STM JOURNALS

Research & Reviews: Journal of
Herbal Science

https://journals.stmjournals.com/rrjohs

ISSN: 2278-2257 (Online)
ISSN: 2348-9553 (Print)
Volume 14, Issue 2, 2025
May–August
DOI (Journal): 10.37591/RRJoHS

Review RRJoHS

Phytochemical, Pharmacological, and Toxicological Studies of *Solanum americanum*: A Systematic Review

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Abstract

Solanum americanum, a plant widely used in folk medicine, has recently gained attention in the scientific community due to its diverse therapeutic potential. The bioactive compounds found in different plant parts, such as alkaloids, flavonoids, and tannins, have significant medicinal effects. These compounds exhibit several pharmacological properties, such as antimicrobial, anti-inflammatory, anticancer, and antioxidant effects. However, despite these medicinal benefits, some compounds show significant toxicity to the human body if taken at a high dosage. For example, solanine, one of the glycoalkaloids found in the plant's unripe fruits and leaves, can exert significant toxicity by disrupting the cell membranes of the gastrointestinal tract, leading to nausea, vomiting, diarrhea, and abdominal pain. This dual character highlights the necessity of exact dosage and thorough processing in order to maximize its medicinal benefits safely. In this article, we review the therapeutic potential and toxicological concerns of Solanum americanum, shedding light on its pharmacological properties, mechanisms of action, and associated risks. This comprehensive analysis aims to provide a balanced perspective, emphasizing the importance of controlled usage and further research to unlock its full medicinal potential while minimizing its adverse effects.

Keywords: *Solanum americanum*, folk medicine, solanine, glycoalkaloids

INTRODUCTION

Medicinal plants play a crucial role in developing modern drugs. Today, many parts of the world still use plant extracts as a medicine due to their therapeutic nature [1]. Among those plants, the Solanaceae family deserves particular attention because of its diverse pharmacological properties. *Solanum americanum,* commonly known as American Black Nightshade, is one of the plants from this family which is been used for centuries to treat various kinds of ailments [2].

Solanum americanum, a small herbaceous plant, adapts well to tropical and subtropical regions across Asia, Africa, and the America [3]. Depending on the local environment, its height ranges from 30 cm to as much as 120 cm [4]. The leaves are ovate to lance-shaped with a rough and hairy texture on both sides. The flowers are small, star-shaped, and sizes around 1–2 cm in diameter [5]. Usually, they consist of pale violet-colored five petals with a yellow centre. This plant also produces small, round berry fruits that are green at first and later turn black when they are ripe [6]. The green fruits contain toxic alkaloids called solanine [7]. However, the ripe berries and cooked leaves are edible and are often used as medicine to treat various conditions, such as infections, inflammation, and digestive disorders [8].

Despite its well-known use in folk medicine, its full potential as a therapeutic medicine remains unexplored. In other words, few studies have been

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Received Date: February 19, 2025
Accepted Date: March 29, 2025
Published Date: April 01, 2025

Citation: Sinthia Parvez, Most. Nazma Parvin. Phytochemical, Pharmacological, and Toxicological Studies of *Solanum americanum*: A Systematic Review. Research & Reviews: Journal of Herbal Science. 2025; 14(2): 52–62p.

conducted to understand its pharmacological effects, particularly the mechanisms explaining its medicinal properties. Additionally, the presence of toxic compounds, such as solanine in certain parts of the plant makes it challenging for its safe use [9]. There has been a clear literature gap in the existing knowledge about its proper dosages, preparation methods, and potential side effects.

This review aims to explore the medicinal properties of *Solanum americanum*, focusing on its antimicrobial, anticancer, thrombolytic, and other pharmacological activities, while addressing its toxicological aspects. By synthesizing existing research, this paper highlights the plant's potential as a source of novel therapeutic agents and identifies areas requiring further study.

TAXONOMICAL CLASSIFICATION

Here is the taxonomical classification of *Solanum americanum* [10].

- *Kingdom:* Plantae.
- *Phylum:* Angiosperms.
- *Class:* Magnoliopsida.
- *Order:* Solanales.
- *Family:* Solanaceae.
- *Genus: Solanum.*
- *Species: Solanum americanum.*

As part of its taxonomical classification, *Solanum americanum* exhibits distinct morphological traits. Figure 1 provides a visual representation of the plant, detailing its root, leaf, flower, and fruit.

Figure 1. Morphological features of *Solanum americanum*, showing its root (top-left), leaf (top-right), flower (bottom-left), and fruit (bottom-right, unripe green and ripe black).

