

Pongamia pinnata L: A Comprehensive Review

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Abstract: Traditional system of medicine consists of large number of plants with various medicinal and pharmacological importances and hence represents a priceless tank of new bioactive molecules. *Pongamia pinnata* (Linn.) Pierre is one amongst these, found all over the world. It is commonly known as 'Karanj', and has been recognized in different traditional system of medicines for the treatment of varied diseases of human beings. The phytoconstituents present in it mainly belong to the category of flavonoids and fixed oils. Different parts of this plant are traditionally claimed to be used for the treatment of broad spectrum of ailments including bronchitis, whooping cough, rheumatism, diarrhea, dyspepsia, flatulence, gonorrhoea and leprosy to list a few. There has been a tremendous interest in this plant as evidenced by the voluminous work in last few decades. Its oil is a source of biodiesel. It has also alternative source of energy, which is renewable, safe and non-pollutant. Therefore, the present review aimed to compile up to date and comprehensive information of *Pongamia pinnata* with special emphasis on its phytochemistry, various scientifically documented pharmacological activities, traditional and folk medicine uses alongwith its role in biofuel industry.

Key words: Karanj, *Pongamia pinnata*, phytoconstituents, traditional uses.

INTRODUCTION:

The role of traditional medicines in the solution of health problems is invaluable on a global level. Medicinal plants continue to provide valuable therapeutic agents, both in modern and in traditional medicine [1]. With the associated side effects of the modern medicine, traditional medicines are gaining importance and are now being studied to find the scientific basis of their therapeutic actions [2]. Research work on medicinal plants has intensified and information on these plants has been exchanged. This research will go a long way in the scientific exploration of medicinal plants for the benefit of man and is likely to decrease the dependence on synthetic drugs [3].

Pongamia pinnata (Linn.) Pierre is a medium sized glabrous tree popularly known as Karanja in Hindi, Indian Beech in English and Pongam in Tamil [4]. Most of the Tamil Nadu physicians of Indian system of traditional medicine Ayurveda and Siddha use *Pongamia pinnata* to treat various kinds of diseases including diabetes mellitus [5]. It is a medicinal plant

native to Western Ghats and chiefly found in tidal forests of India [4]. *Pongamia pinnata* also called as Derris indica, is a monotypic genus and grows abundantly along the coasts and riverbanks in Myanmar. The tree is known for its multipurpose benefits and as a potential source of biodiesel [6]. The seeds are reported to contain on an average about 28–34% oil with high percentage of polyunsaturated fatty acids [7]. Historically, *Pongamia* has been used as folk medicinal plant, particularly in Ayurvedha and Siddha systems of Indian medicine [8]. All parts of the plant have been used as a crude drug for the treatment of tumours, piles, skin diseases, itches, abscess, painful rheumatic joints wounds, ulcers, diarrhea etc [8, 9]. Besides, it is well known for its application as animal fodder, green manure, timber and fish poison. It has also been recognized to possess applications in agriculture and environmental management, with insecticidal and nematicidal activity. More recently, the effectiveness of *P. pinnata* as a source of biomedicines has been reported [10], specifically as antimicrobial and therapeutic agents.

TAXONOMY ^[11]:

Kingdom - Plantae
 Subkingdom - Tracheobionta
 Superdivision - Spermatophyta
 Division - Magnoliophyta
 Class - Magnoliopsida
 Subclass – Rosidae
 Order - Fabales
 Family - Fabaceae
 Genus - *Millettia* Wight & Arn.
 Species - *Millettia pinnata* (L.) Panigrahi – pongame oil tree

GEOGRAPHICAL DISTRIBUTION:

It is widely distributed throughout tropical Asia and the Seychelles Islands, South Eastern Asia, Australia, India and locally distributed throughout the State of Maharashtra (India) along the banks of rivers; very common near the sea-coast in tidal and beach-forests in Konkan; along Deccan rivers ^[12].

