Traditional Medicinal Plants

Volume - 6

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Message

Prof. LB Laxmikanth Rathod
Vice Chancellor

I am immensely happy to know that, Dr. P Shivakumar Singh, Department of Botany, Palamuru University has authored the Book entitled "Traditional Medicinal Plants Vol. 6". I congratulate him for his academic dedication. I hope this book will be useful for the faculty, students of plant science and interdisciplinary studies of life sciences.

I am sure the volumes books have all the content and wisdom in the related areas and will prove highly useful in enriching the knowledge and skill of readers.

I convey my best wishes and hope the author will come out with many more such works in the days to come.

I also appreciate AkiNik Publishers for their effort in volumes of books.

Vice Chancellor

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Chapter - 5

Pharmacological Importance of *Sterculia foetida*

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Abstract

Sterculia foetida (Java Olive or Wild Almond) is a large, straight, attractive, umbrella-shaped, spreading deciduous tree in the Sterculiaceae family. Plant parts such as bark, leaves, roots, flowers, and seeds have been used in herbal medicine. The leaves and bark have traditionally been used as diaphoretics, diuretics, and aperients, as well as in the treatment of rheumatism, obesity, gonorrhoea, edoema, skin conditions and other ailments. The seeds of *S. foetida* are safe to eat and contain a good amount of fat (30–36%) and protein (11.4%). Pharmacological studies show that the plant has anti-diabetic, anticonvulsant, anti-dermatophytic, antioxidant, antimicrobial, anticancer, CNS depressant, anti-inflammatory, antifeedant, anti-obesity, anti-fertility, bronchodilator, mitogenic, and diuretic activity. The bioactive compounds found in *S. foetida* include flavonoids, fatty acids, alkaloids, phenols, saponins, triterpenoids, and steroids. The active phytoconstituents present in the plant may be responsible for its pharmacological properties, which have significant activity against a variety of ailments. This chapter summarizes the overall investigation of phytochemicals, pharmaceutical and pharmacological activities of *Sterculia foetida* over the last few years.

Keywords: *Sterculia foetida*, sterculiaceae, java olive, wild almond, phytochemical, pharmacological, pharmaceutical

Introduction

Traditional medicine is becoming increasingly popular as an alternative therapy around the world. According to the World Health Organization (WHO), any part of a plant can be used as a precursor in the production of natural drugs. Because of the toxicity of modern synthetic drugs, approximately 80% of the world's population prefers plant-based natural drugs for treatment. Furthermore, scientists and researchers began working on identifying natural compounds from traditional plants that have various pharmacological properties. Because of its higher efficiency and non-toxicity,

the pharmaceutical industry has also shifted its focus to the production of natural products as drugs [1]. Traditional plants are a rich source of novel drug molecules that can be used in modern medicines, pharmaceutical intermediates and lead compounds in natural drugs. These natural compounds can be found in traditional plant leaves, barks, vegetables, fruits, roots and even stems, and they act as a defence mechanism in humans, protecting them from a variety of diseases. The plant cells have the ability to produce both primary and secondary metabolites. Primary metabolites are involved in plant growth and development, while secondary metabolites are involved in plant defence mechanisms as well as some metabolic activities [2]. In developing countries like India, more than 60% of the population depends solely on traditional medicine to treat their physical ailments. Without knowing the actual secondary constituents present in plant material, traditional medicine has been more commonly practiced in ayurvedic treatment. Secondary plant constituents play an important role in healing and curing a variety of human diseases. The screening of phytoconstituents of traditional plants was the first and most important step in *in vitro* drug design [2].

Plants' medicinal value is derived from phytochemicals such as flavonoids, alkaloids, tannins, phenol, steroids, and phenol compounds, which have higher inhibitory activity against infectious diseases than synthetic drugs [1]. Plant compounds that belong to the flavonoids group have a variety of biological functions, including protecting plants from UV radiation and phytopathogens. The phenol compounds act as antimicrobial metabolites and also contribute to lignin, pigment biosynthesis, and plant reproduction. Plants that contain tannin compounds have astringent, hemostatic, antiseptic, and toning properties [2]. According to the WHO, bacteria and viruses are the primary causes of severe pathogenic diseases. Due to a lack of public awareness, there is currently a sudden increase in the emergence of bacterial disease among the poor socioeconomic population in India. Though the Indian government is taking steps to control or eradicate the spread of these diseases, they remain a challenge to overcome. As a result, natural medicines that are highly effective, have few side effects, and are inexpensive may be considered for future treatment [1].

