



# A Tangy Twist Review on Hog-Plum: *Spondias pinnata* (L.f.) Kurz

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## Abstract

*Spondias pinnata* (L.f.) Kurz., belongs to the Anacardiaceae family, generally referred to as Indian Hog plum, a deciduous, glabrous tree with a healthy fruit to eat. Hog plum is a mild deciduous tree plant of high nutritional value, stubby calories and abundant in vegetable proteins, zinc, chitin, starch, vitamins and minerals. Traditional use of various parts of *S. pinnata* includes diarrhea, dysentery, stomach troubles, hyperacidity, wounds, sprain, rheumatism, gonorrhoea, tuberculosis, aphrodisiac, arrow poison antidote, dyspepsia, dysentery, ring worms, abscess painful joints, refrigerant, tonic, antiseptic, astringent, mental disorders, tuberculosis, vomiting and many more. A number of pharmacological activities were reported from several extracts of *S. pinnata* and its parts that include hypoglycemic, anti-cancer, ulcer-protective, antidiarrhoeal, anti-microbial, hepatoprotective, thrombolytic, anti-inflammatory, antiarthritic, analgesic, antipyretic, antihypertensive, anthelmintic, diuretic and laxative, anti-tuberculosis, cytotoxic, antioxidant, anti-hyperlipidemic, ischemia reperfusion injury and preconditioning of heart, anxiolytic, reduce side effects of chemotherapy, ameliorating, platelet aggregation inhibitory activity and acute and sub-chronic toxicity. A few phytochemicals were detailed on this plant. The chemical components of *S. pinnata* include different amino acids, carbohydrates, terpenoids, flavonoids, polysaccharides, steroids and so on. Various solvent extract and their gas chromatography-mass spectrometry analysis have confirmed the structures of a number of important phytoconstituents. Hence this review can be a good reference for researchers who would undertake further investigation about *S. pinnata*.

**Keywords:** Hog Plum, Pharmacological Activities, Phytoconstituents, *Spondias pinnata*, Traditional Use

## 1. Introduction

Now-a-days medicinal plants and herbs are playing a significant role in the progress of human culture. Since the Vedic period, plants and herbs have been used to cure and prevent different kinds of diseases alongside epidemics. Many medicinal plants are often used as good condiments, to taste, to dye, to preserve food, etc. Nearly every part of the plant has its own medicinal heritage<sup>1</sup>. Herbal medicines have traditionally been used as tinctures,

powders, poultices and teas accompanied by formulas and eventually, as an angel compound. Information about the use of medicinal plants resides within cultures, within the local traditions open to communities, tribes and societies, and is passed on from generation to generation<sup>2</sup>. In recent years, there has been an increase in the use of plant-derived health products in developed countries as well as in developing countries, which has resulted in an exponential growth of herbal products holistically

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alongside upward trend, which has also been observed in herbal exploration<sup>3</sup>.

Hog-plum is a small deciduous tree species with a beneficial nutritional quality, low in calories and high in vegetable protein, zinc, chitin, fiber, nutrients and minerals, domestically called 'Ambate' or 'Ambade Kaai'. 'This tree has received non secular significance as it is worshiped in Nakshathra Vana' for 'Hastha' nakshathra<sup>4</sup>. It incorporates very good quantity of citric acid and ascorbic acid (Vitamin C). Hog-plums are typically consumed uncooked and can be used to prepare pickles, chutneys and processed foods; however, the use of hog-plum remains unorganized and primitive. The shelf-life of shimmering hog-plums is also constrained by bacterial spoilage and enzymatic browning<sup>5</sup>.

The *Spondias* is one of the first genera of the Anacardiaceae family circle consisting of 70 genera and six hundred species and is endogenous primarily in the tropics and subtropics globally but also extends to the temperate field, which is useful in traditional medicinal products for the treatment of many diseases<sup>6,7</sup>. *Spondias* has records of use going returned as a minimum as far as 6500 B.C., in Tehuacan valley of Mexico and it consists of 18 species, particularly, *S. acida*, *S. admirabilis*, *S. chinensis*, *S. dulcis*, *S. expeditionaria*, *S. globosa*, *S. macrocarpa*, *S. malayana*, *S. mombin*, *S. novoguineensis*, *S. pinnata*, *S. purpurea*, *S. mexicana*, *S. radlkoferi*, *S. tefyi*, *S. testudinis*, *S. tuberosa*, *S. venulosa*, and *S. xerophila*<sup>8</sup>.

Pharmacological studies of different species of *Spondias* have shown that they possess vegetation, hypoglycemic, cytotoxic, antioxidant, ulcer protective, hepatoprotective, photo-protective, analgesic, antipyretic, anti-inflammatory, antiarthritic, antihypertensive, antimicrobial, anti-dementia, antifertility, thrombolytic and anthelmintic activities due to the massive variety of phytoconstituents that may be found in this genus. Plants of the genus *Spondias* include tannins, flavonoids, sterols, triterpenes, saponins, essential oils, amino acids and polysaccharides<sup>6-9</sup>.

*Spondias pinnata* (L.f.) Kurz., (family: Anacardiaceae) commonly referred to as Indian Hog plum, a deciduous, glabrous tree with edible fruit growing up to 25 m in height<sup>10</sup>. The unripe fruits are salty, even as the ripe ones are tangy-twisty in taste<sup>11</sup>. The fruits are utilized in worship, as a vegetable and for flavouring in curry, these and are also eaten up by herbivorous mammals<sup>12</sup>. In the Western Ghats of Karnataka, flower buds and culmination of *S. pinnata* are used in pickling, while the leaves possess fragrant, acidic and astringent properties. The bark is beneficial to treat dysentery and diarrhea, and is also consumed to prevent vomiting. The roots are consumed

for regulating menstruation. This is a crucial medicinal plant having usages in conventional, folk medicines and ethnomedicinal programs<sup>13,14</sup>.

*S. pinnata* is in great demand in natural habitats owing to domestic consumption by locals. Commercial exploitation of this species often exists on a day-to-day basis for fruit and other medicinal usage by locals. This defines *S. pinnata*, with particular focus on diverse ethnobotanical usage.

## 2. Taxonomic Position and Synonyms

Indian Hog plum, *Spondias pinnata* (L.f.) Kurz, belongs to the Anacardiaceae family. The genus *Spondias* is a flowering flora consisting of 18 species described, of which eight are native to the Neotropics and approximately 10 are native to the tropics<sup>10,15-17</sup>. The information of the taxonomic function and synonyms of *S. pinnata* are indexed in Table 1.

## 3. Vernacular Names

*S. pinnata* is a species of tree first described by Carl Linnaeus the Younger. This species is now and again loosely known as the "wild (or forest) mango" and has been positioned within the genus *Mangifera*<sup>18</sup>. *S. pinnata* is considerably grown all over India and is known by numerous names at various locations and commonly it's by far called Wild Mango, Andaman mombin, Indian hog plum, Indian mombin<sup>10,19-21</sup>. Etymology of *S. pinnata* derived from Greek words *Spondias* or *spodias* "ashes", the classical name for the wild plum tree (Theophrastus) and *Pinnata* with pinnate leaves. The information of vernacular names is listed in Table 2.

## 4. Geographical Distribution and Cultivation

The *S. pinnata* is native to Central America and Southern Mexico and herbal populations are observed in both dry and wet regions, such as an extensive range of semi-deciduous forests<sup>22</sup>. It is also distributed extensively within the tropics and abundantly in the eastern and northeast location of Indian. Indian Hog Plums are discovered to grow as wild or cultivated up to 1500 m altitude, at some places in the tropical Indian subcontinent, Sri Lanka, Andaman Islands, Thailand, China, Myanmar and Malaysia, also widely dispensed inside the Philippines.<sup>10</sup> In Florida, this plant grows abundantly. There has been a great strive to introduce this species to the semiarid conditions of Anand, Gujarat. However, the saplings

**Table 1.** Taxonomical classification and synonyms of *S. pinnata*<sup>10,15-17</sup>

<b>Kingdom</b>	<b>Plantae</b>
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Infradivision	Angiospermae
Class	Magnoliopsida
Subclass	Rosidae
Superorder	Rosanae
Order	Sapindales
Family	Anacardiaceae
Genus	<i>Spondias</i>
Species	<i>pinnata</i>
Binomial name	<i>Spondias pinnata</i> (L.f.) Kurz
Synonyms	<i>Spondias paniculata</i> Roxb.ex Wight & Arn.,
	<i>Spondias mangifera</i> Willd.,
	<i>Spondias macrophylla</i> Wall.,
	<i>Spondias bivenomarginalis</i> K.M. Feng & P.Y. Mao,
	<i>Spondias amara</i> Lam.,
	<i>Spondias acuminata</i> Roxb.,
	<i>Poupartia pinnata</i> (L. f.) Blanco,
	<i>Evia amara</i> Comm. ex Bl.,
	<i>Mangifera pinnata</i> L. f.,
	<i>Tetrastigma megalocarpum</i> W. T. Wang,
	<i>Wirtgenia decandra</i> Jungh.

were heavily infested with leaf spots (*Colletotrichum* spp.) leading to mortality of the plants<sup>23</sup>. In India, this vegetation is observed to be developing thoroughly in the tropical and Himalayas areas, however it is seldom discovered in western India, despite growing wild in the wooded area of Karnataka<sup>24</sup>.

