REVIEW ARTICLE

RECORDS OF PHARMACEUTICAL AND BIOMEDICAL SCIENCES

Solenostemma argel: A Comprehensive Review of its Photochemistry and Pharmacological Activities

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Abstract

Solenostemma argel (*S. argel*), a species belonging to the Asclepiadaceae family, is widely distributed across North Africa and certain parts of Asia. Despite its broad geographical range, the plant faces considerable conservation challenges. *S. argel* is recognized for its significant biological activities, which are attributed to its diverse phytochemical profile. Key active compounds include kaempferol, hesperetin, quercetin, gallic acid, pyrogallol, 3-hydroxytyrosol, 4-aminobenzoic acid, protocatechuic acid, chlorogenic acid, catechol, epicatechin, catechin, caffeine, *p*-hydroxybenzoic acid, vanillic acid, ferulic acid, iso-ferulic acid, resveratrol, ellagic acid, *α*-coumaric acid, benzoic acid, 3,4,5-trimethoxycinnamic acid, coumarin, salicylic acid, *p*-coumaric acid, and cinnamic acid. This review consolidates the reported biological activities of *S. argel*, including its anti-obesity, hypoglycemic, anti-inflammatory, anti-rheumatic, antioxidant, anti-Alzheimer, antimicrobial, and gastroprotective effects. This review summarizes the chemical profiling of *S. argel* and its diverse biological activities across various therapeutic applications.

Keywords: *Solenostemma argel*, phytochemical, biological activity.

1. Introduction

In Africa, the use of herbs has a profound and extensive history, intricately woven into cultural traditions, medicinal practices, and culinary arts. Traditional medicine, a cornerstone of healthcare in many cultures, encompasses the entire body of knowledge, skills, and practices that draw from indigenous theories, beliefs, and experiences (**Gossell-Williams *et al.*, 2006**). These approaches, whether scientifically validated or not, are vital for maintaining health and for the prevention, diagnosis, improvement, or treatment of physical and mental illnesses (**El-Khalafy *et al.*, 2023**). It's within this framework, alongside complementary practices, that herbs have long found their place in medicine.

Herbal medicines consist of herbs, herbal materials, preparations, and finished products that derive their active ingredients from plants. These medicinal herbs are well-known for their therapeutic properties and are utilized in traditional, complementary, and even some conventional medical settings to prevent, relieve, or treat diseases (**Sabeeh *et al.*, 2025**). Their efficacy comes from their phytochemical constituents, which produce various biological effects in the body.

