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# *SAPINDUS MUKOROSSI*: A COMPLETE REVIEW ON PHARMACOLOGY, PHYTOCHEMISTRY AND TOXICOLOGICAL DATA

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## ABSTRACT

A deciduous tree known as *Sapindus mukorossi* is found in Asia's tropical and subtropical climates. It has been used for many years to treat a variety of illnesses in Ayurvedic and traditional Chinese medicine. This article examines *S. mukorossi* pharmacological, phytochemical, and ethnomedicinal applications. The current review's objective is to give a concise overview of the phytochemical makeup, pharmacological characteristics, and toxicological research of this adaptable tree. Oleanane, dammarane, tricullane, and lupane type triterpenoid saponins are the primary plant ingredients that have been isolated and identified from various portions of this plant. All varieties of triterpenoid saponins have been described with their chemical names and structures. Numerous studies have been done to show that the plant has the potential to be used as a spermicide, contraceptive, hepatoprotective, emetic, anti-inflammatory, and antiprotozoal. Toxicological testing of *Sapindus mukorossi* on Wistar rats has also been done, which is shown to have LD50 above 5000 mg/kg in rats.

## KEYWORDS

*Sapindus mukorossi*; Pharmacological effects; Saponins Isolation; Phytochemistry; Traditional medicine; Acute Toxicity.

## INTRODUCTION

There are numerous names for *Sapindus mukorossi* (Sapindaceae), including soapnut, soapberry, reetha, aritha, dodan, and dodani.[13] It is a deciduous tree that grows widely in the upper Sub-Himalayan, Shivalik, and the Indian Gangas Plain.[13] In medicine, *Sapindus mukorossi* is used as an expectorant, emetic, contraceptive, and to treat migraines, excessive salivation, epilepsy, psoriasis, and freckles.[4] It has been used as a treatment for millennia in China and Japan. In traditional medicine, *Sapindus mukorossi* is used to treat "KAPHA" as an expectorant, as recorded in Aryabhishak,[57] and "DAM" as reported in ayurvedic jadi buti rahasya-2.[56]

## MORPHOLOGICAL CHARACTERISTICS

The medicinal herb *Sapindus mukorossi* is indigenous to China, Japan, and India.[1]

*S. mukorossi* can grow up to 18 metres tall, but its typical height is 12 to 15 metres.

The plant's leaves contain pinnate leaflets in an alternating arrangement. Small, bisexual, greenish-white blooms are arranged in complex panicles.[13] Flowers bloom in May and June, and fruit on a tree without leaves ripens between October and November. The fruit is a globose, glossy, leathery drupe that is yellow in colour and contains one to three loose, spherical, black seeds.[3] [53] Fruit's colour changes from yellow to orange to dark brown as it ripens.[54] The pericarp makes up around 56.5% of the fruit, with the remaining portion being the seed.[12] In Japan, the pericarp is known as "enmei-hi," which means "prolonged life pericarp," and in China, "wu-Huan-zi," which means "sympathetic fruit".[40] The seeds are globose, smooth, and black, measuring between 0.8 and 1.3 cm in diameter.[4]

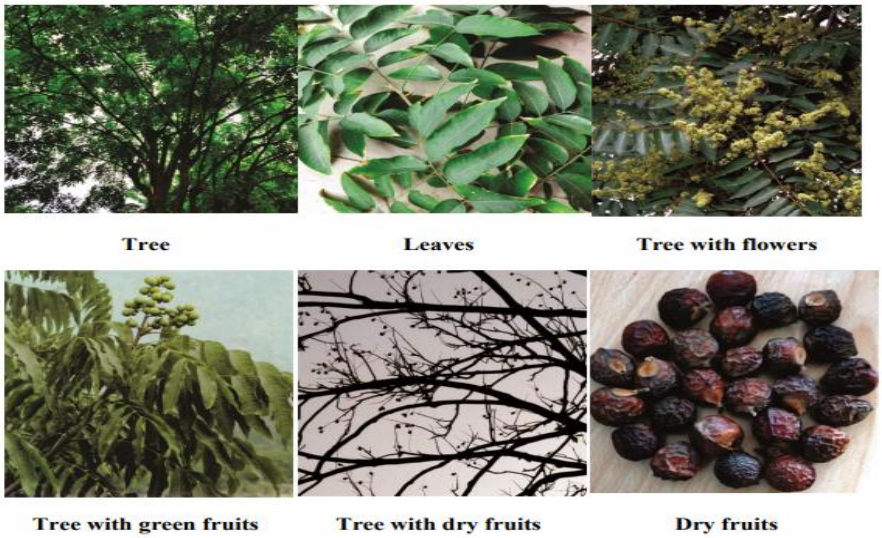


Figure 1. Parts of *Sapindus mukorossi*

## Botanical description

A significant family with 2000 plant species in 150 genera is the Sapindaceae.[2] The three principal species that make up the genus Sapindaceae are:

(1) American species:[1]

- *Sapindus saponaria*

(2) Two Asian species:[3]

- *Sapindus mukorossi*
- *Sapindus trifoliates*

(3) Other Sapindus species:[1]

- *Sapindus delayaye*
- *Sapindus detergens*
- *Sapindus emariginates*
- *Sapindus laurifolia*
- *Sapindus marginatus*
- *Sapindus vitiensis*
- *Sapindus tomentosus*
- *Sapindus oahuensis*
- *Sapindus rarak*

## Vernacular names [4]

- Assamese: Haithaguti
- Bengali: Ritha
- Hindi: Aritha, Dodan, kanmar
- Punjabi: Aritha, Dodan, Ritha, Thali
- Sanskrit: Aristha, Phenila, Urista
- Telugu: Kunkudu

## Taxonomical classification[4]

- Kingdom: Plantae (Plants)
- Subkingdom: Tracheobionta(Vascular plants)

- Superdivision: Spermatophyta (seed plants)
- Division: Magnoliophyta (Flowering plants)
- Class: Magnoliopsida (Dicotlyedons)
- Subclass: Rosidae
- Order: Sapindales
- Family: Sapindaceae
- Genus: Sapindus L. (Soapberry)
- Species: *Sapindus mukorossi* Geartn (Chinese soapberry)
- Morphological parts used: Woods, seeds, pericarp extracts, kernels etc.

