Suresh Reddy Yanala et al /J. Pharm. Sci. & Res. Vol. 8(3), 2016, 132-140

ISSN:0975-1459
Journal of Pharmaceutical Sciences and Research
www.jpsr.pharmainfo.in

A Recent Phytochemical Review – Fruits of *Tribulus terrestris* Linn

Suresh Reddy Yanala[1]*, D. Sathyanarayana[2], K. Kannan[3]

Department of Pharmacy,
Annamalai University,
Chidambaram, Tamil Nadu, India

Abstract

The genus *Tribulus*, belonging to family Zygophyllaceae, comprises about 20 species widely distributed across the world, of which three species, viz. *Tribulus terrestris*, *Tribulus cistoides* and *Tribulus alatus*, are of common occurrence in India. Among them, *T. terrestris* commonly known as gokharu or puncture wine is a well known medicinal herb has been used for a long time in both the Indian and Chinese alternative systems of medicine for treatment of various kinds of diseases. This review summarized the current knowledge on the phytochemistry. Fruits of the *Tribulus terrestris* contain a variety of chemical constituents which are medicinally important, such as flavonoids, flavonol glycosides, steroidal saponins, steroidal glycosides, furostanol saponins, furosteroidal saponins, furostanol glycosides, sapogenins and alkaloids. It has diuretic, aphrodisiac, antiurolithic, immunomodulatory, antidiabetic, absorption enhancing, hypolipidemic, cardiotonic, central nervous system, hepatoprotective, anti-inflammatory, analgesic, antispasmodic, anticancer, antibacterial, anthelmintic, larvicidal, and anticarcinogenic activities. For the last few decades or so, extensive research work has been done to prove its pharmacological activities of its various extracts.

Keywords-*Tribulus terrestris* L. fruit, Gokhru, Zygophyllaceae, Phytochemicals

1. INTRODUCTION

1.1 Botany and occurrence.

Tribulus terrestris L. is awell known and widely distributed species of the genus *Tribulus*. The genus *Tribulus*, belonging to family Zygophyllaceae, comprises about 20 species in the world, of which three species, viz. *Tribulus terrestris*, *Tribulus cistoides* and *Tribulus alatus*, are of common occurrence in India. Among them, *T. terrestris* (TT) is a well practiced medicinal herb by Ayurvedic practitioners as well as by modern herbalists [1]. It is known with several common names: puncture vine, goat head, devil's thorn and Gokhru [2]. It is an annual creepinng herb found in Mediterranean, subtropical, and desert climate regions around the world, viz. India, China, Southern USA, Mexico, Spain, and Bulgaria [3, 4]. It is a common weed of the pasture lands, road sides, and other waste places, chiefly in hot, dry, and sandy regions in India [5]. It is used as traditional medicine in India, China, South Africa and Bulgaria against oedemas, cardiovascular diseases, and abdominal dysfunction, to increase spermatogenesis, for treatment of eye troubles, leucorrhea and impotence [6].

1.2 Taxonomical classification

Kingdom: Plantae
Division : Phanerogams
Subdivision: Angiospermae
Class : Dicotyledonae
Order :Zygophyllales
Family :Zygophyllaceae
Genus :Tribulus (puncturevine)
Species :*T.terrestris* (*Tribulus terrestris* L.) [7, 8].

1.3 Common and Vernacular Names

Tribulus terrestris has a list of alternative names almost as long as its history. In Traditional Chinese Medicine it is known as Ci Ji Li, Bai Ji Li or just Ji Li [9].
Latin Name: *Tribulus terrestris*-Semen
European common names: Maltese cross, Small caltrops
Sanskrit Names: Gokshura, Shuuadamshtra, Swadukantaka, Trikantaka, Vanashrungata, Chanadhruma, Ikshugandhika [10].
Local Names (in India): Gokharu (Hindi), Gokuri (Bengali), Kante gokaru (Marathi), Land caltrops (English), Nerinci (Tamil), Palleru Kayalu (Telugu).

1.4 Traditional Uses

The Latin name *Tribulus terrestris* sounds like an earthy Roman emperor. Some people think it rules among muscle-building supplements.The fruits of *T. terrestris* L. have been used in traditional Chinese medicine for the treatment of eye trouble, edema, abdominal distention, emission, morbid leucorrhea, sexual dysfunction and veiling. Roots and fruits are useful in rheumatism, piles, renal and vesical calculi, menorrhagia, impotency, premature ejaculation.
It is indicated for use in treating headaches, dizziness, premature ejaculation and spermatorrhoea (escape of sperm without orgasm) [11]. To Indian Ayurvedic practitioners the herb is called Burra Gokhru and is regarded as a diuretic, demulcent, antiseptic, anti-inflammatory and aphrodisiac. Ancient Greeks used *Tribulus terrestris* as a diuretic and a mood-enhancer. In ancient Chinese medicine, it was used for a variety of liver, kidney, and cardiovascular diseases. More recently, eastern European athletes have used it to improve strength and stamina [12].

1.5 Botanical Description of *Tribulus terrestris* Linn.

Fig 1: *Tribulus terrestris* Linn natural habitat

Fig 2: *Tribulus terrestris* Linn dried fruits

It is small prostrate, 10-60 cm height; hirsute silky hairy shrub. It is a tap rooted herbaceous perennial plant that grows as a summer annual in hot and colder climates [13, 14].

Stems

The stems radiate from the crown to a diameter of about 10 cm to over 1 m, often branching. They are usually prostrate, forming flat patches, though they may grow more in shade or among taller plants [15].

Leaves

The leaves are pinnately compound , in opposite pairs, 3 to 6 pair, upto 8 cm long with leaflets less than a quarter-inch long [16].

Flowers

The flowers are 4 to10 mm wide, with five lemon yellow petals. A week after each flower blooms, it is followed by a fruit that easily falls apart into four or five single-seeded nut lets. Flowers are usually silky, white or yellow, solitary, arises from the axils of leaves. Ovary briskly, style short and stout [17].

Fruits

Fruits are globose, spinous or tuberculate; consisting of fine hairy or nearly glabrous, often muriculate and woodi cocci, each with two pairs of hard sharp spines, one pair longer than the other. Fruit often cling to clothes and bodies of animals and humans [18].

Seeds

The nutlets or "seeds" are hard and bear two to three sharp spines, 10 mm long and 4 to 6 mm broad point-to point. It is a trailing and spreading herb, densely covered with minute hair. Seeds are many in woodi cocci [18].

2. Secondary Metabolites Of Fruits Of *Tribulus terrestris*

2.1 Seven steroidal saponins

Seven previously unidentified steroidal saponins were isolated from fruits of *Tribulus terrestris.* The structures of the saponins were established by using 1D and 2D NMR spectroscopy, mass spectrometry, and chemical methods. The compounds were identified as: 26-*O*-*β*-d-glucopyranosyl-(25*R*)-furost-4-en-2*α*,3*β*,22*α*,26-tetrol-12-one (terrestrinin C), 26-*O*-*β*-d-glucopyranosyl-(25*R*)-furost-4-en-22*α*,26-diol-3,12-dione (terrestrinin D), 26-*O*-*β*-d-glucopyranosyl-(25*S*)-furost-4-en-22*α*,26-diol-3,6,12-trione (terrestrinin E), 26-*O*-*β*-d-glucopyranosyl-(25*R*)-5*α*-furostan-3*β*,22*α*,26-triol-12-one (terrestrinin F), 26-*O*-*β*-d-glucopyranosyl-(25*R*)-furost-4-en-12*β*,22*α*,26-triol-3-one (terrestrinin G), 26-*O*-*β*-d-glucopyranosyl-(1→6)-*β*-d-glucopyranosyl-(25*R*)-furost-4-en-22*α*,26-diol-3,12-dione (terrestrinin H) and 24-*O*-*β*-d-glucopyranosyl-(25*S*)-5*α*-spirostan-3*β*,24*β*-diol-12-one-3-*O*-*β*-d-glucopyranosyl-(1→4)-*β*-d-galactopyranoside (terrestrinin I) [19].