Phytochemistry

The plant *Solanum americanum* contains various bioactive compounds, such as alkaloids, flavonoids, saponins, tannins, and other secondary metabolites [11]. These compounds contribute to the plant's pharmacological activities, such as antimicrobial, anti-inflammatory, anticancer, and antioxidant effects [12].

EXTRACTION METHODS

One can separate the active elements from the plant extracts in several ways. Here, though, we will only address the most often used and successful techniques: solvent extraction, steam distillation, and supercritical fluid extraction [13–15].

Solvent Extraction

The solvent extraction technique is the most cost-effective and extensively applied one. Usually, the bioactive molecules from the extract are dissolved in ethanol or other alcoholic solvents. This technique has some restrictions in terms of purity and safety, even if it is efficient for separating a wide spectrum of compounds [16].

Steam Distillation

Steam distillation is still another method of extracting compounds. This approach, meanwhile, is only useful for separating volatile molecules like essential oils. Under this approach, plant waste is heated, and subsequently, steam carries the volatile oil to a condenser. The oil gathers later on as it condenses [17].

Supercritical Fluid Extraction

Supercritical fluid extraction (SFE) is a recommended method for compounds with lipophilic character, such as steroids and saponins. In this sense, CO_2 is utilized in its supercritical form, where it shows both liquid and gaseous characteristics. Targeted molecules dissolve into CO_2 to be separate. This approach is quite costly, even though it works rather precisely [18].

KEY COMPOUNDS AND BIOLOGICAL SIGNIFICANCE

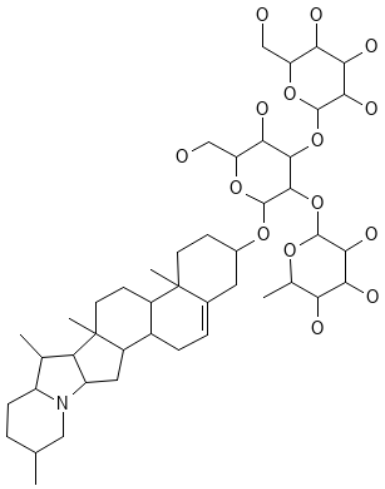
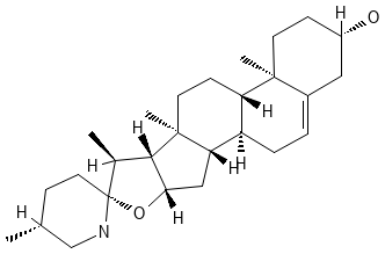
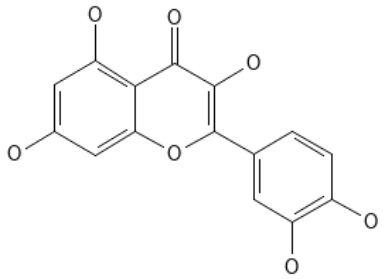
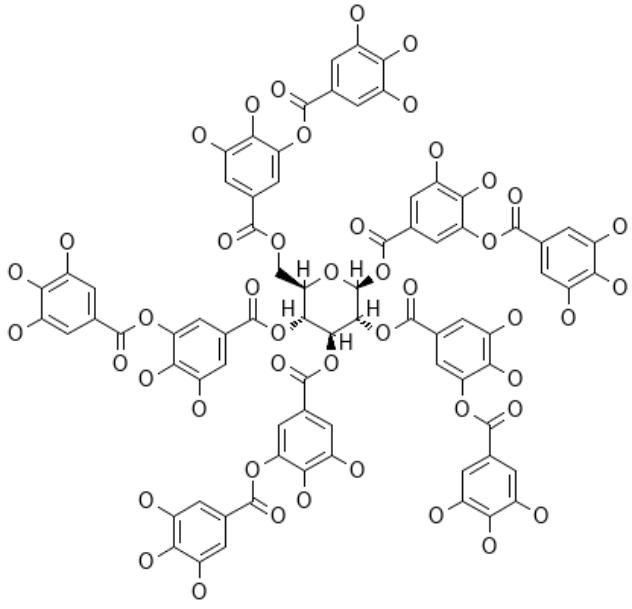
The extract of *Solanum americanum* contains several bioactive substances. Among them, alkaloids are rather important. Solanine is a toxic alkaloid that is found in some parts of the plant and the unripe berries [19]. Though solanine is toxic, several studies have shown that it can fight cancer and dangerous microorganisms [20]. Stated differently, solanine is a fundamental chemical in many pharmaceutical companies since it has antibacterial and anticancer effects. Furthermore, solasodine is an alkaloid present in the plant. Solasodine has anticancer effects, the same as solanine [21]. Researchers have found that solasodine can inhibit tumour cell growth, making it an ideal choice for cancer treatment [22].

