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A review of geographical distribution, phytochemistry, biological properties and potential applications of *Pongamia pinatta*

Farwa Nadeem[1]*, Summayia Inam[1], Umer Rashid[2], Rabia Kainat[3] and Azhar Iftikhar[1]

[1]Department of Chemistry, University of Agriculture, Faisalabad-38040-Pakistan, [2]Institute of Advanced Technology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia and [3]Department of Biochemistry, University of Agriculture, Faisalabad-38040-Pakistan

Abstract

Pongamia pinatta is a normal sized deciduous or evergreen plant, glabrous shrub and a tree with approximate height ranging from 15 to 25 meters having 50 to 80 centimeters crooked trunk with drooping branches and a broad spreading crown. *Pongamia pinnata* is a fast growing leguminous tree that is capable of high seed production and enormous plant growth thus known to have several pharmaceutical applications and traditional uses in number of customary medicines for treatment of different diseases. It contains distinctive phytoconstituents having a place with class flavonoids and fixed oils. In conventional system of medicines, this plant is preferably used to treat inflammation, diarrhea and hostile to plasmodial, hostile to nonciceptive, hostile to hyperglycaemics, hostile to lipidoxidative, hostile to ulcer, against hyperammonic and cancer prevention agent. *Pongamia pinatta* is also known as diesel tree as it is the second most abundant waste material on earth that possesses enough potential to produce high quality biodiesel from second generation feedstock. Potential pharmacological activities of this plant include anti-hyperglycemic, anti-inflammatory, anti-plasmodial, anti-oxidant, anti-hyperammonemic, anti-diarrhoeal, anti-ulcer and anti-lipid peroxidative activities.

Key words: Diesel tree, phytoconstituents, anti-hyperglycemic, anti-inflammatory, anti-oxidant, anti-hyperammonemic, anti-diarrhoeal, anti-ulcer, anti-lipid peroxidative activity

Full length article **Corresponding Author*, e-mail: farwa668@gmail.com

1. Introduction

The *Pongamia pinatta* is a normal sized deciduous or evergreen plant, glabrous shrub and a tree with approximate height ranging from 15 to 25 meters having 50 to 80 centimeters crooked trunk with drooping branches and a broad spreading crown. Bark of this plant is vertically fissured, smooth and grey brown in colour while branchlets are quite hairy, bearing stipule scars. Leaves are imparipinnate and alternate in arrangement with pinkish red to dark green hairless leafstalk and a prominent arrangement of veins on maturity. Five to nine paired leaflets are found at the end of short stalk with oblong or ovate elliptical shape having obtuse apex, rounded base and slightly thickened toothed edges. Raceme like inflorescence contains many pairs of fragrant flowers on 6 to 27 centimeters long axile. Campanulate calyx is finely pubescent and truncate with 4 to 5 millimeters length. Cluster of flowers is found at shorter base that is drooping and slender with 15 centimeters in length. Generally, two or four flowers are found together on pea shaped stalk with approximate length ranging from 15 to 18 millimeters. Corolla of this flower is pink to purple in colour from inside and brown in shade from outside with oblong wings, silky hairs and basal auricles [1].

The pods of *Pongamia pinatta* are smooth in texture with oblique to ellipsoid shape and approximate dimensions of 3-8×2-3.5×1-1.5 cm. Seeds pods are usually flat but are sometimes slightly curved, swollen and pointed having thick walled, brown, hard, leathery and indehiscent seeded short stalk. Seeds of this plant are usually elliptical to ovoid in shape just like bean with 1.5-2.5×1.2-2×0.8 cm seed dimension having oily, dark brown and flattened seed coat. The *Pongamia pinatta* is native to humid sub-tropical climatic zones and generally grows along seashore and waterways with roots deeply immersed in saltwater or freshwater. It can tolerate the harsh saline conditions and naturally found on rocky corals and limestone in lowland forest all along rivers/streams and along forest mangrove. *Pongamia pinatta* is a shady tree that prefers to grow under shady trees nevertheless shade is not an ultimate requirement for proper growth as it can be grown with full over-headed light. It can resist the prolonged drought conditions and is known to be adapted to severe climatic

conditions along with fluctuating soil moisture. Nevertheless, small seedlings are adversely affected by long-term drought. Mature tree of the *Pongamia pinatta* can withstand high temperature (approximately 50°C), severe water logging and withstand light frost [2].

