Journal of Applied and Natural Science
16(3), 1317 - 1334 (2024)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Review Article

Pharmacognostical, phytochemical and phytopharmacological activities of *Solanum torvum* utilized as a traditional medicinal herb: A review

Paramita Ganguly
Department of Pharmaceutical Technology, Brainware University, Kolkata-700125 (West Bengal), India
Sandip Chatterjee*
Gopal Narayan Singh University, Narayan institute of Pharmacy, Sasaram- 821305 (Bihar), India
Sabita Kumari
Department of Pharmacy, Sarala Birla University, Birla Knowledge City, Ranchi-835103 (Jharkhand), India
Prangyan Paramita Pati
Gayatri College of Pharmacy, Sambalpur- 768200 (Odisha), India
Kazi Julekha
Department of Pharmaceutical Technology, Brainware University, Kolkata-700125 (West Bengal) India

*Corresponding author. E-mail: sandip.chatterjee@gnsu.ac.in.

Article Info
https://doi.org/10.31018/jans.v16i3.5799
Received: May 25, 2024
Revised: September 01, 2024
Accepted: September 07, 2024

How to Cite
Ganguly, P. *et al.* (2024). Pharmacognostical, phytochemical and phytopharmacological activities of *Solanum torvum* utilized as a traditional medicinal herb: A review. *Journal of Applied and Natural Science*, 16(3), 1317 - 1334. https://doi.org/10.31018/jans.v16i3.5799

Abstract
Turkey berry, also known as *Solanum torvum* Swartz, is native to Africa, Asia and South America. This tropical plant of the family Solanaceae has versatile uses in both food and medicine in tropical and subtropical countries. It has been employed in traditional medicine all over the world. Chemical composition of this fruit, its pharmacological properties as ascertained through scientific investigations and its clinical applications are discussed. *S. torvum* contains numerous important metabolites such as saponins steroids and flavonoids, which function as antioxidants, antifungal, antidiabetic, anticancer, antiulcer, antianxiety and immunomodulators. Various notable roles in ethnomedicinal uses and approaches as a traditional medicinal herb. These have been found in large amounts and have various functions, including antioxidant properties against cardiovascular diseases and immune-modulating activities. Notably leaves extracts, fruits etc. have beneficial therapeutic traits. For a long time now, "*Solanum torvum"* has been used to treat numerous conditions such as fever, wounds, etc. Research backs up these traditional uses by pointing out the plant's blood pressure management, kidney protection nature, and immune-boosting capabilities. The review summarizes the importance of ethnobotany, its chemical composition, and the scientifically proven pharmacological activities of *S. torvum.*

Keywords*:* Ethnomedicinal, Phytopharmacological, Phytochemical Studies, Physical studies, *Solanum torvum*

INTRODUCTION

Solanum torvum is a common Cameroon folk medicine brazed in humid Indian farms; these fruits and leaves are used in various treatments. The fruits are suitable for human consumption, although in South Indian markets, they are more commonly recognized as a fundamental Southward Indian vegetable. This species, a member of the Solanaceae family, is commonly referred to as the turkey berry *S. torvum* is also native to Africa and has been cultivated in the West Indies (Adjanohoun *et al*.1996; Siemonsma and Piluek, 1994 ; Jaiswal, 2012). *S. torvum* is a particular concern within the well-known family of Solanaceae, which many other medicinal plants accompany. The name of the genus arises from the Latin and, almost probably, denoted a medicinal plant to treat epilepsy. This large and difficult genus is undoubtedly the most widespread among angiosperms (Hussain *et al*., 2023). It is also widely used in traditional medicine for its multi-disease usage. *S. torvum* has prominent antimicrobial, antibacterial, and antiviral properties and can be used as an effective remedy against various infectious diseases. This characteristic of the plant is highly respected in

folk medicine. For inflammatory diseases, leaves can be ideally used as a pain reliever. The most noticeable anti-inflammatory action against inflammatory conditions is the supportive treatment of pain, such as in wounds, fever, and other prominent inflammatory conditions. The leaves can also be used as a sedative. The main use of sedatives may help with gastrointestinal problems, which are also the most experienced diseases (Kannan *et al*.,2012; Muhammad., 2011; Bhagyashree *et al*.,2012; Yousafa *et al*., 2013; Karumari *et al*., 2014; Karmakar *et al*., 2015). Similar macroscopic characters observed served as another plant belonging to Solanaceae family named *S. indicum* (Chatterjee *et al*., 2024).Turkey berry, scientific name *S. torvum,* is a prickly drug that grows to a height of 1.5-3 m. The stem is covered with soft, fine hair, and the leaves are even and polished. This plant bears lobed tiny fruits seated on the calyx and white bell-shaped flowers. Turkey berries are regularly distributed throughout the Indian subcontinent, West Indies, Bermuda, Southeast Asia, and tropical America. They are also an integral part of traditional medicine (Muhammad, 2011; Chopra *et al*.,1956; Rajan *et al*., 1993)

S. torvum is a potential source for developing therapeutic plant-based bioactive agents. This plant's fruits reportedly comprise flavones and lignans, which are major constituents (Senizza *et al*., 2021). The anticholinesterase activities of *S. torvum* fruit. *S. torvum,* commonly known as Turkey berry, is an important vegetable belonging to the Solanaceae family. As reported previously, leaves and fruits of *S. torvum* showed a range of biological activities, such as anticancer, antimicrobial, antioxidant, analgesic, and cardioprotective activities (Aljabri *et al*., 2023). Various food plants are used in traditional medicine in Togo, one of them being *S. torvum*. It forms part of the diet in Togo, while its fruits have been reported with antioxidant and antimicrobial properties (Melila *et al*., 2021)

Various chemical substances, including steroids, phenols, steroid alkaloids, and steroid saponins, are found in *S. torvum*. Pharmacological research suggests that these components are involved in the wide range of therapeutic benefits of stems and roots. These characteristics, including anti-inflammatory, antiviral, antitumour, and antibacterial actions, suggest that *S. torvum* may have therapeutic applications for various illnesses (The State Pharmacopoeia Commission, 2000). *Solanum torvum* Sw (*S. torvum*) is a family of flowering plants in the nightshade family, Solanaceae, a slender shrub whose leaves and fruits are effective against various microbial diseases. When heated, the leaves of *S. torvum* are applied to cure skin infections (Obiang *et al*., 2019). *S. torvum* (Sw.) is a small shrub of the family Solanaceae that grows abundantly in tropical India, Malaysia, and Pakistan. Different chemical compounds have been isolated from this plant: steroids, saponins, alkaloids, and phenols. Hence it helps to treat several diseases. The tribal people use it as a source of food and medicine, especially against dental problems and intestinal parasite larvae (Murugesan *et al*., 2024). Because of its tart, juvenile flavour, edible fruits from *S. torvum*, a common ingredient in Thai cooking, are frequently sold in markets and grown in tropical climates. Fruits and leaves high in alkaloids are used in traditional medicine in addition to their culinary purposes. Several plant components can be utilized ceremonially, and fruits are frequently used to alleviate hypertension (Lim, 1992; Agrawal *et al*., 2010) Studies utilizing an ethanol extract from *S. torvum* berries have shown promising outcomes in terms of preventing Ehrlich ascites carcinoma cells from proliferating. This discovery suggests that the berries may have anticancer effects (Klein, 1950).