Sterculia foetida is a large, straight, umbrella-shaped, spreading deciduous tree in the Sterculiaceae family. It is also known as ‘Java-Olive’, 'Bastard poon tree', 'Hazel sterculia', 'Skunk tree’, 'Poon tree' and 'Sam-rong' in Thai [3]. It is a soft, attractive, woody tree native to India, Thailand, Indonesia, Ghana and Australia, with a variety of medicinal properties [1]. It is known as Jangli Badam (Hindhi) or Gorapu Badam (Tamil) in India. Carolus

Linnaeus described it for the first time in 1753. The name Sterculia is derived from the Roman God Sterquilinus, who was the God of fertilizer or manure [4]. The plant's generic name, "Stercus", means "manure," and the species name, “foetida”, means "stinking" [1]. The plant has a life expectancy of more than 100 years [5]. The seeds, oil, leaves, bark, and gum of *S. foetida* have significant medicinal value [3]. *Sterculia foetida* is widely used to treat rheumatism, emphysema, laxative, diuretic, asthma, arthritis, antipyretic and other conditions. A pharmacological study of *S. foetida* extracts revealed anticancer, antibacterial, anti-inflammatory, and analgesic activities; anti-diabetic and anti-hyperlipidemic effects; and anti-oxidant, antiobesity and anti-fertility properties [6, 7]. The raw leaves have been reported to have antioxidant, anticonvulsant, antidermatophytic and anti-inflammatory properties [8]. The seeds of *S. foetida* contain 65-78% cyclopropene fatty acids (CPE-FAs). CPE-FAs from *S. foetida* are plant lipids with a highly strained propene ring in their carbon chains that are linked to a variety of biological properties [8]. The seed oil has antifungal, insecticide, antibiotic, antiviral, hormonal, carcinogenic and antitumoral properties [3]. *S. foetida* seeds are safe to eat raw or cooked and are not toxic to humans or animals [9]. A number of flavonoids, phenolics, steroids, coumarins, phenylpropanoids and cerebrosides have been found in the roots, leaves, seeds and barks of this species [10]. The *S. foetida* phytochemical survey concentrated on flavonoids as the main ingredients. Triterpenoids, steroids, and fatty acids were also discovered [6]. This plant also contains bioactive components such as acetamiprid, α-BHC, tetradecanoic acid, methyl ester, terbufos, benfuresate, dichlofluanid, DEP (trichlorfon), 1-azuleneethanol, acetate, captan, etridiazole, diethofencarb, etobenzanid, cyfluthrin, cypermethrin, pendimethalin, kresoxim-methyl, tetraconazole and pyributicarb [11, 12].

Taxonomic classification [4]

Kingdom	Plantae
Sub Kingdom	Tracheophyta
Division	Mangoliophyta
Class	Magnoliopsida
Subclass	Dilleniidae
Order	Malvales
Family	*Sterculia*ceae
Genus	*Sterculia*
Species	*foetida*

Fig 1: *Sterculia foetida* tree

Common names [4]

Java Olive, Poon tree, Wild Indian Almond, Sterculia nut, hazel sterculia, skunk tree.

Vernacular names [4]

Bengali	Jungli Badam
Hindi	Jangli Badam
Kannada	Bhatala penari
Konkani	Kuvem ruk
Malayalam	Pinar
Marathi	Punava
Sanskrit	Putidaru
Tamil	kutiraippitukkan
Telugu	Adavibadamu

Habitat

Sterculia foetida is a wild plant that thrives in tropical and subtropical climates (30° North Latitude to 35° South Latitude) [5]. It's a massive evergreen tree, found in Europe, Africa and Asia's tropical zones [3, 13]. It is native to

Australia, India, Bangladesh, Pakistan, Sri Lanka, Myanmar, Indonesia, Kenya, Malaysia, Thailand, Philippines, Somalia, and Tanzania [3]. West Bengal, Bihar, Orrisa, Andhra Pradesh, Maharashtra, Tamil Nadu and Kerala, are among the Indian states where it has been reported. In southern India, it is found in plains from the coast to 800 m up, on slopes, in crevices of rocks, by stream banks and so on. It is uncommon in natural stands. It is frequently found planted near temples. It is a rare tree in Konkan Forest areas [14]. In Indonesia, *S. foetida* is primarily found in West Java, East Java, Madura and other small Java islands. According to the Germplasm Resources Information Network of the United States Department of Agriculture, thirty-three species are found in this family, with seeds and leaves being the primary distinguishing factors [3].

Botanical description

S. foetida is a large, straight deciduous tree that can grow to be 40 m tall and 3 m wide, with branches arranged in whorls and spreading horizontally [13, 15]. The diameter of trees is approximately 100-120 cm, and the ideal planting pitch has been determined to be 3×3 m [5]. The young bark is smooth and grey, while the old bark is dark brown and rough. The bark has a brown spot and is slightly ridged. The bark is about 25-30 mm (2.5-3 cm) thick. The bark is naturally more fibrous [4]. In the transverse section, the characteristic microscopic features of bark were observed as cork, cortex, medullary rays, phloem parenchyma and sclerenchyma. The presence of lignified fibres, xylem vessels, stone cells, cortex and calcium oxalate crystals was revealed by microscopical examination of powdered bark [16]. The roots are thick, strong, and brown in colour [4]. Leaves are crowded at the ends of branchlets, digitate, and have 7-9 leaflets; leaflets are elliptic or elliptic-lanceolate, acuminate, 10-17 cm long, briefly petioluled, and have an unpleasant odour; the petiole is 12.5-23 cm long [13, 15]. Inflorescence of racemose panicles 15-30 cm long [14]. Flowers in many panicles, subterminal, 10-15 cm long; rather large, green or dull purple; unisexual, with male and female flowers on separate trees; calyx dull, orange-colored, deeply 5-partite; lobes 1-1.3 cm long [13, 15]. The flowers have an unpleasant odour [14]. Follicles are scarlet, 7.6-9 x 5 cm in size, very stout and eventually woody [13, 15]. The fruit is large and contains about 10-15 seeds [5]. *S. foetida* seeds are exalbuminous, with starchy cotyledons and a small radical. It is numerous (10-15), 3-4 inches long, ellipsoid, oblong, 1.5-1.8 cm, slatecolored with a yellow caruncle on one side at the base [3]. A shell and a thin 1-2 mm layer of pulp surround the single large seed. *Sterculia foetida* produces approximately 200-350 kg of seed per year [5].