**ISOLATION OF TOTAL SAPONINS**

The primary determinants of saponin extraction, including extraction solvents, temperature, duration, and material ratio, were examined separately.[58]

| | Extracting solvents | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | MeOH | EtOH | Acetone | BuOH | $H_2O$ | 95% MeOH | 95% EtOH | 95% Acetone | 95% Butanol |
| Mass of Saponins (g) | 0.68 ± 0.12 | 1.54 ± 0.09 | 1.00 ± 0.12 | 0.98 ± 0.02 | 0.63 ± 0.11 | 1.19 ± 0.09 | 1.51 ± 0.06 | 1.37 ± 0.10 | 1.45 ± 0.07 |
| Purity (%) | 63.62 | 72.63 | 73.48 | 69.90 | 35.03 | 59.15 | 70.48 | 72.42 | 67.80 |
| Desiccation situation | Easy | Easy | Easy | Easy | Difficult | Little viscosity | Easy | Easy | Easy |
| Characters of the dry substance | yellow powder | Off-white powder | yellow powder | yellow powder | Brown glue | Yellow powder | Off-white powder | Off-white powder | yellow powder |
| Volatiles (fragrance) | Slightly sweet | Special | Special | Special | Heavily sweet | slightly sweet | Special | Special | Special |

Table 1. Effects of solvents on the characteristics of *Sapindus mukorossi* Saponins (means ± SD).

The best combination occurs when the powder of the pulp is extracted with EtOH (solid-to-solvent ratio = 1:8, w/v) three times at 60 ℃ for three hours. The other factors that affect

saponin extraction are listed in the following order: extraction time, and solid-liquid ratio. 10 gram of raw material will yield approximately 1.63 gram of saponins under these circumstances.[58]

## PHYTOCHEMISTRY

The saponins, glycosides, and cyclitols found in Sapindaceae plants. Different substances have been isolated from various *S. mukorossi* parts. The plant's fruits are abundant in saponins.[10] The fruit has 10% sugars and 11.5% saponins.[11] *S. mukorossi* seeds have a crude protein content of about 21.6%.[12] The fruit, seeds, roots, and leaves of *Sapindus mukorossi* contain more than 103 phytochemicals, including flavonoids, triterpenoids, carbohydrates, fatty acids, phenols, fatty oils, and saponins.[5]

*S. mukorossi* seeds have 92% triglycerides and 23% oil. Glycerides, dioleo-palmitin, dioleo-stearin, and dioleo-arachidine are all present in the oil fraction of triglyceride.[1] Cyanolipid, a non-glyceride component, is also present in seed oil (1-cyano-2-hydroxymethylprop-1-en-3-ol). Oleo-palmitoarachidine glycerides (30%), oleo-diarachidine glycerides (13%) and diolein-type glycerides (56.7%).

Flavonoids such quercetin, apigenin, kaempferol, and rutin can be found in the leaves of *Sapindus mukorossi.*[14]

Sesquiterpenoid glycosides and six different fatty acid esters of tetracyclic triterpenoids are present in the fruits of *S. mukorossi*.[15] *S. mukorossi* galls, fruits, and roots have been found to contain a variety of triterpenes, including oleanane, dammarane, and tricullane saponins,[13] as well as the recently found lupane-type found in the plant's pulp.[52]

Saponins, which are primarily in charge of various pharmacological activities, make up the majority of the phytochemicals present in *S. mukorossi* (10%–11.5%). One or more oligosaccharide units are connected to saponins via glycosidic linkages. Saponins are a large family of structurally related compounds of steroidal or triterpenoid aglycones (sapogenins). There may be one or more unsaturated C-C linkages in aglycones or sapogenins.[16]

### Phytoconstituent

According to the properties of the active ingredient, the bioactive molecules can be isolated using a range of polar and non-polar solvents, including water, ethanol, methanol, acetone, and n-hexane. The galls, fruits, and roots of *Sapindus mukorossi* have yielded a variety of triterpenes, including oleanane, dammarane, tricullane, and lupane type saponins.

| Sr. No. | Chemical constituent | Part of the plant |
|---|---|---|
| 1. | Triglyceride [17]<br>● Oleo-palmito-arachidin glyceride<br>● Oleo-di-arachidin glyceride<br>● Di-olein | Seed |
| 2. | Lipid [51] | Seed |
| 3. | Sesquiterpenoid glycosides [10] | Fruits |
| 4. | Flavonoids[30]<br>Quercetin, Apigenin, Kaempferol, Rutin | Leaf |
| 5. | Saponin [13]<br>Triterpene<br>● Oleanane [29]<br>● Dammarane [27]<br>● Tricullane[25]<br>● Lupan [52] | Gall, fruit & root<br>Fruit<br>Gall<br>Gall & root<br>Fruit pulp |

Table 2. Parts of *Sapindus mukorossi* with phytoconstituents

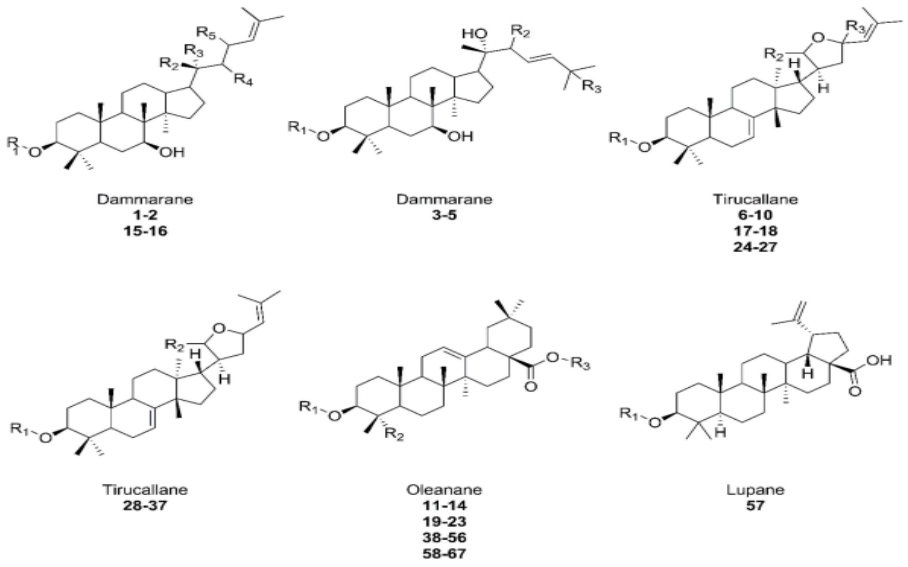

Figure 2. Overview of saponin structures present in *S. mukorossi*. The structure extensions are shown in the table with the corresponding numbers.