Plant taxus biological classification

The devil‘s thorn *S. torvum* or the wild tomato *S. torvum* has an amazing ancestry. It is a member of one of life's extensive communities, known as Plantae, whereas all the plants form the Union. This plant is from Monocotyledon as a flowering plant and is above Polycotyledon as well. Proceeding even further, that is the Angiospermae class, also known as the flowering plants. The *S. torvum* venture remains within the Solanales order, which has tomatoes and potatoes as family members (Jaiswal, 2012; Starr *et al*., 2003) (https://www.iplantz.com/plant/1432/solanum-torvum/) .

Pharmacognostical standardization

Pharmacognosy deals with medicines obtained from natural sources: plants, animals, and microorganisms. This branch of science deals with complex multi compound products' safety, purity, and efficacy. Herbal pharmacognosy applies this science to traditional herbal medicine sources. Traditional medicines, especially herbal remedies, continue to be a chief source of healthcare for many countries and cultures worldwide (Leisegang, 2021). The identification process includes macroscopic and microscopic characteristics, chemical tests, and chromatographic or spectroscopic patterns. Macroscopic characteristics include parameters of sensory evaluation such as shape, size, color, texture, odor, and taste. Microscopic characteristics identify herbal drugs from known cytological and histological features. Sometimes, schematic drawings of the main microscopic features of powdered drugs may also be a part of the monographs (Fursenco *et al*., 2023). Without authentication and characterization of the tested drug, herbal products cannot be considered scientifically valid to ensure reproducibility during manufacture. Quality assurance is also called for in cultivation, harvesting, primary processing, handling, storage, packaging, and distribution (Umamaheswani *et al*., 2021). Herbal drugs

are in great demand and much required, not only in developing but also in developed nations. The reasons associated with the increasing consumption of herbal drugs are their efficacy, safety, and fewer side effects that are linked with synthetic molecules (Wanjari *et al*., 2019). The failings of conventional pharmaceutical treatments and availability, many individuals are resorting to or using herbal medicine. This chapter will discuss the need for the standardization of herbal medicine so that consistent quality, safety, and efficacy issues in herbal products come to the fore (Paul *et al*., 2024). Pharmacognostical standardization determines the quality and standard of herbal drugs or any natural product. This entails a sequence of assessments and tests to determine the effectiveness and suitability of natural products in curative practices. The standards that make up pharmacognostical standardization include identification that checks the right plant species used for the plant material, macroscopy and microscopy to get a physical and structural characterization of the plant material. Quantitative analysis determines the kind and concentrations of the active pharmaceutical ingredients and other related chemical components. Also, the moisture content, ash values, and extractive values are calculated as physicochemical characteristics. Also known as source identification, pharmacognostical standardization is a vital component of the active development and application of medicinal plants in the form of pharmaceuticals. This, in turn, mediates herbal drugs and natural products that focus on quality, safety, efficacy and standardization through pharmacognosy's physical and chemical examination. These evaluations ensure the organization of true plant materials, ensure the plant material is pure, and help eliminate inferior material.The concentration of primary and secondary constituents, as well as identify toxin levels, and set guidelines that help maintain product and batches' quality (Ahmad *et al*., 2014).

Physicochemical studies of *Solanum torvum*

S. torvum is a plant with significant physicochemical properties and beneficial health effects. Its rich phytochemical composition and nutritional value make it an important plant for both medicinal and dietary uses. Ongoing research is essential to fully understand its potential and develop safe and effective applications in various fields. The physicochemical studies are tabulated in Table 1.

Phytochemical approaches of *Solanum torvum*

Phytochemicals are found in all plant foods but are especially abundant in whole grains, broccoli, Brussels sprouts, cauliflower, citrus fruits, dark green leafy vegetables, garlic, tea, herbs and spices, onions, tomatoes, soybeans, and wine (Biney *et al*.,2019). Preliminary phytochemical screening of *S. torvum* Sw. involved qualitative analysis using petroleum ether, distilled water, and methanol extracts. Phytochemical screening results were as follows: the fruit extracts of *S. torvum* in petroleum ether had alkaloids, steroids, phenols, flavonoids, saponins, and amino acids. The distilled water extracts showed the presence of alkaloids, steroids, reducing sugars, and amino acids. The methanol extracts had saponins, tannins, and quinones (Hemalatha

Table 1. Physicochemical studies evaluation of *Solanum torvum*

Sl no.	Standardization parameter	Physicochemical studies result	Reference
01	Measurements were made of the following physical-chemical standards: loss on drying, water-soluble ash soluble in water, total Ash conceded on heating, and foreign matter, extractive value.	According to the study, total ash makes up 3.5% of the sample. The two types of ash that may be separated further are water-soluble ash and acid-insoluble ash. Water-soluble ash accounts for 1% of the sample, whereas acid-insoluble ash makes approximately 1.5%. While after performing loss on drying, extractive values are 20 and 20.80% of water-soluble extractive value.	World Health Organization (1998); Janarthanan et al. (2019)
02	Its moisture content, water-soluble ash, and total ash were measured to evaluate the sample's composition. Foreign matter was checked for potential contaminants or impurities. Additionally, extractive value was assessed to determine soluble components. This analysis offers an in-depth view of the sample's physical and chemical properties.	The composition of the sample was documented, and many notable variables were produced. The moisture level of 12% was reported to be the case. This water-soluble ash content was 0.09%, with a further 0.11% acid-insoluble ash content of 0.30%. The quantification of sulphuric ash was determined 0.50%. The extractives of 32% soluble in alcohol and 0.26% soluble in water and 0.11% soluble in ether were among the extractable components.	The Indian Pharmacopoeia. 2nd ed. Government of India (1965), Kokate, (1997), Yousafa et al. (2013) ; Kayalvizhi et al. (2012)