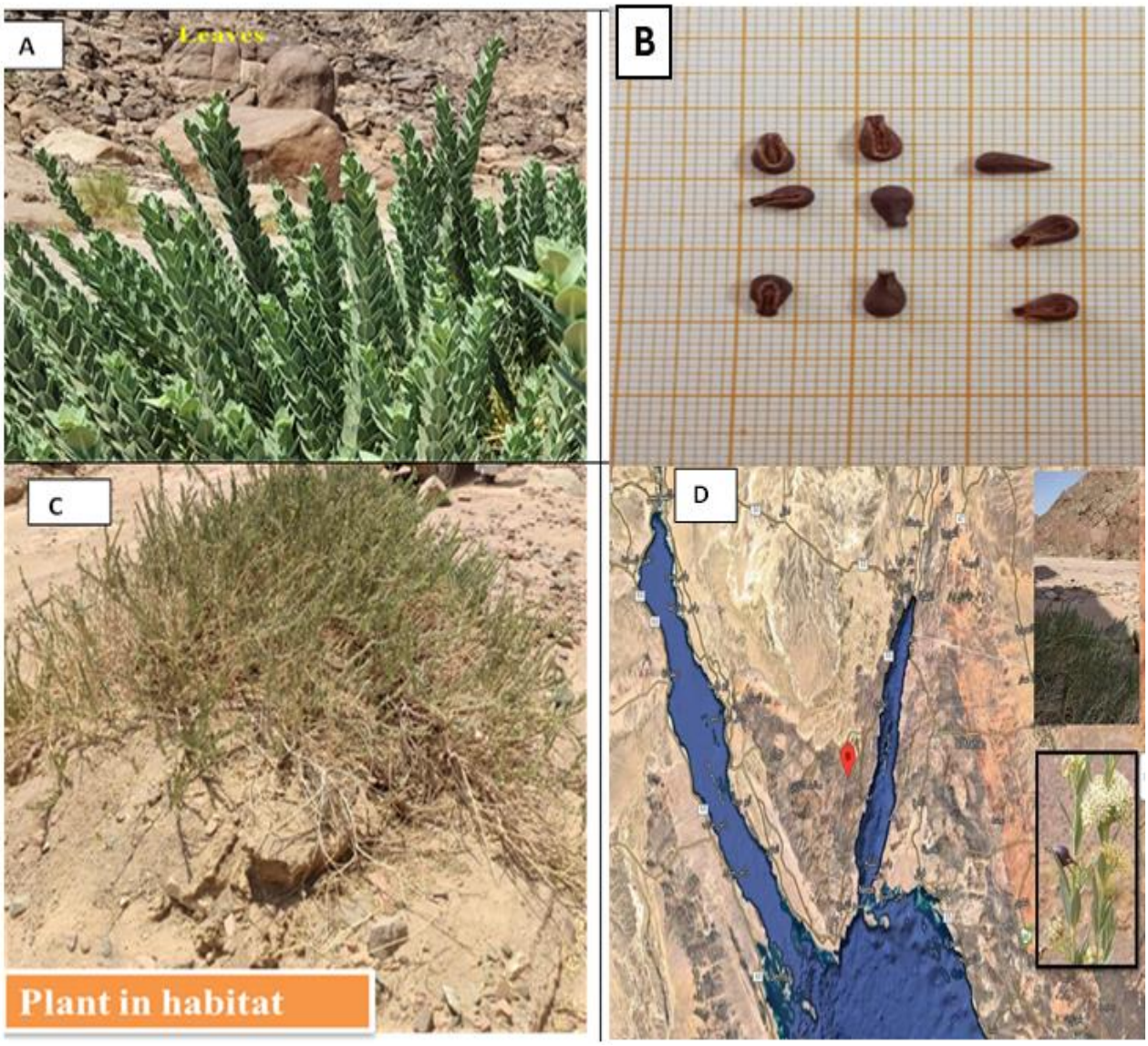

Figure (1): Photographs of *Solenostemma argel* (Del.) (A) leaves of the *S. argel* during growing stage; (B) seeds of the *S. argel*; (C) the whole plant during flowering and fruiting stages in habitat; (D) A location of the site of the collected plants.

Identifying promising herbal remedies for their diverse therapeutic properties is a significant focus in herbal medicine research. *Solenostemma argel* (Del.) Hayne, a prominent perennial shrub of the Asclepiadaceae (milkweed) family, is particularly noteworthy given its widespread distribution throughout North African countries, such as Egypt, Sudan, and Libya.

Despite its widespread distribution, *S. argel* faces significant threats; overexploitation has led to its classification as an endangered medicinal plant in South Sinai, Egypt (**Amar, 2010**). Beyond macronutrients, the leaves also contain essential minerals, including potassium (0.54%), calcium (0.06%), magnesium (0.03%), and sodium (0.01%). Additionally, trace amounts of manganese (0.002%), iron (0.002%), lead (0.001%), and copper (0.0001%) were detected (**El-Kheir and Murwa, 2010**). This rich nutritional and phytochemical profile underscores *S. argel*'s potential.

Its phenolic compound profile is extensive, with total phenolic content varying from 12.63 to 32.9 g GAE/Kg (**Al-Juhaimi *et al.*, 2018**). These include gallic acid, pyrogallol, 3-hydroxytyrosol, 4-aminobenzoic acid, protocatechuic acid, chlorogenic acid, catechol, epicatechin, catechin, caffeine, p-hydroxybenzoic acid, vanillic acid, ferulic acid, iso-ferulic acid, resveratrol, ellagic acid, α-coumaric acid, benzoic acid, 3,4,5-trimethoxycinnamic acid, coumarin, salicylic acid, *p*-coumaric acid, and cinnamic acid. *S. argel* also contains a variety of flavonoids, such as naringenin, rutin, hesperidin, quercetin, quercetrin, kaempferol, hesperetin, apigenin, and 7-hydroxyflavone.

Furthermore, **Demmak *et al.* (2019)** isolated and identified eight additional compounds from *S. argel*: kaempferol-3-*O*-glucopyranoside, kaempferol-3-glucopyranosyl (1→6) rhamnopyranose, dehydrovomifoliol, *p*-hydroxybenzoic acid, and two pregnane derivatives (14,15-dihydroxypregn-4-ene-3,20-dione and its 15β-D-glucopyranoside). Analysis by **Abdelmuhsin *et al.* (2024)** identified 4H-Pyran-4-one, 2,3-dihydro-3.5-hydroxy- as the predominant component in a sample, constituting 11.8% of its total composition. Among *S. argel's* diverse secondary metabolites are pregnanes, pregnane glycosides, phenolic acid derivatives, sterols, triterpenoids, and monoterpene glycosides (**Abdel-Sattar and El-Shiekh, 2024**). Earlier studies by **Hassan *et al.* (2001)** also reported the presence of campesterol, α- and β-amyrin in *S. argel* leaves.

The therapeutic potential of *S. argel* is well-substantiated by its rich phytochemical composition, especially in its leaves and fruits. This is reinforced by extensive traditional use and scientific uses detailing its anti-obesity (**El-Shiekh *et al.*, 2019a,b**), hypoglycemic (**Taha *et al.*, 2014**), anti-inflammatory (**Benmaarouf *et al.*, 2020; El-Shiekh *et al.*, 2019a**), anti-rheumatic (**El-Shiekh *et al.*, 2021b; Ibrahim *et al.*, 2015**), antioxidant (**Elsanhoty *et al.*, 2022; El-Zayat et al., 2021**), anti-Alzheimer (**Demmak *et al.*, 2019**), antimicrobial (**Shafek *et al.*, 2012; Abdel-Motaal *et al.*, 2022**), and gastroprotective (**El-Shiekh *et al.*, 2021a; de Souza *et al.*, 2019**) activities.

To underscore the documented biological benefits of *S. argel* extracts from different botanical parts and their bioactive components, this comprehensive review was undertaken.

2. Morphological description of *S. argel* (Del.)

The *S. argel* (Del.) is a perennial shrub 60-100cm high with several vigorous stems (Figure 1) (**Fawzy *et al.*, 2008**).

