

# AN EDIBLE BERRY, SOLANUM NIGRUM A MEDICINAL PLANT AND ITS NEW FOOD PRODUCTS IN HEALTH IMPROVEMENT: A REVIEW

## Abstract

*Solanum nigrum* is an unexploited source of nutritional and medicinal properties. The plant belongs to the family Solanaceae, popularly known as black nightshade, and Makoya is an herbaceous and cotyledon plant. The most useful part of the plants is ripe blackberries, leaves, and to some extent young roots. The leaves and berries are abundant sources of nutrients, minerals, vitamins, and phytochemicals such as flavonoids, polysaccharides, glycoproteins, glycoalkaloids, and polyphenols. The plant is popularly known to contain a toxin named solanine, but as the berries mature the solanine content gets reduced and it can be edible. The plant is known to possess many positive health benefits such as hepatoprotective, anti-cancerous, antipyretic, anti-inflammatory, anti-ulcerative, and cytoprotective. As it holds lots of medicinal properties, we cannot waste the plant. So, food product development is the key to protecting their medicinal property and bringing it into the daily diet, to overcome several health issues. Very few products have been made from *S. nigrum* like vegetable soup, protein-based snacks, probiotic products, and natural antioxidants in refined oils. Lots of research shows its medicinal properties, about its nutrient content, so we can say *S. nigrum* is a storehouse of nutrients and nutraceuticals and can be a future food.

**Keywords:** *Solanum nigrum*; *S. nigrum*; solanine; Food products; edible berries, black nightshade

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## I. INTRODUCTION

Going back to Indian civilization and its old literature such as Bhagavad-Gita, Manu Smriti, and Purana's, every section of the society had its clear and separate belief systems regarding food and its selection [1]. Plants have always been a part of human life, since the paleolithic age. From our primordial literature of Ayurvedic (Indian and Chinese Traditional Medicine), Unani, and Siddha have an overabundance of knowledge, information, and benefits have been encountered in it. One of the latest concordats of Indian medicine shows 1000 years B.C, Charaka Samhita described the use of above 2000 medicinal herbs, whereas over 5700 herbal plants in the Chinese pharmacopeia have been listed [2]. Traditional sagacity about food processing, preservation, and therapeutic activity has been built for numerous generations. Through dietary components, food systems help to provide various physiological functions. As Indian conventional foods are considered a functional food because their components are rich in macro-micro nutrients, antioxidants, dietary fibers, and probiotics, which combinedly help in immunity, weight reduction, diabetes, and hypertension management [3].

*Solanum nigrum* belongs to the family Solanaceae is not an effectively used food crop that is known for its medicinal and nutritional bio-components. The plant is commonly known as Black nightshade (in English), Makoya or Kakamachi (in Hindi), Vanbhutka (in Bihar, India) is an herbaceous and dicotyledon plant. It is widely distributed across the world and mostly found in wild and exists as a famine food crop [4]. The plant of *Solanum nigrum* is erect, branched, divaricately, suffrutescent and unarmed. The plant is an annual herb with a growing size 90 cm and arranged with a multicellular glandular head. The leaves of *S. nigrum* are simple, ovate or oblong, alternate arrangement, glabrous, sinuate-toothed, and 3-7 cm long. The flowers 3-8 in extra-axillary drooping with umbellate cymes, petals are in whitish color with bright yellow anther. The fruit or berries of *S. nigrum* is purplish-black or orange-yellowish with many intact minute seeds, 5-10 mm in diameter in the globose shape. The seeds are too tiny (0.75-2.5 mm long), ovate and whitish-yellow in color [4,5,6]. **Table 1** describes the taxonomical classification and vernacular names depicted in **Table 2**.

**Table 1: Taxonomical Classification [4,5]**

<b>Kingdom</b>	<b>Plantae</b>
Subkingdom	<i>Tracheobionta</i>
Superdivision	<i>Spermatophyta</i>
Division Class	<i>Magnoliophyta</i>
Class	<i>Magnoliopsida</i>
Subclass	<i>Asteridae</i>
Order	<i>Solanales</i>
Family	<i>Solanaceae</i>
Genus	<i>Solanum</i>
Species	<i>Solanum Nigrum</i>
Authority	Linn.