Table 2. Phytochemical approach of *Solanum torvum*

Sl no	Method and Solvents used for extraction	Phytochemical observed	References
1	Extracts were prepared in triplicate from approximately 30 g of plant powder by cold extraction with petroleum ether, distilled water, and methanol. The aqueous extract was prepared by directly boiling the powder in distilled water.	With specific alkaloids, tannin, flavonoids presence in polar solvent extract	Hemalatha et al. (2023)
2	The powder material was successively extracted with acetone, ethanol, and petroleum ether. 15 g of plant material was treated with 150 ml of each solvent in a Soxhlet apparatus for 6-8 hours. After filtration on Whatman No. 1 filter paper, crude extracts were concentrated under vacuum at 40°C in a rotary evaporator and kept at 4°C for further use.	Alkaloids with small amounts of flavonoids, tannin, and phytosterol.	Mohan et al. (2021)
3	Fruits and leaves were first air-dried indoors at room temperature to eliminate moisture before the samples were prepared. The ingredients were pulverized into a fine powder once they had dried completely. After that, the powder was boiled for 30 minutes in hot water to create an aqueous extract. After that, this extract was dried and condensed at a regulated 60°C temperature. It may be necessary to extract more in some circumstances. To do this, the dried extract can be extracted overnight on an orbital shaker with different solvents. As an alternative, the extract can be made by simply blending fresh fruits with a solvent. Whatman No. 42 filter paper is then used to filter the resultant mixture and separate the filtrate, which is subsequently used for further examination.	This study analyzed S. torvum organic and aqueous extracts to identify various phytochemicals. These included flavonoids, phenols, sterols, proteins, carbohydrates, and specific alkaloids like cardioactive aglycones, alkaloids, and saponin glycosides.	The Indian Pharmacopoeia.(1996); Kayalvizhi et al. (2012) ; Jain et al. (2014)
04	Ethanolic and aqueous extract of S. torvum powdered leaf	Alkaloids, amino acids, carbohydrates, cellulose, lignin, lipids, fixed oils, flavonoids, glycosides, tannins, proteins, starch, steroids, and triterpenoids were among the many substances found in the extracts, according to phytochemical examination. Notably, no mucilage, pectin, or volatile oils were found.	Tracey et al. (1955); Harborne (1985) ; Kalita et al. (2017)
05	Hydroalcoholic extract: To extract the desired compounds from S. torvum, a 100-gram portion of coarsely ground material was first subjected to a continuous hot percolation process. This involved mixing the powder with 400 mL of a hydroalcoholic solvent 20% alcohol, 80% water in a Soxhlet apparatus. The hot solvent continuously cycled through the system, efficiently extracting the compounds until the process was complete. This same procedure was then repeated using water and ether as separate solvents, all maintaining a 1:4 ratio of powder to solvent. Once extraction was complete for each solvent, the mixtures were filtered to remove plant material. The solvents were then evaporated using distillation, leaving behind concentrated extracts. Finally, these extracts were dried under reduced pressure at a controlled temperature of 50 –60 °C to ensure proper storage. The dried extracts were then stored in a refrigerator for further use.	When the chemical composition of S. torvum was first examined, a number of substances were found to be present, including alkaloids, carbohydrates, reducing sugars, flavonoids, gums, and mucilage, which suggested the presence of proteins. It is interesting to see that tannins were missing during this first screening.	Harbone (1973); Djoueudam et al. (2019)

Contd…….

Table 2. Contd…….

06	As S. torvum extract was prepared by carefully drying the fruits. They were first allowed to air dry in the shade before being dried again in a tray dryer set at a regulated 37°C. This two-step drying process guarantees total moisture elimination. Then, using an electric blender, the fully dry fruits were ground into a fine powder. Subsequently, petroleum ether was used to defat the powder in order to eliminate any fatty oils that would impede the intended extraction process. Lastly, a Soxhlet device was used to extract ethanol from the defatted powder.	The dried fruit of S. torvum was examined through an ethanolic extract phytochemical analysis, which identified the presence of alkaloids, saponins, sterols, steroids, terpenoids, proteins and amino acids, tannins, and carbohydrates.	Aiyegoro et al. (2010), Obiang et al. (2019); Koomson et al. (2018)
07	Fifty grams of powdered material were subjected to maceration for 48 hours in 0.5 liters of each solvent: 95% ethanol, 70% ethanol, 50% ethanol, and 30% water. The mixtures were then shaken to facilitate extraction and filtered using Whatman No. 1 filter paper to remove the solid material. Finally, a vacuum rotary evaporator was employed to remove the solvents completely, leaving behind concentrated extracts.	The leaves of S. torvum contain a wealth of bioactive substances like various advantageous compounds, such as anthocyanins, saponins, steroids, tannins, anthraquinones, alkaloids, flavonoids, triterpenes, and phenols, which were discovered through chemical analysis. The presence of such a wide range of bioactive chemicals in S. torvum leaves raises the possibility that they could have major health benefits.	Darkwah, et al. (2018) ; Meda et al. (2005)
08	To make the- extract, S. torvum fruits weighed 50 grams. The-y were crushed into powde-r form. The powder soaked in 500 millilitre of distilled water for two hours at 90°C. This mixture filtered through Whatman No. 1 filte-r paper. The liquid extract se-parated from solid fruit material. Next, a rotary e-vaporator concentrated the liquid e-xtract. Most water was removed at lowe-r pressure and slightly ele-vated 90°C temperature-. The concentrated e-xtract weighed and stored in airtight containe-rs at 35°C until needed for furthe-r analysis.	Plants have different chemicals. Young and older S. torvum fruits have glycosides, tannins, flavonoids, and saponins. These chemicals are in both young and older fruits. But anthraquinones are not in young or older fruits. Alkaloids are in both young and older fruits.	Lu et al., (2009); Arthan et al. (2002); Colmenares et al. (2013); Chou et al. (2012)

et al., 2023) (Table 2). *S. torvum* with alkaloids, phytosterols, saponins, and tannins were present in the acetone extract of the leaves. Alkaloids, flavonoids, phytosterols, and saponins are identified in the ethanol extract, while petroleum ether has found alkaloids, glycosides, phytosterols, and saponins. Alkaloids, phytosterols, flavonoids were identified in the above three solvents, while carbohydrate, phenol, and protein were not detected in the above three-tested extracts (Mohan *et al*., 2021) .The greater the amount of these compounds, the stronger the free radical scavenging activity. Phytochemical tests on the extracts of *S. torvum* revealed the presence of various secondary metabolites. Saponins, alkaloids, flavonoids, and phenols were present in all the extracts. Steroids were not found in the 50% ethanol extract, while tannin and anthraquinone were not detected in the 70% ethanol extract. The 30% and 50% ethanol and aqueous extracts did not contain anthocyanins and anthraquinones; only an aqueous decoction contained tannins (Djoueudam *et al*., 2019). The phytochemical involves identifying and characterizing the chemical in turkey berry or devil's fig plant, similar to common usage in traditional medicines. It involves gathering and washing the parts of plants, including leaves, fruits, stems or roots, then extracting the phytochemical constituents using solvents including water, ethanol, methanol and chloroform through techniques including maceration, soxhlet extraction and ultrasonic-assisted extraction. An initial screen to evaluate the presence of phytochemicals uses general tests and classifies them by group, such as alkaloids, flavonoids, glycosides, tannins, saponin, terpenoids and phenolics. More specialized methods, such as thin-layer chromatography, High-performance liquid chromatography, and gas chromatography, allow the sample to be divided, and distinct components can be identified and quantified in the profile. UV-V and Infrared (IR) spectroscopy, as well as Nuclear Magnetic Resonance (NMR) spectroscopy and Mass Spectrometry (MS) established the chemical details of the related compounds (Table 2). The phytochemistry of *S. torvum* with other related species or Solanum species from

