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Phytochemical and biological studies of *Solanum torvum* L. in folklore medicine of Assam

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Abstract

Most of the plants have some therapeutical properties, because of certain secondary metabolites present. These secondary metabolites produced by plants have many health benefits. This article reports the phytoconstituents and medicinal properties of *Solanum torvum* L. plant. To find material on the subject, a search was made using database websites including Google Scholar, PUBMED, and Web of Science as well as various other types of literature available in public libraries. Although, *S. torvum* is not only used as food but widely used in traditional medicine. We found the several medicinal properties of *S. torvum* such as cardio, hepato and nephro protection, antidiarrhoeal, antihypertensive, analgesic, anti-inflammatory, antiulcer and antimicrobial activities due to the presence of several secondary metabolites. This knowledge is anticipated to provide researchers with well justified data on *S. torvum* health assistance resources and associated phytochemicals, which warrant further research for novel pharmaceuticals intended to treat illnesses or diseases and for potential application in preventive medicine.

1. Introduction

One of the most important angiosperm families in terms of commerce and medicine is the Solanaceae family. One of the most varied taxa in this family is the genus Solanum. The world's 2000 species of Solanum are primarily found in tropical and subtropical regions with a limited number also occurring in temperate regions. Small solanaceous shrub *Solanum torvum* L. is commonly cultivated in Malaysia, China, Philippines, Pakistan, India, Malaya and tropical America, commonly known as Turkey berry. For many years, several ethnic groups have utilized the dried stem and root of this plant to treat a variety of illnesses. Jinniukou is its Chinese medical name. A crucial member of the Solanaceae family from the perspective of pharmacology is *S. torvum* (Yousaf *et al.,* 2013). The genus Solanum most likely derived its name from the Latin name of a plant that was traditionally used medicinally to treat epilepsy. One of the biggest and most intricate genera of angiosperms was thought to be Solanum. The genus, often known as "jurubeba" (derived from the Tupi Guarni word "Yubeba," which alludes to the presence of prickles in some of them), is strongly represented in Brazil and is extensively spread from North to South in varied phytogeographic zones. Spreading or sprawling shrubs that are 2-3 meter tall, with prickles that are 3-7 mm long, somewhat hooked, laterally flattened, dispersed on stems, and that have stellate hairs on both the top leaf surface and the surfaces of the main veins. Ayurvedic therapies; it has digestive and diuretic effects. It is used to treat liver disorders and coughs. *S. torvum* is utilized to strengthen the body and minimize body heat (Marikani *et al.*, 2011; Sharma, 2021).The Ayurveda and Chinese pharmacopoeia both stress the traditional medical applications of *S. torvum*. There has been a lot of research done on the chemical components of *S. torvum*. Fruit, leaves, and roots are among the sections used to isolate a variety of chemicals. *S. torvum* is a great source of glycosides, tannins, saponoins, flavonaoids and alkaloids (Arif and Fareed 2011). Total glycoalkaloids (0.038%), total alkaloid content (0.12%) and glycosylated substances derived from the percentage conformation of various chemicals within this species is made up of solasodine, including solasonine (0.0043%) and solamargine (0.0028%). According to Munoz *et al.* (2007); Ranjitha *et al.* (2022). According to Kusirisin *et al.* (2009), polyphenolic substances comprised tannin, flavonoids, and phenol. These substances were present in quantities of 65.91, 104.36 and 160.30 mg/g, respectively.