- Leaves: They are oval, opposite, leathery glaucous, and enclosed with fine hairs.
- Flowers: The numerous flowers have white petals, and a strong smell.
- Inflorescences: Their inflorescences are dense umbels that give the plant an attractive look.
- Fruits: The fruits are thick, pyriform follicules, 5 cm long and 1.5-2 cm wide, green with violet lines; they contain pubescent seeds.
- Seeds: seeds seem to be black, small, oval, and hairy seeds.
- The plant has a long flowering period from March to June (**Abdel-Sattar and El-Shiekh, 2024**).

2.1. Taxonomy of *S. argel*

Solenostemma belongs to the Asclepiadaceae subfamily, commonly known as the milkweed family. This family comprises a diverse group of perennial shrubs, herbs, and, less frequently, trees, encompassing over 2900 species in 348 genera. Asclepiadaceae plants are widely distributed throughout tropical and subtropical regions, including the Arabian Peninsula and North and Central Africa.

Kingdom: Plantae
Class: Dicotyledonae
Subclass: Gamopetalae
Order: Gentianales
Family: Apocynaceae
Sub-family: Asclepiadaceous
Genus: *Solenostemma* Hayne

Despite its widespread distribution, *S. argel* faces significant threats; overexploitation has led to its classification as an endangered medicinal plant in South Sinai, Egypt (**Amar, 2010).**

2.2. Phytochemistry of *S. argel* (Del.)

Literature consistently demonstrates that *S. argel* is a rich source of diverse phytochemicals, predominantly found in its seeds and leaves. A study by **El-Kheir and Murwa (2010)** on the chemical composition of S. argel leaves from Sudan revealed their macronutrient content as follows: 64.8% carbohydrates, 15% protein, 7.7% ash, 6.5% crude fiber, and 1.6% oil. The leaves are also relatively rich in essential minerals, including sodium (0.01%), potassium (0.54%), magnesium (0.03%), and calcium (0.06%). Trace amounts of manganese (0.002%), copper (0.0001%), iron (0.002%), and lead (0.001%) were also detected.

Its phenolic compound profile is extensive varies from 12.63 to 32.9g GAE/Kg, encompassing gallic acid, pyrogallol, 3-hydroxytyrosol, 4-aminobenzoic acid, protocatechuic acid, chlorogenic acid, catechol, epicatechin, catechin, caffeine, *p*-hydroxybenzoic acid, vanillic acid, ferulic acid, iso-ferulic acid, resveratrol, ellagic acid, *α*-coumaric acid, benzoic acid, 3,4,5-trimethoxycinnamic acid, coumarin, salicylic acid, *p*-coumaric acid, and cinnamic acid (**Al-Juhaimi *et al.*, 2018**).

The *S. argel* also contains a variety of flavonoids, including naringenin, rutin, hesperidin, quercetin, quercetin, kaempferol, hesperidin, apigenin, and 7-hydroxyflavone. Additionally, **Demmak *et al.* (2019)** isolated and identified eight further compounds from *S. argel*: kaempferol-3-*O*-glucopyranoside, kaempferol-3-glucopyranosyl (1→6) rhamnopyranose, dehydrovomifoliol, *p*-hydroxybenzoic acid, and two pregnane derivatives (14,15-dihydroxypregn-4-ene-3,20-dione and its 15*β*-D-glucopyranoside).

Analysis conducted by researchers identified 4H-Pyran-4-one, 2,3-dihydro-3.5-hydroxy- as the predominant component in the sample, making up 11.8% of its total composition (**Abdelmuhsin *et al.*, 2024**).

Among Argel's diverse secondary metabolites are pregnanes, pregnane glycosides, phenolic acid derivatives, sterols, triterpenoids, and monoterpene glycosides (**Abdel-Sattar and El-Shiekh, 2024**). Studies have reported campesterol, α- and β-amyrin to be present in *S. argel* leaves (**Hassan *et al.*, 2001**).

The two novel pregnane glycosides, designated argelosides A and B, in addition to two distinct 14,15-secopregnane glycosides characterized by two hemiketal functions integrated into two five-membered rings were isolated (**Plaza *et al.*, 2005**). Other significant phenolics identified were chlorogenic acid (3221.41 mg/g), ferulic acid (3221.41 mg/g), and gallic acid (2730.85 mg/g). Among the flavonoids, naringenin (2262.80 mg/g) and quercetin (1750.25 mg/g) were the prominent compounds detected (**Alkuwayti, 2023**).