*S. pinnata* is not grown on a wide scale due to its high pressure in the natural environment due to its increased demand for local domestic consumption. Because of its hard seed coat, it is prone to attack by various pests, pathogens and insects and the seed radical tends to dry easily and there is a problem in seed germination and breeding activities<sup>14</sup>. The trees grows best in fertile, well-drained soils but if adequate nutrition is provided, they can grow satisfactorily in a variety of poorer soils. The

**Table 2.** Vernacular names of Indian Hog plum (*S. pinnata*)<sup>10,19-21</sup>

Sanskrit	Aamraata, Amraatakah, Pitan
Hindi	Ambara, Ambari, Amra, Bhiringi-phal, Metula, Pashu-haritaki, Jangliam
English	Indian Hog Plum, Wild mango, Hog plum
Bengali	Aamada, Aamraata, Aamraataka
Telugu	Adavimamidi
Oriya	Ambaada
Marathi	Amada, ambada, Dholamba, Khatamba, Ranamba
Tamil	Kincam, pulima
Assamese	Aamraata
Gujarati	Ambaada
Khasi	Dieng-sohpier
Konkani	Ambade, Ambado
Mizo	Tawitaw
Malayalam	Ampazham
Manipuri	Heining, Eikhoi
Tangkhul	Khursongthei
Kannada	Ambatte Mara, Goddada kayi, Kodalmavu, Vrykshamla, Muthiga
Nepali	Amaro
German	Mangopflaume
Spanish	Ciruela mango, Jobo de la india, Mango jobo
Japanese	Amura tamagonoki
Portuguese	Cajamangueira, Caja-manga, Imbu manga
Chinese	Bin lang qing, Mu ge, Zhao wa wen po, Wai mu ge.
Thai	Makok, Ma kok pa.
Vietnamese	Coc chua.

species *Spondias* is best adapted to areas with a marked dry season. Mature trees are quite drought resistant, and do not require additional irrigation. Some irrigation is suitable for established order of young timber at some point of the primary year after planting. These days Anita *et al.*,<sup>25</sup> pronounced the impact of seed orientation on germination of wild mango for monetary benefit. Every year a major crop is produced. From June to October the fruits mature and are generally harvested at maturity. This wild edible fruit tree has been added to the local people making chutney, jam and pickle. By manufacturing and selling these goods, the field of people's socio-economic

popularity is growing and there is a high degree of scope to enhance earnings by such consumption<sup>14</sup>.

## 5. Botanical Characters

*S. pinnata* belongs to the group of deciduous ornamental tree which grows 10-15 m tall (sometimes up to 25 m tall) with a division of a small branch colored yellowish brown [Figure 1a,b] [Table 3]. With irregular cracks, the surface of the bark is smooth, gray to light reddish brown, exuding a clear, sticky sap with a turpentine smell [Figure 2]<sup>26</sup>. The bark has general thickness of 2.6 mm and differentiated into outer bark (periderm) and internal bark (secondary phloem). Simple homogenous cork cells are found in outer bark; calcium oxalate crystals are distributed at random in the internal bark's axial parenchyma. The phloem ray cells are closely loaded with tannins. In powder barks are fibrous flesh, brown in shade with slight turpentinic odour and mucilaginous astringent flavour, starch grains are also present and cork cells are stratified and seem like benzene ring, whereas stone cells have an elongated shape in groups and barrels, and phloem fibers are found in linear fusiform<sup>27</sup>. The wood has a fine textured luminous colour, no lustre and is odourless. Growth rings are indistinct, the grain is straight and the vessels are medium in size, with yellow deposits visible to the naked eye. The wood with more solitary pores is diffuse-porous, and there are few multiple pores which are also present. The vessels are shaped round to oval and arranged in tangential bands and a section diagonally. Tyloses and gummy deposits have been found in vessels. Rays encompass numerous rows of procumbent cells. Starch grains are typically located in ray cells. The wooden is mild weight with 0.45 specific gravity and 0.44 g/cm<sup>3</sup> density at 12% moisture content and hardness is 2795.85 N<sup>28</sup>.

Leaves of *S. pinnata* are imparipinnate compound leaf, 25-45 cm long, alternating and spiral, elliptic-oblong leaflets (4-6 pairs), acuminate apex, sub-rounded base, sometimes asymmetric, with wonderful marginal vein and along with entire margin [Figure 3a-d]; Midrib flat above, obtuse secondary veins, widely parallel, reticulating tertiary veins and stipules are absent<sup>14,29</sup>. The leaves are green in colour, while the dried leaves are brownish green in color with characteristics odour and slightly bitter or astringent in taste. Reported anatomical structure of the leaf can be seen in both adaxial and abaxial surfaces, consisting of simple and short unicellular trichomes. An intramarginal vein is hardly ever present. Resin canals are to be found in leaves and reproductive structures of Anacardiaceae. Resin canals in leaf petioles and major lamina veins run parallel to the phloem, and are absent handiest in the most minor veins<sup>30</sup>. The midrib has

biconvex symmetry with collateral vascular bundles. The dermis blanketed with an epicuticular wax layer on both aspects and the mesophyll is found in dorsiventral palisade layers. In the intercellular spaces several layers of spongy parenchyma are loosely associated. The angular collenchyma is present, externally surrounding via the xylem and phloem. The reported microscopic powder character of the leaves is composed of fibres, calcium oxalate prismatic crystals along with starch grains and elongated stone cells. There are also distinct stomata, sclereids, palisade cells, upper and lower epidermal cells<sup>27,31,32</sup>.



(a)

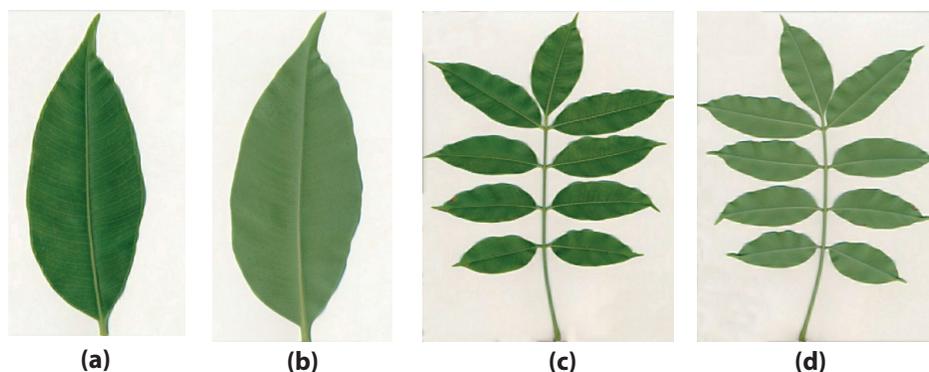


(b)

**Figure 1.** (a) *S. pinnata* tree with fruits (b) *S. pinnata* tree.



**Figure 2.** *S. pinnata* bark.



**Figure 3.** (a) *S. pinnata* compound leaf (upper side), (b) *S. pinnata* compound leaf (lower side), (c) *S. pinnata* compound leaflet (upper side) (d) *S. pinnata* compound leaflet (lower side).

**Table 3.** General botanical description of *S. pinnata*

Seeds	Stone semi woody, fibrous with many cavities outside.
Fruits	Drupe, ovoid or oblong, fleshy, smooth, yellow when ripe.
Inflorescence	Paniculate, terminal, glabrous, and basal
Flowers	Polygamous tiny white to cream colour, stalk-less, triangular sepals, pointed ovate-oblong petals and dusty pollen grains.
Leaves	Compound leaf, imparipinnate, alternate, spiral, distinct marginal vein, and flat midrib, with a tapering tip.
Trunk and Bark	Bole straight, bark pale grey, smooth with rounded knobs
Branches and twigs	Terete and hairy.
Root	Deep tap roots

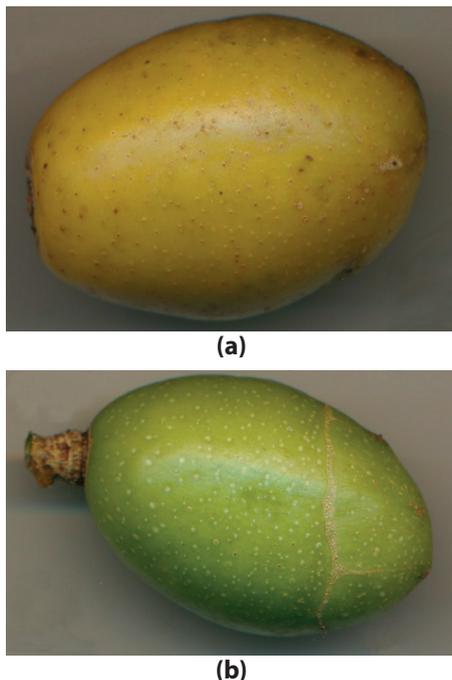
The thickness of the matured root is not uniform but cylindrical [Figure 4]. In colour, it's whitish grey, fissures. Taproot is branched, and there are true rootlet forms. The powder of the root is odourless and without taste. Root bark can't be effortlessly scraped. In mature root of the tree extended up to 5-8 metres<sup>33</sup>. Documented microscopic characters of the *S. pinnata* root measuring five mm thickness have wide periderm and stable vascular cylinder. The periderm is membranous with shallow irregular fissured crevices containing phellem and phellogen. The phellem cells are rectangular brick fashioned, skinny walled and arranged radially. There is a narrow phellogen stripe inside the phellem. The wide cortex consists of tangentially elongated parenchyma cells along with secondarily wide phloem containing sieve tubes and phloem parenchyma. Xylem vessels are present between the medullary rays. The root powder also consists of vessel components, fibers and few cork cells<sup>34</sup>.

The fruit is simple 1.5-2.5 cm long and 0.7-1.13 cm in diameter, rounded, succulent and a single-seeded type of drupe, fleshy with a pulp that's finely flavoured and safe to eat. The Epicarp is thin, greenish yellow when ripe [Figure



**Figure 4.** *S. pinnata* compound Roots.

5a). Mesocarp is gentle acidic, juicy when ripe, aromatic, 6-8 celled inner a part of endocarp is tough, woody and grooved, outer part is fibrous<sup>35</sup>. The unripe fruits are extremely sour while the ripe ones have a tangy twist with pleasant aroma [Figure 5b]. The seeds bear ridges, semi-woody, outside fibrous and pitted with cavity<sup>36,37</sup> [Figure 6].