Fig 2: *Sterculia foetida* plant parts A). Stem B). Bark C). Root D). Leaf E). Fruit F). Seed

Cultivation

A plant of the hot, tropical lowlands, where it can be found at elevations of up to 1,500 metres. It thrives in climates with annual daytime temperatures ranging from 18 to 32 °C, but it can tolerate temperatures ranging from 16 to 36 °C. It prefers a mean annual rainfall of 1,100-1,800 mm, but can tolerate 900-2,000 mm, and can grow in areas with or without a distinct dry season. It prefers deep, fertile soil that is moist but well-drained in a sunny, sheltered location. It thrives in a wide variety of soils. It prefers a pH of 6-7.5 but will tolerate 5-8 [17].

Propagation

The seed should be sown as soon as possible. Seedlings sprout quickly and develop long taproots. They must be placed in permanent positions as soon as possible. The hard seed coat of many species in this genus causes physical dormancy, which can be overcome by scarifying the seed. This is accomplished by removing or abrading some of the seed coat to allow water to enter while taking care not to damage the embryo. The aril that surrounds the seed should also be removed; this is easiest to do after it has been softened

by soaking in water. Temperatures ranging from 20 to 30 °C are ideal for seed germination. They can be planted in a nursery seedbed or in pots. If the seed has been properly treated, a germination rate of about 95% can be expected in about 2 weeks [17].

Traditional uses and benefits

Sterculia foetida has traditionally been found to have significant medicinal value. Almost every part of *S. foetida* can be used to treat a variety of ailments. In addition, this multi-purpose tree provides a variety of materials for local use.

Leaves: Traditionally, the leaves have been used in herbal medicine as an aperient, diuretic, and diaphoretic. It is also used to treat rheumatism, obesity, gonorrhoea, edoema, dropsy, and skin diseases [4, 9, 18]. Decoction of leaves is used for difficult labour. It is also used to treat suppurative cutaneous eruptions in the Philippines. Fresh leaf juice is used to repel insects [4, 19]. To treat eczema, grind wild Indian leaves into a paste and apply it to the affected areas. The leaves are used to wash the head. Pounded leaves were used to treat broken limbs and dislocated joints. To treat fever, heated oiled leaves are applied to the abdomen of children, followed by the placement of used leaves on the chest [19]. *S. foetida* leaves contain up to 2.66% calcium and are a good source of protein and phosphorus, meeting ruminant nutritional needs [2, 19]. The raw leaves of the tree have been reported to have antioxidant, anticonvulsant, antidermatophytic, and anti-inflammatory properties [1]. In the Philippines, leaf extracts are used as an antibacterial, antifungal and antibiotic agents [11].

Seed: The seeds are edible and have a laxative effect when roasted and eaten raw [4]. In times of scarcity, seeds are roasted and eaten like chestnuts [18, 19]. Seeds of *S. foetida* contain 30-36% fat and 11.4% protein [12]. In Ghana, seeds are used as a purgative [19]. “Sterculia oil”, an edible non-drying oil, is found in both the testa and the kernel. It is a yellow oil with a bland, sweet flavour and a high melting point. The total oil content is approximately 34% [3, 17]. On a small scale, oil from the seed is extracted and used in medicine to treat itches and other skin diseases internally and externally as a paste [3]. The wood is boiled with seed oil and applied externally to treat rheumatism [4]. The kernels have a cacao flavour but are not bitter and are used to adulterate cacao. The oil extracted from the kernels is used for lighting purposes [13]. *S. foetida* oil has been found to be biofuel, compatible with sunflower, soybean and rapeseed oils. Paint is made by mixing oil with white earth [19]. By sensitising receptors, seed oil may aid in the reduction of belly fat and insulin resistance [15].

Bark: Bark decoction is used as an aperient, diaphoretic, and diuretic in the treatment of dropsy and rheumatism [4]. It has traditionally been used to treat emphysema, asthma and arthritis [11]. In Indonesia, a decoction of the bark is used as an abortifacient [19]. The bark produces fibre [14]. Fibre has a lace-like character when freshly stripped, making it suitable for fancy work. It is used in the production of mats, bags, cordage, and paper [17].

Fruit: Fruit decoction is mucilaginous and is used as an astringent in the treatment of gonorrhoea and diarrhoea. A fruit decoction is used to treat blenorrhagia in Java [19].

Root: Young plant rootstock can be eaten raw. It is high in starch and has a flavour similar to jicama. A root infusion is used for bathing a sick child or a patient suffering from jaundice [19].

Gum: The gum of *S. foetida* is used in medicine. Gum similar to "gum tragacanth" is extracted from the trunk and branches and used for bookbinding and other similar purposes [17].

