Review article

Potential pharmacological activities of *Solanum mammosum*: a general review

Actividades potenciales farmacológicas de *Solanum mammosum*: una revisión general

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ABSTRACT

Introduction: *Solanum mammosum* L. is a plant native to Central and South America and is found in tropical and subtropical regions throughout the world. It has a wide range of traditional uses in different cultures and regions due to its pharmacological potential.

Objective: to investigate the medicinal and biotechnological potential of *S. mammosum* in the context of traditional and modern medicine, with a particular focus on its application as a source of bioactive compounds for the development of new therapeutic treatments and environmentally friendly pesticides.

Methods: A literature and document review was conducted across several major databases, including PubMed, Web of Science, MDPI, Springer, Elsevier, Google Scholar, and Yahoo Search. Bibliometric graphs were generated using the Scopus scientific database.

Results: The review focuses on major molecules, including sterols, triterpenes, saponins, steroidal alkaloids, and phenolic compounds. These compounds confer anticancer, antioxidant, antimicrobial, hypoglycemic, antiviral, antithrombotic, anti-inflammatory, insecticidal, molluscicidal, and other properties.

The scientific research and technological development of *S. mammosum* have the potential to facilitate the discovery of new therapeutic treatments and sustainable agricultural practices. These developments could contribute to human health, environmental sustainability, and economic development.

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Conclusion: This review underscores the significance of recognizing and harnessing the potential of *S. mammosum* to integrate it into conventional medicine within modern healthcare systems. This could pave the way for evidence-based medical practices that would benefit society. Although the plant is highly valued culturally and biotechnologically, further research is needed to determine safe doses and to confirm its medicinal properties through toxicity testing and clinical trials.

Keywords: *Solanum mammosum*; traditional uses; phytochemical components; pharmacological properties.

RESUMEN

Introducción: *Solanum mammosum L.* es una planta originaria de Centroamérica y Sudamérica, presente en regiones tropicales y subtropicales de todo el mundo. Esta especie tiene una amplia gama de usos tradicionales en diversas culturas y regiones debido a su potencial farmacológico.

Objetivo: investigar el potencial medicinal y biotecnológico de *S. mammosum* en el contexto de la medicina tradicional y moderna, con especial atención a su aplicación como fuente de compuestos bioactivos para el desarrollo de nuevos tratamientos terapéuticos y pesticidas amigable con el medio ambiente.

Métodos: se realizó una revisión de la literatura y de documentos en varias bases de datos de amplio alcance, como PubMed, Web of Science, MDPI, Springer, Elsevier, Google Scholar y Yahoo Search. Se generaron gráficos bibliométricos a partir de la base de datos científica Scopus.

Resultados: la revisión se centra en sus moléculas principales, como esteroles, triterpenos, saponinas, alcaloides esteroidales y compuestos

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fenólicos. Estos compuestos confieren propiedades anticancerígenas, antioxidantes, antimicrobianas, hipoglucemiantes, antivirales, antitrombóticas, antiinflamatorias, insecticidas, molusquicidas y otras.

Conclusión: esta revisión subraya la importancia de reconocer y aprovechar el potencial de *S.mammosum* para integrarlo en la medicina convencional dentro de los sistemas de salud modernos. Esto podría allanar el camino para prácticas médicas basadas en la evidencia que beneficien a la sociedad. Aunque la planta es muy valorada en los ámbitos cultural y biotecnológico, se necesitan más investigaciones para determinar dosis seguras y confirmar sus propiedades medicinales mediante pruebas de toxicidad y ensayos clínicos.

Palabras clave: *Solanum mammosum*; usos tradicionales; componentes fitoquímicos; propiedades farmacológicas

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Introduction

Solanum mammosum L., commonly known as "teta de vaca", "ubérrima" or "manzana de Sodoma" is a plant native to Central and South America, it has an annual or perennial life cycle, depending on the climate. Contrary to popular belief, it is not a tropical American species, but is part of the Solanaceae family.[1,2] Solanaceae is a botanical family with about 2700 species, distributed across 98 genera, found worldwide. Among its best-

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known members are potatoes (S. tuberosum), eggplant (S. melongena), green bell pepper (S. capsicum), and tomato *(S. lycopersicum)*, four crops of great economic importance.[3,4] In Ecuador, the Solanaceae family is represented by 338 plant species.[5] These species are known for their high alkaloid content and have a prominent place in various traditional medicinal systems. Both in Ayurveda in India and in Traditional Chinese Medicine, through Siddha, Unani and Homeopathy, these plants have been used to treat a wide range of ailments.[4] Its anti-cancer, anti-microbial, insecticidal, anti-infectious, and even poisonous properties have given it a fundamental role in traditional pharmacopeias.[6] Of these, *S. mammosum* is notable for its frequent use as an insecticide in many communities.[3,5] Various cultures and regions around the world have documented different applications for the leaves, seeds, flowers, and fruits of this plant.