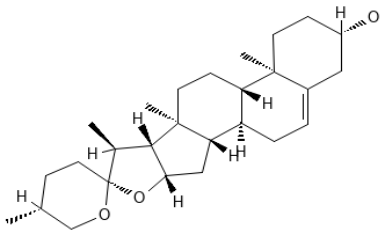
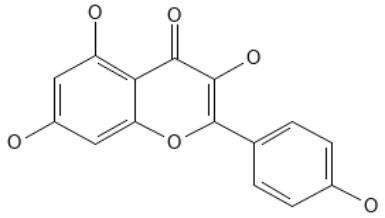
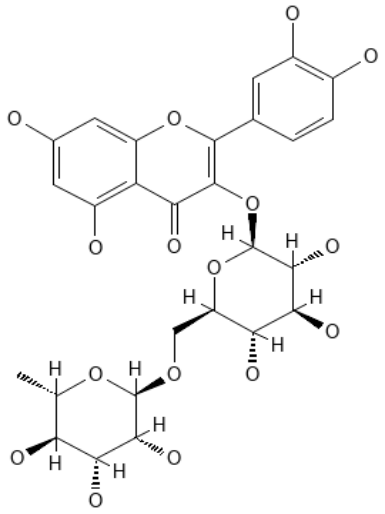
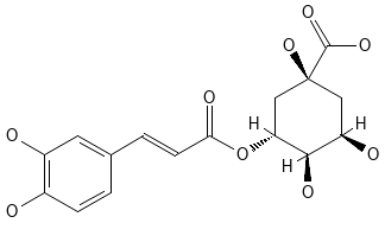
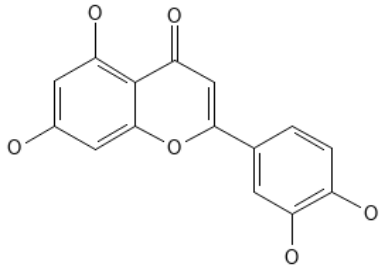
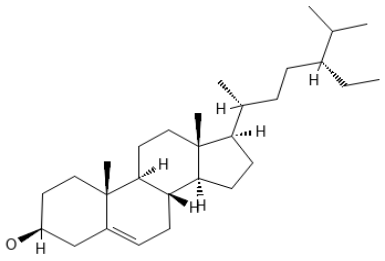
Another vital molecule found in the plant is flavonoids [23]. These polyphenolic compounds show antioxidant, anti-inflammatory, and antimicrobial activities [24]. Quercetin is one of the flavonoids that helps to reduce oxidative stress and inflammation. For this reason, quercetin is extensively used to treat cardiovascular disease and arthritis [25].

Additionally, the presence of tannins in the plant's extract further enhances its medicinal value. Tannin mostly exists in the plant as tannic acid [26]. Because of its anti-inflammatory and antimicrobial qualities, this polyphenolic compound is used extensively for healing wounds [27]. Apart from that, *Solanum americanum* also includes polyphenols, sterols, and saponins as secondary metabolites [28]. These phytochemicals are taken together to enhance their several medicinal purposes.

Emphasizing their chemical variety and medicinal importance, Table 1 offers a clear visual representation of the major bioactive compounds in the plant. It highlights the need for more research on these substances to fully utilize their therapeutic implications.

Table 1. Key phytochemical compounds identified in *Solanum americanum* and their chemical structures [29–31].

Compound	Class	Chemical Structure
Solanine	Alkaloid	
Solasodine	Steroidal alkaloid	
Quercetin	Flavonoid	
Tannic acid	Tannin	

Diosgenin	Saponin	
Kaempferol	Flavonoid	
Rutin	Flavonoid	
Chlorogenic Acid	Polyphenol	
Luteolin	Flavonoid	
β-Sitosterol	Sterol	

MEDICINAL PROPERTIES

Studies have highlighted the diverse therapeutic properties of *Solanum americanum*. Among them, the most well-known pharmacological activities include antimicrobial, anticancer, anti-inflammatory, and antioxidant effects. The bioactive compounds found in the plant's body, such as alkaloids, flavonoids, and tannins, are responsible for these medicinal properties [32].