Timber: The wood is greyish-white and soft, but it is harder than the wood of most other species in the genus. It is simple to saw and work with, finishes reasonably well, and is very perishable when exposed to the weather or in contact with the ground, despite being relatively durable for interior work. It is locally used for hut doors, dugout canoes, boat planking, guitars, and carved toys [17].

Pharmacological activities

1. Anti-diabetic activity

The methanolic extract of *Sterculia foetida* (MESF) seeds was tested for anti-diabetic activity. The results of the antidiabetic study provided strong evidence that the glucose level in the MESF was gradually decreased by inhibiting the function of α-amylase enzymes when compared to standard acarbose [12]. Another study used Wistar albino rats to evaluate the antidiabetic and antihyperlipidemic activity of a methanolic extract of *S. foetida* leaves. Glibenclamide was used as a control. The extract was discovered to lower blood glucose, cholesterol and triglyceride levels. As a result, it is reported that *S. foetida* leaf extract demonstrated significant anti-diabetic and anti-hyperlipidemic activity comparable to the standard [20]. An *in vitro* α-amylase inhibition method with acarbose as a control was used to investigate the anti-diabetic activity of *S. foetida* stem. The methanol extract of *S. foetida* stem inhibited α-amylase at 25 g/mL, whereas the standard drug acarbose has an IC_{50} of 20 g/mL for α-amylase inhibition. The methanolic extract of *S. foetida*

(stem) also contains the greatest number of flavonoids, which may result in the greatest α- amylase inhibition [15].

2. Anticonvulsant activity

Sterculia foetida ethanolic leaf extract was found to have anticonvulsant activity in pentylenetetrazole and maximal electric shock induced convulsions in albino rats. It showed a significant anticonvulsant effect at a high dose of 500 mg/kg, reducing the duration of tonic-clonic seizures, recovery time (131.2-5.02) and increasing the percentage of convulsion inhibition (68.09%) [21].

3. Antidermatophytic activity

The antidermatophytic activity of petroleum ether and methanolic extract of *Sterculia foetida* seeds was tested *in vitro* using the Agar well diffusion method. When compared to petroleum ether extract, methanolic extract had the highest antidermatophytic activity against *Candida albicans*, *Candida rubrum*, *M. gypseum*, and *Candida tonsurans*. With streptomycin as a control, it showed the maximum antibacterial activity against *E. coli* and *B. subtilis*. As a result, *S. foetida* seed extract was discovered to have antidermatophytic and antibacterial activity [22].

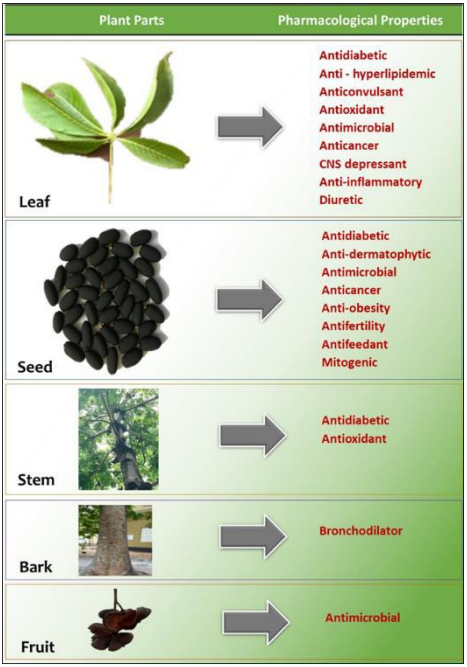

Fig 3: Important pharmacological properties of *Sterculia foetida*

4. Antioxidant activity

The antioxidant activity of a methanolic extract of *Sterculia foetida* leaves was assessed *in vitro* using free radical scavenging, 1-diphenyl-2-picrylhydrazyl (DPPH), nitric oxide radical inhibition, beta-carotene oxidation inhibition, superoxide anion radical scavenging, and inhibition of xanthine oxidase activity methods. *Sterculia foetida* was discovered to have both primary and secondary antioxidant properties. It scavenges free radicals, inhibits lipid peroxidation, and has a protective effect against disease. When compared to the standard drug, the methanolic extract demonstrated significant antioxidant activity [23]. In another study, the antioxidant activity of a methanolic extract of *Sterculia foetida* stem extracts was evaluated using the DPPH method. In the DPPH method, *S. foetida* stem methanol extract was found to have an IC_{50} at a lower concentration of 20 g/mL. Standard ascorbic acid has a DPPH IC_{50} of 20 g/mL. The methanol extract of *S. foetida* stem exhibits remarkable antioxidant activity, which could be attributed to the presence of a higher concentration of flavonoids [15].