2.2 Two oligosaccharides and other compounds

Two oligosaccharides (1, 2) and a stereoisomer of di-*p*-coumaroylquinic acid (3) were isolated along with five previously known compounds. The structures of the compounds were established by using spectroscopic methods including 1D NMR and 2D NMR experiments. The compounds were identified as: *O*-β-d-fructofuranosyl-(2 → 6)-α-d-glucopyranosyl-(1 → 6)-β-d-fructofuranosyl-(2 → 6)-β-d-fructofuranosyl-(2 → 1)-α-d-glucopyranosyl-(6 → 2)-β-d-fructofuranoside (1), *O*-α-d-glucopyranosyl-(1 → 4)-α-d-glucopyranosyl-(1 → 4)-α-d-glucopyranosyl-(1 → 2)-β-d-fructofuranoside (2), 4,5-di-*p*-*cis*-coumaroylquinic acid (3) [20].

2.3 Distribution of steroidal saponins in various regions

Samples of *T. terrestris* collected in Bulgaria, Greece, Serbia, Macedonia, Turkey, Georgia, Iran, Vietnam and India were analyzed by LC-ESI/MS/MS for the presence and the concentration of Protodioscin, Prototribestin, Pseudoprotodioscin, Dioscin, Tribestin, Tribulosin and the flavonoid Rutin [21].

2.4 Two furostanol saponins

Two new furostanol saponin were identified as 3-*O*-{β-*D*-xylopyranosyl(1→3)-[β-*D*-xylopyranosyl(1→2)]-β-*D*-glucopyranosyl (1→4)-[α-*L*-rhamnopyranosyl (1→2)]-β-*D*-galactopyranosy}-26-*O*-β-*D*-glucopyranosyl-5α-furost-12-one-22-methoxyl-3β,26-diol (named as terrestroside A) and 3-*O*-{β-*D*-xylopyranosyl(1→3)-[β-*D*-xylopyranosyl(1→2)]-β-*D*-glucopyranosyl(1→4)-[α-*L*-rhamnopyranosyl(1→2)]-β-*D*-galactopyranosy}-26-*O*-β-*D*-glucopyranosyl-5a-furost-22-methoxyl-3β,26-diol [22].

2.5 Two new furostanol glycosides

Two new furostanol glycosides, named terrestrinones A1/A2, were isolated from the fruits of *Tribulus terrestris* L. and their structures were determined by spectroscopic methods, including 2D NMR experiments [23].

2.6 Five new steroidal saponins

Five new steroidal saponins were identified as (23*S*,25*S*)-5*α*-spirostane-24-one-3*β*,23-diol-3-*O*-{*α*-l-rhamnopyranosyl-(1 → 2)-*O*-[*β*-d-glucopyranosyl-(1 → 4)]-*β*-d-galactopyranoside} (1), (24*S*,25*S*)-5*α*-

spirostane-3*β*,24-diol-3-*O*-{*α*-l-rhamnopyranosyl-(1 → 2)-*O*-[*β*-d-glucopyranosyl-(1 → 4)]-*β*-d-galactopyranoside} (2), 26-*O*-*β*-d-glucopyranosyl-(25*R*)-5*α*-furostan-2*α*,3*β*,22*α*,26-tetraol-3-*O*-{*β*-d-glucopyranosyl-(1 → 2)-*O*-*β*-d-glucopyranosyl-(1 → 4)-*β*-d-galactopyranoside} (3), 26-*O*-*β*-d-glucopyranosyl-(25*R*)-5*α*-furostan-20(22)-en-2*α*,3*β*,26-triol-3-*O*-{*β*-d-glucopyranosyl-(1 → 2)-*O*-*β*-d-glucopyranosyl-(1 → 4)-*β*-d-galactopyranoside} (4) and 26-*O*-*β*-d-glucopyranosyl-(25*S*)-5*α*-furostan-12-one-22-methoxy-3*β*,26-diol-3-*O*-{*α*-l-rhamnopyranosyl-(1 → 2)-*O*-[*β*-d-glucopyranosyl-(1 → 4)]-*β*-d-galactopyranoside} (5) [24].

2.7 Two new furostanol glycosides

Two new furostanol glycosides, named as 26-*O*-β-d-glucopyranosyl-(25S)-5α-furost-3β, 22α, 26-triol-3-*O*-β-d-rhamnopyranosyl-(1 → 2)-[β-d-glucopyranosyl-(1 → 4)]–β-d-galacto pyranoside (1) and 26-*O*-β-d-glucopyranosyl-(25S)-5α-furost-20(22)-en-2α,3β,26–triol-3-*O*-β-d-glucopyranosyl-(1 → 2)-*O*-β-d-glucopyranosyl-(1 → 4)-β-d-galactopyranoside (2) were isolated from the fruits of *Tribulus terrestris* L. The structures of two new furostanol saponins were fully elucidated by spectroscopic and chemical methods [25].

2.8 A novel furostanol saponin

The phytochemical investigation of *Tribulus terrestris* has resulted in the isolation of the new novel furostanol saponin, named tribol, together with two known spirostanol saponins and sitosterol glucoside. The structure of tribol was determined as (25R)-furost-5(6)-ene-3β,16,26-triol-3-*O*-α-rhamnopyranosyl-(1→2)-[α-rhamnopyranosyl-(1→4)]-β-glucopyranoside, by 1D and 2D-NMR experiments [26].

2.9 Steroidal glycosides

The structures of the new saponins were established as 26-O-β-d-glucopyranosyl-3-O-[{β-d-xylopyranosyl(1 → 3)}{β-d-galactopyranosyl(1 → 2)}-β-d-glucopyranosyl (1 → 4)-β-d-glucopyranosyl]-5α-furost-20(22)-en-12-one-3β,26-diol and 26-O-β-d-glucopyranosyl-3-O-[rm[{β-d-xylopyranosyl(1 → 3){β-d-galactopyranosyl(1 → 2)}-β-d-glucopyranosyl (1 → 4)-β-d-glucopyranosyl]-5α-furostan-12-one-3β,22,26-triol [27].

2.10 steroidal saponins

The fruits of *Tribulus terrestris* led to the isolation of five new steroidal saponins. The structures of the new saponins were elucidated on the basis of various spectroscopical analytical techniques. The compounds were named as (25R,S)-5α-spirostan-3β-ol-3-O-β-d-galactopyranosyl(1-2)-β-d-glucopyranosyl(1-4)-β-d-galactopyranoside (terrestrosin A), (25R,S)-5α-spirostan-3β-ol-3-O-β-d-glucopyranosyl(1-4)-[α-l-rhamnopyranosyl(1-2)]-β-d-galactopyranoside (terrestrosin B), (25R,S)-5α-spirostan-12-on-3β-ol-3-O-β-d-galactopyranosyl(1-2)-β-d-glucopyranosyl(1-4)-β-d-galactopyranoside (terrestrosin C), hecogenin 3-O-β-d-galactopyranosyl(1-2)-[β-d-xylopyranosyl(1-3)]-β-d-glucopyranosyl(1-4)-β-d-galactopyranoside (terrestrosin D) and (25R,S)-5α-spirostane-2α,3β-diol-3-O-β-d-galactopyranosyl(1-2)-β-d-glucopyranosyl(1-4)-β-d-galactopyranoside (terrestrosin E) [28].

2.11 Alkaloids and other constituents

Three new compounds, terrestribisamide, 25*R*-spirost-4-en-3, 12-dione and tribulusterine, along with 10 known compounds, *N*-*p*-coumaroyltyramine, terrestriamide, hecogenin, aurantiamide acetate, xanthosine, fatty acid ester, ferulic acid, vanillin, *p*-hydroxybenzoic acid and *β*-sitosterol, were isolated and from dried fruits of *Tribulus terrestris*. Structures of these compounds were determined by using two-dimensional NMR techniques, and chemical reactions [29].