In Ecuador, extracts from the fruit have been used as potential insecticides and molluscicides.[3,7] The leaves, fruits, and seeds of the plant are used by Guatemalan and Philippine populations to treat respiratory ailments.[8] In Bolivia and Peru, the fruits and leaves are used as a home remedy to treat various skin conditions, such as ulcers, scabies, athlete's foot, furunculosis, and rashes.[9,10]

Reports suggest that the fruit of *S. mammosum* contains several potentially toxic compounds, including solasodine, solasonin, solamarginine, β-solamarginine, diosgenin, and phytosterols. Despite their toxicity, these phytochemicals also provide to the plant various pharmacological activities, such as antioxidant, anticancer, antimalarial, and molluscicide properties.[11,12] The biotechnological value of this plant is high, however, there are few reviews about it in the literature. From this perspective, it is crucial to investigate each phytochemical compound documented in the

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literature to advance research and sustainable utilization for the benefit of human health and the environment.

Methods

A bibliographic and documentary review was conducted through a critical analysis of 55 articles written in English and Spanish from 1968 to 2023. These studies contributed to the recognition of important information related to the phytochemical components, pharmacological properties, toxicity, and metabolite extraction of *S. mammosum* in traditional medicine. The current review included articles from PubMed, Web of Science, MDPI, Springer, Elsevier, Google Scholar, and Yahoo search. Only articles of high quality and relevance were considered. The bibliometric graphs were created using the Scopus scientific database.

Metadata shows Indonesia as the country that has studied this species the most, followed by Brazil and Colombia. Ecuador ranks fourth (Fig. 1). The Scopus database indicates that only 55 articles have been published on S. mammosum up to 2023 (Fig. 2).

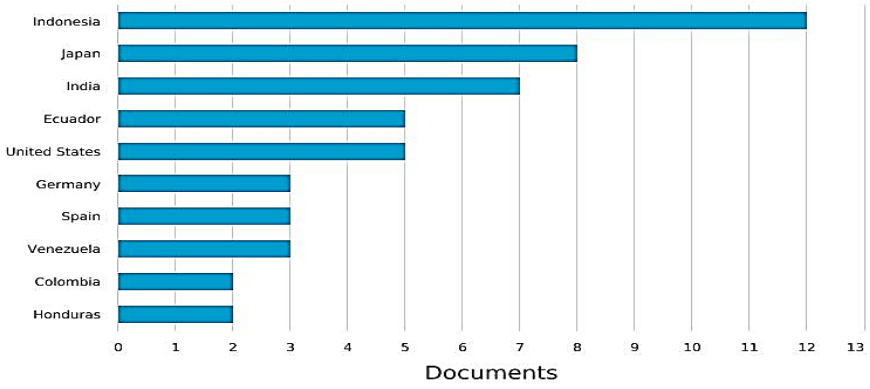


Fig. 1- Main countries that have researched the species and published their articles in the Scopus database.

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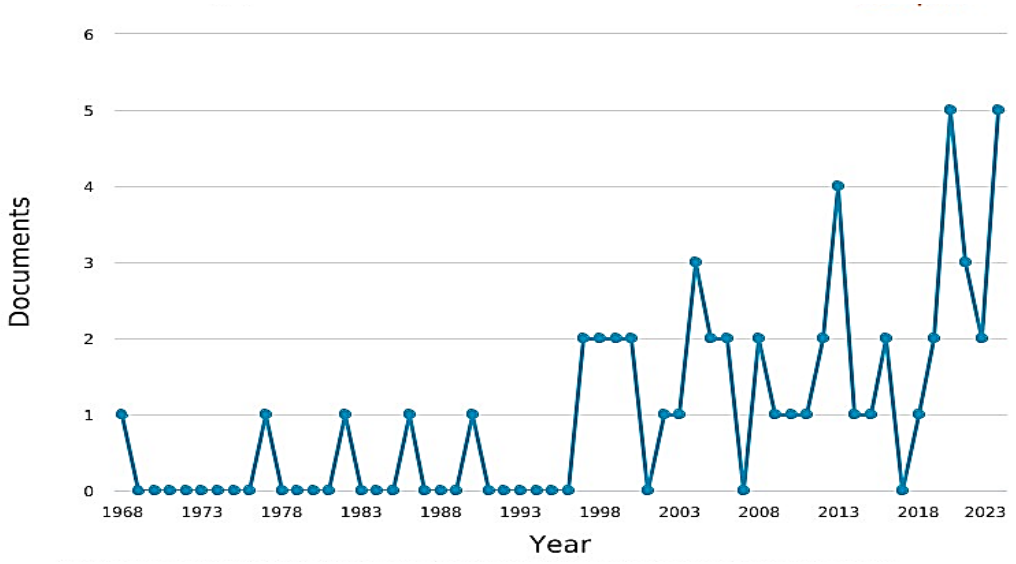


Fig. 2- Number of published articles of *S. mammosum* until 2023.