5. Antimicrobial activity

Sterculia foetida fruit extract was converted into silver nanoparticles and tested for antimicrobial activity. Silver nanoparticles demonstrated antibacterial activity against human pathogenic bacteria such as *E. coli*, *Pseudomonas putida* and *Klebsiella pneumonia* [4]. In another study, ethanolic extracts of *S. foetida*. leaves were evaluated for antibacterial and antiprotozoal properties. The extracts were found to have antibacterial properties, as they inhibited the growth of *Staphylococcus aureus* and *Escherichia coli*. Antiprotozoal assays against *Entamoeba histolytica* demonstrated that *S. foetida* can inhibit parasite growth, with effects comparable to metronidazole [24]. The fruit shell extract of *Sterculia foetida* demonstrated antibacterial activity against *S. aureus* and *E. coli* bacteria [25]. In a study, green route was used to create CuO nanoparticles (CuO NPs) from *Sterculia foetida* leaf aqueous extract. The GEA-CuO nanocomposite was created by combining green synthesised CuO NPs with GEA hydrogel. FTIR spectra confirmed the formation of green synthesised CuO NPs and GEA-CuO nanocomposite. The antibacterial properties of a synthesised polymer hydrogel (GEA) and a nanocomposite of green synthesised CuO nanoparticles introduced into a polymer hydrogel (GEA-CuO) were tested against *S. aureus* (gram-positive bacteria) and *E. coli* (gram-negative bacteria). In comparison to GEA hydrogel, green synthesised CuO NPs incorporating GEA-CuO nanocomposite showed significant bacterial resistance against *S. aureus* and *E. coli* organisms [7].

6. Anticancer activity

Ethanol extracts of *Sterculia foetida* L. leaves were investigated for their anticancer activity. Using the *in situ* cell death detection kit, *T. vaginalis* exposed to *S. foetida* was observed to fluoresce in red surrounded by a yellow signal, indicating apoptotic-like changes [24]. In another study, *S. foetida* seeds were tested for anti-proliferative and apoptotic activity on human MG-63 osteosarcoma cells. It was investigated using the 3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyltetrazolium bromide (MTT) colorimetric assay, reactive oxygen species (ROS) generation, decrease in mitochondrial membrane potential (MMP) and nuclear fragmentation assay. *S. foetida* extract (SFE) anti-cancerous activity on MG-63 osteosarcoma cells resulted in decreased cell viability, increased ROS, induced nuclear fragmentation, and decreased MMP in a concentration-dependent manner. This showed that SFE had potent anti-cancer activity on MG-63 cells [26]. In a study, Silver-(protein-lipid) nanoparticles (Ag-PL NPs) were created using a seed extract from *S. foetida*. These nanoparticles demonstrated potential mosquito larvicidal activity as well as anti-proliferative activity against the HeLa cancer cell line [11]. According to a study, a green route was used to create CuO nanoparticles (CuO NPs) from *S. foetida* aqueous leaf extract. Green synthesised CuO NPs were combined with GEA hydrogel to create the GEA-CuO nanocomposite. MTT assay was used to investigate the anticancer effects of synthesised GEA hydrogel and GEA-CuO nanocomposite against the lung cancer cell line (A549). The results showed that the GEA-CuO nanocomposite had a significant cytotoxicity effect on the lung cancer cell A549 [7].

7. CNS Depressant activity

An alcoholic extract of *Sterculia foetida* L. leaves was tested for pharmacological activity in various animal models. In mice, the extract reduced exploratory activity. Pentobarbitone sleeping time was also increased in normal and chronic pentobarbitone-treated mice. It also increased the duration of barbital sodium-induced hypnosis, indicating central nervous system depressant activity. As a result, the extract was discovered to have CNS depressant activity [14].

8. Anti-obesity activity

According to one study, oil obtained from *S. foetida* seeds reduces belly fat and protects against obesity-related problems. The oil contains fatty acids that inhibit the action of an enzyme linked to insulin resistance, thereby reducing belly fat indirectly. It was reported that it could be used to create a natural nutritional supplement [4].

9. Toxic and anti-feedant activity

The crude acetone seed extract of *Sterculia foetida* Linn. was tested for anti-feedant and toxicity activity against *Achaea janata* L., *Spathodea litura* F., caterpillar and semilooper. According to the findings, the seed extract of *S. foetida*. acts as a potential insecticide against *S. litura* F. and *A. janata* L. [4]. In another study, *S. foetida* (L.) seed extracts, were investigated for insecticidal activities against three major stored product pests, namely *Sitophilus oryzae* (L.), *Callosobruchus chinensis* (L.) and *Tribolium castaneum* (H.), using contact and fumigation bioassay. Individual responses varied with test chemicals, insect species, exposure times, and doses. By spectroscopic analysis, the biologically active constituent of *S. foetida* seeds was identified as a cyclopropene fatty acid, structurally elucidated as (2n-octylcycloprop-1-enyl)-octanoic acid (I). The filter paper application of (2n-octylcycloprop-1-enyl)-octanoic acid (I) at 0.2 mg/cm^2 resulted in 100% mortality of all test insects two days after treatment (2 DAT). Only the pure hexane-eluted fraction caused % mortality to *S. oryzae* and *C. chinensis* 2 DAT at 0.3 mg/cm^2, whereas the dose required to achieve the same percentage of mortality with the crude seed extract was 0.6 mg/cm2. *T. castaneum* was less susceptible to all treatment conditions, taking longer than the other insects to show toxicity symptoms. In terms of fumigant activity, the compounds appeared to be more effective against all three insects in closed containers than in open containers in vapour form. These findings suggest that the insecticidal activities of the test compounds were due to their contact mode of action, despite significant fumigant toxicity. The result suggests that the bioactive compound isolated from *S. foetida* could be a powerful insecticide against populations of *S. oryzae, C. chinensis,* and *T. castaneum* [8].