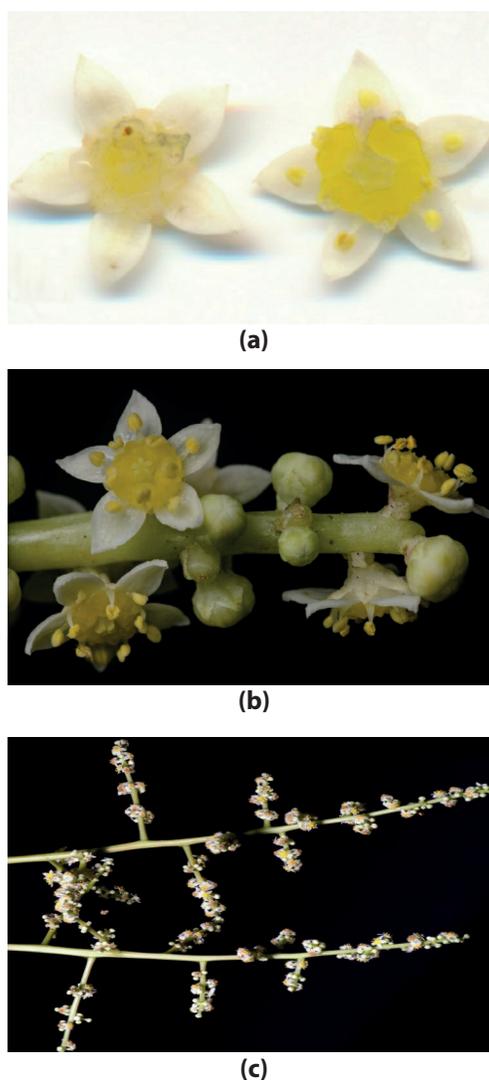
**Figure 5.** (a) *S. pinnata* ripe fruit, (b) *S. pinnata* unripe fruit.



**Figure 6.** *S. pinnata* stone seed.

Flowers are stalk-less and white in coloration, sepals are triangular, while petals are ovate-oblong and pointed [Figure 7a, b]. The calyx consists of five caducous, triangular and short, inexperienced-colored, light lobes. The corolla consists of five white and glamorous petals. The ovate petals are acutely apex, 2 mm long and 1,5 mm wide. The androecium consists of 5 stamens, which are inserted into the disk base. The filaments are thin (1 mm), and the anthers are globose. The ovary is 5-celled

with five stout patterns. The pollen grains are dusty<sup>13</sup>. Inflorescences with first order branches are paniculate, terminal, glabrous and basal [Figure 7c]. Flowers arranged on the same tree (polygamous plant) in a multi flowered inflorescence, in upper axils, bisexual and unisexual flowers, and pedicels up to 3 mm in length. Flowers appear earlier than the leaves or accompanied via very younger ones [Table 4]. The time of blooming and fruiting is from June through October. With the advent of the spring season the flowering takes place on naked shoots<sup>38</sup>. The seasonal natural phenomena and pharmacognostic parameters of *S. pinnata* are depicted in Tables 5 and 6.



**Figure 7.** (a) *S. pinnata* flowers, (b) *S. pinnata* flowers and buds (c) *S. pinnata* inflorescences.

**Table 4.** Reproduction and dispersal of *S. pinnata*

Sex distribution	Polygamous (male, female and bisexual flowers on the same plant)
Mode of pollination	Pollinated by a wide variety of insects.
Dispersal of seed	Dispersed by way of numerous fruit-ingesting birds and mammals.

**Table 5.** Seasonal natural phenomena of *S. pinnata*

Blossoming season	February to May.
Fruity season	August to November.
Seeding season	August to November.
Leaves falling	During the winter season.

**Table 6.** Pharmacognostic parameters of *S. pinnata*

Parameter	Fruit (% w/w)	Leaf (% w/w)	Bark (% w/w)	Root (% w/w)
Total Ash Values	5.49	10.42	12.87	4.8
Acid Insoluble Ash Values	0.81	0.20	2.46	2.5
Water Soluble Ash Values	4.62	3.23	7.33	1.48
Loss on Drying	13.77	6.23	13.40	9.86
Water Soluble Extractive Values	2.96	23.2	4.17	7.5
Alcohol Soluble Extractive Values	1.55	10.97	11.67	3.8

## 6. Nutritive and Mineral Potential

Drupaceous fruit of *S. pinnata*, is maximum popular within the food and nutraceutical industries for its taste and fitness advantages with low in energy, high in vegetable proteins, minerals (zinc, calcium, iron), chitin, fibers, vitamins like A, B<sub>1</sub> and B<sub>2</sub><sup>11,39</sup>. It incorporates superb amount of vitamin C (ascorbic acid) and half of what is found in sparkling one<sup>40,41</sup>. The plant's green fruit is pickled in brine and widely used in culinary preparations such as condiments, jams, curies, sherbet and as soothing drinks prepared by Assam's Ahum people and some other North-eastern Indian tribes<sup>42</sup>. *S. pinnata* end results are slightly acidic in nature<sup>43</sup>. The fresh *S. pinnata* fruits commonly used for sauce preparation indicated that sugar, vinegar and their interactions have a major effect on the usual acceptability of Hog plum sauce improvement. Sugar had a superior influence on universal acceptability instead of vinegar<sup>44-48</sup>. The nutritional potential suggested with biochemical profile of *S. pinnata* is shown in Table 7.

## 7. Aboriginal Drug Programmes

*Spondias pinnata* is utilized in Ayurveda, Unani and Siddha drugs. The bark is utilized in treatments of dysentery, diarrhea, biliousness, menstrual disarranges,

joint pain, tuberculosis and for skin rubbing over sore joints. The bark paste is also used to treat stomach and frame discomfort or outline throb. The bark paste is used externally in articular and muscular rheumatism. The bark juice is consumed to treat diarrhoea and dysentery and additionally applied on ringworm, pores and skin diseases. The juice from the leaves is dropped in the ear to treat earache. The fruit is used as an astringent, antiscorbutic, blood purifier, and in opposition to dyspepsia. The fruit juice is used to treat earache and often used to avoid blood dysentery. The root has been used to control menstruation<sup>49,50</sup>. The dried stem bark of *S. pinnata* possesses Rasa, Guna, Virya and Karma characteristics. In essence the therapeutic uses of *S. pinnata* are ksata, ksaya, raktapitta and daha, in Ayurveda. Dosage of stem bark is 5–10 g powder for decoction and 1–3g powder for medicinal purposes. It is not ideal for consumption by people with high pitta and kapha dosha, since the unripe fruit is sour and can increase kapha and pitta dosha. In gastritis it is not suitable whereas ripe fruit is perfect for gastritis<sup>17,51</sup>. The Indigenous system benefits and indications of *S. pinnata* are summarized in Table 8.

**Table 7.** Nutritional potential with biochemical profile of *S. pinnata*<sup>43-47</sup>

Parameters	Fruit	Bark	Leaf
Total protein (g%)	17.32	3.21	11.04
Crude fat (g%)	12.23	5.14	4.8
Carbohydrate (g%)	23.54	16.3	68.9
Crude fibres (g%)	42.53	33.9	10.5
Flavonoids (mg%)	710.23	350.5	76.03
Polyphenol (mg%)	634.53	91.47	27.76
Moisture (%)	82.02	23.6	15.13
pH	3.93	-	-
Calcium (mg%)	115	72	10.85
Iodine (mg%)	24	9	-
Iron (mg%)	150	128	0.09
Sodium (mg%)	96	-	0.85
Potassium (mg%)	1.78	3.05	9.50
Copper (mg%)	123	90	-
Aluminium (mg%)	87	58	-
Phosphorous (mg%)	0.68	-	0.24
Riboflavin (mg%)	0.09	-	-
Niacin (mg%)	0.16	-	-
Ascorbic acid (mg%)	87.45	-	59.05
Thiamine (mg%)	1.8	0.8	-
Food energy value (kcal/g)	168.76	-	-

## 8. Ethnobotanical Information

The plant is known to play an important economical, ecological, as well as medicinal role. Several parts of *S. pinnata* are used to treat a number of health hazards. Each and every plant part is used for the preparation of several medicines.

The juice of the leaves is dropped in the ears and externally applied for earache. The powder of the dried leaves is used in diarrhoea and dysentery treatment. The stem bark decoction is also used similarly. New, tender leaf juice is used to treat stomach disorders. The tender, fresh leaves are used in hyperacidity along with raw sugar candy and the fruit paste is applied externally on wounds. The bark paste is applied topically for sprain and rheumatism. The bark decoction is used in gonorrhoea treatment. *S. pinnata* fruits, leaves, and bark are effective anti-scorbutic agents. The fruit and the root serve as a remedy against thirst. The young flowers and leaves are used to prepare curries<sup>14,25,52,53</sup>.

All parts of this plant were used in folkloric remedy as an anti-tubercular agent, whereas the unripe fruits were

used as an aphrodisiac. Powdered ripe *Spondias pinnata* fruits are used as poison arrow antidote in India<sup>54</sup>. The tribes of Mayurbhanj District of Odisha were the historic users of this fruit, as a medicinal agent to treat diverse ailments like madhumeha, amlapitta and uttaravaruni<sup>55</sup>.

The fruit juice is beneficial antiscorbutic. The pulp of the fruit prevents rheumatism and is utilized in bilious dyspepsia<sup>56</sup>. At the same time 10 g of gentle fruit juice blended with 50 g of candy sugar and 0.6-0.8 g of black pepper powder is used as a home-made remedy for biliousness<sup>57</sup>. The Sonowal Kachari Tribe of Dibrugarh district of Assam consume the fruit for curing dyspepsia and dysentery. The fresh seed paste is externally applied to skin diseases such as ring worms, abscesses<sup>58</sup>.