PHYTOCHEMISTRY:

Phytochemical investigation of *Pongamia pinnata* indicated the presence of abundant prenylated flavonoids such as furanoflavones, furanoflavonols, chromenoflavones, furanochalcones and pyranochalcones ^[13, 14-16]. Yin et al. ^[17] isolated two phenylated flavonoid derivatives with a modified ring A, pongaflavanol (1) and tunicatachalcone (2) from stem bark of *Pongamia pinnata*. Pongaflavanol was a new compound and its structure was elucidated on the basis of spectroscopic data interpretation. Pongaflavone represented the first example of a naturally occurring prenylated flavan-4-ol with a modified ring A, while compound 2, tunicatachalcone was isolated for the first time from *Pongamia pinnata* ^[17]. The structures of these compounds are shown in figure 1 ^[17].

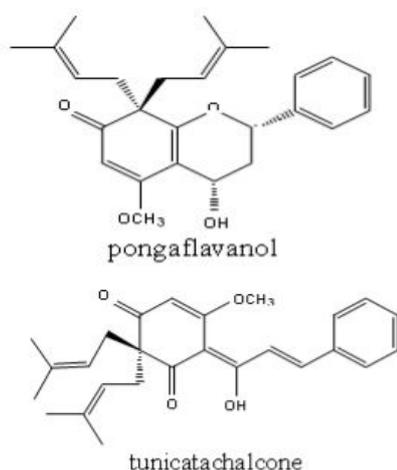


Figure 1. Structures of Pongaflavone and Tunicatachalcone

Yadav et al. ^[18] isolated four new furanoflavonoids, pongapinnol A–D, and a new coumestan, pongacoumestan along with thirteen known compounds from the fruits of *Pongamia pinnata*. They elucidated the structures of isolated compounds on the basis of spectroscopic data interpretation ^[18].

Isolation and characterization of five structurally unusual flavonoids pongamones A–E, along with 16 known flavonoid metabolites were carried out by Li et al. ^[19] from the stem of *Pongamia pinnata*. Their structures were determined on the basis of spectroscopic analyses and by comparison of their spectroscopic data with those of related compounds reported in the literature ^[19].

Karanja (*Pongamia pinnata*) seed oil contains karanjin, a bioactive molecule with important biological attributes ^[20]. Vismaya et al. ^[20] developed a facile method for efficient recovery of karanjin. They subjected the seed oil to liquid–liquid extraction with methanol. The extract was further purified by chromatography on alumina followed by crystallization to afford karanjin, whose purity was ascertained by HPLC. They obtained the recovery of karanjin as 20% with >95% purity. The structure of the compound was elucidated by MS and NMR spectral analysis ^[20].

Six compounds (two sterols, three sterol derivatives and one disaccharide) together with eight fatty acids (three saturated and five unsaturated) have been isolated from the seeds of *Pongamia pinnata*. Their structures were elucidated with the help of physicochemical methods and spectroscopic techniques. The metabolites, beta-sitosterol acetate and galactoside, stigma sterol, its galactoside and sucrose are being reported for the first time from this plant. The saturated and unsaturated fatty acids (two monoenoic, one dienoic and two trienoic) were present in exactly the same amount. Oleic acid occurred in highest amount (44.24%), stearic (29.64%) and palmitic (18.58%) acids were the next in quantity. Hiragonic and octadecatrienoic acids were present in trace amounts (0.88%). Karanjin, pongamol, pongagalabrone and pongapin, pinnatin and kanjone have been isolated and characterized from seeds. Immature seeds contain a flavone derivative 'pongol'. The other flavonoid isolated from the seeds includes 'Glybanchalcone, isopongachromene'. The leaves and stem of the plant consist of several flavone and chalcone derivatives such as Pongone, Galbone, Pongalabol, pongagallone A and B ^[21]. The structures of Karanjin, isopongachromene, Glybanchalcone and pongal are shown in figure 2.

