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Overview of the Biochemical Potential of *Solanum Nigrum*

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***Abstract*— *Solanum nigrum* is known locally as the nightshades amily, and it is considered one of the widespread plants that possess great biochemical potential. This review dealt with providing a comprehensive summary of the biochemistry of this plant, as it contains Solanum nigrum. It contains an important group of biologically active substances, including flavonoids, and some phenolic derivatives. It also contains some alkaloids, epoxy derivatives, and other important compounds. These substances have important biological activity, including significant and powerful antioxidant and anti-inflammatory properties, as well as strong antimicrobial and anti-cancer properties, and other medically important properties. This plant has been used for medicinal purposes for a long time in treating many diseases. Finally, this review indicates the wide biological diversity in biochemistry. The study also touched on some potential applications in various fields, including nutrition and medicine.**

***Keywords*— Solanum nigra, Solanaceae family, antioxidant, anti-cancer, flavonoids.**

I. INTRODUCTION

Human have used plants found in nature as folk medicine throughout the ages [1], as more than 2,000 tropical and subtropical regions around the world have different species belonging to the Solanaceae family [2] and the Solanum nigrum plant was one of the very important plants for treating different types of diseases. Including inflammatory fever and some intestinal diseases, it has also been used as a pain reliever and has also been used against some sexually transmitted diseases [3]. The reason is that different ethnics have been using this plant in different forms of traditional medicine due to the medicinal properties obtainable. Moreover, it is used to solve rectum and colorectal issues, sexually transmitted diseases, and other infections. It is also used as an anticytokine drug, addressing abnormalities such as inflammation, any skin disorder, digestive tract malfunctions, and other complications of the respiratory system. It is equally used for diuretic purposes and muscle-free pains [4]. The bioactive chemicals present in this composition include flavonoids, alkaline substances, phenolic molecules, and glycoalkaloids such as solasonine and solamargine, among others. Some studies have shown that these chemicals are responsible for certain pharmacological effects such as antioxidant properties which provide an anti-inflammatory action toward cells or tissues thereby preventing damage from free radicals' oxidation, inhibiting microorganisms and fungi leading to prevention against infections by them on wounds or any other body parts exposed to bacteria among others, while some argue that they prevent cancer by killing cancerous cells leading to the death of malignant tumor cells originating from it; still others hold this substance acts on the liver reducing oxidative stress therefore protecting it from any damage whatsoever caused by oxidant species or those toxins that cause intoxication while yet since these components work within the pancreas organ therefore may be useful towards managing diabetes mellitus not forgetting about the great potential implicated in this particular disease's treatment schematic [5]. Solanum nigrum is a weed found in nitrogenous grounds, areas with amentaceous vegetation, and gardens. An infusion of the plant may be used as an enema for children going through abdominal upsets. It is a home remedy for anthrax pustules and it is locally applied. A freshly prepared extract from this plant is effective against cirrhosis of the liver, additionally; it acts as its opium-poisoning antidote [6]. Even though Solanum nigrum appears to be an important medicinal plant, it must be noted that further studies are still needed to understand the mechanisms of action involved, establish an optimal dosing regimen, and evaluate safety profiles. The objectives of the research are to describe and identify the bioactive components of Solanum nigrum, comprehend how they interact with biological systems, and investigate possible traditional medicinal applications for it.

II. TAXONOMY OF PLANT [7]

Kingdom:	**Plantae**
Division:	**Magnoliophyte**
Class:	**Mangoliopsida**
Genus:	***Solanum***
Species:	***nigrum***

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III. Description and Distribution of Botany

Herb *S. nigrum*, also known as nigrum, is an annual. Its upright, 25–100 cm high leaves are dull to dark green, with bifurcated stems and ovate, oblong, or lanceolate, sinuate, or toothed see Picture (1) (2). It has 3–8 white flowers and tiny, mature berries, about 10 mm in diameter, that are usually reddish brown or black [5, 8]. Based on the traits of its leaves, flowers, and fruits that set it apart from deadly nightshade, it has several other descriptive names. Despite its origins in Eurasia, people from that continent brought it to Australia, the Americas, and South Africa. Still, it was there that it was initially found. In addition, several other nations, including some Asian countries like India, Afghanistan, Bangladesh, Bhutan, Indonesia, Iraq, Iran, Japan, Pakistan, Europe, North America, South America, Brazil, Peru, Colombia, and a variety of other countries [7].