Additionally, **Shafek *et al.*, (2012)** isolated two novel kaempferol glycosides from *S. argel*: kaempferol-3-*O*-*α*-D-glucopyranosyl-(1/2)-*β*-D-xylopyranoside and kaempferol-3-*O*-*α*-L-arabinopyranosyl-(1/2)-*β*-D-galactopyranoside. The study also identified several known kaempferol derivatives, including: kaempferol-3-*O*-*α*-L-arabinoside, kaempferol-3-*O*-*β*-D-xyloside, kaempferol-7-O-α-L-rhamnoside, kaempferol-7-*O*-*α*-L-arabinoside, kaempferol-3, 7-di-*O*-*β*-D-glucoside, kaempferol-3,7-di-*O*-*α*-L-rhamnoside and kaempferol itself. These newly identified kaempferol glycosides exhibited moderate antibacterial activity (**Shafek *et al.*, 2012**). Also, **Shafek *et al.*,** (2012) isolated two novel natural kaempferol glycosides; specifically, kaempferol-3-*O*-*α*-D-glucopyranosyl-(1→2)-*β*-D-xylopyranoside and kaempferol-3-*O*-*α*-L-arabinopyranosyl-(1→2)-*β*-D-galactopyranoside, together with the known glycosides; 7-*O*-*α*-L-arabinoside, 3,7-di-*O*-*β*-D-glucoside, 3,7-di-*O*-*α*-L-rhamnoside; kaempferol-3-*O*-*α*-L-arabinoside; 3-*O*-*β*-Dxyloside; 7-*O*-*α*-L-rhamnoside, and kaempferol. The extract and the new kaempferol glycosides showed a moderate antibacterial activity. **Table 1** summarizes the most prominent active compounds identified in *S. argel.*

Research by Ibrahim et al., (2015) investigated how extraction methods influence the phytochemical composition of *S. argel*. The acetone extracts yielded higher levels of phenolics (81.45 mg/g), flavonoids (37.39 mg/g), and tannins (54.04 mg/g) compared to aqueous or ethanol extracts. Further, **Elsanhoty *et al.*, (2022)** identified gallic acid as the greatest abundant phenolic acid in *S. argel*, followed by syringic and *p*-coumaric acids. Their study also detected the flavonoids catechin, quercetin, luteolin, kaempferol, and rutin in the methanolic extract, which notably exhibited greater antioxidant capacity than extracts prepared with ethanol or acetone (**Elsanhoty *et al.*, 2022**).

3. Biological importance of *S. argel* (Del.):

Historically, local Bedouin populations have utilized S. argel to treat colon disorders **(Ofir *et al.*, 2023**). Traditional applications also include its use as an anti-inflammatory, anti-rheumatic, and antispasmodic agent, and in the management of diabetes mellitus (**Innocenti *et al.*, 2005; Ibrahim *et al.*, 2015; Benmaarouf *et al.*, 2020**). Specific uses of its leaves encompass remedies for neuralgia, sciatica, abdominal cramps, jaundice, and cystitis (**Ibrahim *et al.*, 2015**).

S. argel has confirmed a broad spectrum of biological activities such as antioxidants, cytotoxic, antidiabetic,

antihypertensive, analgesic, anti-inflammatory, antifertility, insecticidal, antiparasitic, antihyperlipidemic, protective, antimicrobial, antithrombotic, antiurolithiatic, and hemodynamic effects.

3.1. Anti-obesity activity :

Aqueous and alcoholic extracts of *S. argel* leaves demonstrate promising hypolipidemic effects, particularly in hypercholesterolemic conditions (**Osman *et al.*, 2015).** An aqueous extract of *S. argel* was shown to prevent increases in serum cholesterol and low-density lipoprotein-cholesterol (LDL) in hypercholesterolemic rats, while it had no significant effect on the lipid profiles of normocholesterolemic rats. Similarly, an alcoholic extract of *S. argel* also exhibited a beneficial impact on high serum lipid profiles in rats consuming a high-cholesterol diet over four weeks (**Osman *et al.*, 2015**). These findings suggest the potential of *S. argel* extracts in managing dyslipidemia.

S. argel has demonstrated significant inhibitory effects against key metabolic enzymes, including α-amylase, lipase, and α-glucosidase (**El-Shiekh et al., 2019a**). Phytochemical analyses of *S. argel* leaves have revealed a rich array of bioactive molecules, such as sterols, pregnane glycosides, flavonoids, monoterpenes, and acylated phenolic glycosides. More recent research by **El-Shiekh *et al.*, (2019b)** provided compelling evidence for *S. argel*'s anti-obesity potential in rats. Their study showed that the *S. argel* consumption significantly controlled weight gain, improved lipid-related markers, attenuated liver steatosis, and modulated adipokine activity.

Furthermore, the extract increased β-oxidation gene expression while decreasing lipogenesis-related gene expression, alongside an improved inflammatory and lipid peroxidation balance. The observed anti-obesity properties of *S. argel* are potentially attributed to its pregnane glycoside content. These compounds, commonly found in plants belonging to the Asclepiadaceae subfamily, are recognized as appetite suppressants that exert their effects, in part, by modulating digestive enzymes (**Choucry *et al.*, 2021**).

3.2. Hypoglycemic activity

The methanolic extract of *S. argel* leaves exhibited both hypoglycemic and antioxidant potential. Furthermore, the aqueous extract of *S. argel* demonstrated anti-diabetic activity by significantly reducing blood glucose, HDL cholesterol, and α-amylase activity in a rat model (**Taha et al., 2014**). The precise mechanism by which S. argel exerts its hypoglycemic effect remains to be fully elucidated. However, **El-Shiekh et al., (2021a**) suggested that the pregnane glycosides present in *S. argel* may contribute to its effects by attenuating hepatic steatosis, improving lipid profile, reducing lipogenesis, and modulating adipokine activity in rats.