Metadata shows Indonesia as the country that has studied this species the most, followed by Brazil and Colombia. Ecuador ranks fourth (Fig. 1). The Scopus database indicates that only 55 articles have been published on S. mammosum up to 2023 (Fig. 2).

Development

Botanical characteristics and geographical distribution

S. mammosum is a plant that can grow annually or perennially and is most commonly found in tropical and subtropical regions of Central and South America, especially in Mexico, Guatemala, Costa Rica, Colombia, Ecuador, Peru, Bolivia, and Brazil, but it can also grow in other parts of the world, such as Africa, Asia, and the Caribbean, where it has become naturalized. This plant

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typically grows in tropical forests, grasslands, and disturbed areas, primarily at low altitudes.[12,1] It is rare in temperate European countries and becomes rarer in the north and at higher altitudes. This wide geographical distribution shows the adaptability of the species to different climates and environmental conditions.[12]

It is characterized by spiny stems that reach a height of 1.5 m, simple leaves with pubescence on both sides, moderately cleft edges with conspicuous spines on the veins and an acuminate apex, and an inflorescence in raceme. The flowers have peduncles and consist of a yellowish-green calyx with five sepals and a purple corolla with five petals. Moreover, the fruit is a bright yellow, cone-shaped berry with a spongy white mesocarp and numerous semi-lenticular seeds at maturity. Typically, each fruit develops several small lobes at the base, giving it the shape of a cow's udder. Although considered attractive, the fruit is toxic to humans.[3] In ancient times, many indigenous communities cultivated this plant for both ornamental and therapeutic purposes because of its wide range of bioactive compounds and the unique shape of its berries.

Ancestral wisdom of *Solanum mammosum*: An invaluable legacy of knowledge and tradition

Various cultures and regions around the world possess ancient wisdom regarding the healing properties of *S. mammosun.*[5] Since pre-Columbian times, indigenous cultures have used its medicinal properties to treat various ailments.[1] Mainly, leaves, fruits, seeds, and roots are used in preparations to treat respiratory, digestive, inflammatory, and even antitumor conditions.[3,12,13] The oral transmission of this ancestral knowledge has allowed the preservation

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of medicinal traditions related to *S. mammosun* to this day. These traditions represent an invaluable cultural heritage and a source of inspiration for modern scientific research. In summary, *S. mammosum* is a valuable source of knowledge and tradition that enhances the culture and well-being of indigenous communities.[14] Table 1 summarizes the traditional uses of *S. mammosum* in various regions of the world.

Table 1- Countries studied, preparations, and diseases treated with *S. mammosum*

Countries	Preparations	Doses	Diseases	References
Peru, **Belize,** **Trinidad and Tobago**	Infusion of leaves. Maceration of stems Fruit Decoction Infusión de las hojas	Poultice	Fungal infections (athlete's foot) Dry tumors Respiratory disorders Rheumatic problems.	(15,16,17,18)
Costa Rica and **Dominican Republic**	Extracts from fruits, tender leaves or buds	Inhalation Poultice	Acute sinusitis Eliminates liver stones Mouth infections, skin cuts Weight loss Decrease blood pressure and cholesterol	(19)
Guatemala and **Philippines**	Decoction of roots, fruits, leaves and seeds	Poultice	Kidney diseases Respiratory diseases Inflammatory problems Fungal diseases Loss of appetite Syphilis treatment	(8, 20)
Ecuador and Colombia	Fresh fruit Seed spray mixed with coca Leaf decoction	Vaporization Poultice	Insecticide and repellent Mucous membranes and irritated tongue Headache Diuretic	(21,22,23)

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El Salvador, Mexico and Nicaragua	Leaf maceration	Poultice	Chronic skin diseases: syphilis, pains, and inflammations Cleaning wounds caused by dog bites	(24)
Bolivia	Decoction/crude fruits Seed oil Infusion of tender leaves and buds	Poultice	Skin diseases such as scabies and ulcers Combats elephantiasis Antimalarial Hemorrhoids	(9,10,25)
Malaysia, Sarawak, Cambodia, Laos and Vietnam	Leaf sap Fresh fruit extract	Oral Poultice	Antipyretic (fever) Heal rash caused by caterpillars Treat eye wounds in children Induce narcosis	(19)

It is important to note that most of these traditional uses have not been scientifically validated. More research is needed to confirm the efficacy and safety of *S. mammosum* in the treatment of these conditions. However, preliminary studies have shown that the plant has several pharmacological activities, including antimicrobial, anti-inflammatory, and anticancer activities. These results suggest that *S. mammosum* has great medicinal potential and could be a source of new drugs for the treatment of various diseases.