Picture (1, 2): *Solanum nigrum* plant.

IV. Toxicity of Solanum nigrum plant

Black nightshade is an annual plant that grows wild in India's shady regions up to an elevation of 7000 feet. It is small and erect. It usually grows next to crops used as fodder. This fast-growing toxic plant often taints animal grazing areas, endangering livestock as well as humans who consume the meat and milk from these animals. The toxicity of silver is a result of several chemicals and factors. Berries from this plant provide steroidal glycoalkaloids such as α-solanine and α-chaconine [9]. The leaves and stalks are also a good source of calcium, magnesium, phosphorus, iron, and nitrates, among other minerals [10]. The main contributors to the toxicity are the glycoalkaloids and nitrates present in different parts of this plant. Nitrates are dangerous for human health. When they are absorbed and transformed to nitrites, they interact with Fe2+ ions that exist in hemoglobin, decreasing the quantity of oxygen in blood [11, 12]. The often observed high levels of nitrates in this plant, which peak when the plant goes into blossom, may potentially cause N-NO poisoning by interacting with the –NH-group of the glycoalkaloids. After investigating this causal issue, suitable remedial measures are suggested. The study investigates the toxicity of Solanum nigrum extract (Sn) and its potential remedy. The -N-NO derivative, produced through HNO2, was found to cause toxicity in animals. The study also found that magnesium conjugation with Sn glycoalkaloids prevented N-nitrosation and reduced toxicity. The study also highlighted the beneficial role of other metal ion conjugation with Sn-glycoalkaloids [9].

V. Chemical constituents

Over 180 phytochemical compounds have been identified in different parts of S. nigrum. These include alkaloids, steroidal molecules, flavonoids, organic acids, glycosides of phenylpropanoids along with other groups of compounds such as polysaccharides [9].

A. Alkaloids

Although other types of alkaloids have been identified, the main alkaloids present in S. nigrum consist of steroidal alkaloids such as solanine, which are present as glycosides in the leaves, fruits, roots, and stems [13]. The immature fruit has a concentration of these compounds reaching levels as high as 4.2% content. However, as the plant grows the content gradually decreases. Respectively, solasonine and solamargine make up 0.2% and 0.25%, and after alkaline hydrolysis, the glycoside of both compounds is solasodine [14]. Solamargine has been identified to have inhibitory activity against cancers of the cervix, liver, lung, larynx, and esophagus, as well as cholangiocarcinoma cancer [15, 16].
As the leaf grows, the total amount of alkaloid in it increases, but the concentration becomes diminished. The small green fruit contains high levels of solasodine, and as with the leaf, as it matures, the absolute amount and concentration of solasodine in each fruit decreases [17]. Throughout most of the plant, the glycoalkaloids, solanine is present as a phytoalexin making up some 95% of its total alkaloid content. When raw, the fruit has the highest level of solanine, but as the plant matures, the concentration eventually becomes lower [18, 19].

B. Saponins

Solanum nigrum leaves contain a family of compounds known as Saponins. These chemicals have been researched for their ability to inhibit the growth of fungi, kill microorganisms, and reduce inflammation [20]. Solanum nigrum leaves have historically been employed for several therapeutic applications. The following are documented medical applications of Solanum nigrum leaves. It is worth noting that these uses have been traditionally associated with Solanum nigrum leaves [21].

C. Phenylpropanoids

These include phenylpropionic acids and their esters, coumarin, and lignans, which have been identified in the whole plant [14].

D. Flavonoids

Flavonoids have various effects which are typically anti-inflammatory and antioxidant [22, 23] . The latter activity is closely aligned to the flavonoid content of the plant. Flavonoids, polyphenolic compounds with medicinal effects, are crucial in assessing species relationships and phylogenetic relationships. They are often used in GC-MS analysis to characterize favonol aglycons in plants like tomatoes and Propolis. However, there is a lack of research on analyzing flavonoids of the S. nigrum Complex using GC-MS and chemotaxonomy. This study aims to study their flavonoid profiles by comparing total flavonoid contents, quantitative comparison of quercetin aglycon, and qualitative study of their glycosides using Total Linguistics (TLC) [18, 24].