In India, the bark of *Spondias pinnata* is used as a rubefacient for the treatment of sore joints, refrigerant, tonic, antiseptic, astringent, psychological illnesses, tuberculosis and vomiting by various ethnic groups<sup>15</sup>. It is additionally used to treat looseness of the bowels and diarrhoea and to prevent vomiting. Once rubbed to the skin, the paste or lotion of the bark extract provides relief from the sprain and strain, it is also beneficial for both

joint and muscular rheumatism<sup>59</sup>. To control feminine cycle and treat gonorrhoea a decoction arranged from the root bark is utilized. In Thailand the bark was used for its diuretic properties<sup>60</sup>. To relieve stomach pains, ringworms and skin diseases, a bark paste is applied<sup>58</sup>.

In India, the gum obtained from *S. pinnata* is applied as a demulcent to treat bronchitis, unfastened bowels, ulcers, diarrhoea and skin ailments<sup>61</sup>. The Bicolano tribe of the Philippines used the younger leaves of *S. pinnata* in meat stew and as fillings for angle sinanglay, a Bicolano delicacy<sup>10</sup>.

Roots of the plant is customarily utilized for controlling feminine cycle. The tribes of Ganjam district of Odisha drink the root paste duly suspended in water to reduce blood sugar<sup>62</sup>.

## 9. Phytochemistry

Salma et al.,<sup>63</sup> reported that the GC / MS technique analysed essential oils obtained from the *S. pinnata*

leaves, flower and fruits. Sesquiterpenes hydrocarbons were the predominant constituents in the leaf and flower essential oils (57.7% and 61.2), followed by oxygenated monoterpenes (30.4% and 28.8%). Whereas, the essential fruit oil was high in long-chain alkanes (51.1%), and esters of fatty acids (25.7%). It also recorded that  $\beta$ -caryophyllene was the most prevalent compound (49.9% and 53.3%) of leaf and flower essential oils, while nonacosane (25%) was the most prevalent component of the plant.

*Spondias pinnata*'s chemical constituents contain various amino acids, carbohydrates, terpenoids, flavonoids, polysaccharides, steroids and so on. The extensive chemical constituents from plant sections are recorded in Table 9 and their structures are delineated in Table 12. The LC-MS/MS evaluation of *S. pinnata* fruit and GC-MS evaluation of *S. pinnata* hexane and ethyl acetate extracts with their phytoconstituents are indexed in Tables 10 and 11.

**Table 9.** Chemical constituents obtained from various parts of *Spondias pinnata*

Plant Parts	Chemical Constituents
Fruit <sup>56,59,62,114,118-121,123,124</sup>	$\beta$ -amyrin, Oleanolic acid, Glycine, Cystine, Cysteine, Serine, Alanine, Leucine, Arginine, Polysaccharide, Stigmast-4-en-3 one, $\beta$ -sitosterol, Oleanic acid, Daucosterol, Cycloartane-24-methylene, Lignoceric acid, Ellagitannins, Galloyl-geraniin, $\beta$ -carotene, D-Galactose, D-Xylose, L-Arabinose, 2,3,4,6-Tetra-O-methyl glucose, 2,3,6-Tri-O-methylglucose, 2,3-Di-O-methylglucose, 3-O-Methylglucose, 1,2,3,6-tetra-O-methyl-D-glucose, Propan-1,2-dioic acid-3-carboxyl- $\beta$ -D-glucopyranosyl-(6'1'')- $\beta$ -D-glucofuranoside. Apigenin. Ascorbic acid, Riboflavin, Niacin, Galacturonic acid.
Fruit Peel <sup>90</sup>	Hexanal, Furfural, 2-Hexanal, (Z)-3-Hexen-1-ol, 2-furyl methyl, $\alpha$ -Pinene, Camphene, 5-Methyl-2-furaldehyde, $\beta$ -Pinene, $\beta$ -Myrcene, 3-Carene, (3E)-Hexenyl acetate, Isocineole, p-Cymene, Limonene, Benzeneacetaldehyde, (E)- $\beta$ -Ocimene, $\gamma$ -Terpinene, 2-Furaldehyde diethyl acetal, (E)-Linalool oxide, Furanoid, Benzoic acid, Methyl ester, Linalool, Nonanal, 2-Fenchanol, $\beta$ -Terpineol, Ocimenol, Isoborneol, Ethyl benzoate, Terpinen-4-ol, $\alpha$ -Terpineol, methyl salicylate, $\gamma$ -Terpineol, (E)-2-Decenal, $\beta$ -(E)-Damascenone, Caryophyllene, Ethyl cinnamate, $\gamma$ -Eudesmol, Ethyl hexadecanoate, 5-hydroxy methyl furfural, 1,4-pentadiene, 3,5-dihydroxy-2-methyl-5,6-dihydropyran-4-one, Hexadecanoic acid, 9,12,15-octadecatrien-1-ol.
Aerial Parts <sup>62,115</sup>	$\beta$ -Sitosterol- $\beta$ -D-glucoside, Daucosterol, Cycloartanone-24-methylene, Lignoceric Acid, Stigmast-4-en-3 one.
Bark <sup>33,68,89,116</sup>	Gallic acid, Methyl gallate, 7-hydroxy-6-methoxyquinoline-2(1H)-one, Quinoline, cinnamic acid, Ergosteryl triterpene 1, Ergosteryl triterpene 2, Ellagitannins, lignoceric acid, $\beta$ -sitosterol.
Roots <sup>117</sup>	Echinocystic acid-3-O- $\beta$ -D-galactopyranosyl-(1 $\rightarrow$ 5)-O- $\beta$ -D-xylofuranoside.
Whole plant <sup>59,115,122</sup>	Cycloartanone-24-methylene, Stigmast-4-en-3-one, Lignoceric acid, $\beta$ -sitosterol, Ellagitannins, Galloyl geraniin, Lignoserpic acid, $\beta$ - carotene, Naringenin, Apigenin, Stigmastrol, Campesterol, D-galactose, D-galacturonic acid, L-arabinose.

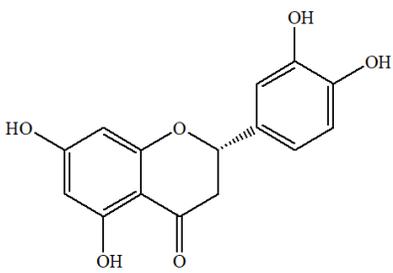
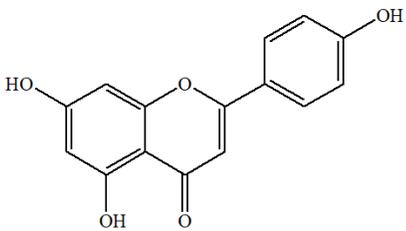
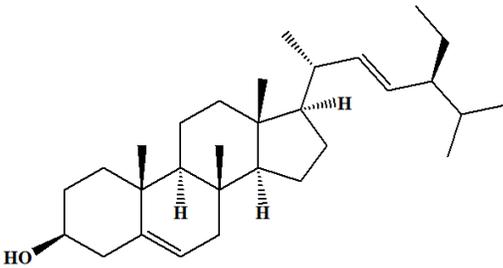
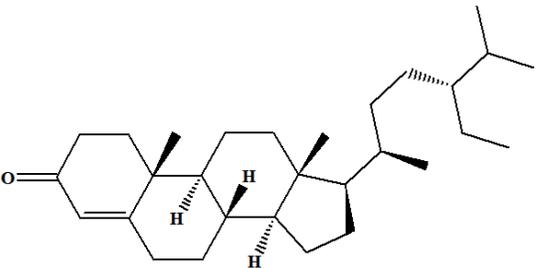
**Table 10.** LC-MS/MS analysis of *Spondias pinnata* fruit<sup>125-127</sup>

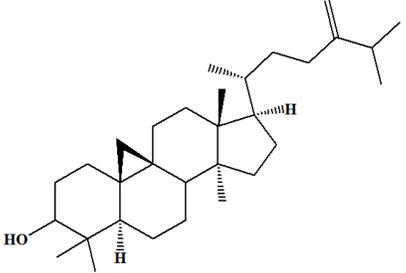
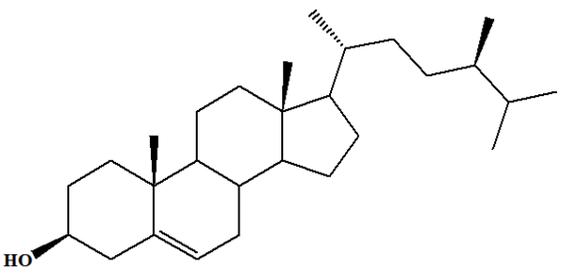
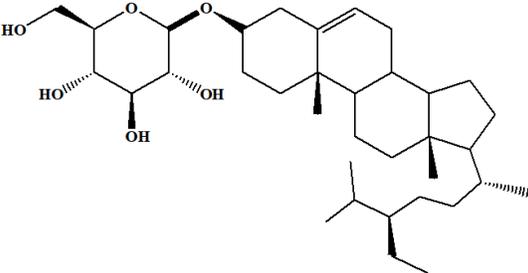
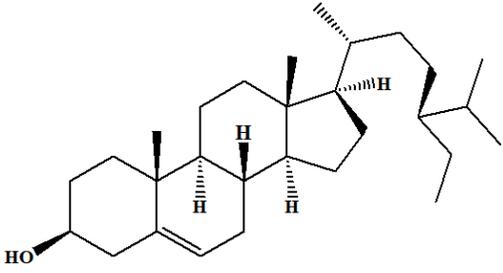
Types of Compound	Name of Chemicals
Carboxylic acids and esters	Gallic acid, Salicylic acid, Chlorogenic acid, 6-hydroxy-2,5,7,8-tetramethyl chroman-2-carboxylic acid (Trolox), Ellagic acid, p-coumaric acid, Tetradecanoic acid, Ethyl decanoate, Ethyl-3-phenylpropenoate, Hexadecanoic acid, Methyl-14-methylpentadecanoate.
Alcohols	cis-3-hexenol, Hept-5-en-2-ol, 9,12,15-octadecatrien-1-ol.
Aldehydes and Ketones	Furfural, 6,10,14-trimethyl-2-pentadecanone.
Isopropyl myristinate and aromatic hydrocarbons	1-methyl-4-propan-2-ylcyclohexa-1,3-diene.