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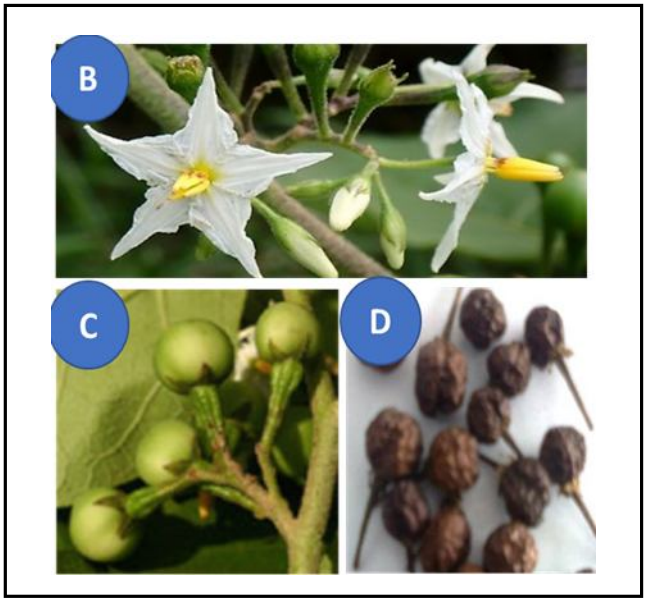


Figure 1: *Solanum torvum* L. Whole plant (A); Flowers (B); Fresh fruits (C); Dry fruits (D).

2. Pharmacological activities

It is utilized to treat skin infections and stomach aches (Siemonsma *et al.,* 1994). It possesses antiviral (Arthan *et al*., 2002), antiplatelet aggregation and cardiovascular activities (Nguelefack *et al*., 2008), anti-inflammatory and analgesic (Ndebia *et al*., 2007), antioxidant (Sivapriya *et al.,* 2007), antiulcerogenic (Nguelefack *et al*., 2008), immunoprotective (Israf *et al*., 2004) and antimicrobial (Ajaiyeoba *et al.,* 1999; Chah *et al*., 2000). Several essential pharmacologically active substances, including steroidal glycosides and isoflavonoids are found in *S. torvum* (Yahara *et al*., 1996; Arthan *et al*., 2002). Neochlorogenone and chlorogenone (Carabot *et al*., 1991) triacontane derivatives (Mahmood *et al*., 1983) 26-O-b-glucosidase (Arthan *et al*., 2006) 22-b-O-spirostanol oligoglycosides (Iida *et al*., 2005). *In vitro* measurements were made of *S. torvum* capacity to eliminate free radicals on DPPH (2,2-diphenyl-1-picrylhydrazyl). It is known that a number of substances with antioxidant properties display a defense against toxicities brought on by DOX.

It is possible to achieve both diuretic and sedative therapeutic effects from *S. torvum* as a hemostatic, the leaves are employed. Studies on phytochemistry revealed that the species' fruits have alkaloids, flavonoids, saponins, tannins, and glycosides in good quantities that are necessary for pharmacological actions. Fruit decoctions are therefore not only utilized for nutritional grounds but also for cough problems and are thought to be good treatments for liver and spleen swelling. The ripening fruits are utilized to make tonics and hemopoietic medicines, as well as pain relievers. Fruits and leaf methanolic extract of *S. torvum* have been found to have antibacterial effects on both human and animal clinical isolates. Additionally, many steroidal glycosides and an antiviral isoflavonoid sulfate were identified from fruits *S. torvum*, however, demonstrated modest antioxidant activity and the ability to repair damaged DNA after oxidative stress brought on by free radicals (Yousaf *et al.,* 2013).

Table 1: Traditional applications of *S. torvum*

Standard uses	Part used	Utilization methods	Populations using *S. torvum*	Reference
To treat liver diseases, antianaemic and as antituberculosis	Roots	Root juice	Northeastern Brazile	(Sarmento *et al*., 2005)
Vermifuge	Fruit	Cooked fruit	Tirunelveli, Tamil Nadu, India	(Mohan *et al*., 2008)
Asthma, diabetes and hypertension	Root and leaves	juice made of both roots and leaves	Garo Tribe, Bangladesh	(Mahmudur *et al*., 2017)
To control bacterial and fungal diseases of *S. melongena*.	Whole plant	Intercropping cultivation	Indonesia	(Mahanta *et al*., 2022)
Edible fruit	Fruit	Cooked fruit as an important ingredient of soups and sauces	India	(Badola *et al*., 1993)
Lethal to mice	Fruit extract	Aqueous extract of berry	Mexico	(Tapia *et al*., 1996)
To reduce body heat	Leaf extract	Leaf juice take orally	Kancheepuram	(Muthu *et al*., 2006)
Curing coughs	Fruit (after frying)	fried fruit is taken for cough	Kancheepuram	(Muthu *et al*., 2006)
Curing cracked foot	Root extract	Applied externally on cracks, also used as powdered form	Kurichyas, Kannur district	(Rajith *et al*., 2010)
Relief from colds and coughs.	Leaves (after dryingin shade)	Powder is administrated orally mixed with hot water or cow milk	Puducherry, Karaikal, Maheand Yanam, India	(Udayakumar *et al*., 2009)