| Sr. No. | Chemical Name | Abbreviations | Type |
|---|---|---|---|
| 1. | 3β,7β,20(S),22-tetrahydroxydammar-24-ene-3-O-α-Lrhamnopyranosyl-(1→2)-β-D-glucopyranoside | R1: -Glc2[a] -Rha[b]<br>R2: -CH3<br>R3: -OH<br>R4: -OH<br>R5: -H | Dammarane |
| 2. | 3β,7β,20(S),22,23-pentahydroxydammar-24-ene-3-O-α-Lrhamnopyranosyl-(1→2)-β-D-glucopyranoside | R1: -$Glc_2$-Rha<br>R2: -CH3<br>R3: -OH<br>R4: -OH<br>R5: -OH | |
| 3. | 3β,7β,20(S),22,25-pentahydroxydammar-23-ene-3-O-α-Lrhamnopyranosyl-(1→2)-β-D-glucopyranoside | R1: -$Glc_2$-Rha<br>R2: -OH<br>R3: -OH | Dammarane |
| 4. | 25-methoxy-3β,7β,20(S),22-tetrahydroxydammar-23-ene-3-O-α-Lrhamnopyranosyl-(1→2)-β-D-glucopyranoside | R1: -$Glc_2$-Rha<br>R2: -OH<br>R3: -$OCH_3$ | |
| 5. | 25-methoxy-3β,7β,20(R)-trihydroxydammar-23-ene-3-O-α-Lrhamnopyranosyl-(1→2)-β-D-glucopyranoside | R1: -$Glc_2$-Rha<br>R2: -H<br>R3: -$OCH_3$ | |
| 6. | 21β-methoxy-3β,21(S),23(R)-epoxytirucalla-7,24-diene-3-O-α-Lrhamnopyranosyl-(1→6)-β-D-glucopyranoside | R1: -$Glc_6$-Rha<br>R2: β-$OCH_3$<br>R3: β-H | Tirucallane |
| 7. | 21α-methoxy-3β,21(S),23(R)-epoxytirucalla-7,24-diene-3-O-α-Lrhamnopyranosyl-(1→6)-β-D-glucopyranoside | R1: -$Glc_6$-Rha<br>R2: α-$OCH_3$<br>R3: β-H | |
| 8. | 21α-methoxy-3β,21(R),23(R)-epoxytirucalla-7,24-diene-3-O-α-Lrhamnopyranosyl-(1→2)-β-D-glucopyranoside | R1: -$Glc_2$-Rha<br>R2: α-$OCH_3$<br>R3: β-H | |
| 9. | 21β-methoxy-3β,21(S),23(R)-epoxytirucalla-7,24-diene-3-O-α-Ldirhamnopyranosyl-(1→2,6)-β-D-glucopyranoside | R1:-$Glc_{2,6}$Rha,Rha<br>R2: β-OCH3<br>R3: β-H | |

| | | | |
|---|---|---|---|
| 10. | 21α-methoxy-3β,21(R),23(R)-epoxytirucalla-7,24-diene-3-O-α-Ldirhamnonopyranosyl-(1→2,6)-β-D-glucopyranoside | R1: -$Glc_{2,6}$-Rha,Rha<br>R2: α-$OCH_3$<br>R3: β-H | |
| 11. | Hederagenin-3-O-(3-O-acetyl-α-L-arabinopyranosyl)-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1:-$Ara_2$-$Rha_3Ara_3^c$-OAc<br>R2: -$CH_2OH$<br>R3: -H | Oleanane |
| 12. | Hederagenin-3-O-(4-O-acetyl-α-L-arabinopyranosyl)-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1:-$Ara_2$-$Rha_3$-$Ara_4$Oac<br>R2: -$CH_2OH$<br>R3: -H | |
| 13. | Hederagenin-3-O-(2,3-O-diacetyl-β-D-xylopyranosyl)-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1:-$Ara_2$-$Rha_3Xyl_{2,3}^d$OAc,OAc<br>R2: -$CH_2OH$<br>R3: -H | |
| 14. | Hederagenin-3-O-(2,4-O-diacetyl-β-D-xylopyranosyl)-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1:-$Ara_2$-$Rha_3$-$Xyl_{2,4}$OAc,OAc<br>R2: -$CH_2OH$<br>R3: -H | |
| 15. | 3,7,20(S)-trihydroxydammar-24-ene-3-O-α-L-rhamnopyrnosyl-(1→2)-βD-glucopyranoside | R1: -$Glc_2$-Rha<br>R2: -OH<br>R3: -$CH_3$<br>R4: -H<br>R5: -H | Dammarane |
| 16. | 3,7,20(R)-trihydroxydammar-24-ene-3-O-α-L-rhamnopyrnosyl-(1→2)- β-D-glucopyranoside | R1: -$Glc_2$-Rha<br>R2: -$CH_3$<br>R3: -OH<br>R4: -H<br>R5: -H | |
| 17. | 21α-methoxy- 3β,21(R),23(S)-epoxytirucall-7,24-diene-3-O-β-Dglucopyranosyl-(1→2)-β-D-glucopyranoside | R1: -$Glc_2$-Glc<br>R2: α-$OCH_3$<br>R3: β-H | Tirucallane |
| 18. | 21α-methoxy-3β,21(R),23(S)-epoxytirucall-7,24-diene-3-O-α-Lrhamnopyranosyl-(1→6)-β-Dglucopyranosyl-(1→2)-β-D-glucopyranoside | R1: -$Glc_2$-$Glc_6$-Rha<br>R2: α-$OCH_3$<br>R3: β-H | |
| 19. | Hederagenin-3-O-(3,4-O-di-acetyl-β-D-xylopyranosyl)-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1:-$Ara_2$-$Rha_3$-$Xyl_{3,4}$OAc,OAc<br>R2: -$CH_2OH$<br>R3: -H | Oleanane |