**Table 2: Vernacular Names [4,5]**

Australia	Blackberry nightshade
Europe	Black nightshade, annual nightshade, garden nightshade
South Africa	Nightshade
New Zealand	Black nightshade
India	Dhvansamaci in Sanskrit
	Pitkachi in Assam
	Gudakamai in Bengal
	Makoya, Kakamachi, Kali makoy in Hindi
	Ganikesopu in Kannada
	Manatakkali in Malayalam
	Kamoni in Maharashtra
	Lunlunia in Orissa
	Mako, Peelak, Mamoli in Punjab
	Mako in Urdu

- Habitats and Distribution:** *Solanum nigrum* is found mostly around wastelands, in the cracks of old buildings, on roadsides, in cultivated lands with other crops, under the trees, and in shaded areas. The plant is mostly found in Europe and the African region, in North America, and it is cultivated for its fruit [6,7]. The species is considered a culinary herb and is reported in different continents of the world (such as in India, Japan, Kenya, Hawaii, Pakistan, China, Zimbabwe, and Mauritius) [13].
- Traditional Use:** The people of Uganda, Nigeria, Australia, and Tanzania consume the leaves as the vegetable source and the people of Ethiopia take the fruits when its violet-black in color. The people of Tanzania also take the root as a remedy for stomach aches [4]. In Mexico, Zimbabwe, and Rhodesia, the plant was used as a remedy for neurological diseases and also for dysentery, malaria, and blackwater fever [21, 22]. In Arab, the leaves were used in peptic ulcer and burn. In India, the root utilized in the treatment of wool sorter's disease and psoriasis, whereas ripe berries were used as tonic and diuretics for fever, ulcers, and diarrhea. In China green leaf juice was used during renal inflammation, bladder swelling, and gonorrhoea, whereas in Kenya green berries were used during toothache to relieve the pain [5,23].
- Ethnomedicinal Properties:** Apart from the whole plant, the fruits and leaves of *S. nigrum* are used as therapeutic intention. The leaves paste is used as a poultice in the gouty joint which helps in lowering the pain. The leaves are also used in dermatitis and skin-related diseases, used in tuberculosis treatment and it also induces diaphoresis, helping to reduce edema, vomiting, and nervous disorders. The leaves of the *S. nigrum* are well known for their high antioxidant and phenolic components and are still being discovered for curative usage for diseases like cancer and liver cirrhosis [11,12]. The decoction prepared from ripe berries and flowers is helpful in erysipelas and also reduces cough. Whereas the juice of ripe berries is used as a remedy for pulmonary-related diseases such as bronchitis and tuberculosis. It is also used in gastrointestinal disorders such as diarrhea, ophthalmopathy, anasarca, and heart-related diseases. Berries have

cathartic and diuretic properties. The tinny seeds have also medicinal properties which help in dizziness, dermatitis, and recurring thirst. The white taproot of *S. nigrum* is helpful in ophthalmopathy, rhinopathy, otopathy, and hepatitis. The whole plant is effective in curing various health issues such as cardiopathy, dropsy, nephropathy, and hemorrhoid as it has anti-inflammatory and antiseptic properties [6,8].

## II. PHYTOCHEMISTRY

*Solanum nigrum* holds various active components that are amenable to various activities. The major active compounds are polysaccharides, glycoproteins, glycoalkaloids, and polyphenol (such as catechin, gallic acid, caffeic acid, protocatechuic acid, epicatechin, naringenin, and rutin) [9,10].

The unripe berries are known to contain high glycoalkaloids (such as  $\alpha$  and  $\beta$ -Solamargine, solasonine, Solasodine, solanidine, and solanine) and their consumption is toxic to the human as well as to cattle. Solamargine and solasonine are basically present in leaves whereas solanine is known to be present in overall plants. As the plant grows the quantity of solanine content also increases [14]. Whereas the ripe berries contain very less alkaloids and it can be taken without any ill effects. There are various factors that can fluctuate the glycoalkaloid concentration in green berries such as environmental, genetics, edaphic, and seasonal factors. These glycoalkaloids are known to be responsible for anti-cancer activity. During fruiting and flowering, the solasonine and solamargine concentrations were found at their peak [15].