2.1 Antibacterial and antifungal activity

Solasonine, a steroidal glucoalkaloid, is said to be present in leaves. Neochlorogenin, neosolaspigein and steroid sapogenins are also present in solaspigenine. Additionally, such as z-tritriacontanone, campesterol, tetratriacontanic acid, sitosterol, triacontanol and stigmasterol have been discovered in them. Glucoalkaloid sterolin, solasonine (sitosterol-D-glucoside), protein, minerals, and lipids are also present in fruits. Except for *S. lutea*, many gram-positive bacteria at 50 µg disc of crude root extracts displayed a clear zone of growth inhibition. Similar to this, a definite zone of growth inhibition in the root was visible at 200 µg/disc. Only *S. typhi* and *S. dysenterae* exhibit a clear zone of inhibition against nine gram-negative bacteria at both doses of chloroform and methanolic crude extracts of root (Bari *et al*., 2010).

Sundried *S. torvum* fruit extracts shown to have potent antibacterial activity against both human and animal clinical isolates. Glycosides, alkaloids, flavonoids, saponins, and tannins are all present in methanolic extracts, according to biochemical tests (Yousaf *et al.,* 2013). In order to assess the antibacterial activity using the disc diffusion method (Chah et al. 2000) employed methanolic extracts against bacteria (*Actinomyces pyogenes*, *Salmonella typhimurium*, *Bacillus subtilis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and also including *Streptococcus pyogenes* and (*Staphylococcus aureus*). The study found that methanolic extracts significantly suppress the development of bacteria that are frequently linked to pyogenic illnesses. The bacterial and fungal minimum inhibitory concentrations were 0.3125 mg/ml and 1.25 mg/ml, respectively.

2.2 Antiulcerogenic activity

Ulcers are generally breaks or discontinuities in the skin, which can occur on the inner layers of the skin and prevent it from performing its regular protective tasks. Peptic, corneal, venous and genital ulcers are just a few of the different types of ulcers that can result from this breakdown of the skin anywhere in the body. According to reports, *S. torvum* has antiulcerogenic properties. Aqueous and methanolic extracts from *S. torvum* leaves were studied (Nguelefacka *et al*., 2008) for their ability to inhibit the development of ulcers in rats. By using pylorus ligation stress, HCl/ethanol and indomethacin they produced gastric ulcers. Aqueous and methanolic extracts in various doses were examined at rates of 250, 500, and 750 mg/kg. Through, silica gel column chromatography, methanolic extracts were separated into seven distinct fractions (A-G). These fractions were evaluated against HCl/ethanol induced ulceration when administered orally at a dosage of 100 mg/kg. When gastric ulcerations were forced on by pylorus ligation stress, HCl/ethanol and indomethacin, methanolic extracts at a dosage of 750 mg/kg provided 98.12, 99.16, 98.70 and 96.03 % inhibition, respectively. Aqueous extracts at the same dose inhibited ulcerations caused by pylorus ligation stress, HCl/ethanol and indomethacin by 96.55, 96.86, 98.63, and 98.63 % respectively. The production of ulcers was considerably reduced by each fraction of the methanolic extract. The most active fractions had an inhibitory proportion of 84.74 and comprised flavonoids and triterpene. These findings made it clear that aqueous and methanolic extractions increase mucus formation while decreasing stomach acid secretion. Because of this, *S. torvum* extracts should be researched to see if they are useful against peptic, corneal, venous and vaginal ulcers in addition to controlling gastric ulceration (Yousaf *et al.,* 2013).

