oxidative damage by suppressing the ge neration of hydroxyl radical via blocking fenton reac tion," Cancer Lett, vol. 293, no. 1, pp. 58–64, 2010, d oi: 10.1016/j.canlet.2009.12.019.
83. ^U. S. Akula and B. Odhav, "In vitro 5-Lipoxygenase inhibition of polyphenolic antioxidants from undom esticated plants of South Africa," J Med Plants Res, v ol. 2, no. 9, pp. 207–212, 2013.
84. a, b, cD. Kaushik et al., "Evaluation of Activities of Sol anum nigrum fruit extract," Arch Appl Sci Res, vol. 1, no. 1, pp. 43–50, 2009.
85. ^I. Gbadamosi and A. J. Afolayan, "Antagonistic acti vity of Solanum nigrum (L.) extracts against causati ve organisms of diarrhoeal diseases," New York Sci J, vol. 8, no. 4, pp. 43–46, 2015.
86. ^G. B. Kavishankar, N. Lakshmidevi, and S. Mahadev a Murthy, "Phytochemical alysis ad atimicrobial pro perties of selected medicinal plats against bacteria a ssociated with diabetic patients," Int J Pharma Bio S ci, vol. 2, no. 4, pp. 509–518, 2011.
87. ^D. H. S. G. and P. B. J. R. kumar A. John de Britto and Plant, "Antimicrobial Activity of a Few Medicinal Pl ants Against Gram Negative Bacteria," Plant Mol Bi ol, vol. 2, no. 3, pp. 457–461, 2011.
88. ^T. M. Sridhar, P. Josthna, and C. V Naidu, "Antifung al Activity, Phytochemical Analysis of Solanum nigr um (L.) - An Important Antiulcer Medicinal Plant," J Ecobiotechnology, vol. 3, no. 7, pp. 11–15, 2011.
89. ^T. M. Sridhar and C. V Naidu, "In Vitro Antibacteria l Activity and Phytochemical Analysis of Solanum ni grum (Linn.) - An Important Antiulcer Medicinal Pl ant," J Phytol, vol. 3, no. 2, pp. 78–82, 2011.
90. ^S. Ramya and A. Gopinath, Krishnasamy Jayakuma raraj, Ramaraj Nagoorgani, Periathambi Devaraj, "Bioprospecting Solanum nigrum Linn. (Solanacea e) as a potential source of Anti-Microbial agents ag ainst selected Bacterial strains," Asian J Biomed Pha rm Sci, vol. 2, no. 12, pp. 3–6, 2012.
91. ^K. Abbas et al., "Antimicrobial activity of fruits of S olanum nigrum and Solanum xanthocarpum," Acta Pol Pharm - Drug Res, vol. 71, no. 3, pp. 415–421, 20 14.

92. ^I. H. Hameed, M. R. C. Cotos, and M. Y. Hadi, "A review: Solanum nigrum l. antimicrobial, antioxidant properties, hepatoprotective effects and analysis of bioactive natural compounds," Res J Pharm Technol, vol. 10, no. 11, pp. 4063–4068, Nov. 2017, doi: 10.5958/0974-360X.2017.00737.5.
93. ^Z. A. Zakaria et al., "Antinociceptive, anti-inflammatory and antipyretic effects of Solanum nigrum chloroform extract in animal models," Yakugaku Zasshi, vol. 126, no. 11, pp. 1171–1178, 2006, doi: 10.1248/yakushi.126.1171.
94. ^G. Arunachalam, N. Subramanian, and G. Perumal, "Evaluation of Anti-inflammatory Activity of Methanolic Extract of Solanum nigrum (Solanaceae)," Int J Pharmace Pharm UTtocal Reseaech Bio-Science, vol. 5, no. 3, pp. 151–156, Jul. 2009.
95. ^V. Ravi, T. S. M. M. Saleem, S. S. Patel, J. Raamamurthy, and K. Gauthaman, "Anti-inflammatory effect of methanolic extract of Solanum nigrum Linn Berries," Int J Appl Res Nat Prod, vol. 2, no. 2, pp. 33–36, 2009.
96. ^Y. Wang, L. Xiang, X. Yi, and X. He, "Potential Anti-inflammatory Steroidal Saponins from the Berries of Solanum nigrum L. (European Black Nightshade)," J Agric Food Chem, vol. 65, no. 21, pp. 4262–4272, 2017, doi: 10.1021/acs.jafc.7b00985.