E. Phenolic

Gallic acid, caffeic acid, quercetin, catechins, rutin, protocatechuic acid (PCA), epicatechins naringenin, and flavonoids act primarily as antioxidants scavenging free radicals. Total flavonoid and phenolic concentrations were respectively estimated to be 2262.81 mg/g quercetin equivalents and 3222.66 mg/g gallic acid equivalents [16, 25, 26].

F. Polysaccharides

At present, 12 different types of polysaccharides have been identified, that are reported to have immunomodulatory, antitumor, and hepatoprotective effects [14].

G. Benzoic Acids

These include 2, 4-dihydroxybenzoic acid, vanillic acid, protocatechuic acid, 4- hydroxybenzoic acid, 2,5-dihydroxybenzoic acid, and salicylic [9] which have antioxidant, anti-inflammatory, antiviral and antibacterial activities.

H. Other Compounds

These include citric acid, ursolic acid, malic acid, tartaric acid, and acetic acid as well as minerals such as Ca, K, Mg, Na, Fe, Zn, and Mn. The root and fruit also contain vitamin C with the highest concentration in the latter [20] and as well as containing lipids, the seeds also have a moderate amount of protein.

VI. BIOCHEMICAL ACTIVITIES

A. The activity of antioxidants

Antioxidants found in the leaves of Solanum nigrum contribute in the scavenging of free radicals and protect against oxidative stress. Eating the leaves or consuming preparations produced from them may help the body's defense mechanisms against free radicals in general [16, 27-29] . A study revealed that inoculation with endophytes bacteria can enhance plant growth, especially at low concentrations of cadmium, by improving nutrient absorption and antioxidant enzyme activities [30].

B. Anti-inflammatory properties

Given the prevalence of pain and inflammatory diseases among individuals, Solanum nigrum Linn. plays a crucial role in the management of inflammation. Inflammation is caused by the production of complex mediators such as prostaglandins and leukotrienes by leukocytes. Solanum nigrum Linn has the potential to mitigate inflammation. The methanolic extract of the plant's berries was given to experimental animals at a dosage of 375 mg/kg body weight, and it demonstrated strong anti-inflammatory effects. The most prominent and often used approach for examining the anti-inflammatory properties of medicines in animals involves causing localized swelling in rat paws through the injection of an irritating substance such as carrageenan. This study demonstrates that the plant's ability to reduce inflammation is enhanced when extracted using methanol in a rat model of induced edema [14]. Solanum nigrum L.'s methanolic extract showed anti-inflammatory properties in animal models, reducing hind paw edema and exhibiting anti-inflammatory activity at 375 mg/kg body weight [6].

C. Hepatoprotective Activity

Quantitative and qualitative histopathological investigations identified S. nigrum water extract (SNWE) administered to rats for six weeks at dosages of 0.2, 0.5, and 1.0 g/kg in CCl4- -induced chronic hepatotoxicity, reversed organ and body weight loss and fatty degeneration. Furthermore, the extracts also lowered serum liver enzyme marker levels (GPT, GOT, bilirubin, and ALP), hydroxyl, and superoxide radicals and restored SOD and GSH the normal, especially at the two higher doses [31]. When rats with liver damage induced by AAF were supplemented with 1% and 2% SNWE, the liver/body weight ratios were respectively 3.1- and 2.9-fold of those of a control group. Decreased levels of the serum biomarkers APF, GOT GPT,

and γ-GT were observed as well as an induced expression and activation of GST-μ and GST-α, which metabolize a wide range of carcinogens and xenobiotic. In addition, the extract regulated levels of Nrf2 as well as downstream antioxidant enzymes including catalase, SOD-1, and GPx [32]. A different hydroalcoholic extract containing 250 mg/kg caused a significant change in tissue antioxidant status in rats with D-galactosamine-induced hepatic fibrosis and also demonstrated a hepatoprotective effect on the liver [33]. Polysaccharides extracts have been shown to alleviate liver swelling, increase levels of CAT, GSH, and SOD, and reduced MDA concentrations [1]. The study investigated the potential hepatoprotective properties of Solanum nigrum's 95% ethanolic extract, suggesting it could help reduce high cholesterol, liver damage, and kidney issues [34].