Flavanoids, sterols and triterpenes were found in *S. torvum*, which may be the source of its antiulcer properties. By increasing mucus and bicarbonate production, decreasing the amount of gastric acid secreted and neutralizing gastric activity, it strengthens the mucosal barrier (Agrawal *et al*., 2022).

2.3 Analgesic and anti-inflammatory effects

S. torvum has many important theurapeutical substances used as analgesics and anti-inflammatory medications in several traditional medical systems. Chemical and mechanical stimuli were used to assess *S. torvum* analgesic and anti-inflammatory properties. Rats were given 01 % acetic acid (1 ml/100 g body weight) and 0.05 ml of a 01 % sterile solution of carrageenan in saline, respectively, to produce abdominal writhing and paw edema. Aqueous extracts of *S. torvum* were combined with three different medicines to treat abdominal writhing brought on by 01 % acetic acid (1 ml/100 g body weight). *S. torvum* aqueous leaf extracts greatly reduced the level of pain. Indomethacin (10 mg/kg), *S. torvum* 300 mg/kg and 600 mg/kg were used to treat paw edema brought on by 0.05 ml of a solution of 01 % sterile carrageenan. Both extracts of *S. torvum* 300 mg/kg and 600 mg/kg significantly reduced paw edema, while the lower dose (300 mg/kg) did so more quickly than the higher dose (600 mg/kg) (Yousaf *et al.,* 2013; Sridevi *et al.* 2017).

2.4 Antioxidant activity

Phenolic chemicals from several *S. torvum* sections showed antioxidant activity. Utilizing ferric-reducing antioxidant power, 2,2-diphenyl-1-picryl-hydrazyl (DPPH), ABTS, iron chelation and antihemolytic activity, leaves and fruit extracts in chloroform, methanol and acetone were investigated for their *in vitro* antioxidant activity. The amounts of phenol in chloroform extracts were considerably greater (Yousaf *et al.,* 2013).

2.4.1 Percentage of the extract yield and the total phenolic content

Table shows the extract yield and total phenolic content of sample extracts taken from various *S. nigrum* and *S. torvum* sections using various solvents. Acetone and methanol had lower extractive values than chloroform, though. Additionally, the chloroform extracts had considerably (p<0.01) higher total phenolic concentrations. The phenolic content of *S. nigrum* leaves and *S. torvum* fruits was higher than that of the corresponding fruit and leaf samples. According to general reports, plants contain high levels of polyphenols with antioxidant activity, including tannins carotenoids, flavonoids, vitamin C and tocopherols (Siddhuraju *et al.,* 2007). Significant antioxidant activity is reported in *S. torvum* is useful for lowering oxidative stress in diabetes because of its antioxidant property (Agrawal *et al.*, 1989).

2.4.2 Effect on systolic blood pressure

A diet high in fructose is usually known to cause high blood pressure. To prevent and reverse the onset of hyperinsulinemia and limit the rise in systolic blood pressure, *S. torvum* ethanol extracts are used (Mohan *et al.,* 2009). The Mohan group looked at how *S. torvum* affected blood pressure and metabolic changes in the rat model of fructose hypertension. Male wistar rats (150-200 g) were given a high fructose diet (fructose 10%, w/v) *ad libitum* for six weeks in order to cause hypertensive symptoms. Both noninvasive (indirect) and invasive (direct) procedures were employed to measure systolic

blood pressure. The ability of *S. torvum* ethanol extractions to lower systolic blood pressure have been shown (Yousaf *et al.,* 2013).