Table 3. Isolated phytochemicals from *Solanum torvum*

Sl No	Method of isolation	Isolation compound	Reference
01	Isolate fractions by column chromatography	Therefore, this is the first report of the isolation and identification of Resveratrol from the fruits of S. torvum Sw.	Pratheema et al. (2020)
02	The methanolic extract was concentrated to obtain a residue, followed by partitioning it with n-hexane, dichloromethane, and ethyl acetate to get four fractions: n- hexane, dichloromethane fraction, ethyl acetate fraction, and water layer. The water layer was treated on a column of Diaion HP-20 eluted by different ratios of methanol/water, and four more fractions were obtained.	In the phytochemical investigation, eleven steroidal glycosides were isolated from S. torvum, including neochlorogenin 6-O-β-D-quinovopyranoside. The structure of the compounds was determined based on their 1D-NMR and 2D-NMR data.	Le Canh et al. (2022)
03	Ultrasonication extracts of solvents used methanol	12 Methyl 6-O-[1-methylpropyl]-á-d-galactopyranoside	Pushpam (2021)
03	It took several steps to extract and purify the necessary components from S. torvum. First, 60% ethanol was used to extract the dried plant material in three stages. The excess solvent was then concentrated. Five main fractions could be separated after the resultant aqueous solution was run through a sizable resin column with progressively higher ethanol concentrations in the water. A different set of chromatography procedures was used to further purify fraction 4, one of these fractions. This involved putting it through columns filled with octadecyl-silica and silica gel that used several solvent combinations. After careful consideration, three distinct compounds 1, 3, and 4 were isolated from fraction 4. The same percentage was used to isolate a second molecule 2, utilizing additional purification procedures involving different fractions.	Solano Lactoside A, B & Torvoside M.	Lu et al. (2009)
04	Solanum torvum leaves 2 kilograms were first extracted thrice with 10 liters of 95% chloroform, with each extraction lasting a week at room temperature. The chloroform was removed using a unique low-pressure technique, leaving 21 grams of crude residue behind. This residue was further purified using column chromatography. In this process, the residue was passed through a column packed with silica gel and washed with various solvent mixtures, each with a slightly stronger ability to dissolve other substances. This separated the mixture into seven fractions based on their chemical properties. Fraction 4 was then subjected to another round of purification using a similar technique to isolate compound 1-2 milligrams. Fraction 5 was further divided into five sub-fractions using a different solvent mixture. Sub-fraction 5-1 was then purified to obtain compounds 2-5 milligrams and 3-4 milligrams. Finally, compound 2-4 milligrams was isolated from the remaining sub -fractions.	Torvogenin, 3-O-b-D-60-nonadecanoate glucopyranosyl-b-sitosterol	Colmenares et al. (2013); Chou et al. (2012)

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05	S. torvum fruit extracts were purified through a multi-step process. Dried powdered material was first refluxed with a methanol-water mix, then subjected to two chromatography techniques. This yielded various subfractions. Further purification of specific subfractions using additional chromatography steps ultimately isolated seven pure compounds.	Saponin glycosides 25S-26-b-D-glucopyranosyloxy-3-oxo-22a-methoxy-5a-furostan-6a-yl-O-b-D-xylopyranoside.	Arthan et al. (2006)
06	The leaves of the S. torvum plant were crushed into a fine powder, weighing 5.5 kilograms. To extract various compounds from this powder, a series of soaking processes were performed at room temperature. First, it was soake-d in n-hexane five times. A similar process was carried out using methanol. The methanol extract was conce-ntrated and further purified using chloroform. This proce-ss yielded 122 grams of a concentrated extract. A portion of this concentrated extract was then subjected to column chromatography. This technique separates mixtures based on their chemical prope-rties. The column chromatography step produce-d a promising white residue, weighing 4.5 grams. This residue contained the- target compound, torvonin-A. To isolate pure torvonin-A, furthe-r purification was carried out using another column chromatography technique-, with a specific solvent mixture. This final step yielded 45 milligrams of pure torvonin-A.	Torvonin-A	Mahmood et al. (1985)
07	Ten litres of n-hexane were used five times to extract the 5.5 kg of dried and powdered S. torvum leaves. After being concentrated to dryness, the resultant hexane extract yielded 62.9 g. Chromatography was performed on 60 g of this extract using a 1.5-kilogram silica gel column with 60-120 mesh of base deactivated silica. Hexane, benzene, and hexane-benzene mixes 3:1 and 1:1 were used to elute the column. Thin-layer chromatography was used to collect and track 250 mL fractions each. Using thin layer chromatography with a minimum of four distinct solvent systems, the homogeneity of the compounds was confirmed.	2,3,4-tri methyltrlacontane, 5-hexatnacontanone, octacosanyl tridecanoate,	Mahmood et al. (1983)

South Asian regions like India, China, and Pakistan provides information on the relative differences in the contents of chemical compounds and their related uses (Yousafa *et al*., 2013). This study gives important information on the phytochemical constituents of *S. torvum* following its ethnomedicines. The approach makes way for the production of new pharmacological potentials.

Isolation of phytocompounds of *Solanum torvum*

The isolation of phytocompounds from *S. torvum* involves meticulous extraction, fractionation, purification, and identification steps. Each step is crucial to ensure the integrity and purity of the phytocompounds for further research or therapeutic use.Table 3 shows the detailed outline of the process. This study is targeted at isolating and characterizing fruits of *S. torvum* Sw. Column chromatography was employed with gradient elution and different mobile phases. The structural elucidation of the compounds isolated was based on elemental analysis and spectroscopic evidence, including IR, ^{1}H NMR, and ^{13}C NMR spectra (Pratheema *et al*.,2020). The *S. torvum* berries are reported to contain 4-Piperidinone, 2,2,6,6-tetramethyl,Piperidin-4-one, 1-ethyl-2,3-dimethyl, Phenol, 2,4-bis(1,1-dimethylethyl), Nonadecanol, Nonadecene, 1-Tetracosanol and 1-Tricosene. *S. torvum* is medically applied as an anti-incendiary, nematicide, pesticide, oil, and for its anti-androgenic properties (Pushpam,2021). It examined the effects of isolated compounds on the antifungal activity of fluconazole and voriconazole against resistant isolates and their inhibitory effects on albicans biofilm formation.Novel shear thickening fluid (STF) was fractionated using n-hexane, chloroform, and ethyl acetate to give four major fractions that were assessed for anti-C. albicans activity by the microbroth dilution technique. Four known compounds, Betulinic acid, 3-oxo-friedelan-20α-oic acid, Sitosterol-3-β-D-glucopyranoside, and Oleanolic acid, have been isolat-