There are various opinions regarding to the usefulness of karanja as fodder, as its value is supposed to be maximum mainly in arid regions. Its leaves are readily consumed by cattle more specifically goats nevertheless this practice is not very common. Leaves are known to constitute 62% neutral detergent fibre, 18% crude proteins, 43% dry matter and approximately 50% dry matter digestibility. Seed residues or pressed cake obtained after extraction of oil is bitter in taste and found to be unfit to be used as animal feed alone. It has high protein contents but possesses numerous toxic effects because of high tannins, pongamol and karanjin contents. Therefore, it can only be used for short term as a substitute of many other protein sources but never allows 75% or more replacements. The floral part of karanja is considered to be an excellent source for honeybee pollen in India as they yield considerably high concentration of nectar. *Pongamia pinatta* is used as a fuel wood with approximate calorific value of 4,600 kcal per kg. Seed oil was initially used as indispensable source of lightening of lamp but now has been replaced by kerosene oil. Fibre of bark is converted into ropes and strings while wood provides sufficient amount of paper pulp. Colour of wood greatly varies in between white to yellowish grey without any distinction of heartwood having beautifully grained to coarse texture [3].

The wood of *Pongamia pinatta* is a moderately strong timber which can easily be sawed, turned and finished into final products nevertheless its wood is not of best quality as it lacks the durability and tends to be de-shaped when attacked by wood insects. However, generally this wood is used to make comb, tool handles, agricultural implements, posts, cartwheels and cabinet. The "pinnatin" is naturally synthesized by root of *Pongamia pinatta* that was first time synthesized in 1967 while wood ash is used to dye various substances. Seed oil of karanja is used for dressing the leather in tanning industry that is why huge amount of karanja seeds are annually collected in India for commercial scale implementations. Recently, it has been found that the karanja seeds constitutes 27% to 40% yellowish to reddish brown oil that is mainly used for production of the biodiesel. The amount of extracted oil generally varies from 13.4% to 26.97% while changing the feedstock from seed pods to seed kernels. The taste of oil is quite bitter with disagreeable aroma and specific gravity of about 0.9371 at 15°C. It is also used in soap making and as binder of paint and water along with extensive applications in varnishes and lubricants. It is among few natural nitrogen fixing trees which contains significant amount of oil containing seeds. The seed cake when added to soil helps to act as pesticide against nematodes [3].

Dried leaves of this plant are preferably stored in rural areas along with grains in order to repel the insects. Roasted and pounded seeds are mostly used as a fish poison while seed oil is usually rubbed as a liniment on rheumatic parts and skin diseases. It can also be used to treat the sluggish liver, cholagogue dyspepsia and severe stomach infections. The powdered seeds of this plant act as an effective expectorant in whooping cough and bronchitis and sometimes also used as tonic and ferbifuge. Paste of seeds proves to be effective when applied on rheumatic parts and dermal sores. Leave's infusion is commonly used to get rid-off rheumatism while decoction is an excellent remedy for cough. The extracted juice of plant material has traditionally been used for skin itches, herpes and various parasitic diseases. Floral part is known to have the anti-diabetic effects whereas fresh bark decreases spleen enlargement. Young leaves of *Pongamia pinatta* acts as an astringent when taken orally and helps to relieve internal bleeding and heamorrhoids. Bark of the root constitutes slightly bitter alkaloids and is utilized as abortifacient. Root juice is fully antiseptic in nature and proves to be beneficial when used for ulcers and sores and also used to clean the teeth [3].

It is generally used as host for various hemi-parasitic organisms commonly called "sandal wood" and scientifically named as "*Santalum album* L." which can also be used as sand and soil binders due to their extensive lateral root formations. It has generally been observed that grasses grow in shade just beneath larger trees where pastures came into emergence. The diesel tree that is scientifically named as "*Pongamia pinatta*" is intentionally grown as wind breaker in order to ensure the tea plantation in various regions of the world as it can bear moderate salinity level. Pongamia tree proves to be an ideal candidate to recover numerous wastelands strongly affected by high level of salinity and also helps in marginal land's reforestation. Process of nodulation is also evident in pongam as it fields and nurseries the nodule's existence on uninoculated seedling of pongam. That is why this kind of specie is not truly specific in requirements of its Rhizobium strains. It possesses enough potential to fix atmospheric nitrogen through root nodules and with rhizobium. The successful incorporation of pressed cake and leaves of *Pongamia pinatta* tremendously increases soil fertility while decomposed flowers are highly valued in tropical areas having high nutrient availability for plants. This plant is mostly planted as ornamental tree along canal banks, streams, roadsides and in avenue plantings. Nevertheless, huge quantities of the pods, leaves and flowers make it least attractive ornamental plant [3].