2.5 Antiplatelet aggregation activity

S. torvum hemostatic qualities give it an antiplatelet aggregation action (Henty *et al.,* 1973). Aqueous extracts of *S. torvum* were tested *in vitro* for their ability to prevent platelet aggregation brought on by thrombin and ADP. The outcomes demonstrated that concentration is a factor in anti-platelet aggregation activity. At 2 mg/ml, aqueous extract of *S. torvum* inhibited thrombin induced aggregation by decreasing the extent of the signal from 9.27 cm to 4.03 cm, or by 55.27 per cent. In comparison to the effects of the lower dosages of 0.5 and 01 mg/ml, this effect was noticeably stronger. The aggregation brought on by ADP was similarly significantly inhibited by aqueous extract of *S. torvum*, with effects dependent on concentration. At doses of 0.5, 01 and 02 mg/ml, the impact had an inhibitory percentage of 31.63%, 47.7% and 56.40%, respectively (Yousaf *et al.,* 2013).

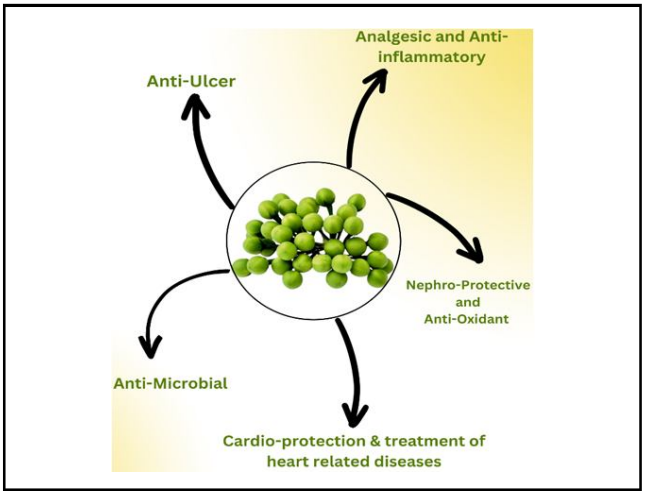


Figure 2: Pharmacological activities of *S. torvum*.

Table 2: Therapeutic properties of *S. torvum* fruits, their underlying mechanisms and phytochemicals

Theraeutic properties	Phytochemicals present	Mechanism	References
Antimicrobial activity	Flavonoids	Nucleic acid synthesis suppression, cytoplasmic membrane function inhibition inhibiting energy metabolism	Chah *et al.* (2000); Travis *et al.*(2002); Xie *et al.* (2015); Cushnie *et al.,* (2005). Xiao *et al.* (2013); Ulanowska *et al.* (2006).
Antiulcer activity	Triterpenes, sterols and flavonoids	Increased protection of the stomach mucosa	Antonio *et al.* (2004); Nguelefack *et al.* (2008); Telesphore *et al.* (2008)
Analgesic and anti-inflammatory activity	Phenols and tannins	Generation of inflammatory mediators is inhibited	Ndebia *et al.* (2007); Vaclavýkova *et al.* (2008)
Nephroprotective and antioxidant effect	Flavonoids and phenols	Free iron is chelated toxicity of DOX is decreased	Abas *et al.* (2006); Loganayaki *et al.* (2010); Vaclavýkova *et al.* (2008); Waghulde *et al.*(2011).
Cardio protection and treatment ofheart related diseases	Flavonoids, and polyphenols	Inhibition of enzymes activities. Hyperinsulinemia reversal and prevention	Fui *et al.,* (2012); Jaiswal *et al.,* (2012); Kamble *et al.* (2009); Liu *et al.* (1977)

Table 3: Phytochemicals in *S. torvum* fruit and their therapeutic applications

Phytochemicals	Therapeutics
Vitamin C	• Protect the body from oxidative stress
Oils	• Optimal performance of the brain • Regulation of reproductive function • Improving bone health • Treatment of rheumatoid arthritis-related pain
Phenols	• Reduced cholesterol levels • Prostate, colon and breast cancer prevention. Used in cancer therapy (Latha K. 2013)
Tocopherols/vitamin E	• Boost immune system and maintain metabolism • prevent the stomach's synthesis of cancer-causing substances • Growth of cataracts in the eyes prevented
Glycosides	• Lower and keep the systolic and diastolic blood pressure levels stable • Nutritive purposes • efficient for coughing disorders • treatment of hepatomegaly and splenomegaly