Phytochemical components

The plant contains catechins, catechin tannins, alkaloids, simple phenols, flavanones, heterosides, cyanogenic tannins, saponins, and triterpenes.(12)

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These compounds are distributed throughout the different parts of the plant, as shown in Figure 3.

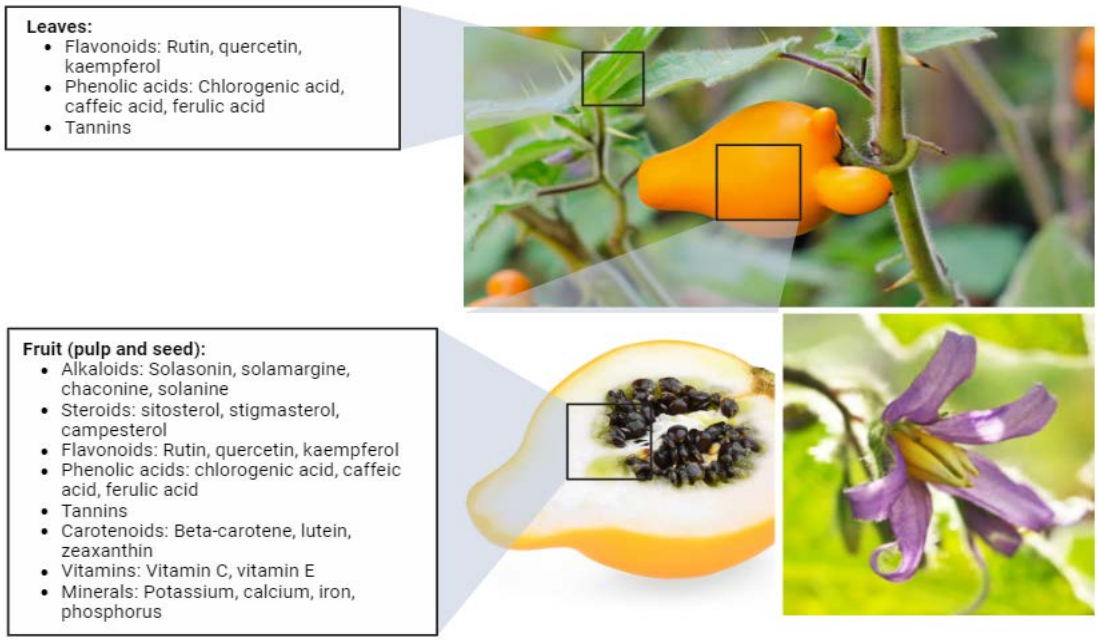


Fig. 3- Main secondary metabolites present in leaves and fruit of *S. mammosum*

Sterol and triterpenes

In a study, fifteen compounds were isolated from *S. mammosum*, a plant species. These compounds included nine sterols and six terpenoids. The sterols were cholesterol, campesterol, stigmasterol, β-sitosterol, isofucosterol, cholesterol acetate, campesterol acetate, stigmasterol acetate, and sitosterol acetate. The terpenoids included cycloartenol, lupeol, and 24-methylcycloartanol. The sample also contained four triterpenoids: lupeol acetate, acetylbetulinic acid, serratenodiol diacetate, and serratenodiol diacetate.[26,27] These compounds show potential in the treatment of cardiovascular diseases, immune system diseases, and cancer.

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For example, betulinic acid directly influences mitochondrial membrane permeabilization, thereby preventing the proliferation of cancer cells.[28]

Saponins

A study conducted in China found a significant presence of saponins in S. mammosum, including protodioscin, pseudoprotodioscin, and indioside D.[29] The study also demonstrated that indioside D has high antiproliferative activity against malignant tumor cells, making it a potential ally in the fight against cancer in humans.[30] Previous studies have identified further saponins in the Solanum genus, including isospirostanol, fursonol, melongoside, and furostanol saponins. These compounds have also demonstrated antitumor properties, further supporting the potential of *S. mammosum* saponins for cancer therapy.[31,32]

Steroid alkaloids

Steroidal alkaloids were found in the Solanaceae and Liliaceae families and have been used for thousands of years in traditional medicine.[33] *S. mammosum* is rich in steroidal alkaloids, particularly solasodine. Solasodine is an essential raw material for producing drugs, including contraceptives, sex hormones, immunosuppressants, corticosteroids, anticarcinogens, and anticancer drugs.[34,35] Solasodine is found in a concentration of 0.2-1.2 % by dry weight in the fruits of *S. mammosum*, while the leaves contain no steroidal alkaloids.[12] Other active principles present in the plant include solanine, solanidine, solasonine, β-solamargine, solamargine, diosgenin, and phytosterols [25,12]

Steroidal compounds are primarily located in the fruits and seeds of *S. mammosum.*[36] The concentration of these compounds varies throughout

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the plant's physiological stages. For instance, solasodine is most concentrated in the green fruit and decreases as the fruit ripens.[37]