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|---|---|---|---|
| 20. | Hederagenin-3-O-(2-O-acetyl-β-D-xylopyranosyl)-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-$Xyl_2$-OAc<br>R2: -$CH_2OH$<br>R3: -H | |
| 21. | Hederagenin-3-O-(3-O-acetyl-β-D-xylopyranosyl)-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-$Xyl_3$-OAc<br>R2: -$CH_2OH$<br>R3: -H | |
| 22. | Hederagenin-3-O-(4-O-acetyl-β-D-xylopyranosyl)-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-$Xyl_4$-OAc<br>R2: -$CH_2OH$<br>R3: -H | |
| 23. | Hederagenin-3-O-α-L-arabinopyranosyl-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-Ara<br>R2: -$CH_2OH$<br>R3: -H | |
| 24. | 21β-methoxy-3β,23α-epoxytirucalla-7,24-diene-3-O-α-Lrhamnopyranosyl-(1→6)-β-D-glucopyranoside | R1: -$Glc_6$-Rha<br>R2: β-$OCH_3$<br>R3: α-H | Tirucallane |
| 25. | 21β-methoxy-3β,23α-epoxytirucalla-7,24-diene-3-O-α-Ldirhamnopyranosyl-(1→2,6)-β-D-glucopyranoside | R1: -$Glc_{2,6}$-Rha,Rha<br>R2: β-$OCH_3$<br>R3: α-H | |
| 26. | 21α-methoxy-3β,23α-epoxytirucalla-7,24-diene-3-O-α-Lrhamnopyranosyl-(1→2)-[α-L-arabinopyranosyl- (1→3)]-β-D-glucopyranoside | R1: -$Glc_{2,3}$-Rha,Ara<br>R2: α-$OCH_3$<br>R3: α-H | |
| 27. | 21α-methoxy-3β,23α-epoxytirucalla-7,24-diene-3-O-α-Lrhamnopyranosyl-(1→2)-β-D-glucopyranoside | R1: -$Glc_2$-Rha<br>R2: α-$OCH_3$<br>R3: α-H | |
| 28. | 3-O-α-L-rhamnopyranosyl-(1→2)-[α-L-arabinopyranosyl-(1→3)]-β-D-glucopyranosyl-21,23R-epoxyl tirucall-7,24R-diene-3β,21-diol | R1: -$Glc_{2,3}$-Rha,Ara<br>R2: -OH | Tirucallane |
| 29. | 3-O-α-L-rhamnopyranosyl-(1→6)-β-D-glucopyranosyl-21,23Repoxyltirucall-7,24R-diene-3β,21-diol | R1: -$Glc_6$-Rha<br>R2: -OH | |

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| 30. | 3-O-α-L-rhamnopyranosyl-(1→2)-[α-L-arabinopyranosyl-(1→3)]- β-D-glucopyranosyl (21,23R)-epoxyl tirucalla-7,24-diene-(21S)-ethoxyl-3β-ol | R1: -$Glc_{2,3}$-Rha,Ara<br>R2: -$OCH_2CH_3$ | Tirucallane |
| 31. | 3-O-α-L-rhamnopyranosyl-(1→2)-[α-L-arabinopyranosyl-(1→3)]- β-D-glucopyranosyl (21,23R)-epoxyl tirucall-7,24-diene-(21S)-methoxyl-3β-ol | R1: -$Glc_{2,3}$-Rha,Ara<br>R2: -$OCH_3$ | |
| 32. | 3-O-α-L-arabinopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-[αL-arabinopyranosyl-(1→3)]-β-D-glucopyranosyl-21,23R-epoxyl tirucalla-7,24-diene-21β-ethoxy-3β-ol | R1: -$Glc_{2,3}$-($Rha_3$-Ara),Ara<br>R2: -$OCH_2CH_3$ | Tirucallane |
| 33. | 3-O-β-D-xylopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-[β-Larabinopyranosyl-(1→3)]-β-D-glucopyranosyl-21,23R-epoxyl tirucalla-7,24-diene-21β-ethoxy-3β-ol | R1: -$Glc_{2,3}$-($Rha_3$-Xyl),Ara<br>R2: -$OCH_2CH_3$ | |
| 34. | 3-O-β-D-xylopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-[α-Larabinopyranosyl-(1→3)]-β-D-glucopyranosyl-21,23R-epoxyl tirucalla-7,24-diene-21β-methoxy-3β-ol | R1: -$Glc_{2,3}$-($Rha_3$-Xyl),Ara<br>R2: -$OCH_3$ | |
| 35. | 3-O-α-L-arabinopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-[αL-rhamnopyranosyl-(1→3)]-β-D-glucopyranosyl-21,23R-epoxyl tirucalla-7,24-diene-21β-ethoxy-3β-ol | R1: -$Glc_{2,3}$-($Rha_3$-Ara),Rha<br>R2: -$OCH_2CH_3$ | |
| 36. | 3-O-α-L-arabinopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-[αL-rhamnopyranosyl-(1→3)]-β-D-glucopyranosyl-21,23R-epoxyl tirucalla-7,24-diene-21β-methoxy-3β-ol | R1: -$Glc_{2,3}$-($Rha_3$-Ara),Rha<br>R2: -$OCH_3$ | |