2.12 **Flavonoids**

Kaempferol, kaempferol-3-glucoside, kaempferol-3-rutinoside and tribuloside (kaempferol-3-β-d-(6″-*p*-coumaroyl) glucoside) have been isolated from the fruits and leaves of *Tribulus terrestris* [30].

2.13 Flavonoid glycosides

Twenty-five flavonoid glycosides were identified in *Tribulus pentandrus* and *T. terrestris*. The glycosides major glycosides were belonging to the common flavonols, kaempferol, quercetin, isorhamnetin and 3-gentiobiosides [31].

2.14 Furostanol saponins

Protodioscin, a new saponin (5, 6-dihydroprotodioscin) and their respective sulfates were detected. The structure of the new compound was elucidated on the basis of NMR and ESI-MS spectral analysis [32].

2.15 Two sapogenins from

Two new steroidal sapogenins, (5*α*, 25*R*)-spirostan-3,6,12-trione and 25*R*-spirostan-4-ene-3,6,12-trione, together with five previously known steroidal sapogenins, tigogenin, hecogenin, gitogenin, hecogenone, and 25*R*-spirostan-4-ene-3,12-dione were isolated. The structures of the new sapogenins were elucidated on the basis of chemical and 2D NMR spectroscopic techniques [33].

2.16 Steroidal saponins

Further investigation on the active principles of the fruits of *Tribulus terrestris* resulted to the isolation of six new furostanol saponins, named as 26-*O*-β- d-glucopyranosyl (25*R*)-furostane-2α,3β,22α,26-tetrol-3-*O*-β-d-glucopyranosyl (1–4)-β-d-galactopyranoside (1), 26- *O*-β-d-glucopyranosyl(25*R*,*S*)-5α-furostane-2α,3β,22α,26-tetrol-3-*O*-β-d-galactopyranosyl(1–2)-β-d- glucopyranosyl(1–4)-β-d-galactopyranoside (2), 26-*O*-β-d-glucopyranosyl (25*R*,*S*)-5α-furostane-3β,22α,26-triol-3- *O*-β-d-galactopyranosyl(1–2)-β-d-glucopyranosyl(1–4)-β-d-galactopyranoside (3), 26-*O*-β-d-glucopyranosyl (25 *R*,*S*)-5α-furostan-12-one-3β,22α,26-triol-3-*O*-β-d-galactopyranosyl(1–2)-β-d-glucopyranosyl (1–4)-β-d-galactopyranoside (4), 26-*O*-β-d-glucopyranosyl (25*R*,*S*)-furost-5-ene-3β,22α,26-triol-3-*O*-β-d-galactopyranosyl(1–2)-β-d-glucopyranosyl(1–4)-β-d-galactopyranoside (5), and 26-*O*-β-d-glucopyranosyl (25*R*)-5α-furost-20(22)-en-12-one-3β,26-diol-3-*O*-β-d-galactopyranosyl(1–2)-β-d-glucopyranosyl(1–4)-β-d-galactopyranoside (6), named terrestrosin F—K, respectively [34].

2.17 Tribulusamide A and B

Tribulusamides A and B, new lignanamides containing two cinnamic amide parts joined in a cis configuration, were isolated from the fruits of *Tribulus terrestris*. The structures were elucidated by 2D-NMR spectroscopy [35].

2.18 Three new saponins

Three new steroidal saponins were isolated from fruits of *Tribulus terrestris*.The structures of the new steroidal saponins were identified as hecogenin 3-O-beta-xylopyranosyl(1-->3)-beta-glucopyranosyl(1-->4)-beta-galactopyranoside (1), hecogenin 3-O-beta-glucopyranosyl(1-->2)-beta-glucopyranosyl(1-->4)-beta-galactopyranoside (2) and 3-O-[beta-xylopyranosyl(1-->2)-[beta-xylopyranosy[(1-->3)]-beta-glucopyranosyl(1-->4)-[alpha-rhamnopyranosyl(1-->2)]-beta-galactopyranosyl}-26-O-beta-glucopyranosyl-22-methoxy-(3 beta,5 alpha,25R)-furostan-3,26-diol (3) [36].

2.19 Two new sulfated furostanol saponins Two new sulfated saponins, sodium salt of 26-O-beta-glucopyranosyl-22alpha-methoxy-(25R)-furost-5-ene-3beta,26-diol-3-O-alpha-rhamnopyranosyl-(1-->2)-beta-4-O-sulfo-glucopyranoside (methylprototribestin) and sodium salt of 26-O-beta-glucopyranosyl-22alpha-hydroxy-(25R)-furost-5-ene-3beta,26-diol-3-O-alpha-rhamnopyranosyl-(1-->2)-beta-4-O-sulfo-glucopyranoside (prototribestin) were isolated from *Tribulus terrestris* [37].

2.20 Terresoxazine, A novel compound with benzoxazine skeleton

Terresoxazine, a novel benzoxazine derivative was isolated from the fruits of *Tribulus terrestris*. Its structure was determined as 7-hydroxy-3, 3a-dihydro-5H-pyrrolo-[1, 2-a] [3, 1] -benzoxazin-1(2H)-one [38].

2.21 A new furosteroidal saponin

The structure of the new furosteroidal saponin, named Tribuluside A, was elucidated by using 1D, 2D NMR and chemical methods, as 26-O-beta-D-glucopyranosyl-(25R)-5 alpha-furost-3 beta, 22 alpha,26-triol-3-O-[beta-D-Xylopyranosyl(1 -> 3)] [beta-D-xylopyranosyl(1 -> 2)]-beta-D-glucopyranosyl(1 -> 4)-[alpha-L-rhamnopyranosyl(1 -> 2)]-beta-D-galactopyranoside [39].

2.22 One new cinnamic imide dervative

One new cinnamic imide derivative, named tribulusimide C, was isolated from the fruits of *Tribulus terrestris*, together with three known compounds, N-p-coumaroyltyramine , terrestriamide, N-trans-caffeoyltyramine [40].