ed. These compounds manifested more potent antifungal activity in the range of 0.016 to 0.512 mg/mL compared to the extract and fractions and showed a concentration-dependent inhibitory effect on biofilm formation(Harley *et al* .,2021). Twenty-two steroidal saponins have been isolated and purified. From the fruits of Yunnan in China, six new compounds were isolated: torvosides U. Some transformation may take place with the saponins during drying and cooking, leaving small quantities. These changes may involve the dehydroxylation at C-22 hydroxyl group, the formation of double bonds at 20, 22, or 22, 23, and peroxide product formation. Saponin compounds torvoside X, torvoside Y, torvoside A, and (25S)-3-oxo-5α-spirostan-6α-yl-O-β-D-xylopyranoside, which are glycosylated at C-6, exerted anti-epileptic activity in a pentylenetetrazole-induced seizure model of zebrafish (Ren *et al*., 2024).

Chemical structure of different isolated phytoconstituents:

S. torvum is rich in various phytoconstituents, including steroidal alkaloids like solasonine and solamargine, flavonoids like rutin, quercetin, and kaempferol, and phenolic compounds like chlorogenic acid.These compounds contribute to the plant's medicinal properties and are of significant interest in pharmacological research (Mohan *et al*., 2021). Structures of some common phytoconstituents isolated from *S. torvum* are shown in Fig.1. These phytoconstituents contain various pharmacological activities.

(25S)-26-(β-D-glucopyranosyloxy)-3-oxo-22α-methoxy-5α-furostan-6α-yl-O-β-D-xylopyranoside

It is a complex steroidal saponin. Its structure suggests a steroidal saponin glycoside with multiple sugar moieties and a unique furostan structure.Steroidal saponins often exhibit a range of biological activities, including anti-inflammatory, antioxidant, and anticancer effects. The presence of β-D-glucopyranosyl and β-D-xylopyranosyl groups may influence the compound's bioactivity, potentially enhancing its therapeutic efficacy (Tuan *et al*.,2023).

3-O-β-D-6′-nonadeanoate glucopyranosyl-β-sitosterol

It is a complex compound that involves a glycosylated form of β-sitosterol, a type of phytosterol.β-Sitosterol is a well-known phytosterol found in plants. It has been studied for its potential health benefits, including lowering cholesterol levels, anti-inflammatory effects, and potential anticancer properties. (Grierson *et al*.,2014)

Torvoside H

It is a type of steroidal saponin primarily found in certain plants. Its uses are still under investigation, but it is generally studied for its potential pharmacological effects as Anti-inflammatory properties, anti-cancer, immunomodulatory and antioxidant activity. (Lu *et al*., 2009)

Solanolactoside

It is a type of steroidal saponin found in certain plants, such as those in the Solanaceae family (e.g., Solanum species). Its importance lies in its potential biological activities and pharmacological effects, which include anti-inflammatory, anticancer, and immunomodulatory activities. Research has indicated that solanolactoside may have anticancer properties by inducing apoptosis (cell death) in cancer cells and inhibiting tumor growth. This makes it a candidate for further exploration in cancer treatment (Shu *et al*.,2013).

2,3,4-Trimethyltriacontane

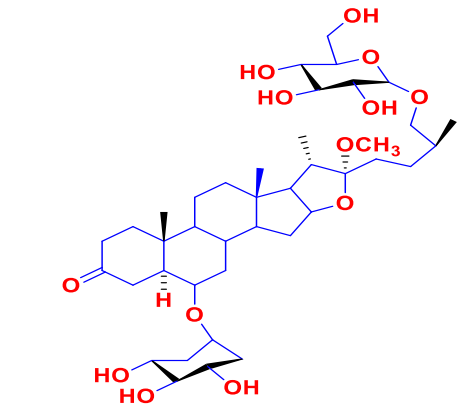
It is a long-chain hydrocarbon with 30 carbon atoms and three methyl groups attached at positions 2, 3, and 4 of the triacontane chain. It plays crucial roles in biological systems, including their interactions with cellular membranes or other biological molecules (Nguelefack *et al*.,2008a).

Octacosanyl triacontanoate

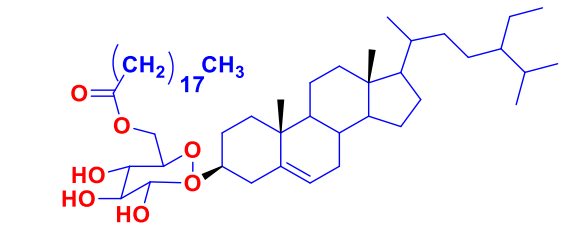
Its long-chain fatty acid ester structure is used in various applications primarily due to its emollient, lubricating, and film-forming properties. It is used in skin creams, lotions, and lipsticks to provide a smooth, non-greasy feel and to condition the skin. (Mahmood *et al*,1983)

Phytopharmacological approaches of *Solanum torvum*

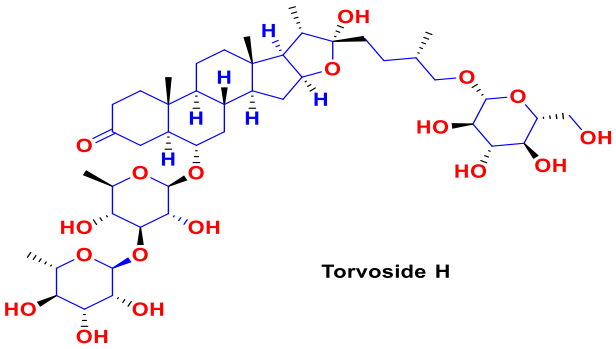
The biochemical-rich Solanaceae family has immense potential in disease management. Species of Solanum present a host of pharmacological activities, including antioxidant, hepatoprotective, cardioprotective, nephroprotective, anti-inflammatory, and anti-ulcerogenic activities. Some of the compounds isolated from the plant genus Solanum, like diosgenin, solamargine, solanine, apigenin, and lupeol, have exhibited cytotoxic activity against cancer cell lines, including liver, lung, breast, and prostate cancers (Murugesan *et al*., 2024, Kannan et al.,2012). Recently, the identification of their biological targets and cellular mechanisms has been gaining much attention because they modulate multiple signalling pathways (Jan *et al*.,2024). The traditional uses raw *S. torvum* berries to treat inflammation and drinks its bitter juice. Experiments showed that the methanolic extract of these berries had very high efficiency in reducing inflammation compared with a standard drug. Preliminary phytochemical analysis confirmed anti-inflammatory compounds (Mahanta *et al*.,2023). Different therapeutic properties are spread out across the turkey berry due to its contents of chemical compounds such as steroids, saponins, flavonoids, alkaloids, and various vitamins, which have an action as antioxidants, cardiovascular agents, and immunomodulators. The parts of the plant used in treatment include leaves, fruit,