10. Anti-fertility activity

Anti-fertility activity of *Sterculia foetida* oil has been reported. *S. foetida* oil delays sexual maturity in groups of weanling 21-day-old female Sprague-Dawley rats. The oil contains sterculic acid, which improves delayed vaginal opening and regularises the estrous cycle through degeneration of the vaginal membrane and lengthening of the estrous cycle according to the vaginal smear [4, 27].

11. Bronchodilator activity

Aqueous extract of the stem bark of *Sterculia foetida* Linn. has bronchial smooth muscle relaxant properties. Preliminary research on *S. foetida* stem bark extract found that it stimulates the bronchial smooth muscle beta-adrenoceptor while inhibiting bronchoconstrictor such as histamine. It showed that stem bark extract has anti-asthmatic properties [4, 28].

12. Mitogenic activity

Sterculic acid, isolated as the methyl ester from *S. foetida* oil, was discovered to have mitogenic properties in the pancreas of male Sprauge Dawely rats. The presence of cyclopropenoid fatty acids from *Sterculia foetida* Linn was responsible for this mitogenic effect [4, 29].

13. Anti-inflammatory activity

An alcoholic extract of *Sterculia foetida* L. leaves was tested for pharmacological activity in various animal models. In the acute carrageenan-induced rat paw edoema and chronic granuloma pouch models, the extract demonstrated significant anti-inflammatory activity [14]. In another study, *S. foetida* L. leaves were discovered to contain the active ingredient Taraxer-14-en-3-ol. The alcohol, its acetate, and ketone showed anti-inflammatory activity against TPA-induced mouse ear oedema with inhibition ratios of 60.0, 58.57 and 40.57 at 0.5 mg/ear, respectively. Each compound's percentage inhibition of inflammation increased with dose [30].

14. Diuretic activity

The diuretic activity of a methanolic extract of *S. foetida* leaf was tested in male albino Sprague Dawley rats. In the study, five groups were used: a negative control, positive control with the drug furosemide and an experimental group with *S. foetida* extract prepared in low to high concentrations of 150, 250, and 350 mg/kg. In 5 hours, urinary volume, pH, specific gravity, and urinary electrolytes were all measured. The extract's diuretic property was determined using the modified Lipschitz method. The results showed that *S. foetida* in low concentration (150 mg/kg) has a moderately positive diuretic index capacity of 1.17 and a lipschitz value of 0.66, with an increase in potassium secretion and low sodium ions in the urine. The percentage increase in urine volume was measured hourly and found to be 12.75% and 337.5%, respectively, in the first and second hours. The results of this study provided scientific support for the folkloric use of *S. foetida* plant extract for its diuretic property using quantitative analysis [31].

Pharmaceutical review

1. Bio-diesel

A biodiesel was prepared from *S. foetida* oil using sodium hydroxide as a catalyst, and it was evaluated for physico-chemical properties such as iodine value (72.6), free fatty acids (0.17%), phosphorous content (0 ppm), flash point (179 °C), cloud point (3 °C), pour point (3 °C), viscosity at 40 °C (4.72 cSt) and trace metals (Group I metals 0.21 ppm). The properties of *S. foetida*

were confirmed with other oils, and it was reported that it is one of the non-edible feed stocks for biodiesel production [32]. In another study, the physical and chemical properties of crude *Sterculia foetida* oil (CSFO) and its methyl ester were investigated. The acid values of the oil were discovered to be 5.11 mg KOH per g, necessitating the acid-esterification and alkali-transesterification processes. The acid value was reduced by esterification using anhydrous sulfuric acid (H_2SO_4) as a catalyst and alkaline (NaOH) catalyst transesterification for the conversion of crude oil to methyl esters. The optimal FAME yield achieved for those *S. foetida* biodiesel conditions was 97.50%. The fuel properties of *S. foetida* methyl ester (SFME) were also determined and assessed. As a result, the biodiesel produced met and exceeded the ASTM 6751 and EN 14214 biodiesel standards. According to the findings, SFME is a potential non-edible feedstock for biodiesel production[33]. Another study looks at the performance, emissions and combustion characteristics of *S. foetida* biodiesel blended with n-butanol in two different ratios (5% and 10%). The transesterification of *S. foetida* kernel oil into biodiesel was catalysed by a base. The n-butanol additive was added in 5% and 10% volumes as an oxygenated fuel to *S. foetida*/diesel blends to reduce emissions and improve thermal efficiency. Findings demonstrated that adding n-butanol to blends improved brake thermal efficiency when compared to 20% *S. foetida* biodiesel + 80% Diesel. Carbon monoxide, smoke opacity and hydrocarbon emissions have all been significantly reduced when compared to standard diesel. In comparison to 20% *S. foetida* biodiesel and 80% diesel, nitrogen oxides (NOX) and carbon dioxide (CO_2) were reduced. Because of the inherent content of oxygen in heat release rate and in-cylinder pressure, butanol/diesel/biodiesel blends performed better in combustion than *S. foetida* biodiesel. As a result of the addition of butanol to *S. foetida* biodiesel, it appears to be a good substitute for straight diesel [34].