Seeds of *Pongamia Pinnatta* are known to have large number of commercially important fatty acids that are economically viable and practically approachable for biodiesel production. The major reported fatty acids in *Pongamia pinnata* crude oil are palmic acid, stearic acid, linoleic acid and ecosenoic acid. Therefore, this oil extracts

exhibited good physical properties and chemical characteristics that make it useful to be used as a biodiesel feedstock and for other industrial applications. The main way of reducing the biodiesel production costs is to use less expensive feedstock containing high contents of fatty acids. Percentage composition of crude oil of *Pongamia Pinnatta* indicates that it constitutes 11.65 percent palmitic acid ($C_{16}H_{32}O_2$) [$CH_3(CH_2)_{14}COOH$], 7.50 percent stearic acid ($C_{18}H_{36}O_2$) [$CH_3(CH_2)_{16}COOH$], 51.59 percent oleic acid ($C_{18}H_{34}O_2$) [$CH_3(CH_2)_{14}(CH{=}CH)COOH$], 16.64 percent linoleic acid [$CH_3(CH_2)_{12}(CH{=}CH)_2COOH$], 1.35 percent eicosanoic acid ($C_{20}H_{40}O_2$) [$CH_3(CH_2)_{18}COOH$], 4.45 percent dosocasnoic acid ($C_{22}H_{44}O_2$) [$CH_3(CH_2)_{20}COOH$] and 1.09 percent tetracosanoic acid ($C_{24}H_{48}O_2$) [$CH_3(CH_2)_{22}COOH$] respectively [4].

The chemical composition of fats and oils indicates that they constitutes triglycerides having long chain fatty acids three in number chemically bonded with glycerol via ester linkage. These fats vary in length and number of carbon chains along with the position and orientation of double bonds inside the chain. Therefore, biodiesel is generally refer to as "lower alkyl esters of relatively long chain saturated/unsaturated fatty acids" that can preferably be synthesized either through esterification of fatty acids or via transesterification along with lower alcohols. Several plant oils mainly constitutes high contents of impurities, odorants, moisture, sterols, free fatty acids and phospholipids due to which plant oil cannot be directly used as a source of fuel. Hence, oil requires various chemical modifications in order to maintain optimum fuel qualities either by emulsification and pyrolysis or through simplest and most common transesterification process. The alcoholysis or transesterification deals with the displacement of an alcohol from ester by a well-known process called "hydrolysis" with the mare exception that alcohol is used in place of water. Such types of processes are mainly used for reduction of viscosities in triglycerides. The basic process behind catalytic transesterification is shown in the equation 1.

$$RCOOR^1_{(Ester)} + R^2OH_{(Alcohol)} \rightleftharpoons RCOOR^2_{(Ester)} + R^1OH_{(Alcohol)} \quad (eq.1)$$

If the process of transesterification is carried out by using methanol as major reactant then this entire process is termed as "methanolysis". Methanolysis of triglyceride is shown in the Fig. 1.

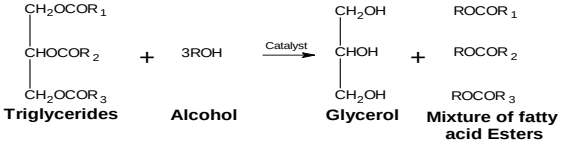

Fig 1 Methanolysis of Triglycerides

The process of transesterification is reversible in nature that essentially proceeds thorough the mixing of reactants. Nevertheless, strong catalyst accelerates the conversion and overall rate of chemical reaction. Fatty acid alkyl esters are produced by transesterification of triglycerides along with production of glycerol as byproduct which settles down at the bottom of separatory funnel. Monoglycerides and diglycerides act as intermediate in this reaction and the mechanism of transesterification is described in equation 1, 2 and 3 [5].