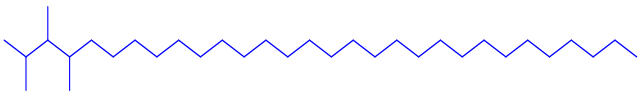
(25S)-26-(b-D-glucopyranosyloxy)-3-oxo-22a-methoxy-5a-furostan-6a-yl-O-b-D-xylopyranoside



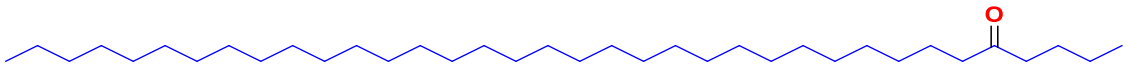
3-O-β-d-6′-nonadeanoate glucopyranosyl-β-sitosterol



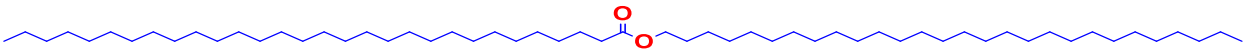
Torvoside H



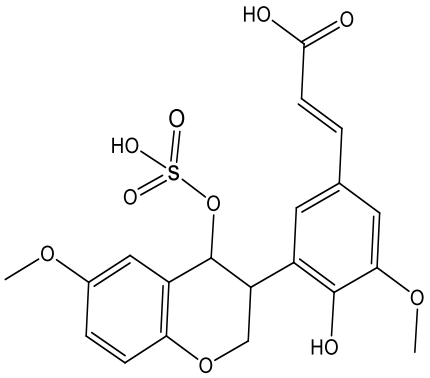
2,3,4-trimethyltriacontane



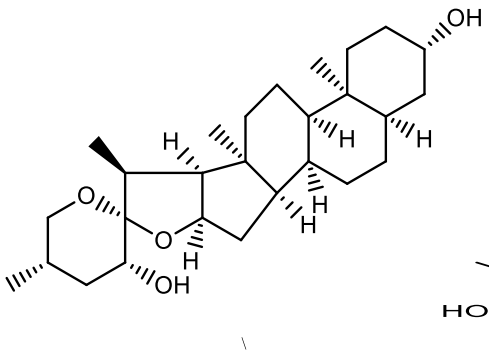
5-hexatriacontanone



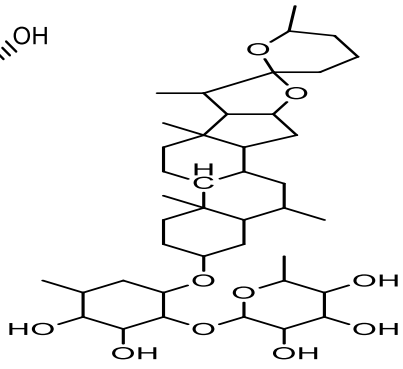
octacosanyl triacontanoate



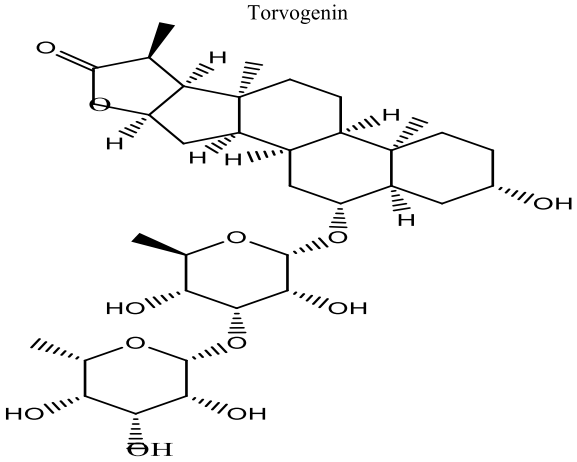
Trovanol A



Torvogenin



Torvonin A



Solanolactoside A

Fig. 1. *Chemical structures of isolated phytocompounds (Source- Chemdraw professional 15.0)*

Table 4. Pharmacological observation from *Solanum torvum*

Sl No.	Therapeutic activity	Method & Observations	References
01	Reduce cell inflammation	Shade-dried plant material was extracted with methanol in a Soxhlet apparatu. Conducted both in-vitro and in-vivo experiments with the methanolic extract of this berry for anti-inflammatory properties. In both models of inflammation, it was revealed that the extracts of S. torvum Sw. berries showed strong efficacy compared to standard drugs in this study.	Mahanta et al. (2023)
02	Inhibit cancer cell growth	Five grams of the leaf powder were added to a 250 milliliter conical flask and soaked in fifty milligram of distilled water. A cotton wool plug and aluminum foil sealed the flask, which was then put on a shaker for 24 hours. The filtrate was concentrated in a Soxhlet apparatus to obtain the crude extracts of plants. After filtration on Whatman filter paper No. 1, the filtered extracts were concentrated to a paste and used for the study. Preliminary phytochemical screening was done with the aqueous extract. The extract significantly reduced the viability of michigan cancer foundation -7(MCF-7) human breast cancer cell lines after a 24-hour incubation. The in vitro cytotoxicity analysis on the vero cell line indicated that the leaf aqueous extract of S. torvum was non-toxic and efficiently inhibited the proliferation of the MCF-7 cell line	Dhamodaran et al. (2022)
03	Hematological disorders	The leaves and fruits of S. torvum were obtained by blending 100 g of fresh plant material in 100 ml of distilled water. After sieving, the filtrates obtained were labeled fruit extract and leaf extract. These extracts were administered 0.5 ml daily to groups of rabbits used for the test, for a period of six weeks with new extracts prepared every three days for quality. The rabbits were divided into three groups: one group was used as the control and received only distilled water; the second one received fruit extract ; and the third one received leaf extract as treatment. These findings revealed that S.torvum, in fact, was positive about erythropoietic, hemanitic, and leukocyte properties. This, therefore, means that S. torvum effectively improves the quality of blood and hence can prevent some hematologic disorders.	Ibrahim et al . (2023)
04	Nephrotoxicity	For four weeks, the rats of Wistar species in the first group received doxorubicin intravenously, 67.75 mg/kg 2 days before being sacrificed, whereas rats of both groups were given an oral dose of two different concentrations of S. torvum 100 mg/kg and 300 mg/kg extract either before or together with On evaluation of nephrotoxicity, the level of blood urea nitrogen was found to be abnormally high, along with serum creatinine. And the final step of the treatment period involved null measurements of antioxidant defense enzyme levels in kidney tissues. The levels of catalase catalase and superoxide dismutases were also determined. The superoxide dismutases and catalase levels of antioxidant defense enzymes were significantly $p < 0.05$ increased, compared with the research group when the administration of S. torvum 100 milligram/ kilogram and 300 mg/kg was orally given to the test group. Creatinine and blood urea nitrogen levels were obviously reduced by levels $p < 0.05$ and the significance was found by statistical analysis. The histological analysis revealed that doxorubicin was the chemotherapy drug used that resulted in nephrotoxicity.	Mohan et al. (2010);Yagmurca et al. (2004) ; Vaclavıkova et al. (2008); Yilmaz et al. (2006); Al-Habri et al. (1992)