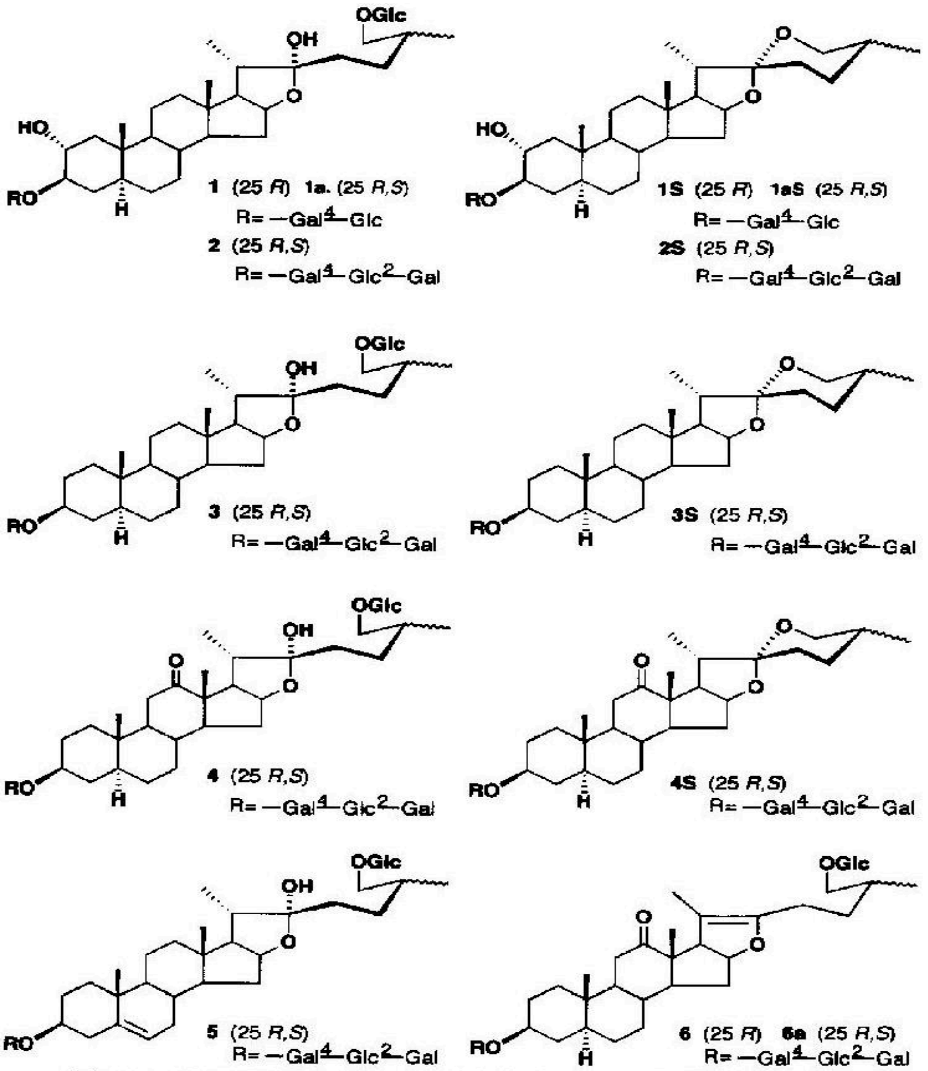
2.23 A new feruloyl amide derivative

A new feruloyl amide derivative was isolated from the fruits of *Tribulus terrestris*. The structure was characterised by a unit of pyrrolidine-2, 5-Dione. The structure was determined on the basis of spectroscopic analysis [41].

Table 1 Reported Phytochemicals from fruits of *Tribulus terrestris* L.

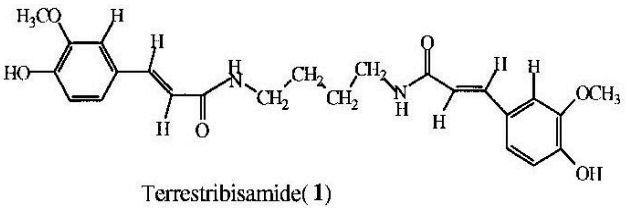
1	26-*O*-*β*-d-glucopyranosyl-(25*R*)-furost-4-en-2*α*,3*β*,22*α*,26-tetrol-12-one (terrestrinin C), 26-*O*-*β*-d-glucopyranosyl-(25*R*)-furost-4-en-22*α*,26-diol-3,12-dione (terrestrinin D), 26-*O*-*β*-d-glucopyranosyl-(25*S*)-furost-4-en-22*α*,26-diol-3,6,12-trione (terrestrinin E), 26-*O*-*β*-d-glucopyranosyl-(25*R*)-5*α*-furostan-3*β*,22*α*,26-triol-12-one (terrestrinin F), 26-*O*-*β*-d-glucopyranosyl-(25*R*)-furost-4-en-12*β*,22*α*,26-triol-3-one (terrestrinin G), 26-*O*-*β*-d-glucopyranosyl-(1→6)-*β*-d-glucopyranosyl-(25*R*)-furost-4-en-22*α*,26-diol-3,12-dione (terrestrinin H) 24-*O*-*β*-d-glucopyranosyl-(25*S*)-5*α*-spirostan-3*β*,24*β*-diol-12-one-3-*O*-*β*-d-glucopyranosyl-(1→4)-*β*-d-galactopyranoside (terrestrinin I).	Li-Ping Kang *et al*, Steroidal saponins from *Tribulus terrestris*. *Phytochemistry*, Volume 107, November 2014, Pages 182-189.
2	*O*-β-d-fructofuranosyl-(2 → 6)-α-d-glucopyranosyl-(1 → 6)-β-d-fructofuranosyl-(2 → 6)-β-d-fructofuranosyl-(2 → 1)-α-d-glucopyranosyl-(6 → 2)-β-d-fructofuranoside (1), *O*-α-d-glucopyranosyl-(1 → 4)-α-d-glucopyranosyl-(1 → 4)-α-d-glucopyranosyl-(1 → 2)-β-d-fructofuranoside (2), 4, 5-di-*p*-*cis*-coumaroylquinic acid (3), 4, 5-di-*p*-*trans*-coumaroylquinic acid (4).	Hala M *et al.* Chemical constituents from *Tribulus terrestris* and screening of their antioxidant activity. *Phytochemistry*, Volume 92, August 2013, Pages 153-159.
3	Protodioscin (1), Prototribestin (2), Pseudoprotodioscin (3), Dioscin (4), Tribestin (5), Tribulosin (6) and the flavonoid rutin (7).	Dragomir Dinchev *et al*. Distribution of steroidal saponins in *Tribulus terrestris* from different geographical regions, *Phytochemistry*, Volume69, Issue1, 2008, Pages176-186.
4	3-*O*-{β-*D*-xylopyranosyl(1→3)-[β-*D*-xylopyranosyl(1→2)]-β-*D*-glucopyranosyl(1→4)-[α-*L*-rhamnopyranosyl(1→2)]-β-*D*-galactopyranosy}-26-*O*-β-*D*-glucopyranosyl-5α-furost-12-one-22-methoxyl-3β,26-diol (terrestrosideA) and 3-*O*-{β-*D*-xylopyranosyl(1→3)-[β-*D*-xylopyranosyl(1→2)]-β-*D*-glucopyranosyl(1→4)-[α-*L*-rhamnopyranosyl(1→2)]-β-*D*-galactopyranosy}-26-*O*-β-*D*-glucopyranosyl-5a-furost-22-methoxyl-3β,26-diol	Wei Hua Yuan *et al.* Two Furostanol Saponins from the Fruits of *Tribulus terrestris*. *Chinese Journal of Natural Medicines*, 6 (3), May 2008.
5	Terrestrinones A1/A2 (1a/1b)	Seong Su Hong *et al.* Two new furostanol glycosides from the fruits of *Tribulus terrestris*. *Tetrahedron Letters*, Volume 54, Issue 30, 24 July 2013, Pages 3967-3970.
6	(23*S*,25*S*)-5*α*-spirostane-24-one-3*β*,23-diol-3-*O*-{*α*-l-rhamnopyranosyl-(1 → 2)-*O*-[*β*-d-glucopyranosyl-(1 → 4)]-*β*-d-galactopyranoside} (1), (24*S*,25*S*)-5*α*-spirostane-3*β*,24-diol-3-*O*-{*α*-l-rhamnopyranosyl-(1 → 2)-*O*-[*β*-d-glucopyranosyl-(1 → 4)]-*β*-d-galactopyranoside} (2), 26-*O*-*β*-d-glucopyranosyl-(25*R*)-5*α*-furostan-2*α*,3*β*,22*α*,26-tetraol-3-*O*-{*β*-d-glucopyranosyl-(1 → 2)-*O*-*β*-d-glucopyranosyl-(1 → 4)-*β*-d-galactopyranoside} (3), 26-*O*-*β*-d-glucopyranosyl-(25*R*)-5*α*-furostan-20(22)-en-2*α*,3*β*,26-triol-3-*O*-{*β*-d-glucopyranosyl-(1 → 2)-*O*-*β*-d-glucopyranosyl-(1 → 4)-*β*-d-galactopyranoside} (4) 26-*O*-*β*-d-glucopyranosyl-(25*S*)-5*α*-furostan-12-one-22-methoxy-3*β* (1 → 2)-*O*-[*β*-d-glucopyranosyl-(1 → 4)]-*β*-d-galactopyranoside} (5)	Lan *et al*, *Steroids*, 2009, Volume 74, Issues 4–5, 399-403.
7	26-*O*-β-d-glucopyranosyl-(25S)-5α-furost-3β,22α,26-triol-3-*O*-β-d- rhamnopyranosyl-(1 → 2)-[β-d-glucopyranosyl-(1 → 4)]-β-d-galactopyranoside (1),	Ya Juan Xu *et al.* Two new furostanol saponins from *Tribulus terrestris* L. *Chinese Chemical Letters*,