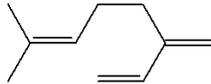
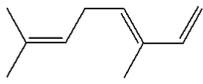
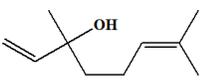
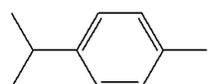
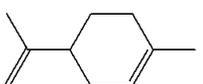
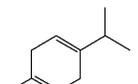
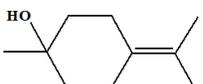
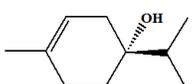
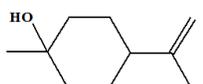
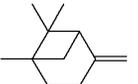
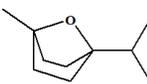
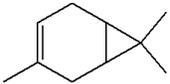
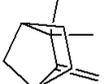
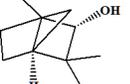
**Table 11.** GC-MS analysis of *Spondias pinnata* extracts<sup>128</sup>

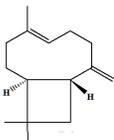
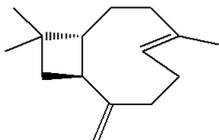
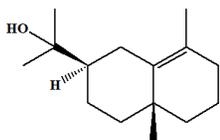
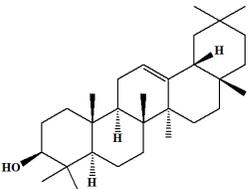
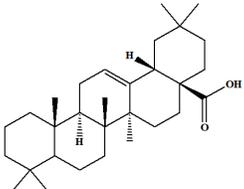
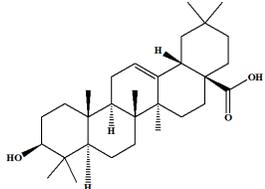
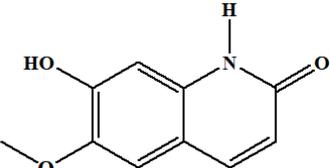
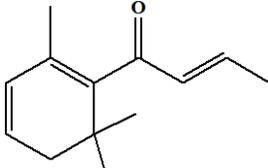
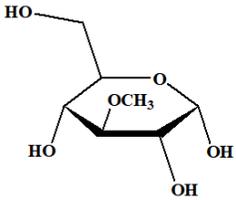
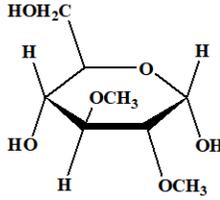
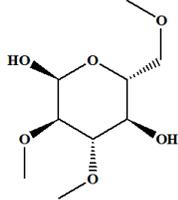
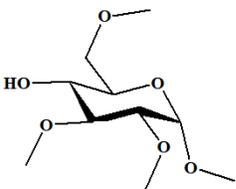
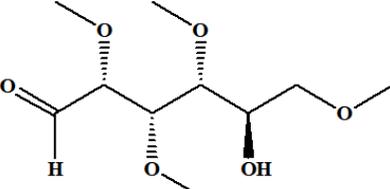
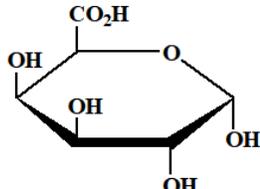
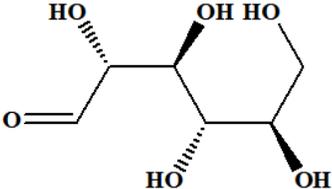
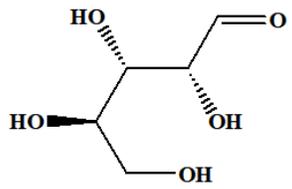
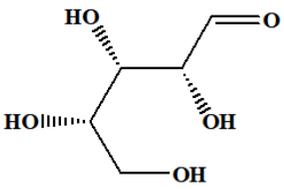
Extract name	Chemical Constituents
Hexane fraction of <i>S. pinnata</i> leaves	Methylbenzene, Nonane, 1,2,3-trimethylbenzene, Dodecane, 1,2,4,5-tetramethylbenzene, 1-dodecene, Tetradecane, 2,3,5,8-tetramethyldecane, 1-hexadecanol, Hexadecane, 1-hexadecene, Eicosanoic acid methyl ester, Eicosane, 9,12-octadecadienoic acid methyl ester, 9-octadecenoid acid methyl ester, Octadecanoic acid methyl ester, Tricosane, Heptadecane, Triacontane, Octacosane.
Ethyl acetate fraction of <i>S. pinnata</i> leaves	2,5-dimethyl-2-hexene, Acetic acid-2-methylpropyl ester, 2-propionic acid-2-methyl ethyl ester, 1-undecene, Dodecane, 1-Dodecene, Dodecane, 1-tetradecene, 1-(1,5-dimethyl-4-hexanyl)-4-methyl benene, 1-tetradecene, Pentadecane, 1-pentadecene, Heptadec-8-ene.

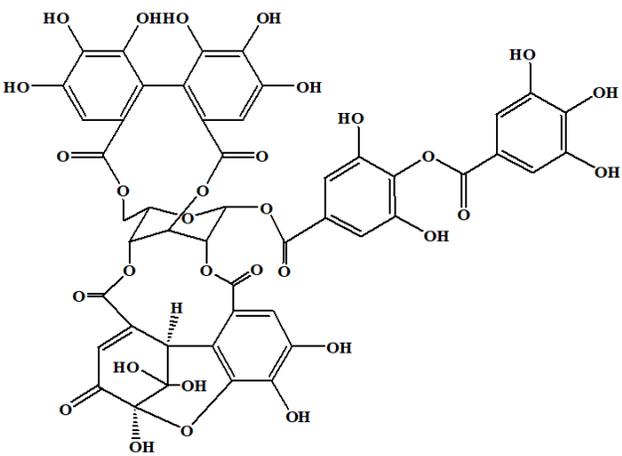
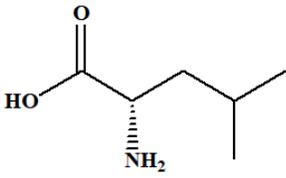
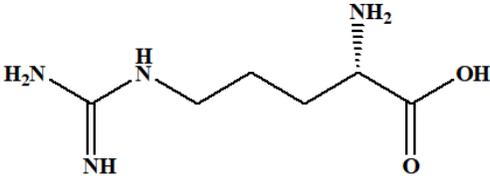
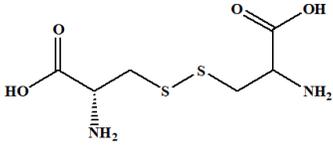
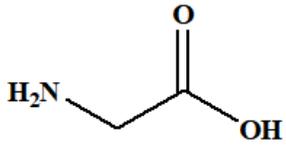
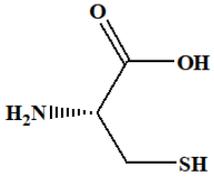
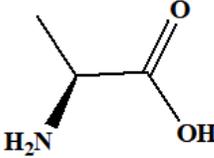
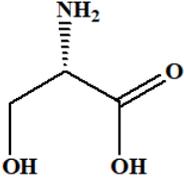
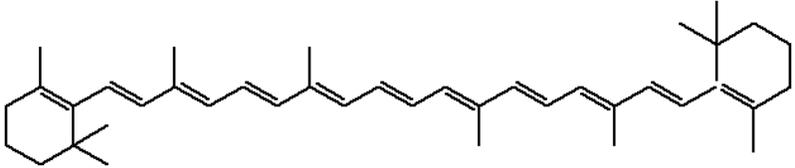
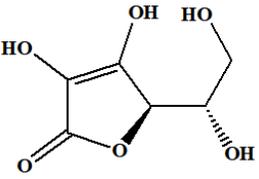
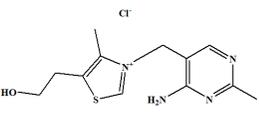
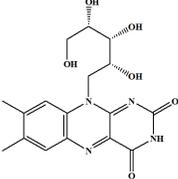
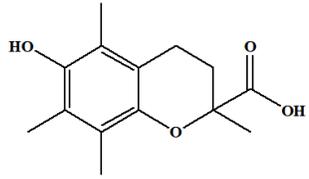
**Table 12.** Details phytoconstituents structures isolated form *S. pinnata*

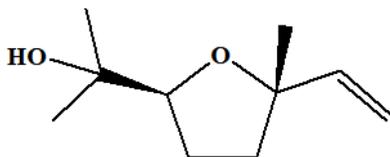
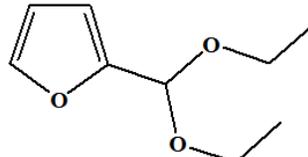
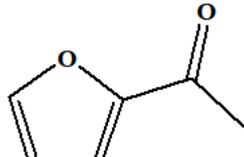
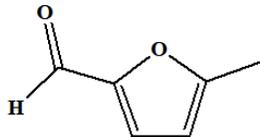
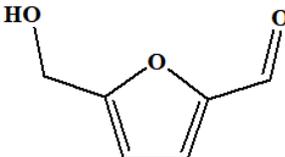
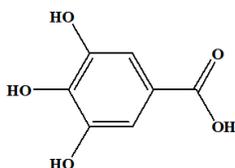
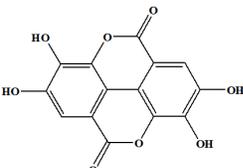
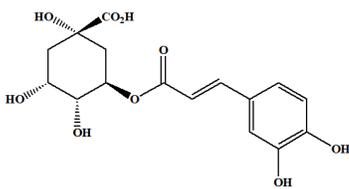
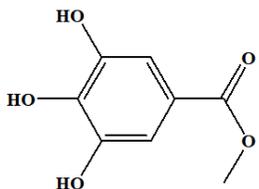
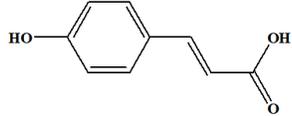
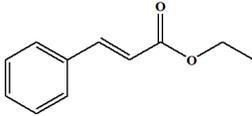
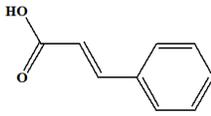
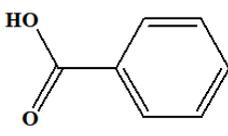
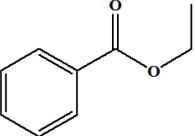
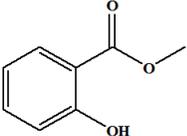
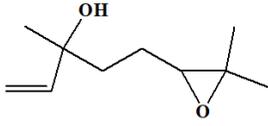
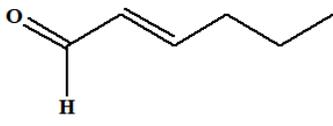
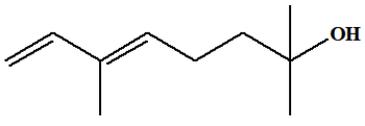
(i) Flavonoids	
	