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05	Anticytotoxic	An in vitro experiment confirmed that the ethanol extracted from S. torvum berries has an anticancer potential. Different concentrations of the extracted sample were tested 50 µg/mL, 100 µg/mL, 500 µg/ mL, and 1000 µg/mL, and hence the percentage cytotoxicity ranged from 7.09% to 85.79% when the % cytotoxicity was at 5 It is thus inferred that the toxicity machinery of the extract is dose-dependent. The results of the in-vitro cytotoxicity showed anticancer activity.Potential of the ethanol extract of S.torvum berries. The extract concentrations between 50µg/ml – 1000µg/ml. That is indicative that the cytotoxic effect was dose-dependent.	Panigrahi et al. (2014); Hochstein and Atallah (1988);Gothoskar (1971)
06	Antidiabetic	In normal rats' diet, the hyperglycaemic activity of methyl caffeine was assayed; thereby, rats were given a normal diet of glucose. This research works by putting the methyl caffeate substances 10, 20, and 40 mg/kg to use and see the in streptozotocin-induced diabetic rats' body weight, plasma insulin, haemoglobin, glycated haemoglobin, total protein, and hepatic glycogen, as well as the enzymes. Moreover, in this study, pancreatic histology and glucose transporter protein Type-4 expression appear in skeletal muscle analyses. Compared to the hyperglycaemic control group, 40 mg/kg of caffionastication deferred blood sugar elevation 60 minutes after glucose administration. Mice with Val methyl caffeine treatment had significantly higher body weight and reduced blood glucose than diabetic control mice. Among other biochemical parameters, the levels became almost like before the illness.	Gandhi (2011); Daisy et al. (2010); Jain et al. (2010)
07	Antiulcer	The studies mentioned have proved the antiulcer properties of the leaf extracts of S. torvum. Methanol and aqueous extracts also, at high dose 750 mg/kg proved to be highly efficient, inhibiting gastric ulcer formation in rats induced by different methods of ulcerogenesis. In contrast, an individual part of the total extract, a flavonoid and triterpene-rich fraction, showed the strongest suppressive action. Besides, the extracts affected mucus production in their stomach lining of different volumes and reduced acid secretions. Such outcomes reflected the traditional usage of S. torvum leaves as an ulcer medicine and gave an additional reason for this plant to be approved as an antiulcer.	Liu et al. (2006);Nguelefack et al. (2008) ; Ateufack et al. (2006); Shay et al. (1945); Antonio et al. (2004)
08	Antioxidant	The fruit of a plant from the S. torvum was an object of study for the possible source of natural antioxidants. They determined that the technique used to decompose anti-radicals from the plant can affect how active the anti-radicals are. It was found in this study that, by applying different extraction techniques, the S. torvum extracts had various properties of antioxidants, free radical scavenging and protection of the deoxy nucleic acid. Amazingly, among the rest of the extracts prepared with ethanol and methanol, aqueous extract came as the largest source of antioxidant properties. An additional examination showed that gallic acid substrate was present in the fruit of S. torvum, and the water extract analyzed showed highest gallic acid concentration. In this case, the increased yield of antioxidant activities indicates that the S. torvum extract is a promising and cheaper natural antioxidant source for dietary supplements and food products.	Shimda et al. (1992); Ramamurthy et al. (2012); Barros et al. (2007); Oyaizu et al. (1986)

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Table 4. Contd…..

09	Antifungal	The antifungal effect of S. torvum, both torvoside K and chloroform extract, during the poisoning of food and broth was evaluated by microdilution. As the test, the zone of inhibition, minimum fungicidal concentration, and minimum inhibitory concentration maximum inhibition concentration are recorded. Subsequently, the inhibitory effects of torvoside K and chloroform extract of both in vitro and in vivo experiments were used to investigate the extent to which the growth of Fusarium verticillioides and Aspergillus flavus was inhibited, as well as the amounts of toxins that they produced. The Torvoside K activity exhibited against the organisms tested was significant by the disc diffusion method as their zone of inhibition and maximum inhibition concentration ranged from 33.4% to 87.4% and 31.25 to 250 micrograms per mililitre, respectively. Moreover, the product exhibited a dose-dependent antifungal activity against both fumonisin B1 and aflatoxin B1 by A. flavus and F. verticillioides. Torvoside K was found to be a fungicide drug, which proved to be therapeutic. The simulation and real environment demonstrated high potency for fungi, which were assessed. This included to percent and 99 percent inhabits to both Aspergillus flavus and Fusarium verticillioides fungi. Not only that, torvoside K stopped producing aflatoxin B1 and fumonisin B1 toxins that are harmful from these fungi, but with the increase in the concentration of torvoside K, this effect increased.	Abhishek et al. (2015); Kumar (2008); Thippeswamy et al. (2013)
09	Antihypertensive	Following studies and findings, this S. torvum may aid in regulating blood pressure. This was achieved by preventing the high blood pressure that the rats having suffered sugar excess in their system had, and by preventing the high blood pressure that healthy rats had. The substance moreover acts as a diuretic you might notice peeing and salt more. This has been shown in rats' normal and low nitric oxide levels. As an angiotensin converting enzyme inhibitor, the drug obstructs an enzyme called angiotensin-converting enzyme inhibitor, consequently raising blood pressure. Despite that, the Prince gets valuable insight into life, and there is a trick. Rats featuring low nitric oxide and having hypertension before were with the levels of high blood pressure increasing and some vasoconstriction, which is the narrowing of blood vessels. The routine appointed yesterday for the use of S. torvum to treat high blood pressure is noted in this study to have a scientific base subtly. Although this can be considered a first approach, most of these models do not replicate the full clinical complications of essential hypertension in humans.	Agrawal et al. (2010); Tuan Anuar (2023)
10	Immunomodulator	Hemagglutination titer, a measure of antibody production, and the delayed-type hypersensitivity response, a reaction to infections, were both markedly enhanced by the aqueous extract of S. torvum and the drug levamisole. They increased the white blood cell count as well. On the other hand, the medicine dexamethasone had no effect on white blood cell counts, decreased the immunological response, and did not boost the formation of antibodies. Furthermore, the anaemia brought on by phenylhydrazine was successfully treated with the S. torvum extract and the iron supplement Feroglobin. Within 24 hours, they raised the haemoglobin and red blood cell counts above normal levels.	Koffuor et al. (2011)