2. *Sterculia foetida* Linn. gum as natural mucoadhesive polymer

A natural mucoadhesive polymer derived from the bark of *S. foetida* was used to create a new *in-situ* mucoadhesive nasal gel formulation. *S. foetida* gum was developed and successfully used as a mucoadhesive natural polymer. It is also used to treat or manage migraines for a longer duration by sustaining drug release [4].

3. Evaluation of gum as controlled release excipient

S. foetida gum was tested as a hydrophilic matrix polymer for controlled release preparation. Characterization of *Sterculia foetida* gum was performed in order to evaluate it as a matrix polymer. The viscosity, pH and scanning

electron micrographs were all measured. The following formulation aspects were considered: gum concentration (10-40%), particle size (75-420 μm), type of fillers, and those for dissolution studies; pH, and stirring speed. Tablets made from *S. foetida* gum were compared to tablets made from Hydroxy methylcellulose K15M. The release rate profiles were assessed using various kinetic equations, including zero-order, first-order, Higuchi, Hixon-Crowell, and Korsemeyer and Peppas models. Scanning electron micrographs revealed that the gum particles were triangular in shape. The viscosity of a 1% solution was determined to be 950 centipoise and the pH ranged from 4 to 5. A suitable matrix release profile could be obtained at a gum concentration of 40%. Greater sustained release profiles were obtained for *S. foetida* gum particles ranging in size from 76 to 125 μm. The type of filler had a significant influence. There were also significant differences in rotational speed and dissolution media pH. The *in vitro* release profiles revealed that tablets made from *S. foetida* gum had a higher retarding capacity than tablets made from Hydroxy methylcellulose K15M. The differential scanning calorimetry results showed that *S. foetida* gum has no interactions with diltiazem hydrochloride. The drug was released via surface erosion and anomalous diffusion, as observed. As a result, *S. foetida* gum can be used as a controlled release matrix polymer [35]. Another investigation was carried out to determine the role of *S. foetida*. gum (SFG) in hydrophilic tablets. The physicochemical properties of *S. foetida*. gum was determined for evaluation, including solubility, grain shape, melting point, swelling index, pH, viscosity and loss on drying. In addition, compressed tablets were successfully prepared for *in vitro* studies at a variety of particle sizes, gum concentrations, rotational speeds, and media to assess the effects of these parameters on the rate of drug release. Furthermore, SFG tablets were compared to tablets made with Hydroxy methylcellulose E15. The results revealed that SFG had high potential in controlled release dosage forms. SFG-based tablets outperformed HPMC E15 forms in terms of drug release. The scanning electron micrographs revealed that the majority of the gum particles had a multi-morphology. The viscosity, pH, loss on drying, melting point, and swelling index were all 176cP, 5.21, 10.9%, 225 °C and 44.4%, respectively. The formulation with 40% gum was appropriate for extending drug release. Fillers had no significant impact on the drug release profile, whereas rotational speed had a significant impact. The results showed that *S. foetida* gum could be a good candidate for a new drug delivery system [36].

4. Herbal siddha formulation

Sengathari Thylum (SKT), a siddha poly herbal formulation found to contain *S. foetida* as one of the plants, was evaluated for anticancer and

antioxidant potential using the MTT assay with SK.MEL 28 cell lines and the DPPH free radical scavenging assay. It was found to significantly reduce tumour cell viability (68.71% vs. 55.82%) in SK-MEL-28 cells treated with 500and 1000 ug/ml of thylum and it also has significant antioxidant activity [4].

Phytochemicals

The various active phytochemical constituents have been discovered to have a wide range of activities, which may aid in the prevention and treatment of a wide range of human diseases. The presence of the phytochemical listed below may explain the reported pharmacological properties of various parts of *S. foetida*.

Leaves: The presence of tannins, 2-deoxysugars, leucoanthocyanin and benzopyrone nucleus was discovered in a preliminary phytochemical screening of ethanol extracts of *S. foetida* leaves [24]. Another study detected the existence of metabolites such as alkaloids, flavonoids, sterols, tannins, and triterpenes in a methanolic extract of *S. foetida* leaf extract [31]. Using various chromatographic methods, six flavonoids were isolated from hexane and chloroform extracts of *Sterculia foetida* Linn. leaves collected in Binh Thuan Province, such as epicatechin, apigenin 7-O-β-D-glucopyranoside, dimethylchrysin, trimethylapigenin, luteolin and quercetin. HR-ESI-MS, ESI-MS, and NMR experiments were used to determine their structures. The first four compounds were discovered in the *Sterculia* genus for the first time [10]. One new oleanane-type triterpenoid, stercufoetin A, as well as four known ones, vergatic acid, β-amyrin, oleanolic acid and maslinic acid, were purified from the leaves of *S. foetida*. using various chromatographic methods. HR-APCI-MS and NMR experiments suggested their structures. Vergatic acid, β-amyrin, oleanolic acid and maslinic acid were discovered for the first time in this species [6]. The active ingredient in the leaves of *S. foetida* has been identified as tartaxer-14-en-3-ol [30]. Linolenic acid was the most abundant acid in *S. foetida* leaf lipids [37].