Tannins	• Prevention of cardiovascular diseases • Anti-inflammatory and analgesic effects • Keep the systolic and diastolic blood pressure lower stablize
Flavonoids	• Prevention of cardiovascular diseases • Possess antiulcer properties
Alkaloids	• Protects the body from oxidative stress • Chemotherapeutic treatment • Used as chemo preventive agents • Reverse, delay, or constrain tumorigenesis

3. Phytochemistry of *S. torvum*

Sun dried *S. torvum* fruit extracts in methanol showed the presence of iron salts, vitamin E (tocopherol), B and C, oils, glycosides, saponins, tanins, flavonoids and alkoloids (Sivapriya *et al.,* 2007; Amarowicz *et al*., 2010; George *et al*., 2011). Lakshmi *et al*. reported that chloroform, petroleum ether and methanol extracts of the fruits, leaves and roots of *S. torvum* were devoid of anthraquinones, cyanides and, surprisingly, glycosides and flavonoids (Lakshmi *et al*. 2013). In methanolic extracts of *S. torvum* fruits, two novel steroidal glycosides torvoside H and torvanol A were discovered in addition to the already known glycoside torvoside A (Arthan *et al*., 2002). Also, Torvanol A was extracted from the leaves (Mahmood *et al*., 1983).

There has been a lot of research done on the chemical components of *S. torvum*. Fruit, leaves and roots are among the sections used to isolate a variety of chemicals. An excellent source of glycosides, tanins, saponins, flavonoids and alkoloids of this plant species (Chah *et al.,* 2000).

3.1 Compounds isolated from fruit

Antiviral isoflavonoid sulphate and steroidal glycosides were also isolated from the fruits of *S. torvum*. In their study of methanol extracts of fruit (Arthan *et al*., 2002) discovered torvanol A, a novel isoflavonoid sulphate, as well as torvoside H, a novel steroidal glycoside and torvoside A, a previously known glycoside and α-tocopherol (Koomson *et al*., 2018).

3.2 Compounds isolated from aerial parts

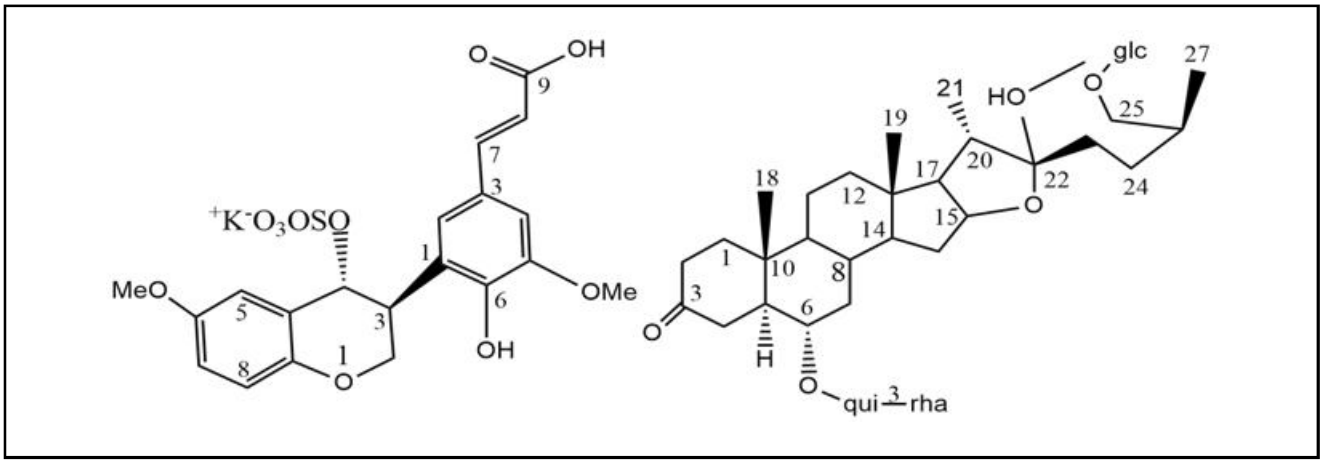
S. torvum aerial portions are a great source of saponins and steroids. Four steroidal compounds were isolated by (Lu *et al*.,1983) solanolide 6-O-[α-l-rhamnopyranosyl- (1 → 3) - O-β-d-quinovopyranoside], yamogenin 3-*O*-[β-d-glucopyranosyl-(1 → 6)-*O*-β-d- glucopyrano side], solanolide 6-*O*-[β-d-xylopyranosyl-(1 → 3)-*O*-β-dquinovop yranoside] and solanolide 6-O- [α-lrhamnopyranosyl-(1 → 3)-O-β-d-quinovopyranoside]. According to (Yuan *et al*. 2011), two new C-22 steroidal lactone saponins were isolated namely solanolactosides A, B and torvosides M and N, two novel spirostanol glycosides.