$$Triglyceride + R^1OH \rightleftharpoons Diglyceride + RCOOR^1 \quad (eq.2)$$

$$Diglyceride + R^1OH \rightleftharpoons Monoglyceride + RCOOR^1 \quad (eq.3)$$

$$Monoglyceride + R^1OH \rightleftharpoons Glycerol + RCOOR^1 \quad (eq.4)$$

2. Botanical Description

Pongamia pinnata is a medium-sized evergreen or quickly deciduous, glabrous shrub or tree that is 15-25 m high with straight or warped trunk of about 50-80 cm or more in distance across and wide crown of spreading or hanging branches. Bark is dim and dark colored, smooth or faintly vertically fissured. Branchlets are bald with pale stipule scars. Leaves are interchange, imparipinnate with long thin leafstalk, bare, pinkish-red when youthful, polished dim green above and dull green with conspicuous veins underneath when adult. Leaflets are 5-9 in number and matched at the end with slight exceptions, short stalked, praise circular or elliptical, heartless taper at summit, adjusted to cuneate at base, not toothed at the edges and marginally thickened. Inflorescence is raceme-like, axillary, 6-27 cm long, bearing sets of emphatically fragrant blossoms; calyx campanulate, 4-5 mm long, truncate and finely pubescent. Blossom bunches at base are shorter than leaves and are about 15 cm long, slim and hanging. Blossoms are 2-4 in number and usually found together, short-stalked, pea-molded and are 15-18 mm long. Calyx is campanulate, 4-5 mm long, truncate, finely pubescent; corolla white to pink, purple inside, tanish veined outside, 5-toothed, standard adjusted obovate 1-2 cm long, with basal auricles, regularly with green focal smear and meager satiny hairs on back; wings elongated and slightly adherent to thick bottom [6].

3. Geographical Distribution

This plant is found native to Myanmar, India, Bangladesh, Thailand and Nepal. Some exotic areas for the proper cultivation of this plant include Australia, Egypt, Indonesia, Fiji, China, Japan, Mauritius, Malaysia, Pakistan, New Zealand, Papua, New Guinea, Samoa, Solomon Island, Philippines, Seychelles, Sudan, Sri Lanka, Tonga and United States of America. Biophysical limits for the efficient growth of this plant are: altitude of about 0-1200 m, mean yearly temperature of about 1-16 to 27-50°C and mean yearly precipitation is 500-2500 mm. Soil type this is supposed to be the best for the growth of *Pongamia pinnata* is well-depleted sandy loams with certain dampness, yet it develops on the sandy soils and substantial swelling mud soils. It doesn't do well on dry sands, in spite of the fact that it endures saline conditions, high alkalinity and waterlogged soils [6].

4. Preferred Habitat and Climate

Pongamia pinatta selects moist tropical and subtropical climates. Nevertheless, it can bear a variety of

situations with mean yearly precipitation of 500-2500 mm and temperatures of 0-16°C minimum and 27-50°C maximum. Established trees can manage with light frosts but need a dry period of 2-6 months only [7]. *Pongamia pinatta* can bear extensive varieties of soils as well as saline, sandy, alkaline, heavy clay and rocky soils (including oolitic limestone) and waterlogged soils. Nevertheless, Orwa *et al*. (2009) recommend that it performs best in deep, well-drained, sandy loams with adequate amount of moisture. It does not produce well in very dry sands. *Pongamia pinatta* can even be developed at altitudes from sea level to nearly 1200 m. It has been defined as a "maritime species" meanwhile it tends to happen naturally along coasts and riverbanks in Bangladesh, Burma and India [8]. In Australia, it displays a preference for coastal parts and waterways.

4.1 Adaptation and Growth

Pongamia pinatta is highly adaptive plant but only shows adaptation to numerous soil types and saline/alkaline conditions and not to dry sand and is observed as a drought tolerant species.

4.2 Soil

Pongamia pinatta can grow on most soil types ranging from stony to sandy and sandy to clayey, including vertisols. It does not do well on dry sands. It is extremely tolerant to salinity. It is commonly and laterally grown on waterways or seashores, with its roots in fresh or salt water. Maximum growth rates are detected on well drained soils with certain level of moisture [2].

4.3 Salinity and Sodicity

Evaluation of *Pongamia pinnata* seedlings for salinity tolerance using pot culture method [9], irrigation with saline water and field studies have been recently reported. The application of gypsum (1.25 t/ha) has proved to be very effective for growth in existence and development of many tree species in saline sodic soil (pH 9–10), but only reasonable gains were verified for *Pongamia pinnata*. The most appropriate time of planting *Pongamia pinnata* in sodic soils was the post-monsoon season, followed by the pre-monsoon. Planting during the monsoon was not favorable for problem soils with a high moisture contents.

4.4 Water Logged Soils

In spite of the fact that most broad aggregations archive that *Pongamia pinnata* is tolerant to water logging, restricted research reports are accessible to help this declaration. Specialists have studied in detail that the system of tolerance of *Pongamia pinnata* to water logged and other issued soils is through the improvement of an expanded horizontal root spread rather than the ordinary profound tap roots. This was finished up depending on an investigation of eight leguminous trees on saline/antacid soils, subject to the water signing in the rainy season situated in Uttar Pradesh, India. According to an estimate, approximately 17–19 years old trees of *Pongamia pinnata* grew great shallow root frameworks with most extreme length of the sidelong roots (9.10 m) among the eight species incorporated into this study [2].