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|---|---|---|---|
| 37. | 3-O-α-L-rhamnopyranosyl-(1→6)-β-D-glucopyranosyl-21,23Repoxyl tirucalla-7,24-diene-21β-ethoxyl-3β-ol | R1: -$Glc_6$-Rha<br>R2: -$OCH_2CH_3$ | |
| 38. | Hederagenin-3-O-β-D-xylopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranosyl-28-O-β-D-glucopyranosyl-(1→2)-β-Dglucopyranosyl ester | R1: -$Glc_6$-Rha<br>R2: -$OCH_2CH_3$ | Oleanane |
| 39. | Hederagenin-3-O-α-L-arabinopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranosyl-28-O-β-D-glucopyranosyl-(1→2)-β-Dglucopyranosyl ester | R1: -$Ara_2$-$Rha_3$-Ara<br>R2: -$CH_2OH$<br>R3: -$Glc_2$-Glc | |
| 40. | Hederagenin-3-O-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranosyl28-O-β-D-glucopyranosyl-(1→2)-β-D-glucopyranosyl ester | R1: -$Ara_2$-Rha<br>R2: -$CH_2OH$<br>R3: -$Glc_2$-Glc | |
| 41. | Hederagenin-3-O-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-Rha<br>R2: -$CH_2OH$<br>R3: -H | Oleanane |
| 42. | Hederagenin-3-O-β-D-xylopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-Xyl<br>R2: -$CH_2OH$<br>R3: -H | |
| 43. | Hederagenin-3-O-β-D-glucopyranosyl-(1→4)-β-D-xylopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-$Xyl_4$-Glc<br>R2: -$CH_2OH$<br>R3: -H | Oleanane |
| 44. | Hederagenin-3-O-β-D-glucopyranosyl-(1→2)-[α-L-rhamnopyranosyl-(1→6)]-β-D-glucopyranosyl-(1→4)-β-D-xylopyranosyl-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1:-$Ara_2$-$Rha_3$-$Xyl^4Glc_{2,6}$Glc,Rha<br>R2: -$CH_2OH$<br>R3: -H | Oleanane |

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| 45. | Hederagenin-3-O-β-D-xylopyranosyl-(1→3)-α-L-rhamnopyranosyl- (1→2)-α-L-arabinopyranosyl-28-O-β-D-glucopyranosyl-(1→2)-[α-Lrhamnopyranosyl-(1→6)]-β-D-glucopyranosyl-(1→4)-β-Dxylopyranosyl-(1→3)-α-L-rhamnopyranosy-(1→2)-α-Larabinopyranosyl ester | R1: -$Ara_2$-$Rha_3$-Xyl<br>R2: -$CH_2OH$<br>R3:-$Ara_2$-$Rha_3$-$Xyl_4$-$Glc_{2,6}$-Glc,Rha | Oleanane |
| 46. | Hederagenin-3-O-β-D-glucopyranosyl-(1→3)-β-D-xylopyranosyl- (1→3)- β-D-xylopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-$Xyl_3$-$Xyl_3$-Glc<br>R2: -$CH_2OH$<br>R3: -H | Oleanane |
| 47. | Hederagenin-3-O-(3,4-O-diacetyl-α-L-arabinopyranosyl)-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1:-$Ara_2$-$Rha_3$-$Ara_{3,4}$-OAc,OAc R2: -$CH_2OH$<br>R3: -H | |
| 48. | 3-O-α-L-rhamnopyranosyl-(1→2)-β-D-xylopyranosyl-(1→6)-β-Dglucopyranosyl-(1→3)-β-D-xylopyranosyl-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranosyl oleanolic acid | R1:-$Ara_2$-$Rha_3$-$Xyl_3Glc_6Xyl_2$Rha R2: -$CH_3$<br>R3: -H | Oleanane |
| 49. | Hederagenin 3-O-(2,4-O-di-acetyl-α-L-arabinopyranosyl)-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-$Ara_{2,4}$-OAc,OAc R2: -$CH_2OH$<br>R3: -H | Oleanane |
| 50. | Hederagenin 3-O-α-L-arabinopyranoside | R1: -Ara<br>R2: -$CH_2OH$<br>R3: -H | |
| 51. | Hederagenin-3-O-β-D-xylopyranosyl-(2→1)-[3-O-acetyl-α-Larabinopyranosyl]-28-O-α-L-rhamnopyranosylester | R1: -$Xyl_2$-$Ara_3$-OAc<br>R2: -$CH_2OH$<br>R3: -Rha | Oleanane |
| 52. | Hederagenin 3-O-α-L-rhamnopyranosyl (3→1)-[2,4-O-diacetyl-α-Larabinopyranosyl]-28-O-β-D-glucopyranosyl-(2→1) [3-O-acetyl-β-D-glucopyranosyl] ester | R1: -$Rha_3$-$Ara_{2,4}$-OAc,OAc<br>R2: -$CH_2OH$<br>R3: -$Glc_2$-$Glc_3$-Oac | Oleanane |

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| 53. | Oleanolic acid 3-O-α-L-arabinofuranosyl-(1→3)-α-L-rhamnopyranosyl- (1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-Ara [e]<br>R2: -$CH_3$<br>R3: -H | Oleanane |
| 54. | Hederagenin 3-O-5000 -O-acetyl-α-L-arabinofuranosyl-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-$Ara_5$[e] -OAc<br>R2: -$CH_2OH$<br>R3: -H | |
| 55. | 23-O-acetyl-hederagenin 3-O-β-D-xylopyranosyl-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-Xyl<br>R2: -$CH_2OAc$<br>R3: -H | |
| 56. | Gypsogenin 3-O-α-L-arabinopyranosyl-(1→3)-α-L-rhamnopyranosyl- (1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-Ara<br>R2: -$CH_2O$<br>R3: -H | |
| 57. | Betulinic acid 3-O-β-D-xylopyranosyl-(1→3)-α-L-rhamnopyranosyl- (1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-Xyl | Lupane |
| 58. | Hederagenin-3-O-β-D-glucopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-Glc<br>R2: -$CH_2OH$<br>R3: -H | Oleanane |
| 59. | Hederagenin-3-O-α-L-rhamnopyranosyl-(1→3)-α-L-rhamnopyranosyl- (1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-Rha<br>R2: -$CH_2OH$<br>R3: -H | Oleanane |
| 60. | Hederagenin-3-O-β-D-xylopyranosyl-(1→3)-α-L-arabinopyranoside | R1: -$Ara_2$-Xyl<br>R2: -$CH_2OH$<br>R3: -H | |
| 61. | Hederagenin-3-O-(4-O-acetyl-β-D-glucopyranosyl)-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-$Glc_4$-OAc<br>R2: -$CH_2OH$<br>R3: -H | |
| 62. | 3-O-β-D-glucopyranosyl-(1→2)-α-L-rhamnopyranosyl-(1→3)-α-Lrhamnopyranosyl-(1→2)-β-D-glucopyranosyl oleanolic acid | R1: -$Glc_2$-$Rha_3$-$Rha_2$-Glc<br>R2: -$CH_3$<br>R3: -H | |
| 63. | 3-O-β-D-xylopyranosyl-(1→2)-α-L-rhamnopyranosyl-(1→3)-α-Lrhamnopyranosyl-(1→2)-β-D-glucopyranosyl oleanolic acid | R1: -$Glc_2$-$Rha_3$-$Rha_2$-Xyl<br>R2: -$CH_3$<br>R3: -H | |