Phenolic compounds

Plants synthesize phenolic compounds, molecules that originate from specific metabolic pathways within the plant, such as the pentose phosphate, shikimate, and phenylpropanoid pathways (38). Several studies have reported that the Solanaceae family contains higher concentrations of phenolic compounds, such as chlorogenic acid, gallic acid, and ferulic acid.[39,40,41] Gallic acid is the main polyphenolic compound present in the highest concentration in the aqueous leaf extract of *S. mammosum.*[42] In a preliminary study, a total flavonoid content of 676 mg quercetin equivalent dry extract and a phenolic content of 275 mg gallic acid equivalent dry extract were obtained.[43]

Pharmacological potential

Anticancer activity

Cancer is one of the leading causes of death in the world.[44] The search for new and more potent weapons to combat the situation has been prompted. Some molecules from *S. mammosum* are emerging as a promising alternative.[45,46] Betulinic acid, a triterpene found in the seeds and pulp of *S. mammosum*, is a natural compound that has been reported to exhibit cytotoxic activity against various cancer cells with high selectivity. A study evaluated the effect of the acetone extract of *S. mammosum* on human cervical carcinoma cells (HeLa) and normal cells (Vero). The results showed that the extract inhibited HeLa cell growth.[47]

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Solamargine is a steroidal glycoalkaloid that has shown potential to affect various tumor cells, including those in the lung, hepatoma, breast, prostate, liver, and colon.[48] Furthermore, solamargine caused 50 % and 80 % cell death in the lung adenocarcinoma cell line at concentrations of 2.9 mM and 7.7 mM, respectively. This effect is dependent on both the dose and the duration of exposure to the cancer cells. In essence, the greater the concentration of solamargine and the longer the exposure time, the higher the rate of cell death.[49] Solasonin is a triglycoside derivative of solamargine and exhibits some anti-proliferative effect on liver cancer cells,(50) human leukemic cells, and human colon carcinoma.[51] On the other hand, it was reported that most steroidal saponins have significant cytotoxic action against various types of tumor cells.[47]

Indioside D, a furostanol glycoside, is effective in killing cancer cells. Indioside D induces apoptosis, a process of programmed cell death, in HeLa cells with high potency.[11] Mitochondrial dysfunction is a crucial factor in the apoptosis induced by Indioside D. Treatment with Indioside D resulted in a rapid loss of mitochondrial membrane potential and an increase in reactive oxygen species production, which activated caspases, enzymes that control apoptosis, ultimately leading to cell death. Similarly, other glycoside derivatives, such as protodioscin, pseudoprotodioscin, and dioscin, have been shown to have the same mechanism of action against various cancer cells.[52,53,54] Given this, the above compounds have potential as natural molecules for treating various types of cancer by inducing oxidative stress. Therefore, it is crucial to conduct further research to isolate and purify antitumor-active compounds from *S. mammosum*.

Antioxidant activity

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Carotenoids, alkaloids, flavonoids, and phenolic acids isolated from *S. mammosum* have been shown to scavenge 1.1-diphenyl-2-picrylhydrazyl (DPPH) and hydroxyl free radicals. Nevertheless, some studies have reported a decrease in antioxidant activity [55,42] It is important to note that there is a lack of studies related to this activity in *S. mammosum*. Further research is necessary to fully comprehend the mechanism of action of the antioxidant compounds in this plant and to confirm their effectiveness in humans.

Antimicrobial activity

S. mammosum exhibits significant antimicrobial activity against bacteria such as *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*, as well as fungi such as *Candida albicans*. This activity is attributed to its secondary metabolites, including alkaloids, flavonoids, saponins, and tannins, which act synergistically to inhibit microbial growth, even in strains resistant to traditional antibiotics. Ramón-Valderrama and Galeano-García[2] conducted a study to evaluate the antimicrobial activity of the ethanolic extract of *S. mammosum* against Gram-positive and Gram-negative bacteria. The evaluation showed that the extract significantly inhibited all tested microbial strains. It was particularly effective against *E. coli* at a concentration of 20 mg/mL. In another study [1], solamargine was identified as the primary compound responsible for moderately inhibiting *T. mentagrophytes* and *C. albicans* (MIC = 64 µg/mL). Solamargine significantly reduced *P. aeruginosa* biofilm formation by approximately 20% at a very low concentration (1.6 µg/mL), and this effect remained constant across concentrations. Additionally, solamargine reduced pyocyanin production by approximately 20 % at concentrations of 12.5 and 50 µg/mL $^{-1}$. Similarly, silver nanoparticles produced from the aqueous extract of *S. mammosum* leaves have been found to have limited antibacterial effects against *Bacillus*

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sp. and *E. coli.*[42] These results indicate that this plant could be used to treat a variety of fungal infections and respiratory disorders.[1]