4.5 Climate

Native to moist and subtropical situations, *Pongamia pinnata* flourishes in zones having a yearly precipitation running from 500 to 2500 mm. In its common environment, the highest temperature ranges from 27 to 38°C and the base temperature usually varies from 1 to 16°C. Developed trees can withstand waterlogging and slight icing. This species can attain the height of 1200 m however in lower regions of Himalayan it is not found over 600 m. Shade had an unfavorable effect on the exhibition of seedlings. Shaded saplings demonstrated reduction in root and shoot development and biomass generation. Net photosynthetic rate also declined in shade developed plants, while leaf number and area expanded. Among all essential phytoconstituents, chlorophyll and carotenoid contents were found to be more in shade developed plants while the chlorophyll a and chlorophyll b proportion was lower in shade developed plants than in sun developed plants. Total protein contents, total lipid contents, total sugar contents and overall calorific value were higher in sun developed plants as compare to counterparts. In vivo nitrate reductase and ribulose-bis-phosphate carboxylase activities were low in shady plants [2].

5. Air Pollution

Among the top ten species assessed for the impact of the mechanical gas (Cl_2 and HCl) contamination exuding from newsprint processes in Madhya Pradesh, India, four-year-old plants of *Pongamia pinnata* were found to be less influenced in comparison with different species. Plantations were watered month to month for the initial three years and trees achieved suitable development, yet mortality was seen when water system was finished. No mortality happened in the region far from the plant site. The consequences of the study propose that the plants were increasingly helpless to contaminations when there was a lack of water [2].

6. Physicochemical Properties of Fatty Oil

As we know the fresh removed raw petroleum is yellowish red/brown and it get obscured during the capacity. The oil of *Pongamia pinatta* is known to have obnoxious scent and harsh taste. The dissolvable extraction strategy gives great quality oil than conventional extraction techniques. According to the Kriakidis, the iodine value is an estimation of the unsaturation of fats and oils. Higher iodine value demonstrated that higher unsaturation is found in fats and oils [10]. All properties are shown in table 1 and are compared according to American Standards' For Testing and Material (ASTM).

6.1 Fatty Acid Composition of Crude Oil

The percentage composition of fatty acids present in *Pongamia pinnata* crude oil is shown in table 2.

6.2 The Diesel Tree

The most significant attribute impacting general commercial achievement of *Pongamia pinnata* as a

promising vitality is its high seed yield combined with high oil content. Furthermore these parameters such as oil quality ought to get considerable attention owing to increasingly productive qualities for biodiesel gauges adding to the general adequacy of biofuels. Critically, the fruitful reception of biodiesel is dependent on the supply of feedstock from non-nourishment crops with the ability to develop on minimal land and not bound to be utilized for development of food crops. *Pongamia pinnata* is a solid contender to contribute significant measures of fuel feedstock, meeting both of these criteria. The seeds of *Pongamia pinnata* contain 30-40% oil, which can be changed over to fatty acid methyl esters by transesterification with methanol within the sight of KOH. The role of *Pongamia pinatta* as a feedstock for biodiesel production was very much characterized and affirmed. Usually the oils of *Pongamia pinatta* are tri-esters of the tri-liquor and glycerol that is known as "triglycerides". In any case, the immediate utilization of Pongamia oils as well as mixes is commonly viewed as inadmissible for diesel motors. The reason is high thickness; free unsaturated fatty acid content just as gum development because of oxidation and polymerization during capacity and ignition. Carbon stores and greasing up oil thickening are some different evident issues.

To defeat these disadvantages, impressive exertion has gone into creating vegetable oils subsidiaries that shows its properties and execution of oil based diesel powers. A portion of the procedures that have been examined are pyrolysis, small scale emulsification and catalytic transesterification. Attempts have been made for the transformation of Karanja oil to unsaturated fatty acid methyl esters [12]. It has explored the ideal response conditions to build the yield of methyl esters by transesterification of Karanja oil with methanol. The response parameters, for example, catalyst concentration, alcohol/oil molar proportion, temperature and rate of blending were enhanced for the yield of Karanja oil methyl esters (KOME). Azam *et al*. (2005) revealed that fatty acid methyl esters (FAMEs) of the oil of *Pongamia pinnata* was discovered most appropriately for use as a biodiesel since it meets the real determination of biodiesel measures of the USA, Germany and European Standard Organization. Broad of studies have demonstrated that triglycerides of *Pongamia pinatta* hold guarantee as alternative diesel motor fuels [13-15].