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|---|---|---|---|
| 64. | Oleanolic acid 3-O-(4-O-acetyl-α-L-arabinopyranosyl)-(1→3)-α-Lrhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-$Ara_4$-OAc<br>R2: -$CH_3$<br>R3: -H | |
| 65. | Gypsogenin 3-O-α-L-rhamnopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-Rha<br>R2: -CHO<br>R3: -H | |
| 66. | Oleanolic acid 3-O-β-D-xylopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-Xyl<br>R2: -$CH_3$<br>R3: -H | Oleanane |
| 67. | Oleanolic acid 3-O-α-L-arabinopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranoside | R1: -$Ara_2$-$Rha_3$-Ara<br>R2: -$CH_3$<br>R3: -H | |

Table 3. Saponins present in different parts of *Sapindus mukorossi*

[a] β-D-Glucopyranosyl

[b] α-L-Rhamnopyranosyl

[c] α-L-Arabinopyranosyl

[d] β-D-Xylopyranosyl

[e] α-L-Arabinofuranosyl

**CLASSICAL USES**

Plants have been a primary source of medicine for treating a variety of illnesses since ancient times. Herbal items can be found in abundance in the Ayurvedic, Unani, and Chinese medical systems.

For its use in traditional medicine, *Sapindus mukorossi* is well-known.[5] Traditional uses of the *Sapindus mukorossi* pericarp include expectorant and a source of natural surfactants.[6] Since soapnuts contain saponins, which are recognised for their cleaning and insecticidal effects, they have long been used to get rid of lice from the scalp. The fruit is crucial in the treatment of numerous conditions because of its therapeutic qualities, including hypersalivation, acne, epilepsy, albinism, migraines, eczema, and psoriasis.[7] The fruit paste of *S. mukorossi* is used as a febrifuge (medicine used to reduce fever). The powdered seeds are used to cure tooth decay, rheumatoid arthritis, colds, constipation, and nausea.[8] In Ayurvedic medicine, *Sapindus mukorossi* seeds are used to treat sunburn and freckles on the skin. Because it rids the skin of oily secretions and produces a thick, natural lather, it is also used as a hair cleanser. Indian jewellers utilised the *Sapindus mukorossi* fruits to polish

tarnished jewellery made of gold, silver, and other valuable metals.[9] Burns are treated with fruit foam.[2]

The roots are used to cure gout and rheumatism, while the leaves are added to bathwater to reduce joint discomfort. Centipede has been used for a very long time as a scarf and silk cleaner.[7]

## PHARMACOLOGICAL EFFECTS OF *S. MUKOROSSI*

In addition to isolated phytochemicals, *S. mukorossi* has been shown to have anti-cancer, anti-microbial, free radical scavenging, skin wound healing, anti-gonorrheal, spermicidal, anti-platelet aggregation, anti-diabetic, hepatoprotective, anti-inflammatory, anti-protozoal, anti-lipid peroxidation activity in diverse extract types and isolated phytochemicals.

| Sr. no. | Activity | Part used | Type of extract or saponins used |
|---|---|---|---|
| 1. | Antibacterial activity [25] | Leaf | Ethanolic and chloroform extracts. |
| 2. | Spermicidal Activity [34] | Fruit Pericarp | Isolated Saponins |
| 3. | Anti-Trichomonas Activity [31] | Fruit Pericarp | Saponins from pericarp |
| 4. | Insecticidal Activity [27] | Fruit Pericarp | Ethanolic extract |
| 5. | Anxiolytic Activity [36] | Fruit & Seed | Methanolic extract |
| 6. | Anticancer Activity [32][33][34] | Galls | Saponin from galls extracts |
| 7. | Hepatoprotective Activity [35] | Fruit | Fruit pericarp extract |
| 8. | Molluscicidal Activity [20] | Fruit | Extract |
| 9. | Piscicidal Activity [42] | Fruit Pericarp | Methanolic extract |
| 10. | Anti-Inflammatory Activity [41] | Plant | Isolated saponin and hederagenin (Ethyl alcohol extract) |
| 11. | Anti-Platelet Aggregation Activity [24] | Galls | Isolation of compounds (Ethanolic extract) |
| 12. | Tyrosinase Inhibition and Free Radical Scavenging [39] | Seed | Methanolic extract |

Table 4. Pharmacological activity of parts of the plant with methods used

1. **Antibacterial activity**: When given orally to male Wister rats for 7 days, ethanol and chloroform extracts of *Sapindus mukorossi* inhibited the growth of *Helicobacter pylori* (both susceptible and resistant) at very low concentrations. In vivo research found *Helicobacter pylori* infection in extracts as low as 2.5 mg/ml, and in vitro tests revealed a large zone of inhibition in the isolate at very low concentrations (10 gm/ml).[25]
2. **Insecticidal activity**:The saponins have insecticidal activity, which causes the caterpillars of the cotton leafworm *Spodoptera littoralis* and the pea aphid *Acyrthosiphon pisum*, which were tested, to die and/or grow more slowly. In an experiment with *Acyrthosiphon pisum*, 0.1% saponin killed every aphid, but in a diet containing 7% saponin, Spodoptera were able to grow into adults who appeared to be normal.[26] To combat pests that have adapted to contemporary agriculture and horticulture, saponins can be employed as a novel natural strategy in Integrated Pest Management (IPM).[27] The protective and insecticidal effectiveness of an ethanol extract of *Sapindus mukorossi* was evaluated against *Sitophilus oryzae* and *Pediculus humanus*. Bioassays revealed that toxicity and repellency were proportional to concentration, and mean mortality suggested that the extract caused significant death and repellency in the target insects.
3. **Anti-Diabetic Property**:The properties of *S. mukorossi* have been shown in numerous studies to lessen a variety of complications related to diabetes mellitus. Hyperglycemia and hyperlipidemia associated with diabetes increase the risk of developing further problems include diabetic kidney disease, cardiomyopathy, neuropathy, and retinopathy.[43][44][45] In diabetic-induced mice, a hydroalcoholic extract of *S. mukorossi* demonstrated antihyperlipidemic and antihyperglycemic activity.[14] In a different investigation, *S. mukorossi* extract helped diabetic rats' motor coordination and blood sugar levels.[47] *S. mukorossi* may contain many substances that can be used to treat diabetic neuropathy, as evidenced by the improved motor coordination in diabetic mice.[46]
4. **Antipyretic, Analgesic, and Wound Healing Properties**: *S. mukorossi* has been demonstrated to have potential for lowering body temperature and pain. Rats given an injection of *Saccharomyces cerevisiae* to induce fever had their rectal temperature reduced by *S. mukorossi* stem bark extract. Additionally, *S. mukorossi* extract has analgesic (pain-relieving) effects.[48] When compared to untreated rats, *S. mukorossi* seed oil treatment sped up the healing of wounds on rat skin.[49]
5. **Spermicidal activity**: There is evidence that the saponins from *Sapindus mukorossi* are spermicidal.[29] Under scanning electron microscopy, the morphological alterations in human ejaculates after exposure to this saponin were assessed. After