D. activity of Anticancer

An assessment was conducted on the anticancer properties of Solanum nigrum fruits against the HeLa cell line. The inhibitory effect of the methanolic extract of Solanum nigrum fruits was investigated on the HeLa Cell Line. The cytotoxicity of Solanum nigrum on HeLa cells was assessed using the Sulforhodamine B colorimetric test (SRB) and MTT assay. The methanolic extract of Solanum nigrum exhibits a notable cytotoxic impact on the HeLa Cell Line.[35]. The findings of this study [36] indicate the antiproliferative effect and apoptosis-inducing property of SNWE in both cell lines. Further studies are warranted on testing the anticancer activity of S. nigrum L. using animal models of cancer. Antitumor Activity Crude Extract Many different solvents were used to extract cancer cell lines from the breast, kidney, esophagus, liver, stomach, colon, and lung leading to significant inhibition of growth. Also, these include crude extracts using various solvents that were able to significantly hinder the proliferation of several cancer cell lines like the ones originating from the breast, colon, liver, stomach, lungs, and kidney [14]. SNWE having 1%, and 2% concentrations respectively decreased carcinogenesis by 40% and 20%, as well as improved the rate of survival in rats with hepatoma after repeated administration of AAF/NaNO2 that attained 90% and 100%. Also a 10 g/L concentration of the same extract induced 43% cytotoxicity as well as inhibited the formation of migratory human mammary cytokine MCF-7 cells (104). In-vitro antitumor activities have been reported using other solvent extracts (water, chloroform, n-butanol, and ethanol) for various types of cancer [14, 37-39]. The study explored the anti-cancer properties of Solanum nigrum water extract on breast cancer cell lines, revealing its ability to induce oxidative stress-induced apoptosis and regulate apoptosis genes [36].

E. Anti-diabetic actions

The blood sugar levels of albino rats were measured after daily oral administration of 250mg/kg b. wt. dose of the crude ethanolic extract of Solanum nigrum for five and seven days. It was observed that prolonged administration of the treatment resulted in a substantial reduction in blood glucose levels compared to the control group. Therefore, it can be inferred that Solanum nigrum possesses antidiabetic effects. The hypoglycemic activity of the aqueous and hydro-alcoholic extracts from several sections of the Solanum nigrum plant, including the leaf, fruit, and stem, was assessed in Sprague Dawley rats. The findings revealed that the leaf and fruit extracts, when dissolved in water, had notable hypoglycemic properties that varied in intensity according to the dosage. Subsequently, the hydroalcoholic extracts also demonstrated similar effects [40]. There are no notable effects of Solanum nigrum stem extract [41]. The study found that extracts of the Solanum nigrum plant, including leaves and fruit had potential anti-diabetic properties in Sprague-Dawley rats [42].

F. Diuretic characteristics

The leaves of Solanum nigrum exhibit diuretic properties, stimulating the generation of urine. This feature has historically been utilized to facilitate the elimination of toxins from the body and promote the well-being of the urinary system [14].

G. Anti-seizure property

Aqueous leaf extract from Solanum nigrum was examined in chicks, rats, and mice There is no text provided. The study found that the aqueous leaf extract provided dose-dependent protection against seizures created by electrical stimulation in chicks and rats, seizures caused by pentylenetetrazole in rats, and seizures induced by picrotoxin in both animals ($P<0.05$). Additionally, amphetamine made the anti-seizure property of the extract more active. Consequently, the findings obtained in the research show that the plant's leaves might have anti-epileptic effects for mice, rats, and even chicks [43]. In a 2023 study, it was discovered that amphetamine significantly enhanced the anti-seizure properties of Solanum nigrum leaves in various animals [44].