3.3. Anti-inflammatory activity

The presence of flavonoids and related polyphenols in *S. argel* extract may be responsible for its anti-inflammatory activity **(El-Shiekh *et al.*, 2019a**). The anti-inflammatory activity of *S. argel* may be due to the inhibition of the release of anti-inflammatory mediators occurring during the intermediate and second phases of edema formation, such as bradykinin and prostaglandins (**Benmaarouf et *al.*, 2020**). Its strength lies in compounds like flavonoids and phenolic acids (including kaempferol and its derivatives), which are well-known for their potent antioxidant and anti-inflammatory effects.

Pregnane glycosides (such as solenoside A and various argelosides) further boost these anti-inflammatory properties, supported by a synergy of other polyphenols in the plant. *S. argel* combats inflammation through several key pathways: It inhibits inflammatory mediators like prostaglandins, bradykinin, and cytokines, preventing them from fueling the inflammatory response. *S. argel* also inhibits enzymes crucial to inflammation, including COX and LOX enzymes, and proteinases (**El-Shiekh *et al.*, 2019a**). By stabilizing cell membranes, it stops pro-inflammatory components from leaking out and worsening inflammation (**Elsanhoty *et al.*, 2022**). Finally, *S. argel* compounds can modulate signaling pathways like NF-κB, which are central to regulating inflammatory gene expression.

3.4. Anti-Rheumatic property

Recent studies have shown that the polar metabolite fraction of *S. argel* (sourced from Aswan, South Egypt) significantly reduced paw edema, pro-inflammatory intermediaries, serum rheumatoid indicators, bone and cartilage degradation enzymes, and oxidative stress biomarkers in animal models (**El-Shiekh *et al.*, 2021b**). This polar fraction, rich in phenolic acids and flavonoid glycosides, demonstrated indicating anti-arthritic activity, surpassing the nano-polar fraction, which was predominantly composed of pregnane glycosides (**El-Shiekh *et al.*, 2021b**).

Rheumatoid arthritis is also considered by preeminent levels of circulating autoantibodies and inflammatory biomarkers such as rheumatoid factor (RF), anti-cyclic citrullinated peptide (anti-CCP), and C-reactive protein (CRP), which are present in about 70% of Rheumatoid arthritis patients. **El-*Shiekh et al.*, (2021b)** reported that *S. argel* treatment normalized these RA markers in a rat model. Additionally, **Ibrahim *et al.* (2015)** found that *S.*

argel's anti-rheumatic arthritis (RA) properties are due to its antioxidant and anti-inflammatory consequences. The same authors identified rosmarinic, quercetin, and naringin as the major flavonoid compounds in *S. argel*, crediting them with the observed antioxidant and anti-inflammatory effects (**Ibrahim *et al.*, 2015**).

3.5. Antioxidant activity

The antioxidant properties of *S. argel* contribute to many of its observed beneficial influences, such as its anti-inflammatory and anti-obesity actions, as oxidative stress often plays a role in these conditions (**Ibrahim *et al.*, 2015**).

Recently, **Elsanhoty *et al.*, (2022),** reported scavenging activity values of 79.36%, 66.17%, and 61.77% for methanolic, ethanolic, and acetone extracts, respectively, indicating that methanol is the most effective extraction solvent for *S. argel*. This aligns with, (**Kebbab-Massime *et al.*, 2017**), who found that the methanolic extract exhibited stronger radical scavenging activity than the aqueous extract using the DPPH assay. The antioxidant properties of *S. argel* have been attributed to its phenolic acid content. Other reports suggested that the antioxidant of *S. Argel* was owed to the existence of phenolic acids (**Al-Juhaimi *et al.*, 2018**) and flavonoid compounds (Benmaarouf et al., 2020). The radical scavenging activity of *S. argel* increased from 32% to 84% with expanding concentrations from 250 to 1000 µg/mL (**Al-Deen and Al-Naqeb, 2014**).

Moreover, (**El-Zayat *et al.*, 2021),** reported that S. argel demonstrated antioxidant activity as measured by DPPH (35.25 mg), ABTS·+ (23.77%), and FRAP (112.5 mmol Fe(II)/g extract) assays. *S. argel* extract was recently employed in the green synthesis of copper nanoparticles (**Sabeeh *et al.*, 2025**). Analysis of the antioxidant activity revealed an IC_{50} value of 0.011 mg/mL for *S. argel* itself, while the prepared nanocomposites had an IC_{50} value of 0.478 mg/mL, indicating both are valuable antioxidants (**Sabeeh *et al.*, 2025**).

3.6. Anti-Alzheimer activity

Alzheimer's disease (AD) is a chronic neurodegenerative syndrome marked by lessened cholinergic neurotransmission. Current treatments primarily utilize acetylcholinesterase (AChE) inhibitors. ChE inhibitors, including pregnane glycosides, have been found in the Apocynaceae family. In 2019, Demmak and coworkers isolated and identified eight compounds from *S. argel*: kaempferol-3-*O*-glucopyranoside, kaempferol, kaempferol-3-glucopyranosyl (1→6) rhamnopyranose, *p*-hydroxybenzoic acid, dehydrovomifoliol, 14,15-dihydroxypregn-4-ene-3,20-dione, 14,15-dihydroxy-pregn-4-ene-3,20-dione-15*β*-D-glucopyranoside, and solargin I. Of these, kaempferol exhibited the strongest inhibitory effect against both butyrylcholinesterase (BChE) and AChE, with slight selectivity towards AChE (**Demmak *et al.*, 2019**). The same study also reported that both kaempferol-3-*O*-glucopyranoside and kaempferol inhibited over 50% of BChE activity at 100 µM (Demmak et al., 2019). This research suggests that *S. argel* holds promise as a source of potential anti-Alzheimer's drugs and underscores the importance of exploring medicinal plants for novel therapeutic agents.