Hypoglycemic activity

Recent research has shown that flavonoids, triterpenoids, alkaloids, and phenolics found in *S. mammosum* may have potential anti-diabetic effects. [56,57]. These metabolites can stimulate insulin secretion from pancreatic β-cells, reduce glucose absorption in the small intestine, promote glucose consumption by the body, and encourage glucose storage in the liver. Additionally, these natural compounds aid in the regeneration of pancreatic cells damaged by diabetes and protect them from oxidative harm.[57] A study demonstrated that solasonin and solamargine can inhibit the rise in serum glucose levels in rats by suppressing the transfer of sucrose from the stomach to the small intestine.[58]

Quercetin is an important flavonoid with a wide range of pharmacological activities. The effects of quercetin on streptozotocin-induced diabetic and normal rats were investigated and compared. A marked reduction in plasma glucose levels in diabetic animals was observed, whereas glucose levels in normoglycemic rats remained unchanged.[59]

Epicatechin has been reported to have insulin-like activity. A study showed that epicatechin protected albino rats against the diabetogenic actions of alloxan.[60,61] Also, this flavonoid has a pronounced insulin-like effect on erythrocyte membrane-bound receptors in patients with type II diabetes.[62] Kaempferol and its derivatives have also been shown to mitigate diabetes.[63] Although there are few studies available, the potential of *S. mammosum* as an anti-diabetic agent is promising and offers new possibilities for future therapies.

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Antiviral activity

The antiviral potential of gold (AuNP) and silver (AgNP) nanoparticles, synthesized from *S. mammosum*, on SARS-CoV-2 surrogate Phi6 and the viral model PhiX174, was investigated.[64] The results showed that both nanoparticles, especially the silver nanoparticle, exhibited high antiviral activity against the surrogate macrophage Phi6, which is an ideal model for studying SARS-CoV-2. Silver nanoparticles achieved 99.94 % viral inactivation at a low concentration, while gold nanoparticles achieved similar inactivation at a higher concentration. Despite the antiviral potential of *S. mammosum*, research into its use for treating viral infections in humans remains in its early stages.

Antithrombotic activity

Nitric oxide is a molecule produced by cells in blood vessels that helps regulate blood pressure by causing blood vessels to dilate and promoting the flow of blood.[65,66] Additionally, it reduces calcium entry into the cells, further contributing to muscle relaxation and blood pressure regulation.[67] Some flavonoids, like luteolin, can increase nitric oxide levels and lower blood pressure.[68] In particular, kaempferol and quercetin, two types of flavonoids found in *S. mammosum*, can combat hypertension by modulating the renin-angiotensin-aldosterone system, improving blood vessel function, and regulating muscle contraction in the arteries.[69,70,71]

In vitro studies have shown that the antihypertensive effects of quercetin and kaempferol depend on nitric oxide synthesized in the endothelium. When the endothelium was removed in these studies, the ability of these flavonoids to relax blood vessels was significantly reduced.[68,72]

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Another important effect of flavones is the inhibition of platelet aggregation, a process crucial for blood clot formation and the prevention of excessive bleeding.[73] This effect is observed even at nanomolar concentrations, meaning that small amounts of flavones can have a significant effect.[74,75] An epidemiologic study found that an increase in flavanol intake of 20 mg per day was associated with a 14 % reduction in the risk of stroke in men.[76]

Antiinflammatory activity

Several studies have shown that *S. mammosum* fruit contains steroidal alkaloid compounds with anti-inflammatory potential. For example, α-solanine has shown anti-inflammatory properties on immune cells. It decreased the production of inflammatory molecules, such as nitric oxide, prostaglandins, TNF-α, and IL-6. α-solanine also activated the NF-κB pathway, which is important in the body's response to infection.[77] In a mouse model of sepsis, oral α-solanine reduced the expression of inflammatory genes and improved animal survival.[33]

Solamargine has also shown promising anti-inflammatory activity, particularly in models of UV-induced inflammation. In a study using human skin cells, solamargine reduced the expression of genes and proteins involved in inflammation and melanin production. Solamargine also activated the p38 MAPK signaling pathway, which is important for stress response and protection against UV radiation.[78] However, not all studies agree on these properties. In particular, one study found no significant effect of aqueous infusions of *S. mammosum* leaves in reducing inflammation in a rat paw edema model.[79]

This discrepancy could be mainly because its steroidal alkaloid compounds are mainly found in the fruit and not in the leaves, as mentioned earlier in this

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article. Despite this controversy, the available evidence suggests that *S. mammosum* and its steroidal alkaloid compounds could be a promising source of new anti-inflammatory agents. Further research is needed to confirm their efficacy and safety in preclinical and clinical models.