Naringenin	Apigenin
(ii) Sterols	
	
Stigmasterol	Stigmast-4-en-3-one

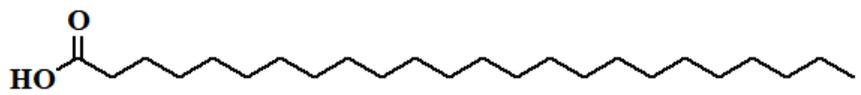
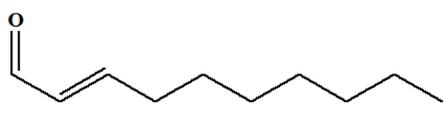
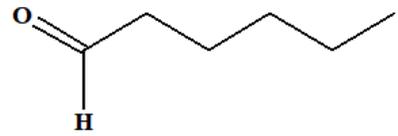
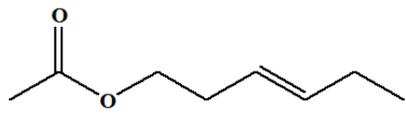
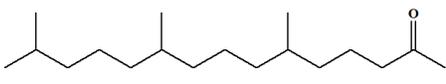
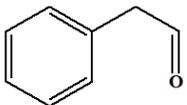
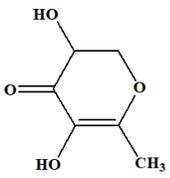
	
Cycloartane-24-methylene	Campesterol
	
Daucosterol	$\beta$ -Sitosterol

<b>(iii) Monoterpenes (acyclic)</b>			
			
Myrcene	(E)- $\beta$ -Ocimene	Linalool	
<b>(iv) Monocyclic Monoterpenes</b>			
			
<i>p</i> -Cymene	Limonene	$\alpha$ -Terpineol	$\gamma$ -Terpinene
			
$\gamma$ -Terpineol	Terpinen-4-ol		$\beta$ -Terpineol
<b>(v) Bicyclic Monoterpenes</b>			
			
$\alpha$ -Pinene	$\beta$ -pinene		Iso-cineole
			
3-Carene	Camphene	Isoborneol	2-Fenchanol

<b>(vi) Bicyclic Sesquiterpenes</b>		
		
Caryophyllene	$\beta$ -caryophyllene	$\gamma$ -Eudesmol
<b>(vii) Pentacyclic triterpenoids</b>		
		
$\beta$ -amyrin	Oleanic acid	Oleanolic acid
<b>(viii) Quinoline derivatives</b>		<b>(viii) Rose ketones</b>
		
7-hydroxy-6-methoxyquinoline-2(1H)-one		$\beta$ -(E)-Damascenone
<b>(x) Saccharides and their derivatives</b>		
		
3-O-Methylglucose	2,3-Di-O-methyl-D-glucose	2,3,6-Tri-O-methylglucose
		
1,2,3,6-tetra-O-methyl-D-glucose	2,3,4,6-Tetra-O-methyl glucose	Galacturonic acid
		
D-Galactose	D-Xylose	L-Arabinose

<b>(xi) Geraniin</b>			
			
Galloyl-geraniin			
<b>(xii) Amino acids</b>			
			
Leucine	Arginine	Cystine	
			
Glycine	Cysteine	Alanine	Serine
<b>(xiii) Carotenoids</b>			
			
$\beta$ -carotene			
<b>(xiv) Vitamins</b>			
			
Ascorbic acid	Thiamine	Riboflavin	Trolox (analog of vitamin E)

<b>(xv) Furan derivatives compounds</b>		
		
Furanoid	2-Furaldehyde diethyl acetal	Furfural
		
5-Methyl-2-furaldehyde	5-hydroxy methyl furfural	
<b>(xvi) Polyphenolic compounds</b>		
		
Gallic acid	Ellagic acid	
		
Chlorogenic acid	Methyl gallate	
<b>(xvii) Derivative of cinnamic acid</b>		
		
<i>p</i> -coumaric acid	Ethyl cinnamate	Cinnamic acid
<b>(xviii) Benzoic acid and its Derivative</b>		
		
Benzoic acid	Ethyl benzoate	Methyl salicylate
<b>(xix) Miscellaneous Compounds</b>		
		
(E)-Linalool oxide	2-Hexanal	Ocimenol

		
Lignoceric acid	Nonanal	
		
(E)-2-Decenal	Hexanal	(3E)-Hexenyl acetate
		
6,10,14-trimethyl-2-pentadecanone	Benzeneacetaldehyde	3,5-dihydroxy-2-methyl-5,6-dihydropyran-4-one,

## 10. Pharmacological Activities

*S. pinnata* is proved to be useful in treating various ailments of mankind. A number of pharmacological activities were reported from several extracts of *S. pinnata* and its parts that include hypoglycemic, anti-cancer, ulcer-protective, anti-microbial, hepatoprotective, thrombolytic, anti-inflammatory, antiarthritic, analgesic, antipyretic, antihypertensive, anthelmintic, diuretic and laxative, cytotoxic, antioxidant and anti-hyperlipidemic activity. The detailed reported pharmacological activities of *S. pinnata* are given in Table 13.

### 10.1 Hypoglycemic Activity

Diabetes is the foremost winning metabolic clutter, thereby Mondal *et al.*,<sup>64</sup> detailed the hypoglycemic activity of the various extracts of the barks of *S. pinnata* on adult Wistar albino rats at dose tiers of 300 mg/kg p.o., the usage of normoglycaemic, glucose loaded and alloxan induced hyperglycaemic rats. Among the extracts tested, the methanol extract has been found to produce promising effects this is akin to that of the reference widespread glibenclamide.

**Table 13.** Reported pharmacological activities of *Spondias pinnata*

Plant Parts	Pharmacological activities
Resin	Anti-microbial.
Fruit	Antidiarrhoeal, thrombolytic, anti-inflammatory, analgesic, antihypertensive, cytotoxic, antioxidant, anti-hyperlipidemic, anxiolytic, platelet aggregation inhibitory.
Fruit pulp	Hypoglycemic.
Bark	Hypoglycemic, anti-cancer, ulcer-protective, antidiarrhoeal, anti-microbial, anti-inflammatory, analgesic, antipyretic, anthelmintic, diuretic and laxative, cytotoxic, reduce side effects of chemotherapy, acute and sub-chronic toxicity.
Stem Bark	Anti-tuberculosis, antioxidant, ischemia reperfusion injury and preconditioning of heart, ameliorating.
Stem heart wood	Hepatoprotective, anthelmintic.
Leaf	Ulcer-protective, thrombolytic, anti-inflammatory, antioxidant, acute and sub-chronic toxicity.
Root	Hypoglycemic, antioxidant.
Whole plant	Antiarthritic.

Further, Acharyya *et al.*,<sup>65</sup> also documented hypoglycemic activity of chloroform, methanol and aqueous extracts of *S. mangifera* root at varying doses (100, 200 and 400 mg/kg, p.o.) on Wistar albino rats by way of following normoglycaemic study, glucose tolerance test and antihyperglycemic trial from which only methanol extract generated promising action.

Devi *et al.*,<sup>66</sup> additionally studied the hypoglycemic impact of *S. pinnata* fruit pulp ethanolic extract on experimental animal models. This research concludes potent hypoglycemic activity of ethanolic extract fruit pulp.

## 10.2 Anti-Cancer Activity

Recent study by Ghate *et al.*,<sup>67</sup> has been shown to have an anti-cancer activity on the bark of *S. pinnata*. Apoptosis in human lung adenocarcinoma cell line (A549) and human breast adenocarcinoma cell line (MCF-7) is promoted by 70% methanol extract of *S. pinnata* bark. It confirmed significant cytotoxicity to both A549 and MCF-7 cells with an IC<sub>50</sub> value of 147.84 and 149 µg/mL respectively. In addition, two isolated compounds (gallic acid and methyl gallate) showed promising cytotoxic activity with IC<sub>50</sub> value of 59.28 and 8.44 µg/ml, reported by Chaudhuri *et al.*,<sup>68</sup> respectively; Gallic acid induced cell death in HL-60RG cells with promyelocytic leukemia<sup>69</sup> and treatment with methyl gallate delayed tumor development in tumor-bearing animals and extended survival by inhibiting tumor infiltration of CD4<sup>+</sup> CD25<sup>+</sup> Treg cells.<sup>70</sup> Similarly Das *et al.*,<sup>71</sup> reported that the chloroform and ethanolic extracts of the bark were tested for anticancer activity by using brine shrimp lethality bioassay test. Ethanolic extract produced LC<sub>50</sub> and LC<sub>90</sub> as 65µg/ml and 160 µg/ml whereas chloroform extract produced LC<sub>50</sub> and LC<sub>90</sub> as 170 µg/ml and 325 µg/ml respectively. Major compounds obtained from ethyl acetate fraction of *S. pinnata* and their compounds were used for anticancer potential against U87 cells. Two compounds namely gallic acid and methyl gallate showed promising activities by spectroscopic methods. Methyl gallate induces an activation and apoptosis in human glioblastoma U87 sustained by extracellular signal-regulated kinase<sup>72</sup>.