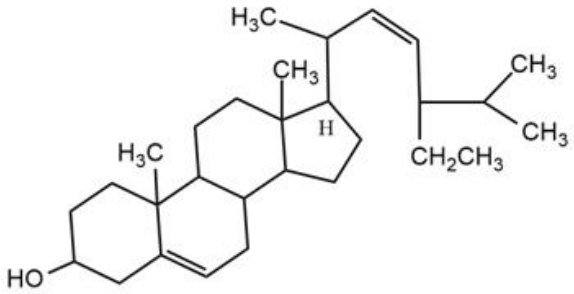
3.3 Compounds isolated from leaves

From the leaves, torvanol A was isolated by (Mahmood *et al*., 1983). Nine novel constituents were successfully isolated by (Yuan-Yuan *et al*., 2011). Namely, neochlorogenin 6-O-β-D-xylopyranosyl-(1.3)-β-D-quinovopyranoside, neochlorogenin 6-*O*-β-D-quinovopyrano -side, solagenin 6-*O*-β-D-quinovopyranoside, neochlorogenin 6-*O*-α-L-rhamnopyranosyl-(1 → 3)-β-d-quinovopyranoside, solagenin 6-*O*-α-L-rhamnopyranosyl-(1 → 3)-β-dquinovopyranoside, isoquercetin, kaempferol, quercetin and rutin.

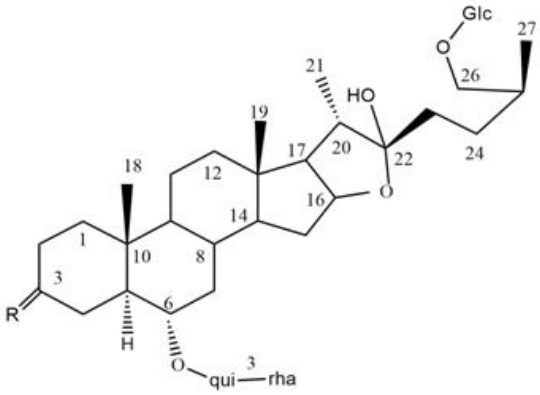
3.4 Compounds isolated from roots

Astorvosides A–G and other steroidal glycosides can be found in Solanum torvum roots. They were structurally characterized as 26-tetraol 6-O-[α-L-rhamnopyranosyl-(1 → 3)-β-dquinovopyurano side], neosolaspigenin 6-O-[α-Lrhamnopyranosyl-(1 → 3)-β-d-quinovopyranoside], and (25 S)-26-hydroxy-22a-methoxy-5a-furostan-3-one 26-O-(β-d-glucopyranoside).