The phytochemical analysis demonstrates the presence of two steroidal oligoglycosides (also known as steroidal saponin) named nigrumnin-I and nigrumnin-II [16]. Some researchers reported three steroidal glycosides isolated from *S. nigrum*, degalactotigonin,  $\beta$ -2- solamargine, and solamargine [17]. The leaves of *S. nigrum* contains two quercetin glycosides are quercetin 3-O- $\alpha$ -rhamnosyl (1 $\rightarrow$ 2)- $\beta$ -galactoside and 3-O-(2<sup>Gal</sup>- $\alpha$ -rhamnosyl)- $\beta$ -glucosyl (1 $\rightarrow$ 6)- $\beta$ -galactoside, along with 3-gentiobioside, 3-glucoside, 3-glucosyl (1 $\rightarrow$ 6) galactoside, and 3-galactoside type quercetin also found in the leaves [18].

The 60% ethanolic extract from the dried herb of *S. nigrum* is known to contain two pregnane saponins named solanigroside-A and solanigroside-B [19]. The non-saponin content from *S. nigrum* was recognized as 6-methoxy-hydroxycoumarin, p-hydroxybenzoic acid, pinosresinol-4-O- $\beta$ -D-glucopyranoside, syringaresinol-4- $\beta$ -D-glucopyranoside, 3,4-dihydroxybenzoic acid, adenosine, and 3-methoxy-4-hydroxybenzoic acid [20]. The diosgenin and tigogenin were pointed out as steroidal saponin from both unripe fruit and vegetative part of the plant and used in manufacturing as hormonal steroids. The fruit of *S. nigrum* is known to contain 15-20% of sugar (such as glucose and fructose) and precursors of vitamin A ( $\beta$ -carotene), whereas the green leaves contain vitamin C of 1mg/100 g [5].

## III. NUTRITIVE VALUE OF *SOLANUM NIGRUM*

*Solanum nigrum* is known to contain several nutrients and other phytochemicals. The leaves, berries, and seeds are good sources of protein and dietary fiber as also vitamins and minerals. The Nutritive value along with the Chemical composition of the seed oil and fatty

acid compositions Vitamin content, Minerals Content, and Anti-nutritional factors of *Solanum nigrum* is depicted in **Table 3, 4, 5, 6, and 7.**

**Table 3: Chemical Composition of the *Solanum Nigrum* Leaves, Berries, and Seed [13]**

Component	leaves	Ripe Berries	Seeds
Calories (Kcal)	60.75	73.98	126.84
Moisture	78	60.30	8.1
Dietary Fibre	1.2	1.5	1.3
Ash	7.8	5.3	3.6
Crude Fat	2.59	3.50	8.56
Crude Protein	5.2	5.5	7
Total Carbohydrates	4.36	5.12	5.45

**Table 4: *Solanum Nigrum* Seed oil and Fatty Acid Compositions [13]**

Parameters	S. Nigrum (value %)
Palmitic Acid	10.19
Linoleic Acid	65.45
Linolenic Acid	0.85
Oleic Acid	16
Stearic Acid	4.8
Palmitic Acid	10.19

**Table 5: Vitamin Content [13]**

Vitamin	Values (mg/Kg)
Vitamin B <sub>1</sub>	3.5
Vitamin B <sub>2</sub>	1.8
Vitamin B <sub>3</sub>	36.2

**Table 6: Minerals Content [13]**

Minerals	Values (mg/100 g)
Sodium	6.18
Magnesium	182.3
Potassium	34.41
Calcium	73
Iron	3.8
Copper	10
Zinc	14