one minute of exposure, the surface topography was unaffected by the lowest effective concentration (0.05% in the spot test). However, after 10 minutes of incubation, the sperm developed large vesicles that ruptured the head's plasma membrane. Nearly identical alterations were generated at higher doses (0.1%, 1.25%, 2.5%, and 5.0%), including vesiculation, vacuolation, and disruption or erosion of membranes in the head area. These findings imply that modifications in glycoproteins connected to the lipid bilayer of the sperm plasma membrane are what cause the observed morphological changes.[10] Contraceptive creams make use of this spermicidal property.[30]

6. **Anti-Trichomonas activity**: The minimum effective spermicidal concentration for human sperm is 0.05%, but the Sapindus saponin mixture demonstrates anti-trichomoniasis efficacy at a concentration (0.005%). The proteolytic activity of parasite cysteine proteinases was decreased and the ability of parasites to bind to HER HeLa cells was prevented by saponin doses. This was connected to decreased adhesin AP65 and membrane-expressed cysteine proteinase TvCP2 gene expression. In mitochondrial reduction potential experiments, saponins had no detrimental effects on the host cells. Saponins interfere with Trichomonas' ability to connect to host cells across the membrane by rupturing the actin cytoskeletal network underneath the plasma membrane.[31]
7. **Anti-cancer activity**: Saponins always demonstrate antitumor effects through several antitumor routes because of the wide structural variation in saponins. Saponins come in more than 11 different varieties, including lupane, hopane, taraxasterane, ursan, cycloartane, lanostane, cucurbitane, and steroids. Ginsenosides, which are members of the dammarane family, have been demonstrated to be effective in reducing vascular endothelial cell inducers and limiting tumour angiogenesis by preventing tumour cell adhesion, invasion, and metastasis.[32] Dioscin, one of the steroidal saponins, and its aglycone, diosgenin, also have significant antitumor actions by arresting cell division and inducing apoptosis.[32] According to preliminary bioassay results, human tumour cell lines (Hepa59T/VGH, NCL, HeLa, and Med) are moderately sensitive to saponins' cytotoxic effects (ED50-9-18 g/ml).[33]The reference substance used in this study was stryquinopentamine. According to reports, all saponins exhibit at least 5-fold reduction in activity compared to the reference molecule.[34]
8. **Hepatoprotective activity**: In vitro primary hepatocyte cultures of *Sapindus mukorossi* (2.5 mg/L) and *Rheum emodi* (3.0 mg/L) extracts and in vivo rat models of carbon tetrachloride ($CCl_4$)-mediated liver injury both showed protective ability. These cultures were given $CCl_4$ treatment along with soapberry and rhubarb extracts. Primary monolayer cultures damaged by $CCl_4$ could show protective action.

In an in-depth investigation, $CCl_4$-damaged male rats with liver damage were given extracts from the pericarp of *S. mukorossi* and the rhizome of rhubarb. By measuring the activity of a serum marker enzyme, sapindus peel extract (2.5 mg/mL) and rhizome (3.0 mg/mL) showed protective effects in rats with liver injury brought on by $CCl_4$. In light of this, it was determined that *Sapindus mukorossi* and *Rheum emodi* extracts have the ability to protect against primary hepatocyte cultures both in vitro and in vivo in a rat model of $CCl_4$-mediated liver injury.[35]

9. **Anxiolytic activity:** When compared to the standard anxiolytics diazepam (2 mg/kg) and fluoxetine (10 mg/kg), *Sapindus mukorossi* methanolic extracts (200 and 400 mg/l) show significant anxiolytic activity.[36]
10. **Molluscicidal activity**: A *Sapindus mukorossi* extract demonstrated molluscicidal action against *Pomacea canaliculata* Lamarck, an Ampullariidae golden apple snail, with LC50 values of 85, 22, and 17 ppm at exposure durations of 24, 48, and 72 hours.[37] A plant molluscicide against *Lymnaea acuminata* may be found in the pericarp of *Sapindus mukorossi*. These snails serve as intermediate hosts for the liver fluke *Fasciola gigantica*, which is responsible for scoliosis in populations of north Indian water buffalo. Chloroform, ether, acetone, and ethanol are all soluble in the fruit of *Sapindus mukorossi*'s potent molluscicidal ingredient. Since the ethanol extract of *Sapindus mukorossi* fruit powder is more poisonous than other extracts, it is likely that the molluscicidal elements it contains are more soluble in ethanol than in other organic solvents.[38]
11. **Tyrosinase inhibition and free radical scavenging**: The tyrosinase inhibitory, free radical scavenger, antibacterial, and anticancer activities of soapberry seed extracts employing methanol (MeOH), ethyl acetate (EA), or hexane as the solvent are demonstrated. Against the growth of human melanoma and lung cell lines, extracts from *Sapindus mukorossi* demonstrated strong, targeted inhibitory effects. Data showed that *Sapindus mukorossi* extract has a great potential for use in dietary supplements, chemotherapy, antibiotics, and cosmetics for the medical industry.[39]
12. **Anti-inflammatory activity**: Rats' hind paw edema caused by carrageenan and their development of granuloma and exudate brought on by croton oil were both prevented by crude saponin and hederagenin extracted from *Sapindus mukorossi*. Investigations were also done into how these substances affected the vascular permeability and the writhing that acetic acid causes in mice. Crude saponins were administered intraperitoneally and orally, and their anti-inflammatory effects on carrageenan edema were seen, although hederagenin and other drugs were only active when administered orally.[41] In-vitro investigations have shown that hederagenin has inhibitory effects on the LPS-induced mRNA expression of iNOS, COX-2, NF-κB and on the production of NO, PGE2, and pro-inflammatory cytokines