	26-*O*-β-d-glucopyranosyl- (25S)-5α-furost-20(22)-en-2α,3β,26–triol-3-*O*-β-d-glucopyranosyl-(1 → 2)-*O*-β-d-glucopyranosyl-(1 → 4)-β-d-galactopyranoside (2),	Volume 21, Issue 5, May 2010, Pages 580-583.
8	(25R)-furost-5(6)-ene-3β,16,26-triol-3-*O*-α-rhamnopyranosyl-(1→2)-[α-rhamnopyranosyl-(1→4)]-β-glucopyranoside (Tribol).	J. Conrad *et al.* A novel furostanol saponin from *Tribulus terrestris* of Bulgarian origin. *Fitoterapia*, Volume 75, Issue 2, March 2004, Pages 117-122.
9	26-O-β-d-glucopyranosyl-3-O-[{β-d-xylopyranosyl(1→3)}{β-d-galactopyranosyl(1→2)}-β-d-glucopyranosyl(1→4)-β-d-glucopyranosyl]-5α-furost-20(22)-en-12-one-3β,26-diol, 26-O-β-d-glucopyranosyl-3-O-[rm[{β-d-xylopyranosyl(1→3){β-d-galactopyranosyl(1→2)}-β-d-glucopyranosyl (1 → 4)-β-d-glucopyranosyl]-5α-furostan-12-one-3β,22,26-triol.	Gong Wu *et al.* Steroidal glycosides from *Tribulus terrestris*. *Phytochemistry*, Volume 42, Issue 6, August 1996, Pages 1677-1681
10	(25R,S)-5α-spirostan-3β-ol-3-O-β-d-galactopyranosyl(1-2)-β-d-glucopyranosyl(1-4)-β-d-galactopyranoside, (25R,S)-5α-spirostan-3β-ol-3-O-β-d-glucopyranosyl(1-4)-[α-l-rhamnopyranosyl(1-2)]-β-d-galactopyranoside, (25R,S)-5α-spirostan-12-on-3β-ol-3-O-β-d-galactopyranosyl(1-2)-β-d-glucopyranosyl(1-4)-β-d-galactopyranoside, hecogenin 3-O-β-d-galactopyranosyl(1-2)-[β-d-xylopyranosyl(1-3)]-β-d-glucopyranosyl(1-4)-β-d-galactopyranoside, (25R,S)-5α-spirostane-2α,3β-diol-3-O-β-d-galactopyranosyl(1-2)-β-d-glucopyranosyl(1-4)-β-d-galactopyranoside.	Yan w *et al.* Steroidal saponins from fruits of *Tribulus terrestris*. *Phytochemistry*, Volume 42, Issue 5, 1996, Pages 1417-1422.
11	Terrestribisamide, 25*R*-spirost-4-en-3,12-dione,Tribulusterine	Tian-Shung Wu *et al.* Alkaloids and other constituents from *Tribulus terrestris*. *Phytochemistry*, Volume 50, Issue 8, 1 April 1999, Pages 1411-1415.
12	Kaempferol, Kaempferol-3-glucoside, Kaempferol-3-rutinoside, Tribuloside(kaempferol-3-β-d-(6″-*p*-coumaroyl) glucoside.	S.P. Bhutani *et al*. Flavonoids of the fruits and leaves of *Tribulus terrestris*: Constitution of tribuloside. *Phytochemistry*, Volume 8, Issue 1, January 1969, Pages 299-303.
13	Flavonols, Kaempferol, Quercetin and Isorhamnetin, 3-gentiobiosides.	Saleh *et al*. Flavonoid glycosides of *Tribulus pentandrus and T. terrestris. Phytochemistry* 21(8): 1995-2000.
14	5, 6-dihydroprotodioscin (neoprotodioscin).	E De Combarieu *et al*. Furostanol saponins from *Tribulus terrestris*. *Fitoterapia*, Volume 74, Issue 6, September 2003, Pages 583-591.
15	(5*α*, 25*R*)-spirostan-3,6,12-trione, 25*R*-spirostan-4-ene-3,6,12-trione	Yi-Xin Xu *et al.* Two sapogenins from *Tribulus terrestris*. *Phytochemistry*, Volume 49, Issue 1, 3 September 1998, Pages 199-201.
16	26-*O*-β- d-glucopyranosyl (25*R*)-furostane-2α,3β,22α,26-tetrol-3-*O*-β-d-glucopyranosyl (1–4)-β-d-galactopyranoside (Terrestrosin F), 26- *O*-β-d-glucopyranosyl (25*R*,*S*)-5α-furostane-2α,3β,22α,26-tetrol-3-*O*-β-d-galactopyranosyl(1–2)-β-d-glucopyranosyl(1–4)-β-d-galactopyranoside (Terrestrosin G), 26-*O*-β-d-glucopyranosyl (25*R*,*S*)-5α-furostane-3β,22α,26-triol-3-*O*-β-d-galactopyranosyl(1–2)-β-d-glucopyranosyl(1–4)-β-d-galactopyranoside (Terrestrosin H), 26-*O*-β-d-glucopyranosyl (25 *R*,*S*)-5α-furostan-12-one-3β,22α,26-triol-3-*O*-β-d-galactopyranosyl(1–2)-β-d-glucopyranosyl(1–4)-β-d- galactopyranoside (Terrestrosin I), 26-*O*-β-d-glucopyranosyl (25*R*,*S*)-furost-5-ene-3β,22α,26-triol-3-*O*-β-d-galactopyranosyl(1–2)-β-d-glucopyranosyl(1–4)-β-d-galactopyranoside (Terrestrosin J), 26-*O*-β-d-glucopyranosyl (25*R*)-5α-furost-20(22)-en-12-one-3β,26-diol-3-*O*-β-d-galactopyranosyl(1–2)-β-d-glucopyranosyl(1–4)-β-d-galactopyranoside (Terrestrosin K).	Yan Wang *et al.* Steroidal saponins from fruits of *Tribulus terrestris. Phytochemistry*, Volume 45, Issue 4, June 1997, Pages 811-817.
17	Tribulusamides A and B	Yan Wang *et al*., *Phytochemistry*, 1997, Volume 45, Issue 4, 811-817.
18	hecogenin 3-O-beta-xylopyranosyl(1-->3)-beta-glucopyranosyl(1-->4)-beta-galactopyranoside (1), hecogenin 3-O-beta-glucopyranosyl(1-->2)-beta-glucopyranosyl(1-->4)-beta-galactopyranoside (2), 3-O-[beta-xylopyranosyl(1-->2)-[beta-xylopyranosy[(1-->3)]-beta-glucopyranosyl(1-->4)-[alpha-rhamnopyranosyl(1-->2)]-beta-galactopyranosyl}-26-O-beta-glucopyranosyl-22-methoxy-(3 beta,5 alpha,25R)-furostan-3,26-diol (3).	Xu, YX (Xu, YX) *et al.* Three new saponins from *Tribulus terrestris*. *Planta med* 2000 Aug; 66(6):545-50.
19	26-O-beta-glucopyranosyl-22alpha-methoxy-(25R)-furost-5-ene-3beta,26-diol-3-O-alpha-rhamnopyranosyl-(1-->2)-beta-4-O-sulfo-glucopyranoside (methylprototribestin), 26-O-beta-glucopyranosyl-22alpha-hydroxy-(25R)-furost-5-ene-3beta,26-diol-3-O-alpha-rhamnopyranosyl-(1-->2)-beta-4-O-sulfo-glucopyranoside (prototribestin).	Kostova, I *et.al*, Two new sulfated furostanol saponins from *Tribulus terrestris*. *Journal of Biosciences*, Volume: 57.
20	7-hydroxy-3, 3a-dihydro-5H-pyrrolo-[1, 2-a] [3, 1] -benzoxazin-1(2H)-one (Terresoxazine).	Huang, JW *et al.* Terresoxazine, A novel compound with benzoxazine skeleton from *Tribulus terrestris*. *Chinese chemical letters*, Volume: 15.
21	26-O-beta-D-glucopyranosyl-(25R)-5 alpha-furost-3 beta, 22 alpha,26-triol-3-O-[beta-D-Xylopyranosyl(1->3)][beta-D-xylopyranosyl(1->2)]-beta-D-glucopyranosyl(1->4)-[alpha-L-rhamnopyranosyl(1->2)]-beta-D-galactopyranoside (Tribuluside A).	Xu, YJ (Xu Ya-Jiuan) *et al.* Isolation and identification of a new furosteroidal saponin from fruits of *Tribulus terrestris* L. *Chemical Journal of Chinese Universities*, Volume: 28.
22	Tribulusimide C	Lv, AL *et al.* One new cinnamic imide dervative from the fruits of *Tribulus terrestris. Natural Product Research*, Volume 22.
23	Pyrrolidine-2, 5-Dione	Zhang, XP *et al. Natural Product Research*, Volume: 26, Issue: 20, 1922-1925.