**Table 7: Anti-Nutritional Factors [13]**

Component	Content (g/100 g Dry Weight)
Trypsin	1.01
Phytate	0.13
Tannins	0.17

#### IV. CLINICAL INDICATION AND MEDICINAL USE

- 1. Antioxidant Activity:** The *S. nigrum* contains glycoprotein was removed and tested for its antioxidant effect by using 1,1-diphenyl-2-picrylhydrazyl (DPPH) on oxygen-free radicals. The glycoprotein found maximal free radical scavenging activity in low pH up to 60<sup>0</sup> C. The glycoprotein found minimum activities under EDTA, and that activity was independent on M<sup>2+</sup> ions (Ca<sup>2+</sup> and Mg<sup>2+</sup>) in the presence of EDTA. When these glycoproteins were treated with pronase E and NaIO<sub>4</sub> (deactivating agents), then the scavenging activity of DPPH was decreased in comparison with glycoproteins. Under the optimal condition, the antioxidant effect of glycoprotein was found high scavenging activity on both superoxide anions and on hydroxyl radicals. The glycoprotein of *S. nigrum* was found more effective antioxidant agent against hydroxyl radical in cell culture (NIH/3T3). The glycoprotein (20mg/ml) found scavenging activity corresponds to vitamin C on superoxide anion, whereas the hydroxyl scavenging activity in corresponds to catalase (0.1mg/ml). So, it shows that the glycoprotein from *S. nigrum* has active antioxidant properties [24]. One more study shows that the leaves and fruits can be used as health supplements as it has a rich source of antioxidants [25]. The Fourier transform infrared spectroscopy shows the leaf extract of *S. nigrum* contains proteins and flavonoids, which strongly reduces the zinc acetate and DPPH free radical scavenging [26].
- 2. Hepatoprotective Effect:** To detect the liver protective effect of *S. nigrum*, the alcoholic extract of berries was used and introduced intravenously at a dose of 250mg/kg in the rat subject. It shows the protective effect against carbon tetrachloride (CCl<sub>4</sub>). When CCl<sub>4</sub> was introduced, the alanine transaminase (ALT), Aspartate aminotransferase (AST), bilirubin, and alkaline phosphatase were increased in serum. When the ethanolic extract was administered was found to lower the bilirubin along with serum enzymes, which proves that the ethanolic extract of *S. nigrum* was effective to maintain the integrity of hepatic cell structure and regenerate the damaged liver cells [27]. The ethyl acetate and methanol leaf extract from *S. nigrum* were found to contain phenolic and flavonoids by using the spectrophotometric method, which shows the hepatoprotective effect and antioxidant activity [28].
- 3. Anti-Cancer Properties:** The crude polysaccharide from *S. nigrum* was inspected on tumor cell. The crude polysaccharide had an inhibitory effect on U14 cervical cancer cells. When the crude polysaccharide was administered for 12 days, found the apoptotic tumor cell significantly increased along with Bax expression where the Bcl-2 and mutant P-53 were considerably reduced in the cervical cancer section. In addition, the crude polysaccharide from *S. nigrum* helped to reduce the level of tumor necrosis factor-alpha in serum. These results suggest that there was a correlation between crude polysaccharide

administration and depletion of tumor necrosis factor-alpha in serum, which results in tremendous necrosis in the tumor cell, and also cause increased the function of Bax and reduce the function of mutant-53 and Bcl-2 gene which set off apoptosis in cancerous cells. These results show that the crude polysaccharide from *S. nigrum* had a potential effect on tumor cells [29]. Additionally, other studies bring attention that the alkaloid from *S. nigrum* intervenes in the anatomy and physiology of tumor cells by disorganizing the DNA formation and cell cycle distribution and thus reduces the tumor cell activity. Whereas, the glycoprotein from *S. nigrum* blocks the anti-apoptotic pathway of NF-kappa B, activates caspase cascades reaction, increases the nitric oxide production, and shows anticancer activity [30]. Two new steroidal alkaloids from ripe fruit of *S. nigrum* show cytotoxicity against HT-29, A549, and lewis cell lines [31].