The studies by Vivek and Gupta (2004) discovered the extreme production of FAMEs up to 89% with molar ratio of MeOH per oil 8-10, KOH 1.5% w/w of oil as catalyst when the reaction was directed for 40 min at 68-70°C. Karmee and Chadha (2005) informed that change of crude Pongamia oil to biodiesel is 92% at 60°C with 1:10 molar ratio (oil: methanol) for KOH (1% w/w) catalyzed transesterification. However Meher *et al*. (2006) proved that the production of FAMEs from Karanja oil is 97-98% under the optimum condition of 1% KOH as catalyst, MeOH/oil molar ratio 6:1, reaction temperature 65°C and rate of mixing 360 rpm for a period of 3 hours [16]. Catalytic production of biodiesel from karanja seed oil is shown in table 3.

6.3 Phytochemistry

Six composites including two sterols, three sterol derivatives and one disaccharide, composed of eight fatty acids where three are saturated and five are unsaturated in nature that have been separated from the seeds of *Pongamia pinnata*. Their shapes were illuminated with the support of physiochemical processes and spectroscopic methods. The metabolites such as stigma sterol and its galactoside, β-sitosteryl acetate and galactoside and sucrose are being described for the first time from this plant. The unsaturated and saturated fatty acids include two monoenoic, one dienoic and two trienoic acids which were found in precisely the similar quantity. Oleic acid is found in maximum amount approximately 44.24%, palmitic acids 18.58% and stearic acids 29.64%. The octadecatrienoic and hiragonic acids were found in trace quantities as only 0.88% was found to be evident. Kanjone, pinnatin, pongagalabrone, pongapin, pongamol and karangin have been separated and categorized from seeds. Juvenile seeds comprise a flavone byproducts "pongol". Some additional flavonoids separated from the seeds constitute "glabrachalcone iso-pongachromene". The stem and leaves of the plant involve a numerous chalcone and flavone byproducts for example pongagallone A and B, pongalabol, pongone and galbone [18].

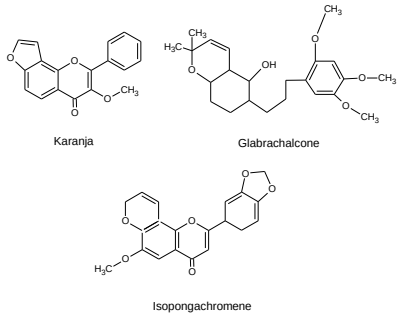

Fig 2 Important chemical constituents of *Pongamia pinatta*

Chemical examination of stems of the mangrove plant such as *Pongamia pinnata*, followed in separation and categorization of five structurally extraordinary flavonoids pongamones A-E, along with sixteen identified flavonoid metabolites. Their structures were found on fundamental basis of spectroscopic studies and also by contrast of their spectroscopic data with those of connected compounds testified in the literature. The Pongamones A-E was assayed compared to DHBV RCs DNAP and HIV-1 RT in vitro. The likely biogenetic pathway of solitary composites are also projected [18][19].

More study of flavonoid ingredients of *Pongamia pinnata* from Japan bring about during the isolation of eighteen flavonoid ingredients plus nine new ones,

pongamones III-XI, were obtained from root bark. It is noted that new structures were resolute to be (2S)-3′,4′-di-methoxy-6″, 6″-dimethyl-pyrano[2″,3″:7,8]flavanone-(III), (2S)-6,3′,4′-trimethoxy-6″, 6″di-methyl-pyrano[2″,3″7,8]-flavanone-(IV), (2S)-7-methoxy-6-O-γ,γ-dimethylallyl-3′,4 methylene-dioxy-flavanone-(V), 2′-hydroxy-3,4,5′-tri-meth-oxy-6″,6″-dimethyl-pyrano[2″3″:4′3′]chalcone(VI), 2′,4′-di-meth-oxy-3,4-methylene-dioxy-dioxy-dihydro-chalcone-(VII),2′,5′,β-tri-methoxy-3,4-methylene-dioxy-6″,6″-di-methyl-pyrano[2″,3″:4′,3′] di-hydro-chalcone (VIII), 2,β-di-methoxy-3, 4-methylene-dioxy-furano[2″,3″:4′,3′]-dihydro-chalcone (IX), β-hydroxy-2′,4′,6′-trimethoxy-3,4-methylene-dioxychalcone (X) and 3-methoxy-furano-[2″,3″:7,6]flavone (XI), respectively in terms of spectral study and synthesis [5]. *Pongamia pinnata* fruits were found to have three new furanoflavonoid glucosides, pongamosides A-C and also new flavanol glucoside, pongamosides D. The structures of above compounds were studied by spectroscopic analysis. It was for the first time that furanoflavone glucosides has been originated as naturally present compounds [19].