Antisecticide activity

Various studies have highlighted the effectiveness of *S. mammosum* in combating mosquitoes and flies, which are vectors of diseases such as malaria, dengue, chikungunya, zika, Ebola, and filariasis. The fruit extract of *S. mammosum* inhibited the development of the malaria parasite by 62%, indicating moderate activity.[10] The fruit extract demonstrated a lethal effect on larvae and reduced pupae formation in the fruit fly *Drosophila melanogaster.*[43] The extract also inhibited esterase and phosphatase activities in the flies and was more effective than a commercial pesticide in exterminating pupal hatching.

Aqueous extracts of *S. mammosum* and silver nanoparticles derived from the plant were tested against *Aedes aegypti* mosquito larvae. Both the extract and the silver nanoparticles were toxic to the larvae, with the silver nanoparticles proving more effective.

This suggests that *S. mammosum* has the potential to serve as a source of new natural insecticides to combat insect vectors of tropical diseases. However, further research is needed to determine the efficacy and safety of *S. mammosum* in larger studies.

Molluscicidal activity

The toxicity of *S. mammosum* on mollusks is attributed to the presence of steroidal alkaloids like solanine, solasonine, solamargine, solasodine, and

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tomatine. A preliminary study evaluated the steroidal glycoalkaloid mixture from *S. mammosum* fruit against *Lummaea cubensis* and *Biomphalaria glabratus*. It was found that solasonin and solamargine exhibited toxicities of 10 and 25 ppm in both mollusks, respectively.[80] However, tomatidine and solasodine, which are aglycones, did not show any toxicity. This suggests that the molluscicidal properties of *S. mammosum* depend on the type of aglycone and glycosidic bond it possesses.[7] Additionally, the combination of *S. mammosum* with other plants like *Sapindus saponaria* L. and *Jatropha curcas* was found to be more effective in combating *Pomacea canaliculata*.[7]

Other aspects

Toxicity studies

S. mammosum is considered a toxic species due to the presence of steroidal alkaloids and saponins. These compounds give the plant its pharmacological properties, but in large quantities can cause symptoms such as nausea, vomiting, diarrhea, abdominal pain, dizziness, delirium, slurred speech, and ataxia.[81] These effects are consistent with the toxicity of other members of the Solanaceae family; for example, solanine is toxic to humans at a concentration of 0.02 %. High doses can lead to serious complications such as tachycardia and, in some cases, coma and death.[82] The negative physiological impacts of glycoalkaloid steroids are primarily caused by membrane disruption, acetylcholinesterase inhibition, interference with sterol-steroid metabolism, or a combination of these factors.[83] The effects on the membrane may be even more pronounced when solanine is combined with solamargine, as there is a marked synergistic effect compared to solanine alone.[84] It should be noted that information on the toxicity of *S. mammosum*

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is still limited and under development. Further research is needed to determine the safe dosage and long-term effects of consuming this plant.

Eco-friendly methods used for the extraction of biomolecules

The extraction and purification of bioactive compounds produced by *S. mammosum* are crucial steps for their study and application in the development of new drugs and natural products, such as food supplements or cosmetics.[85] Unfortunately, most of these bioactive compounds are thermosensitive and present in very low concentrations. Traditional extraction techniques, such as maceration or decoction, often require large volumes of solvents, are time-consuming, and can degrade heat- and light-sensitive bioactive compounds. To address these issues, alternative extraction methods have been developed that use less solvent, require less energy, and are more environmentally friendly.[86]

The most commonly used solvents in these techniques can be toxic and pose a risk to consumers, operators, and the environment.[86] High-efficiency, non-toxic extraction techniques that use less solvent and are more environmentally friendly are increasingly being developed and implemented. Techniques such as ultrasound-assisted, microwave, supercritical fluid, or enzyme-assisted extraction offer a sustainable and safer alternative for extracting bioactive compounds from *S. mammosum*.[87]

Table 2- Effective techniques and parameters for the extraction of the main biomolecules present in *S. mammosum*.

Molecules	Extraction and purification techniques	Extraction parameters	Concentration	References

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Dioscina **Diosgenin**	Ultrasonic Assisted High Performance Liquid Chromatography	Liquid-solid ratio: 10:1 (ml/g) Solvent concentration: ethanol 85 % (v / v) Extraction time: 75 min Temperature: 50°C	1.77mg/g dry weight	(88)
Solanine	Ultrasound-assisted High-performance liquid chromatography with UV detector	Ethanol-acetic acid (100:30, V/V)	0.01-200 mg/100 dry weight	(89)
Total polyphenols **(gallic acid catechin quercetin resveratrol kaempferol)**	Microwave assisted High-performance liquid chromatography with diode array detector	Extraction time: 90s Power: 800 W pH: 8	826.6 GAE/100 g dry weight	(42)
Carotenoids **(β-carotene** **β-cryptoxanthin)**	Supercritical fluids and supercritical fluid chromatography with triple quadrupole mass spectrometry detection	Solvents (A):CO_2 (B): CH_3OH Gradient: from 0 to 3 min 5% MeOH; from 3 to 4 min 10 % B Flow rate: 2 ml/min Static mode: 0 to 3 min Extraction vessel temperature: 80°C Back pressure regulator: 150 bar	2.5 mg/100g dry weight 3.8 mg/100g dry weight	(90)
Compounds **Polyphenolics** **Gallic acid** **Chlorogenic acid**	Enzyme-assisted	Individual enzymes: (cellulase, xylanase, or β-glucosidase). Enzyme mixture: (cellulase:xylanase:β-glucosidase; 1:1:1) pH: 5.0 (citric acid 0.02 M) Incubation time and temperature : 12 h at 50 °C	438.8 mg/100 g dry weight 71.7 mg/100 g dry weight 47.6 mg/100 g dry weight	(91)