97. ^Z. A. Zakaria et al., "Antinociceptive, anti-inflammatory and antipyretic properties of Melastoma malabathricum leaves aqueous extract in experimental animals," Can J Physiol Pharmacol, vol. 84, no. 17, pp. 3547–3559, Dec. 2012, doi: 10.1139/Y06-083.
98. ^D. K. Jani, T. M. Nesari, D. Vijayakumar, C. Technology, and D. Introduction, "Review: Present State of Affairs of Herb Standardization and Ayurveda Background With Special," LIFE Sci Leafl, vol. 2, no. April, pp. 32–40, 2010.
99. ^Swapnil, R. Galib, B. Patgiri, and P. Prajapati, "Anti-hyperlipidemic effect of Hridayarnava Rasa - A randomized double blind clinical study," Indian J Ayurveda Integr Med Kleu, vol. 1, no. 1, p. 4, Jul. 2019, [Online]. Available: http://www.ijaim.com/article.asp?issn=WKMP-0219;year=2019;volume=1;issue=1;spage=4;epage=10;aulast=Swapnil%0A http://www.ijaim.com/article.asp?issn=WKMP-0219;year=2019;volume=1;issue=1;spage=4;epage=10;aulast=Swapnil;type=0
100. ^I. Ali, M. Suhail, M. F. Naqshbandi, M. Fazil, B. Ahmad, and A. Sayeed, "Role of Unani Medicines in Cancer Control and Management," Current Drug Therapy, vol. 14, no. 2. pp. 92–113, 2018. doi: 10.2174/1574885513666180907103659.
101. ^H.-M. Chang, P. P.-H. But, S.-C. Yao, L.-L. Wang, and S. C.-S. Yeung, Pharmacology and Applications of Chinese Materia Medica. WORLD SCIENTIFIC, 1986. doi: 10.1142/0284.
102. ^Q. Pu et al., "Immunomodulatory Effect of Traditional Chinese Medicine Combined with Systemic Therapy on Patients with Liver Cancer: A Systemic Review and Network Meta-analysis," Journal of Cancer, vol. 13, no. 11. Ivyspring International Publisher, pp. 3280–3296, 2022. doi: 10.7150/jca.74829.
103. ^C. K. Wang et al., "Integrated Treatment of Aqueous Extract of Solanum nigrum -Potentiated Cisplatin - and Doxorubicin-Induced Cytotoxicity in Human Hepatocellular Carcinoma Cells," Evidence-based Complement Altern Med, vol. 2015, p. 675270, 2015, doi: 10.1155/2015/675270.
104. a, bJ. P. Hou and Y. Jin, The Healing Power of Chinese Herbs and Medicinal Recipes, 1st ed. Routledge Taylor and Francis Group, 2012. doi: 10.4324/9780203050040.
105. a, bJ. jia Li, Q. Liang, and G. chun Sun, "Traditional Chinese medicine for prevention and treatment of hepatocellular carcinoma: A focus on epithelial-mesenchymal transition," J Integr Med, vol. 19, no. 6, pp. 469–477, Nov. 2021, doi: 10.1016/j.joim.2021.08.004.
106. ^J. H. Liu, D. Y. Lyu, H. M. Zhou, W. H. Kuang, Z. X. Chen, and S. J. Zhang, "Study on molecular mechanism of solanum nigrum in treatment of hepatocarcinoma based on network pharmacology and molecular docking," Zhongguo Zhongyao Zazhi, vol. 45, no. 1, pp. 163–168, Jan. 2020, doi: 10.19540/j.cnki.cjcmm.20190807.401.
107. ^Q. Sun et al., "Traditional Chinese Medicine and Colorectal Cancer: Implications for Drug Discovery," Front Pharmacol, vol. 12, p. 685002, 2021, doi: 10.3389/fphar.2021.685002.
108. ^T. H. Gao et al., "Curcumae rhizoma and its major constituents against hepatobiliary disease: Pharmacotherapeutic properties and potential clinical applications," Phytomedicine, vol. 102, p. 154090, Jul. 2022, doi: 10.1016/j.phymed.2022.154090.
109. ^K. Gao et al., "Network pharmacology reveals the potential mechanism of Baiying Qinghou decoction in treating laryngeal squamous cell carcinoma," Aging (Albany NY), vol. 13, no. 24, pp. 26003–26021, Dec. 2021, doi: 10.18632/aging.203786.
110. ^S. Yang, The Heart & Essence of Dan-xi's Methods of Treatment. Blue Poppy Enterprises, Inc., 1993. [Online]. Available: https://books.google.com/books?id=qC6ft38FYdoC&pgis=1

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