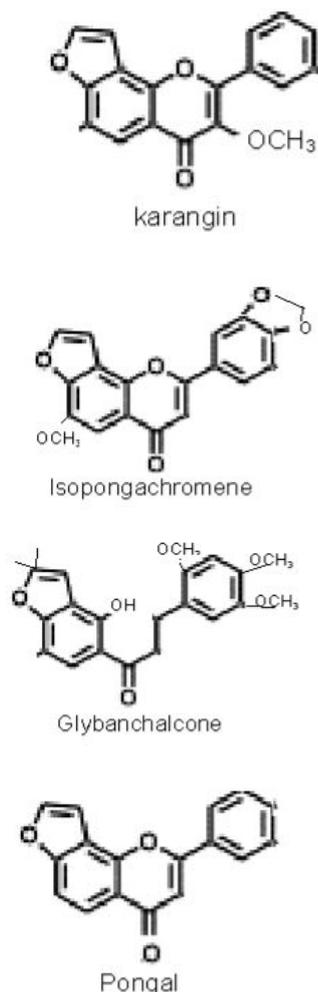


Figure 2. Structures of phytoconstituents isolated from the seeds of *Pongamia pinnata*

BIOLOGICAL AND PHARMACOLOGICAL ACTIVITIES:

During past several years, *Pongamia pinnata* is gaining lot of interest according to researchers' point of view. Recently many pharmacological studies have been conducted on *Pongamia pinnata*. A summary of the findings of these studies performed is presented below.

Antihyperglycemic and antilipidperoxidative effects:

Punitha and Manohar [22] evaluated antihyperglycemic and antilipidperoxidative effects of ethanolic extract of *Pongamia pinnata* (Linn.) Pierre flowers in alloxan induced diabetic rats. They noticed hyperglycemia, elevated lipid peroxidation [thiobarbituric acid reactive substances (TBARS)] and disturbed nonenzymatic [Vitamin E, Vitamin C and glutathione] and enzymatic antioxidants status in alloxan induced diabetic rats. They reported the significant antihyperglycemic and antilipidperoxidative effects of oral administration of ethanolic extract of *Pongamia pinnata* flowers (300 mg/kg bw) alongwith enhancement in antioxidants

defense system in alloxan induced diabetic rats. However, no significant characteristic changes were noticed in blood glucose level as well as in lipid peroxidation and antioxidant status in normal rats treated with the extract. Also, the extract considerably reduced the blood glucose concentration in a similar extent to that of the reference drug glibenclamide (600 mg/kg bw) in alloxan induced diabetic rats suggesting the use of *Pongamia pinnata* as a safe alternative antihyperglycemic drug for diabetic patients [22]. The antihyperglycemic effect of ethanolic extract of *Pongamia pinnata* flowers was attributed to the presence of several bioactive antidiabetic principles and their synergistic properties.

Influence of circadian variation on lipid peroxidation products and antioxidants:

Effects of *Pongamia pinnata* on lipid peroxidation products and antioxidants in hyperammonemic rats: with reference to circadian variations were evaluated by Essa and Subramanian [23]. They analyzed the characteristics of 24 h rhythms (acrophase, amplitude and mesor) of lipid peroxidation products (thiobarbituric acid reactive substances – TBARS) and antioxidants (reduced glutathione (GSH), glutathione peroxidase (GPx), superoxide dismutase (SOD) and catalase (CAT)). Elevated lipid peroxidation (increased mesor of TBARS) associated with decreased activities of antioxidants (decreased mesor of GPx, GSH, SOD and CAT) were found in hyperammonemic rats. They suggested that these alterations could be modulated by *Pongamia pinnata* during hyperammonemic conditions, which may also play a crucial role in disease development [23] with final conclusion that the knowledge of the circadian rhythms in normal and in pathological conditions can be used to improve the understanding of pathophysiological process and therapeutic approach to illness [23].

Antihyperammonemic effect:

Essa *et al.* [24] evaluated the protective influence of leaf extract of *Pongamia pinnata* (Karanja) on blood ammonia and urea levels in ammonium chloride-induced hyperammonemia. A relationship between oxidative stress and hyperammonemia has been well established and evidences point to the fact that ammonium (acetate / chloride) salts induce hyperammonemia partly via oxidative stress [25]. In their study, the levels of blood ammonia, circulatory urea, uric acid, non-protein nitrogen and creatinine increased significantly in rats treated with ammonium chloride and decreased significantly in rats treated with *Pongamia pinnata* leaf extract and ammonium chloride. There were no significant changes in the body weights of the experimental animals when

compared to controls. The antihyperammonemic effect of extract was attributed to its nephroprotective effect by means of detoxifying excess urea and creatinine, its free radical scavenging property and its antioxidant property [24]. Furthermore, Flavanoids are potent antioxidants and are known to modulate the activities of various enzyme systems due to their interaction with various biomolecules [26]. The plant is known to contain a number of bioflavonoids like kaempferol, quercetin, karanjin, kanjone, pongaglabrone, gammatin, pongaglabol, kanugin etc. [27].