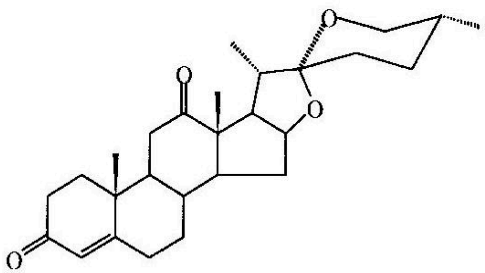


Scheme. 1. Chemical formulae of compounds 1–6 and prosapogenins 1S, 2S, 3S and 4S.

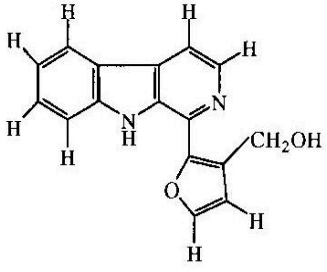
Fig 3: Steroidal saponins (Terrestrosin F-K)



Terrestribisamide(**1**)



25*R*-Spirost-4-en-3,12-dione(**2**)



Tribulusterine(**3**)

Fig 4 Alkaloids

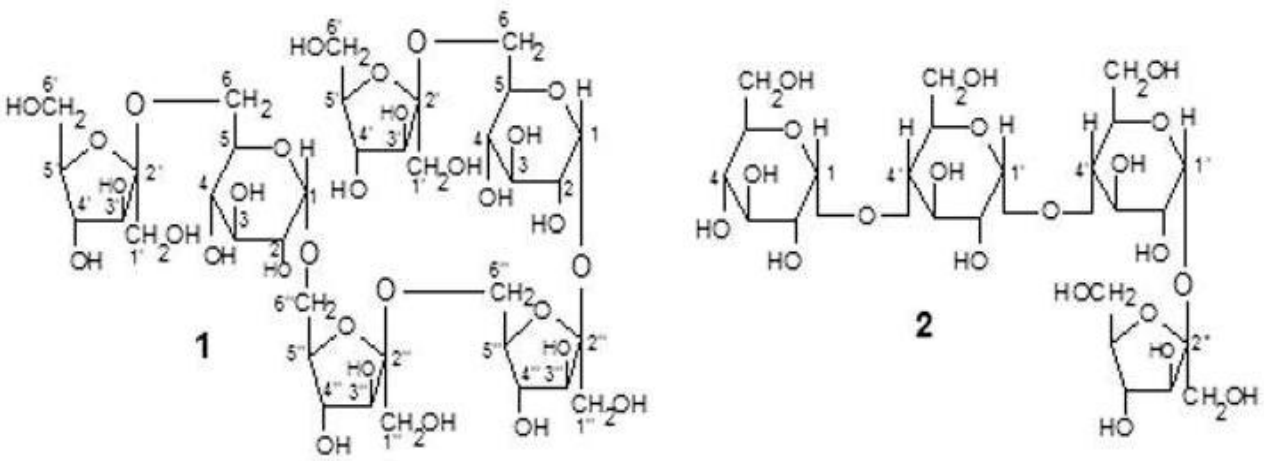


Fig 5: Two oligosaccharides

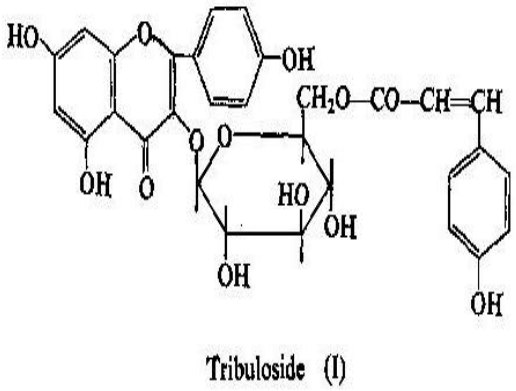
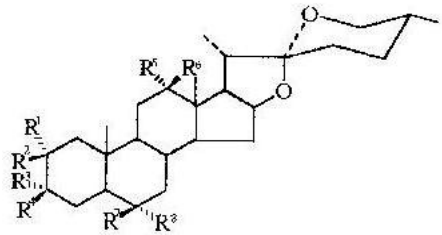


Fig 6: A flavonoid



R"=H unless otherwise stated

1 R^4 = OH
2 R^4 = OH, R^5R^6 = O
3 R^1 = R^4 = OH
4 R^3R^4 = R^5R^6 = O
6 R^3R^4 = R^5R^6 = R^7R^8 = O

Fig 8: Steroidal sapogenins

(5*α*, 25*R*)-Spirostan-3, 6, 12-trione, 25*R*-spirostan-4-ene-3, 6, 12-trione, tigogenin, hecogenin, gitogenin, 25 R-spirostan-4-ene-3, 12-Dione.

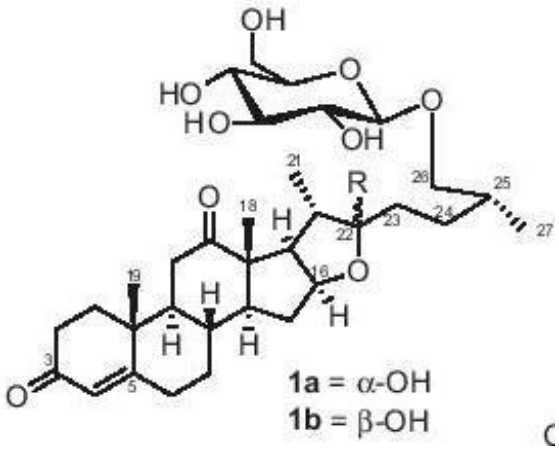
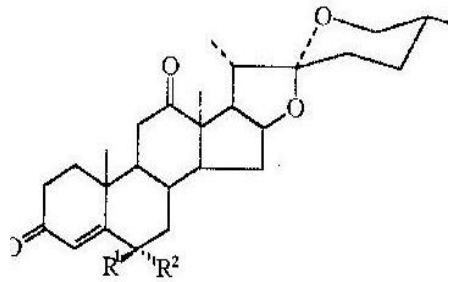
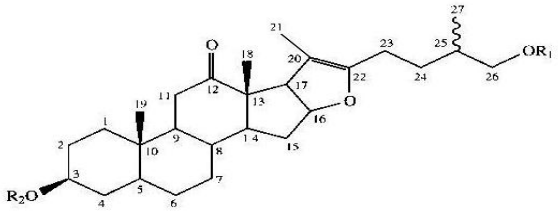