The label compound, $C_{18}H_{12}O_4$ was recognized as pinnatin and it is also a furanoflavone compound that was isolated from *Derris indica* furanoflavone nucleus that is known to have planar structure. It was observed that phenyl ring is axially committed or attached to the furanoflavone skeleton. It is said that methoxy group departs slightly from the plane of molecule. This molecule is linked in a zigzag fashion through C-OH interactions into molecular ribbons sideways of β axis. The stabilization is providing by weak C-H interactions.

7. Traditional Uses of *Pongamia pinnata*

Pongamia pinnata seed-oil keeps medicinal properties and found to be fruitful for itches, abscess and other skin diseases [20]. Its flowers are recommended for glycosuria and as a remedy for treatment of diabetes. The bark is widely used internally for bleeding piles, diabetes [21] and beriberis and known to be a potential antimicrobial compound of nature. Karanja seeds are used as a medicinal plant, principally with the Ayurvedic and Sidda system of medicine in India. It was noted that crude seed extract completely prevent the growth of herpes simplex virus type 1 and type 2 in Vero cells and also retains hypoglycemic, analgesic, anti-inflammatory, anti-ulcerogenic and anti-oxidative properties. It is estimated that different parts of the plant are used in outdated medicines for whooping cough, rheumatic joints, bronchitis and to quench dipsia in diabetes. The leaves are anthelmintic, laxative, hot, digestive, and used to cure wounds, piles and other inflammations. A hot infusion of plants leave is consumed as a medicinal bath for releasing rheumatic pains and for cleaning ulcers in scrofulous and gonorrhea enlargement. Distinct abstracts of seeds, leaves and roots are castoff to treat infectious syndrome for example articular and rheumatism, muscular, lumbago, leucoderma and leprosy. Plants leaves were found active along micrococus, their nectar use for leprosy, gonorrhea, cough, diarrhea, dyspepsia, flatulence and cold also. Seed oil is used in lumbago, lever pain, chronic fever, leprosy, piles, ulcers and scabies. Roots are castoff for cleaning ulcers, teeth and gums. The bark is consumed inside for bleeding piles. Nectar from plants in addition to oil is hygienic. It is thought to be an outstanding cure for *pityriasis versicolor*, itch and herps. Powdered seeds are evaluated as tonic, febrifuge and in whooping cough and bronchitis. Flowers are utilized for diabetes. Bark has been used for beriberi.

8. Pharmacological Activities

Pure oil or extracts obtained from different parts of *Pongamia pinatta* are known to have strong anti-inflammatory, anti-plasmodial, anti-oxidant, anti-diarrheal, anti-hyperammonemic, anti-ulcer, anti-hyperglycemic and anti-lipid peroxidative activities.

8.1 Anti-Inflammatory Activity

It has been described that 70% ethanolic extract of *Pongamia pinnata* leaves has found to be effective anti-inflammatory agent beside distinct stages as chronic, acute and sub-acute of inflammation deprived of any side effect on gastric mucosa. They also examined important anti-pyretic actions of the extract beside Brewer's yeast-induced pyrexia [22].

8.2 Anti-Plasmodial Activity

It has been testified that *Pongamia pinnata* is one of the plants which displays anti-plasmodial activities alongside *Plasmodium falciparum* [23].

8.3 Anti-Oxidant and Anti-Hyperammonemic Activity

It has been studied that impacts of *Pongamia pinnata* leave extract on circulatory lipid peroxidation and antioxidant position was estimated in ammonium chloride induced hyper-ammonium mice. It improved lipid peroxidation in the movement of ammonium chloride-treated mice that was conducted by a major reduction in the levels of superoxide dismutase (SOD), glutathione peroxidase (GPx), catalase (CAT), reduced glutathione, vitamin E, vitamin A and vitamin C. It exhibited that PPET moderates these variations through extracting the oxidant-antioxidant imbalance in ammonium chloride-induced hyperammonemia and this could be because of its anti-hyperammonemic impacts by the ways of detoxifying surplus creatinine, ammonia, urea and antioxidant properties [18].