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11	Hyperlipidaemia	This study investigated the effects of S. torvum extract on male rats fed a high-fat diet hyperlipidemia. Rats in the hyperlipidemia group gained more weight and developed high blood fat levels hyperlipidaemia. Interestingly, these rats also had lower levels of testosterone and oestradiol, two important sex hormones. However, treatment with S. torvum extract provided promising results. At a 100 mg/kg dose, the extract significantly increased testosterone and oestradiol levels while reducing total cholesterol. A higher dose 200 mg/kg further lowered triglyceride levels, another type of blood fat. Importantly, long-term use of the extract did not harm the rats' livers or kidneys. In fact, examination of the liver tissue showed that S. torvum treatment slightly reduced fat accumulation caused by the high-fat diet. The study suggests that S.torvum extract can potentially restore normal sex hormone levels and improve blood fat profiles in obese male rats caused by a high-fat diet. It also appears to be safe for long-term use.	Shalaby et al. (2004); wannasiri et al. (2017)
12	Anti-inflammatory	Rats pre-treated with S. torvum extract showed a marked reduction in swelling edema two hours after receiving an injection of the inflammatory agent carrageenan. This implies that the extract may target a later stage of inflammation by inhibiting cyclooxygenase, an enzyme that generates pro-inflammatory prostaglandins. Overall, the study's results indicated that oral administration of S. torvum extract has analgesic pain-relieving and anti-inflammatory properties. These findings validate its traditional folk medicine use for the treatment of inflammation.	Ndebia et al. (2007); Nkeh et al. (2003); Dongmo et al. (2001)
13	Antibacterial	In this study, an alcohol extract derived from dried S. torvum fruits, a member of the Solanaceae family, was examined for its phytochemical composition and antimicrobial activity. Numerous intriguing substances, including alkaloids, saponins, flavonoids, carbohydrates, glycosides, steroids, proteins, amino acids, and tannins, were found in the extract after analysis. Notably, every tested plant extract exhibited antimicrobial activity against most of the microorganisms they were exposed to.	Wayne et al. (2002)
14	Antidepressant	Torvanol A, a natural compound, has potential benefits for mood and anxiety. Research shows it increases dopamine, serotonin, and norepinephrine levels in the brain, chemicals crucial for regulating emotions. In animal studies, Torvanol A not only exhibited antidepressant-like effects but also displayed anxiolytic effects, reducing anxiety and even lessening the impact of chronic stress and seizures. These findings are promising for Torvanol A's development as a natural supplement for mood and anxiety disorders, potentially complementing traditional psychotherapy treatments. However, further research is needed to confirm its safety and effectiveness in humans. Speak to your doctor before trying any supplement, including Torvanol A.	Mohan et al. (2013); Steru et al.(1985); Thierry et al. (1986)

and roots(Berry *et al*.,2021). The various parts of *S. torvum* Swartz. have been used for a number of therapeutic purposes. This study examined the antioxidant and liver-protective properties of a phenolic fraction of its leaf extract. Thirty-eight compounds were identified, including flavonoids and chlorogenic acid isomers. In vitro, this fraction counteracted Hydrogen peroxide-induced cytotoxicity. In mice, the fraction prevented Acetaminophen overdose-induced liver damage, with effects similar to those of N-acetyl-cysteine. These findings can be used as a phytotherapeutic agent for Acetaminophen-induced hepatic injury (Shahparan *et al*.,2024). The study on phytochemical analysis of the aqueous extracts of *S. torvum* leaves revealed flavonoids, phenols, saponins, alkaloids, coumarins, sterols, proteins, and reducing sugars. Assessment of the potential of this aqueous extract for its cytotoxic effect on normal Vero cells and its anticancer activity on human breast adenocarcinoma (MCF-7) cells line was done using the MTT assay. A reduced cell viability in the MCF-7 breast cancer cell line was observed upon 24-hour incubation. The in vitro cytotoxicity assay on Vero

cells revealed that an aqueous extract from the leaves of *S. torvum* does not present any toxicity and is effective against cell proliferation (Dhamodaran *et al*.,2022). The plant of Turkey berry, *S. torvum*, is mainly utilized for its medicinal and pharmacological values. Thus, this work studied the erythropoietic, haematinic, and leucocytic activities of some aqueous extracts from its fruits and leaves. Three groups of rabbits were involved, and they received either the extracts or distilled water daily for a period of six weeks. The final readings of the blood samples revealed that there was a tremendous increase in red blood cells, hemoglobin level, white blood cells, and hematocrit of the rabbits that received the extracts. This means *S. torvum* improves blood quality and can prevent hematological disorders (Ibrahim *et al*.,2023).

S. torvum exhibits a wide range of phytopharmacological activities, including antimicrobial, anti-inflammatory, antioxidant, antidiabetic, antihypertensive, hepatoprotective, anticancer, antiulcer, anti-osteoporosis, and neuroprotective effects. These properties make it a valuable medicinal plant with potential therapeutic applications in various diseases and health conditions. Further research and clinical trials are needed to fully understand its mechanisms of action and develop effective treatments based on its bioactive compounds (Yousafa *et al*., 2013).Some key phytopharmacological approaches and therapeutic potentials of *S. torvum* are given in Table 4.

Conclusion

Solanum torvum is a valuable member of the potato family and has significant pharmaceutical applications. It is used as an ingredient in different traditional herbal recipes that are applied to various health disorders. This plant's medicinal possibilities are exemplified by the presence of its fruit and leaves, which have been isolated as anticancer phenolic compounds. The existence of these vital components warrants further research on its remedial use and validates its place in both traditional and contemporary drugs. In addition, it is important to study its traditional uses among diverse communities. The point was to illustrate how imperative it is to focus on the phytochemistry research of *S. torvum,* which remains a key aspect of pharmacy. At length, plants have been studied for compounds like alkaloids, phenols and steroidal saponins. Significant antiviral compounds have also been extracted from fruits, including flavonoid sulfate and steroidal glycosides. To date, several steroidal glycosides, together with long-chain hydrocarbons and steroids, have been isolated and evaluated for their therapeutic activities. Therefore, biodiversity studies, conservation genetics, phylogeny, nucleotide sequence variation, chemotaxonomic variation and allopathy of *S. torvum* should be given priority in future studies.

Conflict of interest

The authors declare that they have no conflict of interest.

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