3.7. Antimicrobial activity

S. argel has demonstrated antimicrobial activity against several pathogenic bacteria, including *Aspergillus niger, Penicillium italicum, Escherichia coli,* and *Salmonella typhi* (**Sulieman *et al.*, 2009**). This antibacterial effect may be attributed to the presence of phytochemicals like saponins and flavonoids in *S. argel* (**Hamadnalla and Jack, 2019**). Further research has shown that *S. argel* extracts possess strong antimicrobial activity against both Gram-positive and Gram-negative bacteria (**Elsanhoty *et al.*, 2022**). Additionally, (**Shafek *et al.*, 2012**) reported that two kaempferol glycosides isolated from *S. argel* exhibited antimicrobial activity against both types of bacteria. Ether acetate and methanolic extracts of *S. argel* significantly inhibited the growth of the yeast *Candida albicans* and *filamentous fungi* (*Penicillium jensenii, Microsporum cinctum,* and *Penicillium funiculosum*) isolated from wounds (**Abdel-Motaal *et al.*, 2022**). The antimicrobial effect of *S. argel* may be linked to the presence of fatty acids, such as octadecadiynoic acid. In a recent study, **El-Zayat *et al.*, (2021**), found that *S. argel* extract was highly active against several pathogenic bacteria, including *Salmonella typhimurium* and *Bacillus subtilis*, while exhibiting moderate activity against *Salmonella enterica, E. coli, Pseudomonas aeruginosa,* and *Listeria innocua*. Furthermore, *S. argel* has shown potential as an antibacterial agent against *Brucella abortus*, the causative agent of brucellosis, a zoonotic disease in mammals (**Ali *et al.*, 2019**).

S. argel extract was recently used to create copper nanoparticles through green synthesis (**Sabeeh *et al.*, 2025**). When tested for their antimicrobial properties, these copper oxide nanoparticles (CuO-NPs) showed a broad spectrum of activity. They were effective against several pathogenic bacterial strains, *including Salmonella typhimurium, Staphylococcus aureus, Escherichia coli, Bacillus cereus, Staphylococcus epidermis, and Klebsiella pneumonia*. The CuO-NPs also demonstrated efficacy against the pathogenic

fungus *Candida albicans* (**Sabeeh *et al.*, 2025**). **Al-Zoubi (2025)** compared the effectiveness of synthesized silver nanoparticles (AgNPs) when combined with various plant extracts, specifically *S. argel, Citrullus colocynthis, Elettaria cardamomum, Foeniculum vulgare, Syzygium aromaticum,* and *Maerua crassifolia*. The study concluded that the S. argel extract was the most effective in combination with AgNPs. This combination demonstrated high antibacterial activity by inhibiting both the fungus *Candida albicans* and the bacterium *Bacillus subtilis*. *S. argel* exhibits antimicrobial activity due to its rich composition of bioactive compounds, primarily flavonoids, phenolic acids, and saponins. Some studies suggest that the antimicrobial activity of *S. argel* is attributable to its rich content of phenolic compounds and saponins (**Sabeeh *et al.*, 2025**). These compounds can interact with the cell membranes of bacteria and fungi, leading to increased permeability, or interfere with the synthesis of DNA and RNA in microbial cells, or disrupt the energy production pathways within microbial cells.

3.8. Gastroprotective effect

In the study of (**El-Shiekh *et al.*, 2021a**) examined the gastroprotective effect of mucilage fraction (MFA) isolated from *S. argel* against ethanol-induced gastric ulcer in rats. They reported that rats received 100 or 200mg of MFA had lower MDA and MPO and greater levels of GSH. Administration of MFA at 200 mg/kg decreased the intestinal contents of inflammation indices including TNF-α, and IL-6 by 39, 33%, respectively, as compared to ulcer group (**El-Shiekh *et al.*, 2021a**). Moreover, it has been indicated that MFA exerted the protective action against ethanol induced gastric damage, the glandular mucosa appeared apparently normal and the intact epithelial surface appeared covered by health mucus cover. The only remarkable finding was the congestion at the deep mucosa with mild perivascular oedema at the submucosa. There is a strong relationship between gastric ulcer damage and inflammation induced by ethanol (**de Souza *et al.*, 2019**). Ethanol exposure initiates an inflammatory response, where macrophages release pro-inflammatory mediators like TNF-α, IL-6, and MPO. This inflammation, coupled with the accumulation of neutrophils, directly damages the stomach's mucosal barrier. The subsequent release of these cytokines then generates reactive oxygen species (ROS), which further facilitates the development of gastric ulcers. As a result, the ethanol control group exhibited elevated levels of TNF-α, IL-6, and MPO.

(PGE2), a key mediator essential for maintaining the stomach's protective barrier and promoting ulcer healing. PGE2 effectively regulates gastric mucus secretion, enhances blood flow, and increases both mucus and bicarbonate, thereby sustaining the cellular integrity of the mucosa (**Fahmy *et al.*, 2020**). Decreased prostaglandin (PG) levels are a major cause of stomach ulcers. Our results suggest that MFA's stomach-protective effect may be partly due to its stimulation of gastric PG release. Another key protector is HSP-70, a protein that shields stomach cells from damage and aids in repair and ulcer healing (**Fahmy *et al.*, 2020**).