Antimicrobial Activities

Solanum americanum is widely used for its potential to combat harmful microorganisms [24]. Solanine is one of the most common compounds found in the plant's leaves and unripe fruits. Various studies have indicated that this chemical substance shows strong efficacy against a range of bacterial and fungal pathogens [33]. This makes *Solanum americanum* a significant medicinal plant for treating infections caused by harmful microorganisms. However, excess intake of solanine can result in intoxication; therefore, further investigations are required to determine the optimum dosage [34, 35].

Anticancer Properties

The anticancer potential of *Solanum americanum* is attributed mainly to its steroidal alkaloids, particularly solasodine [36, 37]. Several studies have found that solasodine can inhibit tumour cell growth by exhibiting cytotoxic effects. For instance, a recent study has shown that solasodine can induce apoptosis in cancer cells through the activation of the caspase cascade and increasing the Bax/Bcl-2 ratio [38, 39]. Additionally, it inhibits colorectal cancer (CRC) cell motility by downregulating matrix metalloproteinases (MMPs) [40]. These properties make solasodine a very effective anticancer medication. More studies are needed to unravel the full mechanism of this compound and its potential applications in developing targeted anticancer therapies.

Anti-Inflammatory and Antioxidant Effects

Flavonoids found in *Solanum americanum,* for instance, quercetin, have shown both anti-inflammatory and antioxidant effects in several cases [41]. Few *in vitro* studies have recently found that quercetin can inhibit the production of cyclooxygenase (COX) and lipoxygenase (LOX), which are typically induced by inflammation [42]. Although substantial evidence supports quercetin's anti-inflammatory properties, the underlying mechanisms of its efficacy remain poorly understood. Potential mechanisms may involve the molecular-level inhibition of cyclooxygenase-2 (COX-2), inducible nitric oxide synthase (iNOS), nuclear factor kappa B (NF-κB), activator protein-1 (AP-1), or mitogen-activated protein kinase (MAPK) [43]. In addition to anti-inflammatory properties, quercetin demonstrates antioxidant effects as well. Quercetin exhibits antioxidant activity by synthesizing glutathione (GSH) at a high rate [44]. GSH neutralizes harmful free radicals through a redox cycling mechanism. It also supports the enzymatic breakdown of hydrogen peroxide (H_2O_2) into non-toxic water, reducing oxidative stress and preventing cellular damage [45, 46].

Other Medicinal Properties

Beyond its notable antimicrobial, anticancer, anti-inflammatory, and antioxidant activities, *Solanum americanum* has been traditionally used to address various health conditions. For example, the tannins found in the plant's body can be used as a wound-healing agent [47, 48]. Moreover, tannic acid, one of the tannins present in plant roots, can also exhibit antimicrobial properties [49]. Tannins can also be used to treat diarrhea by reducing intestinal inflammation [50]. Additionally, the presence of saponins in the plant's leaves also increases its capability to fight harmful fungi. Saponins are also used to treat cardiovascular conditions as they can lower cholesterol [51].

The key medicinal properties of *Solanum americanum* are summarized in Figure 2, highlighting its diverse pharmacological effects.

These diverse medicinal properties highlight the potential of *Solanum americanum* as a valuable source for natural remedies and pharmaceutical development, though further research is needed to validate its therapeutic efficacy and ensure safe application.

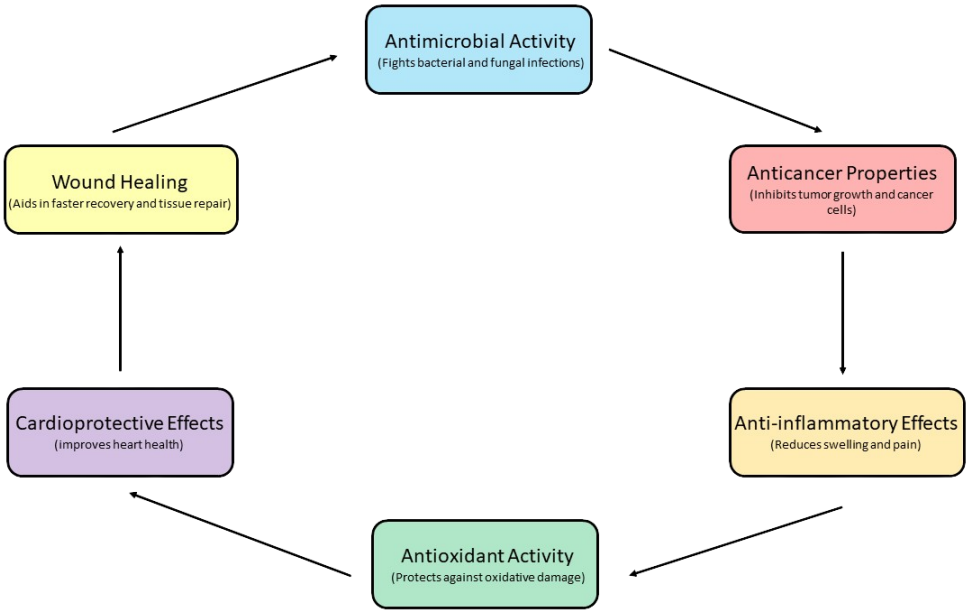


Figure 2. Medicinal properties of *Solanum americanum*.