Antifungal and antibacterial activity:

Evaluation of antifungal and antibacterial activity of different concentration of oil obtained from *Pongamia pinnata* against *Aspergillus niger*, *A. fumigatus*, *Staphylococcus aureus* and *Pseudomonas aeruginosa* was carried out by Wagh *et al.* [28] employing Minimum Inhibitory Concentration (MIC) determination and dry-weight method. Chemical analysis of oil performed by gas chromatography (GC) and gas chromatography/mass spectrometry (GC-MS) showed the presence of fatty acid. They suggested the use of fatty oil of this plant for developing plant-derived antimicrobial drugs [28].

Antiinflammatory activity:

Antiinflammatory activity of various root extracts of *Pongamia pinnata* was evaluated by Singh and Pandey [29]. All extracts of the root showed significant anti-inflammatory activity (compared to phenylbutazone) in carrageenin and PGE1 induced oedema models. Possible mechanism of action was attributed to prostaglandin inhibition, especially by ethanolic extract and acetate extract. The butanol extract was found to be effective in carrageenin, but not in PGE1 model of inflammation. The anti-inflammatory property appears to reside mainly in the intermediate polar constituents and not in lipophilic or extremely polar constituents. Also, the petroleum ether extract of the seeds of *Pongamia pinnata* showed potent acute anti-inflammatory effect whereas the aqueous suspension showed pro-inflammatory effects. In further studies, maximum anti-inflammatory effect was seen in the bradykinin induced oedema model. Possible mechanism of action could be inhibition of prostaglandin synthesis and decreased capillary permeability. Petroleum ether extract and aqueous extract inhibited histamine and 5-hydroxytryptamine induced inflammation, probably by their lipophilic constituents preventing the early stages of inflammation. However, the fractions were not effective against Freund's adjuvant induced arthritic model. The later finding neglects the plant from its use in rheumatoid arthritis [29].

Antiviral activity:

White Spot Syndrome Virus (WSSV) is an extremely virulent, contagious, causative agent of the White spot syndrome of shrimp and causes high mortality and affects most of the commercially important cultured marine crustacean species globally [30]. Rameshthangam and Ramasamy [30] evaluated the antiviral activity of bis (2-methylheptyl) phthalate isolated from *Pongamia pinnata* leaves against White Spot Syndrome Virus of *Penaeus monodon* Fabricius. Oral administration of ethanolic extract and purified compound from the leaves of *Pongamia pinnata* has increased the survival of WSSV infected *Penaeus monodon*. They fed the pelletized feed impregnated with ethanolic extract of the leaves of *Pongamia pinnata* to shrimp prior and after WSSV infection at 200 and 300 microg/g of body weight of shrimp/day. The survival rate for the WSSV-infected shrimp that were fed with 200 and 300 microg extract/g were 40% and 80%, respectively [30].

Antifilarial potential:

Uddin *et al.* [31] investigated the antifilarial potential of the fruits and leaves extracts of *Pongamia pinnata* on cattle filarial parasite. In their investigation, the aqueous and alcohol extracts of fruits and the alcohol extract of leaves caused an inhibition of spontaneous movements of the whole worm and the nerve-muscle preparation of *S. cervi*. The concentration required to inhibit the movements of the whole worm preparation was 250µg/mL for aqueous, 120µg/mL for alcohol extract of fruits and 270µg/mL for alcohol extracts of the leaves. The concentrations of *Pongamia pinnata* extracts required to produce an equivalent effect on the nerve-muscle preparation were 25µg/mL, 5µg/mL and 20µg/mL, respectively suggesting a cuticular permeability barrier [31].