Fig 7: 1a /1b; Terrestrinones 1a /1b



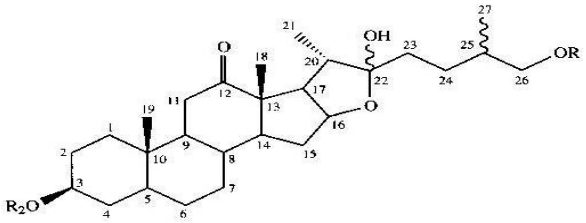
5 R^1 = R^2 = H
7 R^1R^2 = O

Fig 9: Steroidal glycosides: Hemogenin 3-O-β-d-glucopyranosyl (1→4) - β-d-glucopyrinoside (1), 26-O-β-d-glucopyranosyl-3-O-[{β-d-xylopyranosyl(1→3)}{β-d-galactopyranosyl(1→2)}-β-d-glucopyranosyl(1→4)-β-d-glucopyranosyl]-5α-furost-20(22)-en-12-one-3β,26-diol (2),26-O-β-d-glucopyranosyl-3-O-[rm[{β-d-xylopyranosyl(1→3){β-d-galactopyranosyl(1→2)}-β-d-glucopyranosyl (1 → 4)-β-d-glucopyranosyl]-5α-furostan-12-one-3β,22,26-triol (3).

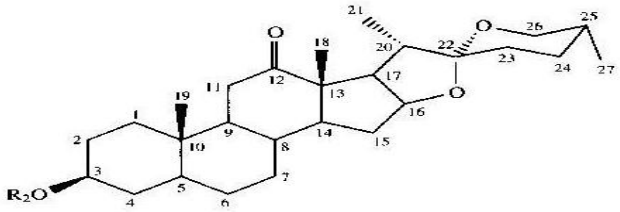


1. R_1 = -β-D-Glc R_2 = -β-D-Glc^4-β-D-Glc^3-β-D-Xyl
   |^2
   β-D-Gal

Ps1. R_1 = -β-D-Glc R_2 = H



2. R_1 = -β-D-Glc R_2 = -β-D-Glc^4- β-D-Glc^3-β-D-Xyl
   |^2
   β-D-Gal



3. R_2 = -β-D-Gal^4-β-D-Glc

Fig 10: Tribol (1), Spirostanol saponins 2 and 3

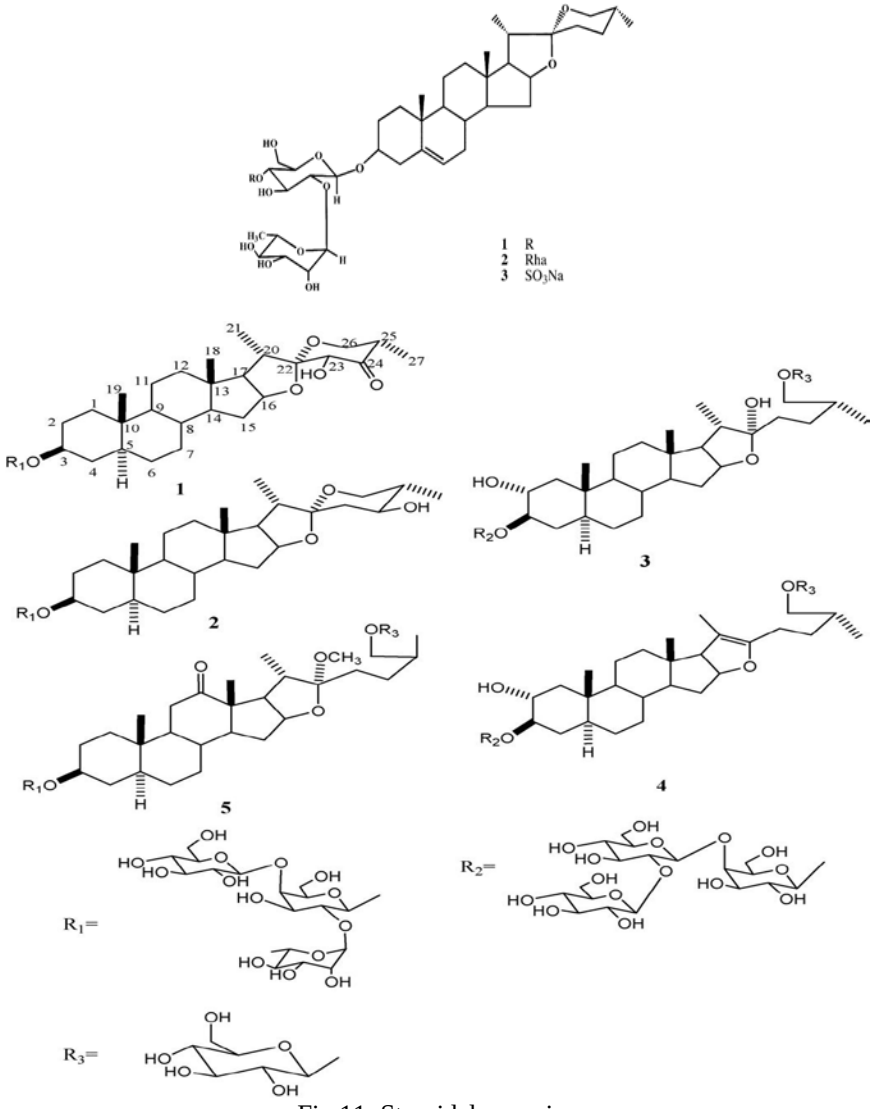


Fig 11: Steroidal saponins

CONCLUSION

In this review many classes of natural secondary metabolites were reported from the fruits of *Tribulus terrestris* Linn. Mostly saponins and glycosides of various classes were reported**.** Biological activities such as aphrodisiac, immunomodulatory, antidiabetic, hypolipidemic, cardiotonic, hepatoprotective, anti-inflammatory, antispasmodic, anticancer, antibacterial, anthelmintic and anticariogenic were reported from various fruit extracts. The aim of this review is to create a database for the isolated active principles and to create further investigations of the discovered phyto chemicals of this plant to promote research. This will help in its value-added utility, eventually leading to higher revenues from the plant.