H. Anti-cholesterol Property

Polyphenols that are in S. nigrum might counter obesity and lead to lower levels of serum triglycerides, reduction in hepatic lipolysis, low-density lipoprotein (LDL)-cholesterol, and total cholesterol through their anti-lipogenetic effect [45]. Nevertheless, hyperlipidemic rats had their total cholesterol, LDL cholesterol, and triglyceride in serum increased, but HDL significantly decreased after being administered orally to an extracted plant [46]. The study found that Solanum nigrum, an ethanolic extract, significantly reduced cholesterol levels in rabbits with hyperlipidemia treated with lipofondin. Administration of the extract at a dose of 300 mg/kg body weight reduced serum total cholesterol, triglycerides, high-density lipoprotein, and low-density lipoprotein levels, suggesting that Solanum nigrum has anti-hyperlipidemia activity [47].

I. Antipyretic activity

The antipyretic activity of Solanum nigrum fruits has been utilized for reducing fever for a long time. These fruits

can be ingested or processed into treatments to reduce temperature in the body during symptoms of fever [23].

J. Regrowing Wounds

Topical use of ripe Solanum nigrum fruits has been utilized to facilitate wound healing. Their antibacterial and anti-inflammatory properties may contribute to the healing process [14].

K. Antimicrobial activity

The antimicrobial activity of Solanum nigrum Linn. has been demonstrated against several microorganisms. Following CLSI regulations, we assessed the efficacy of an extract against E. coli, Bacillus subtilis, and Pseudomonas aeruginosa at doses of approximately 10 µg, 50 µg, and 100 µg, respectively. The inhibition zones were initially recorded in a table. Subsequently, the extract was tested against streptomycin, along with a standard control. When conducting experiments, it is customary to utilize solvents such as ethanol, petroleum ether, chloroform, ethyl acetate, and isobutane [23, 27] A 2012 study by Km. Ruby et al. discovered that methanol, when combined with water extracts from Solanum nigrum leaves, could be an effective antimicrobial agent [48].

L. Skin health

Traditionally, the oil extracted from Solanum nigrum seeds has been used topically to treat skin conditions such as eczema, itching, and inflammation. Nevertheless, additional research is required to validate these applications. Before utilizing Solanum nigrum seeds for medicinal intentions, it is imperative to see a healthcare expert or a skilled herbalist. This is necessary to ascertain the appropriate dosage and guarantee the secure and responsible utilization of this plant. The effectiveness and safety of the seeds have been confirmed in scientific studies conducted on animal models [23].

VII. A Nutritional Value of Solanum nigrum

Solanum nigrum leaves have therapeutic potential due to their rich content of carotenoids, lycopene and vital fatty acids. If eaten in adequate quantities, its green leaves will greatly help in meeting human nutritional needs for healthy growth and adequate defense against diseases associated with malnutrition. Boiling greatly affects the criteria used to determine quality. Nutrients are lost as a result, and this may be due to leaching when heat is applied. After boiling, there is a noticeable decrease in the nutritional value of the leaves. Accordingly, the study recommends that in order to meet the nutritional needs and ensure food security of the population of Ivory Coast, the duration of home boiling of the leafy vegetables under study should be less than 10 minutes [7]. The berries of S. nigrum are rich in vital components required for the maintenance and growth of the body. To increase the nutritional content of meal plans, it can be included. There are always berries in the kitchen and in the backyard. To enhance their use in cooking, further research is necessary to confirm their nutritional value after processing by fermentation or cooking. Berries for eating can easily be found in backyards and kitchens [49].

VIII. Conclusion

The entire Solanum nigrum plant has therapeutic characteristics, with the leaves and berries being the primary components utilized for medical applications. This plant demonstrates a wide array of medicinal advantages, including antitumor, analgesic, anti-inflammatory, anticancer, antioxidant, antibacterial, and hepato-protective properties. Hence, additional investigation is necessary to separate the active constituents from the Solanum nigrum extract in order to assist in the appropriate formulation of drugs and tackle health concerns via supplementary clinical trials.

Conflict of interest

Authors declare that they have no conflict of interest.

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