Action against infectious diarrhea:

Diarrhea is most commonly caused by gastrointestinal infections, which kill around 1.8 million people globally each year, mostly children in developing countries [32]. The main cause of death from diarrhea is dehydration, which results from loss of electrolytes in diarrheal stools [33]. Leaves of *Pongamia pinnata* (L.) Pierre (synonym, *P. glabra* Vent) has been known as a remedy for diarrhea [34]. Shoba and Thomas [35] reported on the effectiveness of *P. pinnata* in controlling castor oil induced diarrhea. While data are available on the effect of medicinal plants on intestinal motility and their antibacterial action, there is a paucity of information on their mode of action on various aspects of diarrheal pathogenicity, namely colonization to intestinal epithelial cells and production/action of enterotoxins [33]. Brijesh *et al.* [33] evaluated the crude decoction of dried leaves of *Pongamia pinnata* for its

antimicrobial (antibacterial, anti-giardial and antirotaviral) effect; and its effect on production and action of enterotoxins (cholera toxin, CT; Escherichia coli labile toxin, LT; and E. coli stable toxin, ST); and adherence of enteropathogenic E. coli and invasion of enteroinvasive E. coli and Shigella flexneri to epithelial cells. The decoction had no antibacterial, anti-giardial and antirotaviral activity, but it was found to reduce the production of CT and bacterial invasion to epithelial cells. These results indicated that the crude decoction of *P. pinnata* has selective antidiarrheal action with efficacy against cholera and enteroinvasive bacterial strains causing bloody diarrheal episodes. They attributed the antidiarrheal activity to antimotility, antisecretory and antimicrobial actions of the compound [33].

Nootropic activity:

In the investigation carried out by Singh *et al.* [36], various extracts derived from the seeds of *Pongamia pinnata* (Karanja) decreased pentobarbitone sleeping time in rats. The probable mechanism of this action was attributed to the stimulation of the hepatic microsomal enzyme system [36]. Furthermore, Singh *et al.* [37] evaluated the similar properties for the *Pongamia pinnata* roots. In their study the petroleum ether extract (PEE) of the roots enhanced pentobarbitone sleeping time, probably due to CNS depression [37]. The PEE of the seed of *Pongamia pinnata* was further tested for nootropic activity in an experimental model of Alzheimer's disease (created by ibotenic acid induced lesioning of nuclear basalis magnocellularis). It reversed both, the cognitive deficits and the reduction in cholinergic markers after 2 weeks of treatment. Reversal of perturbed cholinergic function was considered as the possible mechanism [38].

Antinociceptive activity:

Srinivasan *et al.* [39] evaluated the analgesic activity of the various root extracts of *Pongamia pinnata*. The petroleum ether extract (PEE), n-Butanol extract (BE) and Ethanol extract (EE) of the roots of *Pongamia pinnata* showed significant analgesic effect in the tail flick test. The PEE and direct EE of the seeds also showed significant analgesic activity at doses higher than 100 mg/ kg [39].

Protective effect against nephrotoxicity:

Ethanol extract of flowers of *Pongamia pinnata* was studied for its protective effect against cisplatin and gentamicin induced renal injury in rats by Shirwaikar *et al.* [40]. When the extract (300 & 600 mg/kg) was administered orally for 10 days following cisplatin (5 mg/kg, i.p.) on day 5, the flowers of *Pongamia pinnata* had a protective effect against cisplatin and gentamicin

induced renal injury. The possible mechanism of its protective effect against nephrotoxicity was attributed to its antioxidant activity [40].

Ulceroprotective activity:

The aqueous extract of *Pongamia pinnata* root induced a significant decrease in volume of gastric juice, acid output and peptic activity without any effect on mucin activity in acetylsalicylic acid (ASA)-ulcerated rats. Moreover, it decreased the ulcer index significantly. Ulcer protective effect of methanolic extract of *Pongamia pinnata* roots was attributed to the augmentation of mucosal defensive factors like mucin secretion, life span of mucosal cells, mucosal cell glycoproteins, cell proliferation and prevention of lipid peroxidation rather than on the offensive acid-pepsin secretion. A qualitative change in hexose and fructose contents of carbohydrates was also found, however mucin activity remained unchanged [41, 42].