REFERENCES

1. S K Gupta, R Zafar and D Pathak. Review of phytochemical and pharmacological aspects of Steroidal saponins from Tribulus terrestris . Indian Drugs, 1997; 4 (8): 422-26
2. Quattrocchi U. CRC world Dictionary of Plant Names. Vol. IV, CRC press, Boca Raton, London, New York, Washington, D. C., 2000, 2708.
3. Trease GE, Evans WC. Trease and Evans Pharmacognosy. 15th ed. Singapore: Harcourt Brace and Company Asia Pvt. Ltd; 2002. A taxonomic approach to the study of medicinal plants and animal derived drugs; p. 27.
4. Publications and Information Directorate. Vol. 9. New Delhi: CSIR; 1972. The wealth of India. Raw materials; p. 472.
5. Kokate CK, Purohit AP, Gokhale SB. 13th edn. Pune: Nirali Prakashan Publisher; 2007. Pharmacognosy; p. 370.
6. Ross IA. Medicinal plants of the world. Chemical Constituents, Traditional and Modern Uses. Vol. II, Humana Press Inc., 2001, 411 – 426.
7. Flora of Karnataka, Sharma B.D, 1984, Biodiversity Documentation for Kerala Part 6: Flowering Plants, N. Sasidharan, 2004, Flora of Kolhapur District, Yadav S. R & Sardesai M. M, 2002.
9. P.G. Xiao, Modern Chinese Materia Medica, Vol. I, Chemical Industry Press, Bejing, 2001, P.481.
10. Anomymus, Ayurvedic Pharmacopoeia of India, New Delhi: Department of Ayush, Ministry of Health and Family Welfare, Govt of India part 1. Volume 1. P. 49-51.
11. Arif Adimoelja, Phytochemicals and the breakthrough of traditional herbs in the management of sexual dysfunctions, International Journal of Andrology, Volume pages 82–84, April 2000
12. P.G. Adaikan, K. Gauthaman & R. N. V. Prasad, History of herbal medicines with an insight on the pharmacological properties of Tribulus terrestris, The Aging Male, Volume 4, Issue 3, 2001.
13. J K Scott, Variation in Populations of Tribulus terrestris (Zygophyllaceae).1. Burr Morphology, Australian Journal of Botany 44(2) 175 – 190.
14. Jignesh Kevalia1 and Bhupesh Patel, Identification of fruits of Tribulus terrestris Linn. And Pedalium murex Linn.: A pharmacognostical approach. Ayu. 2011 Oct-Dec; 32(4): 550–553.
15. Yasuji fukuda, Morphological and anatomical studies in Tribulus terrestris. Bot. Mag. Tokyo 95: 183-194, 1982
16 Anna Nikolova & Andon Vassilev A Study on Tribulus terrestris L. Anatomy and Ecological Adaptation, Biotechnology & Biotechnological Equipment, Volume 25, Issue 2, 2011.
17. Mamdouh N. Samy, Mokhtar M. Bishr , Ahmed A. Ahmed , Hanaa M. Sayed and Mohamed S. Kamel, Pharmacognostical Studies on Flower of Tribulus terrestris L. Journal of Pharmacognosy and Phytochemistry, Volume 1 Issue 5.
18. Jayanthy A, Deepak M. Pharmacognostic characterization and comparison of fruits of Tribulus terrestris L. and Pedalium murex L. IJHM 2013; 1 (4): 29-34.
19. Li-Ping Kang, Ke-Lei Wu, He-Shui Yu, Xu Pang, Jie Liu, Li-Feng Han, Jie Zhang, Yang Zhao, Cheng-Qi Xiong, Xin-Bo Song, Chao Liu. Steroidal saponins from Tribulus terrestris. Phytochemistry, Volume 107, November 2014, Pages 182-189.
20. Hala M. Hammoda, Nabila M. Ghazy, Fathalla M. Harraz, Mohamed M. Radwan. Chemical constituents from Tribulus terrestris and screening of their antioxidant activity. Phytochemistry, Volume 92, August 2013, Pages 153-159.
21. Dragomir Dinchev, Bogdan Janda, Liuba Evstatieva, Wieslaw Oleszek, Mohammad R. Aslani. Distribution of steroidal saponins in Tribulus terrestris from different geographical regions. Phytochemistry, Volume 69, Issue 1, January 2008, Pages 176-186.
22. Ya Juan Xu, Tun Hai Xu, Jun Ying Yang, Sheng Xu Xie, Yue Liu, Yun Shan Si, Dong Ming Xu. Two new furostanol saponins from Tribulus terrestris L. Chinese Chemical Letters, Volume 21, Issue 5, May 2010, Pages 580-583.
23. Seong Su Hong et.al. Two new furostanol glycosides from the fruits of Tribulus terrestris. Tetrahedron Letters, Volume 54, Issue 30, 24 July 2013, Pages 3967-3970.
24. Lan Su, Gang Chen, Sheng-Guang Feng, Wei Wang, Zhi-Feng. Steroidal saponins from Tribulus terrestris. Steroids, Volume 74, Issues 4–5, April–May 2009, Pages 399-403.
25. Seong Su Hong, Yun-Hyeok Choi, Wonsik Jeong, Jin Gwan Kwon, Jin Kyu Kim, Changon Seo, Eun-Kyung Ahn. Two new furostanol glycosides from the fruits of Tribulus terrestris. Tetrahedron Letters, Volume 54, Issue 30, 24 July 2013, Pages 3967-3970.
26. J. Conrad, D. Dinchev, I. Klaiber, S. Mika. A novel furostanol saponin from Tribulus terrestris of Bulgarian origin. Fitoterapia, Volume 75, Issue 2, March 2004, Pages 117-122.
27. Gong Wu, Shanhao Jiang, Fuxiang Jiang, Dayuan Zhu. Steroidal glycosides from Tribulus terrestris. Phytochemistry, Volume 42, Issue 6, August 1996, Pages 1677-1681.
28. Yan w, Ohtani K, Kasai R, Yamasaki K Steroidal saponins from fruits of Tribulus terrestris. Phytochemistry, Volume 42, Issue 5, 1996, Pages 1417-1422.
29. Tian-Shung Wu, Li-Shian Shi, Shang-Chu Kuo. Alkaloids and other constituents from Tribulus terrestris. Phytochemistry, Volume 50, Issue 8, 1 April 1999, Pages 1411-1415.
30. S.P. Bhutani, et.al, Flavonoids of the fruits and leaves of Tribulus terrestris: Constitution of tribuloside. Phytochemistry, Volume 8, Issue 1, January 1969, Pages 299-303.
31. Saleh, N. A. M.; Ahmed, A. A.; Abdalla, M. F., 1982: Flavonoid glycosides of Tribulus pentandrus and Tribulus terrestris. Phytochemistry 21(8): 1995-2000.
32. E De Combarieu, N Fuzzati, M Lovati, E Mercalli. Furostanol saponins from Tribulus terrestris. Fitoterapia, Volume 74, Issue 6, September 2003, Pages 583-591.
33. Yi-Xin Xu, Hai-Sheng Chen, Wen-Yong Liu, Zheng-Bing Gu. Two sapogenins from Tribulus terrestris. Phytochemistry, Volume 49, Issue 1, 3 September 1998, Pages 199-201.
34. Yan Wang, Kazuhiro Ohtani, Ryoji Kasai, Kazuo Yamasaki. Steroidal saponins from fruits of Tribulus terrestris. Phytochemistry, Volume 45, Issue 4, June 1997, Pages 811-817.
35. Li, JX (Li, JX); Shi, Q (Shi, Q); Xiong, QB (Xiong, QB); Prasain, JK (Prasain, JK); Tezuka, Y (Tezuka, Y). Tribulusamide A and B, new hepatoprotective lignanamides from the fruits of Tribulus terrestris. Planta Med. 1998 Oct; 64(7):628-31.
36. Xu, YX (Xu, YX); Chen, HS (Chen, HS); Liang, HQ (Liang, HQ); Gu, ZB (Gu, ZB). Three new saponins from Tribulus terrestris. Planta med 2000 Aug; 66(6):545-50.
37. Kostova, I (Kostova, I); Dinchev, D (Dinchev, D); Rentsch, GH (Rentsch, GH); Dimitrov, V (Dimitrov, V);Ivanova, A (Ivanova, A). Two new sulfated furostanol saponins from Tribulus terrestris. Journal of Biosciences, Volume: 57.
38. Huang, JW (Huang, JW); Tan, CH (Tan, CH). Terresoxazine, A novel compound with benzoxazine skeleton from Tribulus terrestris. Chinese chemical letters, Volume: 15
39. Xu, YJ (Xu Ya-Jiuan); Huang, XL (Huang Xiao-Lie); Xie, SX (Xie Sheng-Xu); Xu, TH (Xu Tun-Hai). Isolation and identification of a new furosteroidal saponin from fruits of Tribulus terrestris L. Chemical Journal of Chinese Universities, Volume: 28.
40. Lv, AL (Lv, A-Li) ; Zhang, N (Zhang, Nan); Sun, MG (Sun, Min-Ge); Huang, YF (Huang, Yong-Fu. One new cinnamic imide dervative from the fruits of Tribulus terrestris. Natural Product Research, Volume 22.
41. Zhang, XP (Zhang, Xiaopo); Wei, N (Wei, Na). A new feruloyl amide derivative from the fruits of Tribulus terrestris. Natural Product Research, Volume: 26, Issue: 20, Pages: 1922-1925