TOXICOLOGY

While *Solanum americanum* has diverse medicinal values, several compounds within the plant's body, for instance, solanine, show significant toxicity when consumed in high amounts [52]. This section explicitly discusses the toxicological effects of these compounds.

Toxic Effects of Solanine

Solanine is a glycoalkaloid compound that is very common in the Solanaceae family. This compound is mostly found in the plant's unripe fruits and leaves. It exerts its toxic effects by disrupting cell membranes, particularly in the gastrointestinal tract, leading to nausea, vomiting, diarrhea, and abdominal pain [22]. According to one study, toxic symptoms may be triggered by doses of 2–5 mg/kg of body weight, and on the other hand, doses of 3–6 mg/kg of body weight can be lethal [53]. Additionally, in some rare cases, solanine toxicity might affect the nervous system and might cause neurological symptoms, such as dizziness, confusion, and paralysis [54].

Dose-Dependent Toxicity

The toxic effects of *Solanum americanum* are dose dependent. A small dosage of solanine, typically 0.5 mg/kg body weight, should be metabolized with no harm or symptoms [55]. Moreover, several studies have found that cooking or exposure to heat reduces the toxic potential [56].

Safe Usage Recommendation

From the above discussion, it should be clear that although solanine is a toxic compound, a very small intake dose would not generally cause any harm. Moreover, as cooking and heating up might reduce the toxic nature of the substance, it is usually advised to cook well before consumption. Additionally, the unripe fruits of *Solanum americanum* should be avoided at all costs since they contain a high concentration of solanine. Therefore, it is best to boil up the raw plant material and take only a small dose for safety [57].

DISCUSSION

Solanum americanum has a diverse spectrum of therapeutic properties. Some medicinal effects include antimicrobial, anticancer, anti-inflammatory, and antioxidant activities. Several bioactive compounds in the plant's body, such as alkaloids, flavonoids, and tannins, are responsible for these medicinal properties [3]. These compounds, particularly solanine and solasodine, have demonstrated

significant therapeutic potential *in vitro* and *in vivo* studies [58]. Apart from its medicinal properties, *Solanum americanum* also shows high toxicity. For example, dose-dependent toxicity is demonstrated by solanine, an alkaloid presents in plant bodies and unripe berries. Stated differently, even though solanine has antimicrobial and anticancer effects, excessive intake of it can lead to major problems, including gastrointestinal and neurological issues [22]. This dual character emphasizes the need for precise dosage and complete processing to maximize its medicinal advantages safely.

Besides, when we compared *Solanum americanum* with other *Solanum* species, we also found similar alkaloids, such as solanine in other plants of this genus. Nonetheless, every species shows different degrees of toxicity and medicinal effectiveness [59]. This is why more investigation is required to better grasp the differences in the chemical composition of *Solanum americanum* among other members of the genus. Particularly, the research on solasodine's anticancer characteristics has opened fresh directions for cancer treatment; however, more clinical trials and in-depth investigations are required to clarify its mechanism of action and therapeutic possibilities completely.

CONCLUSION

Solanum americanum possesses diverse pharmaceutical activities, including antimicrobial, anticancer, anti-inflammatory, and antioxidant effects. The bioactive compounds, such as alkaloids, flavonoids, and tannins, found in the plant's body can be used as remedies for various conditions, confirmed by several *in vitro* and *in vivo* studies. However, despite its vast therapeutic properties, the substances found in the plant's extract should be used cautiously. This is because some alkaloids, particularly solanine, are found in the plant's body and can be lethal to the human body if taken at a high dosage. That is why taking these compounds within the safety limit is always advised. In conclusion, even though *Solanum americanum* has a wide range of therapeutic potential, further research is needed to unravel its pharmacological mechanism and to establish its safe usage limit.

Acknowledgments

The authors are grateful to the Department of Pharmacy, Stamford University Bangladesh, Dhaka, for providing all support to carry out this review.

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