Seed: Secondary metabolites found in *S. foetida* seeds include fatty acids, alkaloids, flavonoids and saponins [26]. Fixed oil, proteins, carbohydrates, phytosterols, gums, and mucilaginous substances have been reported in the seeds [3]. Fatty acids are extracted from the seeds and seed oil of *S. foetida*. This fatty acid has been found to have antioxidant, antibiotic, antifungal, insecticide and anti-tumor activity. Tetradecanonic acid (1.65%), Hexadecanoic acid (11.87%), Octanoic acid (Sterculic acid) (6.76%) and 9,10-methylene-heptadec-9-enoate (Malvalic acid) were the fatty acids found in the

oil [4]. *S. foetida* oil also contains minor amounts of oleic, linoleic and saturated acids. Myristic and palmitic acids make up the majority of the saturated components [3, 32]. The oil contains traces of a stearic acid glyceryl ester, tristearin (0.8%) and tristerculin (31.4%), as well as varying amounts of glycerides of the types GS~U, GS~2 and GU3 of other fatty acids [3]. Flavonoids, saponins and alkaloids were discovered in the preliminary qualitative chemical analysis of *S. foetida* ethanol seed extract [18]. When compared to other vegetable oils such as sunflower, groundnut, mustard and soybean, the seeds of *S. foetida* produced a significant amount of oil (58.7 g/100 g). The fatty acid composition of all five tested oils revealed that *Sterculia* seed oil has a higher percentage of total fatty acid as well as unsaturated fatty acid. According to the results of the proximate and mineral composition analysis, *Sterculia* oil is a good source of protein, lipids and macro and micronutrients. The lowest TOTOX value (2.67) and highest iodine value (132-144) indicated higher oxidative stability and the presence of more unsaturated bonds in the fatty acid moieties, both of which are beneficial to human health [38]. A qualitative phytochemical analysis was carried out to evaluate the metabolites in a methanolic extract of *S. foetida* seeds (MESF). Alkaloids, flavonoids, saponins, cholesterols, carbohydrates, phenols, terpenoids, steroids, and proteins were discovered in the extract. Secondary metabolites with long retention times in methanol extract were revealed as acetamiprid, halfenprox, alpha-benzene hexachloride (BHC), beta-BHC, 9-octadecenoic acid (Z), methyl ester, tralomethrin, tetradecanoic acid, methyl ester, hexadecanoic acid, methyl ester, gamma-BHC, terbufos, benfuresate, dichlofluanid, DEP (trichlorfon), sterculic acid, 1-azuleneethanol, acetate, captan, etridiazole, diethofencarb, p,p′-DDT (dichlorodiphenyltrichloroethane), etobennzanid, cyfluthrin, cypermethrin, pendimethalin, CNP (C-type natriuretic peptide), kresoxim-methyl, tetraconazole, pyributicarb, permethrin [9].

Stem: Phytochemical screening of crude extracts of *S. foetida* stem ethyl acetate, methanol, and aqueous extracts yields positive results for biological compounds such as steroids, saponins, steroidal saponins, alkaloids, flavonoids, phenols, carbohydrates, and glycosides. The methanol extract of *S. foetida* contains the most phenolics (38.47mg/gm), while the aqueous extract contains the most alkaloids (43.89mg/gm) [15]. Linoleic acid was the predominant acid in the lipids of *S. foetida* trunk wood and stems [37].

Bark: Eight compounds were isolated from the bark of *S. foetida* in Binh Thuan province, Vietnam: cleomiscosin A, cleomiscosin C, quercetin, kaempferol 3-O-β-D-xylopyranoside, lupeol, lupenone, betulinic acid, and

taraxerol. The MS and NMR spectroscopic analysis, as well as the comparison of their NMR data with the reported data, elucidated their chemical structures. The compounds cleomiscosin A and cleomiscosin C were discovered for the first time in the *Sterculia* genus [11].

Root: An examination of the roots of *S. foetida* revealed the presence of lupeol, n-triacontanol, beta-sitosterol, stigmasterol, and beta-sitosterol-3-O-Beta-Dglucopyranoside [24]. The main acid in the S. foetida root lipids was malvalic [37].

Conclusion

Due to the potential side effects of modern synthetic drugs and the increasing contraindications to their use, a resurgence in the use of medicinal plants has materialised. Traditional medicines have no side effects, they are very effective and safe for human use. They have become inexpensive and widely available drugs for mankind over the centuries. Traditional plants' medicinal values are primarily found in phytoconstituents, which produce biological effects on human bodies when consumed. Ethnomedical and traditional uses of phytoconstituents have received special attention in recent times. *Sterculia foetida* is an attractive, woody tree with a variety of medicinal properties that are typically found in the tropical zones of Europe, Africa, and Asia. Almost every part of *S. foetida* contains a diverse range of phytochemicals. The primary goal of this chapter was to uncover and investigate the pharmacological and medicinal properties of *S. foetida*. Studies revealed that this plant has anti-diabetic, anticonvulsant, anti-dermatophytic, antioxidant, antimicrobial, anticancer, CNS depressant, anti-inflammatory, anti-feedant, anti-obesity, anti-fertility, bronchodilator, mitogenic, and diuretic activity. These activities could be attributed to phytoconstituents found in the plant's roots, stems, bark, leaves and seeds. *S. foetida* has enormous beneficial effects and should be used to promote public health. The biological potential of *S. foetida* remains still unexploited. As a result, more research on *S. foetida* is required in order to use it for the benefit of humanity.

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