- 4. Antiulcerogenic Activity:** The peptic ulcer has multiple etiological disorders, caused due to increased gastric juices (pepsin), HCl acids, indomethacin a non-steroidal anti-inflammatory drug and *Helicobacter pylori* infection which causes damage to the mucosal layer of the stomach. Prostaglandin, that helps in the synthesis of the mucosal layer of the stomach. The extract of *S. nigrum* shows the ulcer protective activity against cold restraint induced ulcer (CRU), pyloric ligation (PL) and indomethacin (IND). The CRU is due to more acid secretion and free radicals in the stomach, the extract had a potential effect against CRU due to its high anti-oxidant activity, which reduces acid secretion and prevents ulceration by inducing prostaglandin synthesis.

Moreover, the acid secretion in the stomach is due to the vagus nerve and proton pumping  $H^+K^+ATPase$ , So *S. nigrum* extracts help in reducing the gastric and pepsin secretion, which shows antisecretory action [32].

- 5. Neuropharmacological Effect:** The ethanolic extract of *S. nigrum* fruit was used to assess the neuropharmacological activity on the Wistar rat, by using a different neuropharmacological test such as motility test, motor incoordination test (such as traction, chimney, rotarod, and inclined test), behavior pattern test (such as Y-maze, evasive and head dip test), pentobarbital-induced sleeping test and anticonvulsant activity tests were used. The effective dose of 255mg/kg of fruit extract decreases restlessness and alertness. The ethanolic extract did not show any motor incoordination or sedation. They reduce spontaneous motor activity and potentiated pentobarbitone-induced hypnosis, which indicates the central depressant effect [21].
- 6. Antinociceptive, Anti-Inflammatory, and Antipyretic Activity:** The chloroform leaf extract of *S. nigrum* shows antipyretic, anti-inflammatory, and antinociceptive activity. The chloroform leaf extract was developed by soaking (1:20; w/v) with leaves powder in chloroform for 72 hours then let for evaporation at 40<sup>0</sup> C to make the dry form of 1.26 g which was then dissolved in dimethyl sulfoxide (in 1:50; w/v concentration). The clear liquid after settling was used as the stock solution with a 200mg/kg dose, which was diluted to 20 and 100 mg/kg by using dimethyl sulfoxide, and the doses were given (10 ml/kg) in the model prior to the test [33]. The aqueous leave extract of *S. nigrum* in the concentration of 10, 50, and 100% was developed by soaking (1:20; w/v) with 20gm dried leaves powder in processed water for 72 hours. The aqueous extract was given to the beneath of the skin in the model prior to 30min of the test, the effect was evaluated by

brewer's yeast-induced pyrexia and the carrageenan-induced paw edema test shows significant ( $p < 0.05$ ), antipyretic, anti-inflammatory, and antinociceptive activity [34].

- 7. Cytoprotective Function:** The cytoprotective effect in Vero cells against gentamycin-induced toxicity was clinically tested by introducing 50% ethanolic extract from the entire plant of *S. nigrum*. The cytotoxicity was evaluated by hydroxyl radical scavenging, mitochondrial dehydrogenase activity, and Trypan Blue exclusion methods. The 50% ethanolic extract was effective to protect the Vero cell from gentamycin, this is due to the increased free radical scavenging enzyme of free radicals [35].
- 8. Molluscicidal and Larvicidal Properties:** The ethanolic extract was formed by soaking the leaves powder of *S. nigrum* overnight in cold 70% ethanol, the extracts show Molluscicidal activity (LC-50 3.37mg/L, within 24 hours) as well as a larvicidal effect against *Culex pipiens* and *Aedes caspius* (LC-50 21.38 and 38.11mg/L within 48 hours and 51.29 and 125.89mg/L within 24 hours, respectively). The ethanolic leaf extract of *S. nigrum* shows Molluscicidal and larvicidal activity [36].

## V. NEW FOOD PRODUCTS FROM *SOLANUM NIGRUM*

As per International Food Information Council, functional foods are the foods that endow significant health advantages beyond underlying nutrition. Almost all the foods that are sold in the markets are processed food with enriched food products, The functional component of food products are oligosaccharides as functional carbohydrates, lipoproteins, and glycoproteins as functional protein, functional lipids, phenolic and isoprenoids, pre-and pro-biotics, mineral and micronutrients [37]. Generally, these constituents are present in the food or formulated with foods that play an effective role in health regulation and in its improvement. This functional component helps to overcome major health complications such as diabetes, cardiovascular disease, and hypertension.