## 10.3 Ulcer-Protective Activity

Arif *et al.*,<sup>59</sup> recorded that the *S. pinnata* bark methanolic extract had substantial ulcer-protective efficacy, the extract induced a dose-dependent inhibition of the indomethacin ulcer effect, reducing the ulcer index from 17.7 (control) to 8.7 and 6.7 for 100 and 200 mg/kg, p.o., respectively, resulting in a preventive ratio of 50.4 and 62.0, respectively. At the same time Mondal *et al.*,<sup>73</sup> stated

that in laboratory animal models the ethanol extract of the leaf also possesses ulcer defensive activities. The decline in ulcer index dose based on hard liquor induced ulcer and ulcer induced in the pylorus ligation. In the case of ulcer caused by pylorus ligation, there are reductions in the volume of gastric juice, free acidity, total acidity and pH changes in gastric content by the extract at a dosage of 100 and 200mg / kg, p.o.

## 10.4 Antidiarrhoeal Activity

The *S. pinnata* bark methanol extract has also been found to possess promising anti-diarrhoeal properties in adult Wistar rats against castor oil induced diarrhoea. The activity was measured against standard diphenoxylate hydrochloride (5mg/kg). After 1 hour of treatment the animals were orally treated with 1 ml of castor oil and examined for the quality of the faecal matter, the animals were treated with extract at doses of 100 and 200 mg/kg, p.o. The extract additionally inhibits intestinal agitation and hydro electrolytic secretion, which are prominent in diarrhoeal conditions and this extract is viable as it exemplifies the antidiarrhoeal effect because of the presence of the flavonoids<sup>59</sup>.

The *S. pinnata* fruit's aqueous extract also recorded in albino Wistar rats for anti-diarrhoeal activity. The aqueous extract was administered by using the oral path at a concentration of 100, 200 and 400 mg/kg, showing substantial dose-dependent anti-diarrheal activity in castor oil and magnesium sulphate induced diarrhea. The anti-diarrhoeal efficacy of the extract assessed was equivalent to that of the wellknown drug Loperamide<sup>74</sup>.

## 10.5 Anti-Microbial Activity

*S. pinnata* barks methanol and aqueous extracts develop *in-vitro* antibacterial activity by method of cup-plate diffusion at concentrations of 50, 100 and 150 mg against three Gram-negative bacteria. They used penicillin and streptomycin as standard drugs. The methanol extract also displayed beneficial antibacterial activity, while the aqueous extract displayed only moderate antibacterial activity against *E. coli*, *V. cholera*, and *S. typhimurium*<sup>59,75</sup>. The antimicrobial activity of *S. pinnata* resin has also been evaluated on *Saccharomyces cerevisiae*, *Bacillus subtilis*, *Escherichia coli*, *Enterobacter sakazakii* and *Acinetobacter baumannii*. Disc diffusion method and macrodilution assays were used to study *in-vitro* antimicrobial activities of the resin extracts. The most susceptible microorganism to the resin extract was found to be *B. Subtilis*. The extracts did not impede the growth of Gram (-) bacteria and *S. cerevisiae*<sup>76</sup>. *S. pinnata* was additionally observed to have anti-microbial activity against fish pathogens<sup>77</sup>. At the

same time ethanol and chloroform extract from the roots of *S. pinnata* also demonstrated promising antibacterial activity against *S. Typhi* and *V. cholera* while chloroform extract demonstrated an excellent antibacterial activity against *S. Typhi* and less activity against *S. aureus* and *V. cholerae*<sup>78-80</sup>.

## 10.6 Hepatoprotective Activity

Ethyl-acetate and methanol extract of *S. pinnata* stem heartwood has detailed hepatoprotective impact against carbon tetrachloride actuated rats. The hepatic damage levels were tested by applying several biochemical markers such as *Alanine transaminase* (ALT), *Aspartate Aminotransferase* (AST), *Alkaline phosphatase* (ALP), and bilirubin in both treated and untreated groups. Ethyl acetate extract administered orally at a dosage of 100, 200, 400 mg /kg decreases ALT, AST, ALP and complete bilirubin. This action has been compared as a standard drug against silymarin. This could be due to the presence of bioflavonoids which have hepatoprotective homes. Histopathological exam became also accomplished on CCl<sub>4</sub> intoxicated rats and revealed that normal hepatic structure became retained in rats treated with extracts<sup>81</sup>. At the same time, the administration of methanol extract of *S. pinnata* bark at doses of 50, 100 and 200 mg/kg reported a significant increase in antioxidant enzymes, together with dose-dependent lipid peroxidation inhibition, protein oxidation and liver fibrosis, in the meantime, the levels of serum enzyme markers and ferritin have been additionally decreased, suggesting that the extract is potentially beneficial as an iron chelating agent for iron overload sicknesses<sup>82</sup>. Chaudhuri *et al.*,<sup>83</sup> reported the isolation of two compounds (gallic acid and methyl gallate) from the fraction of ethyl acetate with an *in-vivo* study stated that compared to gallic acid, methyl gallate produced better iron chelating properties. It changed and proved that methyl gallate overcomes hepatic fibrosis through ameliorating oxidative strain and sequestering the stored iron in cells. The reported result also delineated that gallic acid (10 and 20 mg/kg) prevented sodium fluoride from causing abnormalities within the hepatic biochemical marker; these findings were similar to the reference drug silymarin (10 mg / kg)<sup>84</sup>.

## 10.7 Thrombolytic Activity

The exocarp of *S. pinnata* fruit delivered thrombolytic action. This was performed employing a strategy created by Dagainawala utilizing streptokinase as standard. The test showed that the exocarp of the fruit has factually critical thrombolytic action<sup>85</sup>. Ethanolic extract of *S. pinnata* produced marked inhibition of haemolysis<sup>86</sup>. The

fraction of ethyl acetate exercised the highest thrombolytic activity and stabilised membrane activity<sup>87</sup>. Concurrently *S. pinnata* leaf extract changed into additionally evaluated for thrombolytic interest by using streptokinase as trendy drug. Ethyl acetate soluble fraction produced highest percentage of clot lysis compared to streptokinase and aqueous extract<sup>88</sup>.

## 10.8 Anti-Inflammatory Activity

Ghate *et al.*,<sup>89</sup> reported that Quinoline SPE2 and 7-hydroxy-6-methoxyquinoline-2(1H)-one were isolated from ethyl acetate fraction of *S. pinnata* bark and the anti-inflammatory activity was performed in the lipopolysaccharide-stimulated murine macrophage model, indicating that Quinoline SPE2 has anti-inflammatory activity by inhibiting NF- $\kappa$ B activation. In addition, *S. pinnata* leaf extract was also mentioned for anti-inflammatory activity the usage of 2-acetoxybenzoic acid as a standard drug for activity comparison. Ethyl acetate soluble fractions considerably inhibits the haemolysis of human erythrocyte membrane every in induced by hypotonic solution and by heat respectively in comparison to 2-acetoxybenzoic acid<sup>88</sup>. Fruit peel extract of *S. pinnata* also produce sturdy anti-inflammatory activity with the aid of drastically inhibiting nitric oxide (NO) production prompted by means of lipopolysaccharide (LPS) in RAW 264.7 cell strains at 0.08% without an effect on cellular viability<sup>90</sup>.

## 10.9 Antiarthritic Activity

In some inflammatory processes the nitric oxide plays a dominant role. Bibhabasu *et al.*,<sup>91</sup> proved that the methanolic extract of *S. pinnata* prevents nitrite formation *in-vitro* by interacting directly with oxygen in the nitric oxide reaction. The consequences showed that the methanol extract IC<sub>50</sub> value was 716.32  $\mu$ g / ml, and reference well-known gallic acid was 876.24  $\mu$ g/ml. For *S. pinnata* and gallic acid the scavenging percentages were 22.3 and 15.8 respectively. This stated study proved that the extract exhibited stronger peroxy nitrite radical scavenging activity than the standard gallic acid.

## 10.10 Analgesic Activity

Panda *et al.*,<sup>92</sup> using acetic acid, formalin test, and hot plate model reported the analgesic activity of *S. pinnata* bark ethanolic extract. The extract produced dose dependant analgesic impact (50-100 mg/kg, p.o.). The crude methanolic fruit extract was also recorded for analgesic activity using acetic acid triggered writhing reflex method and formalin triggered licking method. On

the idea of consequences, the methanolic fruit extract had potent dose-dependent analgesic activity<sup>93</sup>.

### 10.11 Antipyretic Activity

Panda *et al.*,<sup>94</sup> tested the antipyretic activity of the *S. pinnata* bark ethanol extract (200 and 400 mg/kg, p.o.). The extract showed a substantial decrease in pyrexia that persisted for five hours after drug administration.

### 10.12 Antihypertensive Activity

The stated aqueous extract of *S. pinnata* fruit (20 µg/ml) produces *in-vitro* antihypertensive activity. Inhibitory behaviour of angiotensin-converting-enzyme (ACE) has been studied using ACE from rabbit and N-hippuryl-L-histidyl-L-leucine as a substrate. This confirmed the inhibition of ACE enzymes by 50%<sup>95</sup>.

### 10.13 Anthelmintic Activity

The suggested ethanolic and acetone extracts of *S. pinnata* bark confirmed promising anthelmintic activity. Kumar *et al.*,<sup>96</sup> also demonstrated that the ethanol extract with a concentration range of 50 and 100 mg/ml exhibited extra amazing activity than the acetone extract. Mondal *et al.*,<sup>97</sup> tested anthelmintic activity of chloroform extract of the bark (10, 15, and 20 mg/ml) and showed promising outcomes in opposition to Indian earthworms. Similarly, on *Pheretima posthuma*, methanolic extract from stem heartwood and bark of *S. pinnata* was tested for *in-vitro* anthelmintic activity. Stem-heartwood methanolic extract was more potent than the bark extract<sup>32</sup>.