8.4 Anti-Diarrhoeal Activity

It has been estimated that anti-microbial impacts of raw decoction of desiccated leaves of *Pongamia pinnata* are known to have enterotoxins i:e *Escherichia coli* stable toxin, *Escherichia coli* labile toxin and Cholera toxin and invasion of enteroinvasive *Escherichia coli*, adherence of enteropathogenic *Escherichia coli* and *Shigella flexneri* to epithelial cells. The decoction had no anti-rotaviral, anti-giardial and anti-bacterial activities, nevertheless reduced generation of bacterial invasion and cholera toxin to epithelial cells is known to have significance influence. The

examined consequences showed that decoction of *Pongamia pinnata* has selective anti-diarrhoeal action with efficacy beside enteroinvasive and cholera bacterial strains producing bloody diarrhoeal episode [18].

8.5 Anti-Ulcer Activity

It has been stated that methanolic extract of *Pongamia pinnata* roots exposed important defense against aspirin and four hour PL, yet not along ethanol-induced ulceration. It indicated propensity to reduce acetic acid induced ulcer after ten days of cure. Ulcer protective impacts of PPRM was because of augmentation of mucosal self-protective aspects for example cell proliferation and prevention of lipid per oxidation rather than on the offensive acid-pepsin secretion, mucosal cell glycoproteins, life span of mucosal cells and mucin secretion [24].

8.6 Anti-Hyperglycemic and Anti-Lipid Peroxidative Activity

It has been described that oral administration of ethanolic extract of *Pongamia pinnata* flower displays important anti-lipid peroxidative and anti-hyperglycaemic impacts and improvements in antioxidant protection scheme in alloxan-induced diabetic mice. These effects advocated that the cure of *Pongamia pinnata* extract could be consumed as a nontoxic alternative anti-hyperglycaemic medication for diabetic patients [18].

Table 1 Physicochemical properties of *Pongamia pinnata* crude oil [4]

Property	Value	Unit
Odor	Characteristic odd odor	-
Color	Yellowish red	-
Viscosity	40.2	mm^2/sec
Boiling point	316	°C
Density	0.924	gm/cc
Iodine value	87	-
Acid value	5.40	mg/KOH
Saponification value	184	-
Unsaponifiable matter	2.9	-
Fire point	230	°C
Flash point	225	°C
Pour point	-3	°C
Cloud point	3.5	°C

Table 2 Fatty acid composition of *Pongamia pinnata* crude oil [4]

Fatty Acids	Percentage	Molecular Formula	Structure
Oleic Acid	51.59	$C_{18}H_{34}O_2$	$CH_3(CH_2)_{14}(CH=CH)COOH$
Stearic Acid	7.50	$C_{18}H_{36}O_2$	$CH_3(CH_2)_{16}COOH$
Palmitic Acid	11.65	$C_{16}H_{32}O_2$	$CH_3(CH_2)_{14}COOH$
Linoleic Acid	16.64	$C_{18}H_{32}O_2$	$CH_3(CH_2)_{12}(CH=CH)_2COOH$
Dosocasonic Acid	4.45	$C_{22}H_{44}O_2$	$CH_3(CH_2)_{20}COOH$
Tetracosanoic Acid	1.09	$C_{24}H_{48}O_2$	$CH_3(CH_2)_{22}COOH$
Eicosanoic Acid	1.35	$C_{20}H_{40}O_2$	$CH_3(CH_2)_{18}COOH$

Table 3 Fuel properties of *Pongamia pinnata* biodiesel using different catalyst [17]

Type of Catalyst	Kinamatic Viscosity at 40°C (mm^2/s)	Specific Gravity at 40°C	Cloud Point (°C)	Flash Point (°C)	Water Content (% wt)	Carbon Residue (% vol.)	Calorific Value (cal/g)
CaO + Eggshell	5.4	-	5	158	0.005	0.02	41.5 kJ/gm
NaOH	34.66×10^{-6} Ns/m^2	0.942	-	-	0.16	-	40.216 kJ/gm
H_2SO_4 + NaOH	4.37	0.883	146	163	-	-	4213
Sulphate Zirconia + KOH	4.33	-	-	170	0.005	0.005	-
Iron Nanoparticles	4.6	0.873	5	178	0.012	0.33	3788

9. Conclusion

Pongamia pinnata is a drought resistant leguminous tree that also fixes nitrogen and is semi-deciduous in nature. It is known to have several advantages owing to its numerous traditional applications and number of pharmacological uses. It cultivates about 15-20 meters in altitude with huge canopy which extends equally in width as well. The transesterification of crude oil of *Pongamia pinnata* is known to possess excellent values for fuel quality parameters such as acid value, cetane number, calorific value and iodine value etc.

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