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p - coumaric acid **Quercetin** **Kaempferol**			258.9 mg/100 g dry weight 11.2 mg/100 g dry weight	
Flavonoids	Supercritical fluid	Temperature: 45°C Pressure: 19.61 MPa Cosolvent: 11.5 % CO2 flow rate: 3.0 ml/min	IC_{50}: 66.063 µg/mL	(92)
Sterols and triterpenes **(β-sitosterol and β-amyrin acetate)**	Pressurized liquid	150 °C/5 min/four cycles	50.21 mg/100 g dry weight 0.56 mg/100 g dry weight	(93)
Total triterpenoid acids	Ultrasound and microwave assisted	Ultrasonic power : 240 to 480 W Microwave power : 100 to 300 W Solid-liquid ratio: 1/10 -1/20 g/mL Time: 9 to 15 min Solvent: 60 % ethanol Temperature: 50°C	281.24 mg/g dry weight	(94)
Indioside D, Solamargine **α-solanine**	Ultrasound-assisted High performance liquid chromatography with UV detector	Extraction time: 30 min, Extraction temperature:45 °C Solvent: methanol Pre-packed RP-18e column Mobile phase (acetonitrile-water containing 0.1 % trifluoroacetic acid) Flow rate: 0.4 ml/min	0.126 mg/g dry weight 0.062 mg/g dry weight 0.060 mg/g dry weight	(95)

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		Column temperature: 25 °C		

Expert opinion and conclusions

S. mammosum is a plant with untapped medicinal potential in Ecuador, a country known for its diverse botanical resources. Despite its classification as an invasive weed, *S. mammosum* has a rich cultural history and is used in traditional folk medicine, indicating its value as a source of therapeutic compounds.

The plant contains bioactive substances such as solasodine, solasonin, solamarginine, β-solamarginine, diosgenin, and phytosterols, which contribute to its pharmacological properties. Solasodine and solasonin show promise as anticancer agents, while solamarginine and β-solamarginine exhibit antimicrobial and anti-inflammatory effects, suggesting potential applications in treating infections and inflammatory conditions.

Additionally, diosgenin exhibits various pharmacological activities, including anti-inflammatory, antioxidant, and antidiabetic effects, making it

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an attractive target for drug development. The phytosterols present in *S. mammosum* are associated with cholesterol-lowering effects and cardiovascular health benefits, emphasizing their importance in preventive medicine and dietary supplementation.

This review highlights the growing trend of integrating traditional herbal medicine into mainstream healthcare systems. It emphasizes the importance of recognizing and harnessing the medicinal potential of plants like *S. mammosum*. Conducting rigorous scientific investigations and clinical trials can bridge the gap between traditional knowledge and modern medicine, paving the way for evidence-based medical practices that leverage the biotechnological and cultural value of *S. mammosum*.

Ecuador is an agricultural country, which makes it important to demonstrate the promising biotechnological applications in the current era. One specific biotechnological use of the current plant is its potential as a source of natural pesticides. *S. mammosum* produces bioactive compounds, including glycoalkaloids such as solasodine and solasonine, which have demonstrated insecticidal properties against a variety of agricultural pests. As concerns about the environmental impact of synthetic pesticides grow, there is growing interest in exploring natural alternatives derived from botanical sources such as the cow's udder plant. By harnessing the insecticidal properties of *S. mammosum*-derived compounds, researchers aim to develop eco-friendly pesticides that offer effective pest control while minimizing harm to beneficial organisms and the environment.

Finally, *S. mammosum* is an important source of pharmacologically active compounds and a platform for biotechnological innovation that could have

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applications in sustainable agriculture. To fully harness its potential, interdisciplinary research collaborations and technological advancements are needed. This could contribute to human health, environmental sustainability, and economic development. However, the medicinal benefits of *S. mammosum* and other Ecuadorian plants have not been fully explored due to the lack of scientific research and knowledge about their properties. Conducting systematic studies would provide a better understanding of these valuable therapeutic resources and their potential use in developing new medicines.

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Conflicts of Interest

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