(TNF-α, IL-1, and IL-6) as well as on the LPS-induced production of iNOS, COX-2, and NF-κB.[55]

13. **Piscicidal activity**: Investigations were conducted into Sapindactylus japonicum's impact on fish. He found that the median survival time was 1.18 hours and that the pericarp of *Sapindus mukorossi* was the most toxic part. Within 12 hours, he was 100% dead. After 48 hours, he is likely to annihilate the fish at concentrations of 3.5 ppm to 10 ppm (LD10, LD50, LD100). Garfish, such as azalea fossils and azaleas, are selectively repulsed by the pericarp of *Sapindus mukorossi*.[42]
14. **Anti-platelet aggregation activity**: The activity of sapinmusasaponins, a chirucharan-type saponin produced from ethanolic extracts of *Sapindus mukorossi*, was shown to be moderate in a 12-O-tetradecanoylphorbol-13-acetate (TPA)-induced Epstein-Barr virus early antigen (EBV-EA) activation assay.[29]

## TOXICOLOGICAL TEST OF SAPONINS FROM *SAPINDUS MUKOROSSI* IN RAT

Since the pulp has a saponin content of 10–11%, it is a great source for extracting saponins. The acute oral toxicity study of ethanolic extract (85% EtOH) of *Sapindus mukorossi* was carried out on Wistar rats. Five dose groups containing rats of each sex were chosen at random. The oral dose volume for dose groups 2150, 4640, and 10,000 mg/kg body weight, where the sample is diluted to 215, 464, and 1000 mg/ml with distilled water, is 10 ml/kg body weight, and the density of the sample is 1.05 g/ml. The oral absorption capacity of the undiluted sample is 20.48 ml/kg body weight for the 21,500 mg/kg body weight group.The LD50 for saponin in Wistar rats, male and female, was 9260 mg/kg (95% CI 6360 - 13,500 mg/kg) and 7940 mg/kg (95% CI 4890 - 12,900 mg/kg) in acute oral toxicity experiments.[50]

| Sex | Dosage mg/kg BW | No. of Rats | No. of death | LD50 and 95% CI (mg/kg) |
|---|---|---|---|---|
| Female | 2150 | 5 | 0 | 9260 (6360 - 13,500) |
| | 4640 | 5 | 0 | |
| | 10,000 | 5 | 3 | |
| | 21,500 | 5 | 5 | |
| Male | 2150 | 5 | 0 | 7940 (4890 - 12,900) |
| | 4640 | 5 | 1 | |
| | 10,000 | 5 | 3 | |
| | 21,500 | 5 | 5 | |

Table 5. Oral acute toxicity of saponins in Wistar rats [50]

The acute dermal toxicity study was also done on Wistar rats. No overt symptoms of poisoning were present. The LD50 of saponin in male and female Wistar rats tested for acute cutaneous toxicity was greater than 5000 mg/kg, according to the data.[50]

| Sex | No. of rats | Dosage mg/kg BW | body weight (gm) | | | No. of deaths |
|---|---|---|---|---|---|---|
| | | | beginning | 7th day | 14th day | |
| Male | 5 | 5000 | 203.3 ± 8.3 | 210.1 ± 8.1 | 218.2 ± 6.4 | 0 |
| Female | 5 | 5000 | 204.2 ± 7.4 | 225.2 ± 7.1 | 259.7 ± 5.3 | 0 |

Table 6. Acute dermal toxicity of saponins in Wistar rats [50]

## DISCUSSION

The medicinal plant *Sapindus mukorossi* is adaptable and highly prized. It is also referred to locally as soapnut, soapberry, dodani, and dodan. A phytochemical analysis of plant extracts revealed that the pericarp contained saponins (10–11%). Scientific investigations that showed the effectiveness of the extract in various experimental models have supported the use of soapberry in traditional medicine all over the world. The pharmacological effects of *Sapindus mukorossi*, which include, anxiety, molluscicidal, bactericidal, anti-inflammatory, and fish-killing, have been noted. Indigenous medical systems use them to treat a range of illnesses. Despite the fact that scientists working in various labs have isolated and identified a large number of *Sapindus mukorossi* phytochemicals, pharmacological/biological studies on these substances' impact on human health have never been carried out.

Most scientific research focuses on developing *Sapindus mukorossi* traditional practices. The saponins of *Sapindus mukorossi* are varied. To be studied in various pharmaceutical trials, it requires individualised treatment. The examined literature presents a sketchy picture of *Sapindus mukorossi's* pharmacological activities. It is urgently necessary to conduct more research on the pharmacological effects of soapberry at the molecular level in order to comprehend its mode of action.

## CONCLUSION

Due to its numerous commercial applications and propensity for reproduction, *Sapindus mukorossi* is a tropical tree of interest on a global scale. In most places where the meteorological circumstances support optimum development, it should be widely grown.

For the benefit of humanity, the greatest possible quantity of various sorts of commodities must be obtained. For a number of diseases, this herb has been used traditionally as medicine. According to earlier publications on chemical analyses and pharmacological assessments, *Sapindus mukorossi* has a wide variety of unique bioactive substances. According to the literature, isolated materials and crude extract fractions demonstrate a wide range of biological and pharmacological properties. To separate the bioactive Sapindus components and track its bioactivity, thorough chemical analysis is also necessary. This leads us to the conclusion that *Sapindus mukorossi* may soon play a significant role in the current healthcare system.

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