### 10.14 Diuretic and Laxative Activity

Mondal *et al.*,<sup>98</sup> argued that the administration of methanol and chloroform extracts of *S. pinnata* bark (300 mg/kg) to Wister albino rats developed substantial diuretic and laxative activity compared to the reference requirements for furosemide and agar.

### 10.15 Anti-Tuberculosis Activity

According to Gupta *et al.*,<sup>99</sup> the anti-tuberculosis activity has been documented using proportion process. Chloroform and ethanol extracts of *S. pinnata* stem bark were added separately into Lowestei-Jensen (L-J) medium in a serial concentration of extract of 1, 10 and 100mg/mL. In the control group only 1% dimethyl sulfoxide was applied. *Mycobacterium tuberculosis* was inoculated and incubated in 5% CO<sub>2</sub> incubator at 37°C for 6 weeks. Colonial growth was observed from 3<sup>rd</sup> to 6<sup>th</sup> week after inoculation on L-J medium. The results suggested that increased concentration of chloroform and ethanol extract

on the medium, results in increased growth inhibition of *M. tuberculosis*<sup>100</sup>.

### 10.16 Cytotoxic Activity

The documented cytotoxic activity of the ethanol extract from *S. pinnata* fruit was determined by the lethality test of Brine shrimp. Use vincristine sulphate as standard, DMSO solutions of ethanolic extract were applied against *Artemia salina* in a one-day *in-vivo* study. After 24 hours of exposure the extract's lethality was determined. The cytotoxicity of ethanol crude extract was found to be significant; LC<sub>50</sub> values were found to be 2.12 µg/mL for crude ethanol extract and 0.32 µg/mL for vincristine sulphate.<sup>56</sup> In addition, Nikhil *et al.*,<sup>101</sup> stated the role of methanol extract of the bark in promoting apoptosis in human lung adenocarcinoma cell line (A549) and human breast adenocarcinoma cell line (MCF-7). This study proved the methanolic extract's anticancer potential against human lung and breast cancer by inducing apoptosis by modulating the Bcl-2 family proteins.

### 10.17 Antioxidant Activity

The free radical scavenging potential by using DPPH method of methanol and aqueous extracts of *S. pinnata* root showed dose dependant effect upto 250 µg/ml<sup>102</sup>. Similarly, methanolic extract of *S. pinnata* fruit also produced promising scavenging effect on ABTS free radical by using standard as Trolox. This activity was mentioned as a percentage with IC<sub>50</sub> and Trolox Equivalent Antioxidant Capacity (TEAC). The IC<sub>50</sub> value showed by Trolox is 10.14 and TEAC is 1.0 whereas fruit extract reported IC<sub>50</sub> was 3769.18 and TEAC is 0.004<sup>60</sup>. Simultaneously, stem bark methanolic extract also possess antioxidant activity using various *in-vitro* models which showed the TEAC value of 0.78±0.02. Increase in reducing power was proportional directly to the amount of extract<sup>91</sup>. The antioxidant activity (*In-vitro*) of hexane, ethanol and ethyl acetate extracts of *S. pinnata* dried leaves were evaluated using multiple models. The results showed that ethanol extract produced high scavenging activity whereas ethyl acetate and hexane extract produced medium and poor scavenging activity. The reducing power was increased in the manner of dose dependent in all the cases<sup>45</sup>. The ethanol fraction of *S. pinnata* dried fruit produced antioxidant activity using modified DPPH assay method. The results indicated scavenging activity with an IC<sub>50</sub> value 48.0 µg/ml. The increasing concentration of sample promoted the *in-vitro* antioxidant activity<sup>103,104</sup>.

### 10.18 Anti-Hyperlipidemic Activity

Raju *et al.*,<sup>105</sup> pronounced anti-hyperlipidemic activity of *S. pinnata* fruits methanolic extract against Triton induced hyperlipidemia in rats. Fenofibrate was used as reference well-known. It was concluded from this analysis that 100 and 200 mg/kg, p.o., extract was successful decreased cholesterol, PL, TG, VLDL, LDL and HDL level in dose-dependent manner.

### 10.19 Ischemia Reperfusion Injury and Preconditioning of Heart

The impact of *Spondias pinnata* stem bark ethanolic extract (100 mg/kg or 200 mg/kg) was once located on ischemia reperfusion injury and ischemic preconditioning of heart. The extract decreased ischemia reperfusion triggered myocardial damage however does not accelerate cardio shielding effect of ischemic preconditioning<sup>106</sup>.

### 10.20 Anxiolytic activity

Jannatun *et al.*,<sup>107</sup> reported anxiolytic activity of *S. pinnata* fruit methanolic crude extract using hole board test method and elevated plus maze test method in mice. The diazepam was utilised as a standard. The results of the methanolic extract of *S. pinnata* fruit showed an increase of head dipping and time spent in open arms in mice which exhibits a significant effect of anxiolytic activity.

### 10.21 Reduce Side Effects of Chemotherapy

Beena *et al.*,<sup>108</sup> exposed rats with etoposide and studied their protective effects using different doses of *Spondias pinnata* bark extracts. Levels of alanine and aspartate aminotransferases had been decided the use of semi-auto analyser and Reduced Glutathione, Glutathione-S-Transferase, overall antioxidants and Lipid peroxidation using spectrophotometry. Variations in parameters were found between control, chemotherapy and *S. pinnata* groups. Reported findings showed substantial increase in levels of Thiobarbituric acid reactive substances that could be recovered via *S. pinnata* therapy. Sudarshan *et al.*,<sup>109</sup> showed that histopathological studies of *S. pinnata* bark extract intervention was able to repair the regular morphology and intestinal sodium potassium ATPase activity.

### 10.22 Ameliorating Effect

Hazra *et al.*,<sup>82</sup> decided iron overloaded liver damage using 70% methanol extract of *S. pinnata* (SPME) stem bark. Swiss albino mice were administered iron-dextran through intraperitoneal route that outcomes liver damage manifested by using growth in serum enzyme markers

and reduction in liver antioxidants. The extract was administered *via* oral direction at extraordinary doses. Extract produced a dose dependant inhibition of lipid peroxidation, protein oxidation, and liver fibrosis and so on. The liver iron content material becomes observed to be less in SPME induced group as compared to control group.

### 10.23 Platelet Aggregation Inhibitory Activity

Sivaprasad *et al.*,<sup>110</sup> evaluated *S. pinnata* fruit ethyl acetate and methanol extracts for inhibitory activity in platelet aggregation. Ethyl acetate extract demonstrated activity for antagonists including collagen and ADP with an IC<sub>50</sub> value of 0.33 mg and 0.43 mg, respectively. Methanol extract produced high activity for antagonists such as collagen and ADP, with low IC<sub>50</sub> values of 0.26 mg and 0.35 mg respectively<sup>111</sup>.

### 10.24 Acute and Sub-Chronic Toxicity

Attanayake *et al.*,<sup>112</sup> pronounced that no mortality or morbidity was observed in rats for the 14-day duration following single oral administration of the selected doses (0.25–2.00g/kg, p.o.) of the *S. pinnata* bark aqueous extract. Similarly, the daily administration of 1.00g/kg, p.o., plant extract to Wistar rats for 30 days determined sub-chronic toxicity. The extract in healthy rats produces no marked changes in food consumption and water intake, as well as biological parameters, hematological parameters and histopathology. The results indicate that toxicologically safe aqueous extract of the *S. pinnata* bark.

Mondal *et al.*,<sup>64</sup> additionally examined the acute in-vivo toxicity of chloroform, methanol, and aqueous extracts of *Spondias pinnata* bark upto 3000 mg/kg, p.o., of the extracts and it was found that the chloroform and methanol extract initiated sedation, diuresis, and purgation at all tried measurements. Nevertheless, by the end of the evaluation period there was no mortality in any of the extracts at the doses assessed.

Further Kumar and Sastry<sup>113</sup> completed acute toxicity of ethanolic extract of *S. pinnata* leaf that was found to be safe at 2000 mg/kg dose frame weight orally as per OECD guidelines No. 423. In continual toxicity studies, the extract was orally administered at doses 100, 200 and 400 mg/kg as soon as in a week for six weeks. After six weeks, biochemical and hematological parameters were determined. No toxicity or deaths were observed in acute toxicity study. No massive remedy related changes inside the tiers of renal, hepatic and haematological parameters were observed after the end of chronic toxicity study. It

can be concluded that the ethanolic extract of *S. pinnata* leaf does not seem to have tremendous toxicity profile.

## 11. Conclusion

Several parts of *S. pinnata* extracts contain a wide variety of phytoconstituents that belongs to amino acids, carbohydrates, terpenoids, flavonoids, polysaccharides, steroids, and others out of which few chemical constituents were identified and structures were determined. These substances are responsible for various pharmacological activities that include hypoglycemic, anti-cancer, ulcer-protective, antidiarrhoeal, anti-microbial, hepatoprotective, thrombolytic, anti-inflammatory, antiarthritic, analgesic, antipyretic, antihypertensive, anthelmintic, diuretic and laxative, anti-tuberculosis, cytotoxic, antioxidant, anti-hyperlipidemic, ischemia reperfusion injury and preconditioning of heart, anxiolytic, reduce side effects of chemotherapy, ameliorating, platelet aggregation inhibitory activity and acute and sub-chronic toxicity. Various solvent extract and their gas chromatography-mass spectrometry analysis have confirmed the structures of some important phytoconstituents. This review mainly focused on pharmacological and phytochemical studies that have explained therapeutic potential and phytoconstituents of *S. pinnata* which needs further research work for identification of phytoconstituents and their structures.

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## 14. Conflicts of Interest

The authors claim no conflicts of interest.

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