Given its increasing economic and medicinal value, overexploitation of *S. argel* has become a significant concern. This medicinal plant is currently classified as vulnerable and endangered due to its intensive overuse (**Amar, 2010; Moustafa and Mansour, 2020**). Beyond overharvesting, its declining status may also be attributed to anthropogenic activities, climate change, habitat destruction, a decline in pollinator populations, loss of suitable symbiotic mycorrhiza, and inferior picking procedures (**Moustafa *et al.*, 2001; Ramadan *et al.*, 2009; Moustafa and Mansour, 2020**).

4. Conclusion

This review focuses on describing the primary compounds and diverse active constituents present in *S. argel*. These compounds have demonstrated numerous biological and therapeutic activities, such as anti-obesity, hypoglycemic, anti-rheumatic, anti-Alzheimer, and gastroprotective effects, largely due to their underlying antioxidant, anti-inflammatory, and antimicrobial actions. To fully elucidate the beneficial effects of *S. argel*, further investigations are warranted to explore its broader biological and therapeutic activities.

Declaration of Conflict of Interest

The authors declare that there is no conflict of interest.

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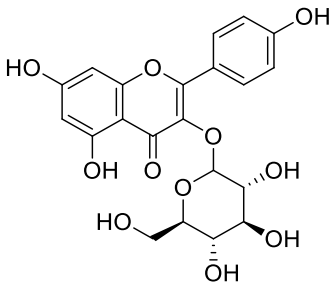
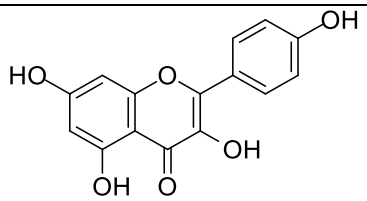
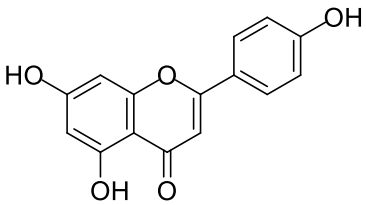
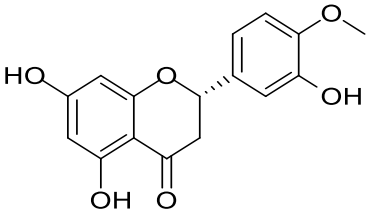
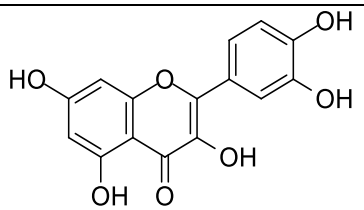
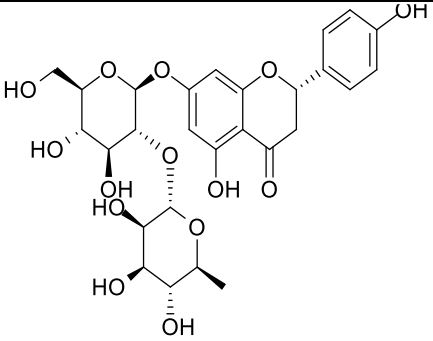
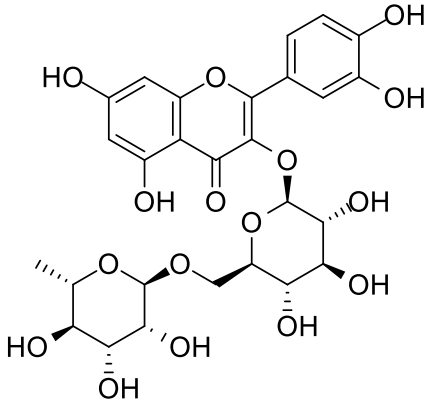
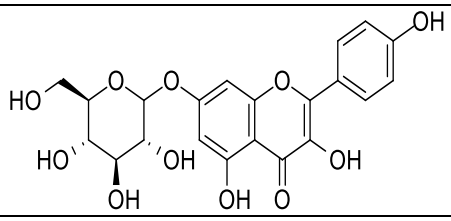
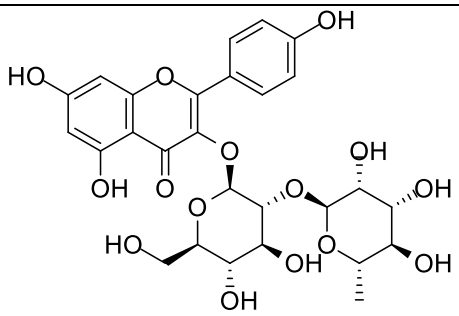
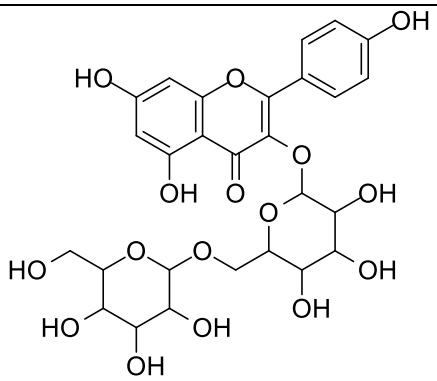
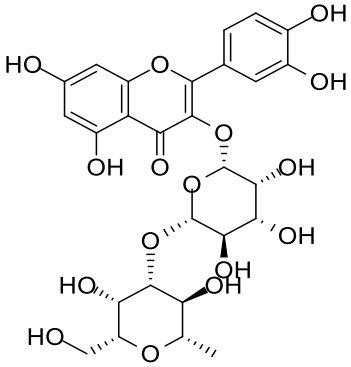
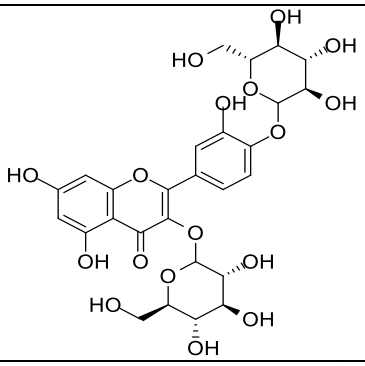
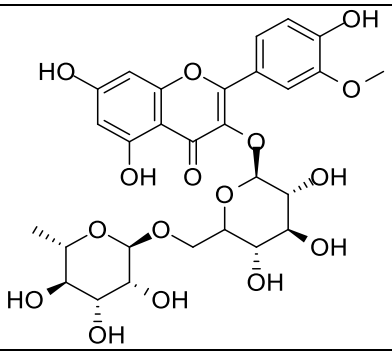
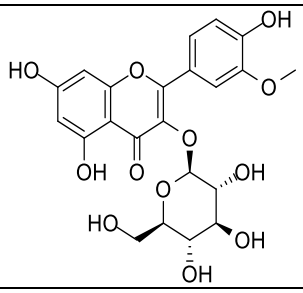
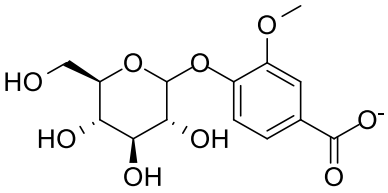
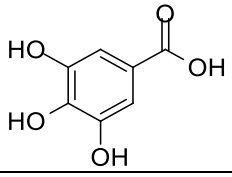
On the other hand, pre-treating with MFA counteracted the elevation of these levels. This highlights the importance of Prostaglandin E2