- 1. Functional Soup Preparation:** The leaves of *S. nigrum* are an unexplored source of medicinal and nutritional properties. A study shows the leaves of *S. nigrum* soup are highly nutritious, for the formulation of leaf soup D-optimal mixture designs were chosen. The soup was found rich in functional properties, and hydration quality and was organoleptic acceptability. The mixture of leaf powder, starch, and spices in the proportion of 4%, 30%, and 66% was found similarity (color, taste, flavor, and mouthfeel) in context with the market available sample. The soup was highly nutritious and rich in gallic acid (32mg), tocopherol (10mM), crude protein (31.74%), carbohydrates (27.3%), and crude fiber content (9%) [38].

Another study also shows the soup prepared from *S. nigrum* leaf was highly nutritious and used as a functional food. In this study, two sensory evaluation test was done to assess its acceptability. The sample soup (3% leaf powder+ 35% starch+ 62% spices) was found more organoleptically acceptable with a sensory score (6.4), but on Fuzzy logic sensory analysis of third number samples (containing 1% leaf powder, 28% starch, and 68% spices) got higher similarity index (0.92) [39].



2. **Chicken Protein-Based Shelf-Stable Snacks:** A chicken protein-based shelf-stable snack was prepared from *S. nigrum*. The snack was found to ameliorate microbial stability as well as lipid peroxidation. In the study, the snack was prepared by using the chicken powder in the concentration of (20%, 30%, and 40%), and the result shows the snacks containing a maximum concentration of chicken powder (40%), *S. nigrum* extract (1%) were having higher sensory attribute along with 75 days of storing capacity at 25<sup>0</sup> C. The total phenolic content and 1,1-diphenyl-2picrylhydrazyl radical scavenging activity were 80 mg GAE/g and 79%. The *S. nigrum* chicken-based snack remarkably lowered the thiobarbituric acid, free fatty acids (FFA), and microbial count and enhances the sensory quality and nutritionally rich and immune booster snack [40].
3. **Thermal Stability And Antioxygenic Activity in the Cooking Oil:** The various solvent leaf extract of the plant *S. nigrum* was used to assess the antioxidation and thermal stability by using sunflower oil. The fraction of leaf powder and methanol/water of 80:20 was found most effective antioxidant activity. The thermal activity at 80<sup>0</sup> C for 24 hours of refined sunflower oil by using leaf powder and methanol/water extract of 80:20 showed to inhibit the thermal oxidation of the oil. The fatty acid content of *S. nigrum* leaf shows 59.1%. So, *S. nigrum* can be used as a natural antioxidant to prevent the oil from peroxidation while cooking the food [41].
4. **Probiotics from *S. Nigrum*:** A value-added pro-biotic food product was developed from *S. nigrum* and *Amaranthus hybridus*. A total of 50 lactic acid-producing bacteria were identified from these vegetables and found active for bile tolerance (12 strains were able to surmount at 0.3% bile broth), and found effective for probiotic activity [42].

## VI. CONCLUSION

*Solanum nigrum*, an extensively used in oriental medicine. The plant holds various activities such as anti-inflammatory, antioxidant, diuretics, hepatoprotective, antipyretics, anti-cancerous, and other positive effects. The in-vivo activity of the isolated component from *S. nigrum* has been also considered in much research. The aqueous and alcoholic extracts from the plant are used in many polyherbal formulations and are an alternative source to nutraceuticals with great advantages. There is a need to pick out a suitable technique to utilize *S. nigrum* for a different purpose. As we have already seen that many researchers claimed its health benefits, so it can advocate as a useful medicinal plant for mankind. The berries are highly nutritious and can include in the diet to restrain hidden hunger. So, the plant especially berries can apply more in food processing industries to develop novel functional food with nutritional and nutraceutical quality.

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