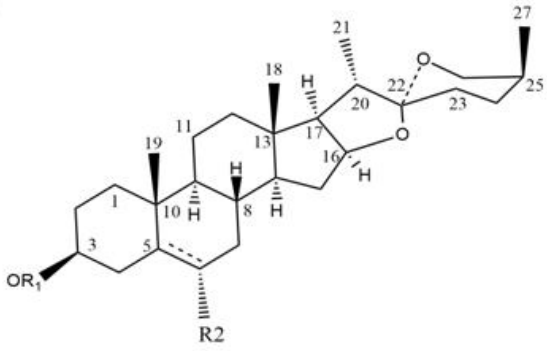




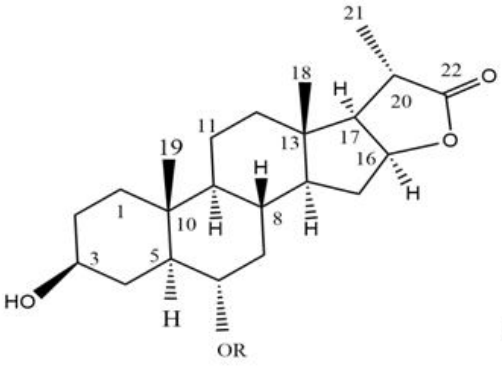
Torvoside B



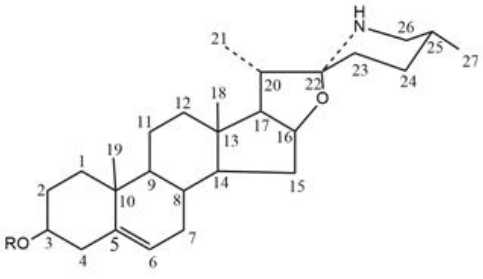
Torvoside A



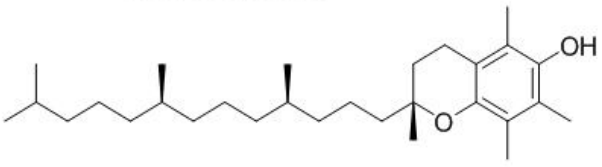
Solanolactoside B



Solanolactone A



Solasodine a



alpha-tocopherol

4. Discussion

A variety of conventional formulations and preparations for the treatment of disorders affecting important organs, such as heart, brain, and urinary system, contain the plant as an ingredient.

The medicinal and nutraceutical potential of the underused, raw, edible fruits of *S. torvum* were studied. The fruits are native to northeastern India. A detailed nutritional investigation of this fruit exposed that it is a good source of minerals, phenolic compounds and natural antioxidants. calcium, phosphorus, iron, vitamin C and other nutrients are all abundant in it. It has an inclusive range of pharmacological effects, like anti-inflammatory, antipyretic, antioxidant, anticancer, antiulcer, antidiabetic, hepatoprotective, cardiovascular, antimalarial, anthelmintic, antiviral and antibacterial action. The *S. torvum* plant is widely cultivated, free of illness and harmful pests, and it also can be used for a variety of medical purposes, for example, the prevention and/or treatment of disorders. Whether spent as raw fruits or any other part of the plant, fruits from plants include bioactive compounds that protect or improve health. The fruit's phytoconstituents can fight off allergies, cancers, ulcers, platelet aggregation and hypertension. There is a knowledge vacuum about the development, use, and diversification needed in Asian and African nations for commercial exploitation.

5. Conclusion

The fruit *Solanum torvum* L. has to be promoted and made known in foreign markets since it is still a relatively new product with untapped potential. It has been recognized as a brand-new tropical fruit with potential medicinal application. The lack of knowledge about the fruit's medical properties, applications, and lack of a reliable organized supply are the key factors limiting demand for this fruit. In order to promote the market, it is required to build large-scale growing units where significant quantities are made available. To debut a product in the domestic and international markets, market promotion should primarily concentrate on raising awareness of the health benefits.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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