TABLE 1. A list of metabolites previously isolated from *S. argel* with biological activity.

No.	Compound	Structure	Biological activity
A. Flavonoids			
1	**Kaempferol-3-*O*-glucopyranoside (Astragalin)**		Anti-obesity (**Muni Swamy *et al.*, 2022**), anti-cancer **(Radziejewska *et al.*, 2022**), anti-inflammatory (**Kim *et al.*, 2022**).
2	**Kaempferol**		Anticancer (**Radziejewska *et al.*, 2022**), neuroprotective action, anti-inflammatory, and antioxidant (**Silva dos Santos *et al.*, 2021**).
3	**Apigenin**		Anticancer, cardioprotective anti-inflammatory, anti-microbial **(Liang *et al.*, 2023; Thomas *et al.*, 2023**), management of skin and inflammatory diseases (**Yoon *et al.*, 2023**).
4	**Hesperetin**		Antidiabetic (**Yang *et al.*, 2022a**), antimicrobial, anti-inflammatory, and antioxidant **(Choi *et al.*, 2022**).
5	**Quercetin**		Antioxidant, and Improving fertility (**Ahmed *et al.*, 2022; Behairy *et al.*, 2022**)
6	**Naringin**		Lipid metabolism and anti-diabetic **(Yang *et al.*, 2022b**).

7	**Rutin**		Improve metabolic function, Anti-inflammatory (**Muvhulawa *et al.*, 2022**), antioxidant, immunomodulatory, (**Ahmed *et al.*, 2022**)
8	**Kaempferol-7-*O*-glucoside**		Anti-viral (**Behbahani *et al.*, 2014**), anti-microbial anticancer (**Lee *et al.*, 2015**).
9	**Kaempferol 3-*O*-neohesperoside**		Glucose lowering (**Zanatta *et al.*, 2008**), and anticancer (**Azab *et al.*, 2013**).
10	**Kaempferol *O*-trihexoside-*O*-deoxyhexoside**		Antioxidant capacity (**Mejía *et al.*, 2023**)
11	**Quercetin 3-*O*-neohesperoside**		Anti-atherosclerosis, and antiplatelet aggregation activities (**Akbari *et al.*, 2022**).

12	**Quercetin 3,4'-diglucoside**		Antioxidant (**Albishi et al., 2013**), Antimicrobial and Antiproliferative (**Fredotović et al., 2021**).
13	**Isorhamnetin *O*-rutinoside (Narcissin)**		Antioxidant, antitumor, and anti-viral **(Owona *et al.*, 2021)**
14	**Isorhamnetin-*O*-glucoside**		Anti-cancer (**Koga *et al.*, 2022**), antioxidant, acetylcholinesterase inhibitory activity, and anti-diabetes (**Lee *et al.*, 2005**).
A. Phenolic acids & their derivatives			
15	**Vanillate glucoside**		Food additives, beverages and cosmetics (**Marion-Letellier et al., 2019).**
16	**Gallic acid**		Antioxidant activity (**Elsanhoty *et al.* 2022)**

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