TRADITIONAL USES OF PONGAMIA

PINNATA:

The seed-oil of *Pongamia pinnata* possesses medicinal properties and used in itches, abscess and other skin diseases [28]. Flowers are prescribed for glycosuria and as a remedy for diabetes [4]. The bark is used internally for bleeding piles, beriberi [43] and diabetes [44] and as an antimicrobial [45]. Karanja seed is used as a medicinal plant, particularly with the Ayurvedic and Siddha medicine systems of India. Crude seed extract can completely inhibit the growth of herpes simplex virus type 1 and type 2 in Vero cells and also possesses hypoglycemic, anti-oxidative, anti-ulcerogenic, anti-inflammatory and analgesic properties [20]. Different parts of the plant have been used in traditional medicines for bronchitis, whooping cough, rheumatic joints and to quench dipsia in diabetes [46]. The leaves are hot, digestive, laxative, anthelmintic and cure piles, wounds and other inflammations. A hot infusion of leaves is used as a medicated bath for relieving rheumatic pains and for cleaning ulcers in gonorrhoea and scrofulous enlargement [27, 47]. Different extracts of leaves, roots and seeds are used to treat infectious diseases such as leucoderma, leprosy, lumbago, muscular and articular and rheumatism [29]. Leaves are active against Micrococcus; their juice use for cold, cough, diarrhoea, dyspepsia, flatulence, gonorrhoea and leprosy and also Seed oil is used in scabies, leprosy, piles, ulcers, chronic fever, liver pain and lumbago. Roots are used for cleaning gums, teeth and ulcers. The bark is used internally for bleeding piles. Juice from plants as well as oil is aseptic. It is said to be an excellent remedy for itch, herpes and pityriasis versicolor. Powdered seeds are valued as febrifuge, tonic and in bronchitis and whooping cough. Flowers

are used for diabetic. Bark has been used for beriberi [43, 46].

ROLE OF *PONGAMIA PINNATA* IN BIOFUEL INDUSTRY:

Mature seeds of karanja have recently gained a great commercial relevance owing to their high oil content, which is explored as an alternate source of fuel and energy [48]. Karanja oil mainly consists of furan flavones, karanjin, pongapin, kanjone and a diketone pongamol. Although the plant has been useful for the treatment of scabies, leprosy, piles, ulcer, chronic fever and liver pain it has recently gained a great commercial interest for serving as an alternative source of energy. Karanjin has been reported to possess potent anti-scabies and anti-leprotic activity [48].

Oil yielding crop plants are very important for economic growth of the energy and agricultural sectors. The oil seeds containing polyunsaturated fatty acids are important source of biodiesel [49, 50]. These organic seed oils are better than diesel fuels in terms of physico-chemical properties and biodegradability [51]. One such plant species is *Pongamia pinnata*. To use this species as a source of biodiesel and biomedicine more research is required. Also, to increase the biodiesel production it's important to have an elite genotype of *P. pinnata* bearing high oil-yielding seeds. The candidate plus tree (CPT) is an individual tree of *P. pinnata* possessing superior morphological characters (girth of the tree, height of the tree, number of leaves $g\ wt^{-1}$, number of buds inflorescence⁻¹, number of flowers inflorescence⁻¹, number of seeds inflorescence⁻¹) than other individuals of the same species [52].

Kesari *et al.* [53] carried out the analysis of oil and antimicrobial activity from seeds of elite genotype of *Pongamia pinnata*. The highest oil yield (33%) from seeds was recovered in n-Hexane. Physico-chemical properties of crude oil established suitability of *P. pinnata* for its use as a potential biofuel crop. The total mono unsaturated fatty acid (oleic acid 46%) present in seed oil was more in comparison to polyunsaturated fatty acid (33%) as analyzed by GC-MS. Seed oil also showed inhibition against the tested fungal and bacterial cultures. However, the efficacy of

antimicrobial activity of the seed oil at four concentration levels (50%, 80%, 90% and 100%) against various pathogenic indicators was found to be concentration- dependent. The obtained results confirmed the use of seed oil from well characterized elite genotype of *Pongamia pinnata* as diesel fuel and in pharmaceuticals [53].

At a time when society is becoming increasingly aware of the declining reserves of oil for the production of fossil fuels, it has become apparent that biofuels are destined to make a substantial contribution to the future energy demands of the domestic and commercial economies. To this, *P. pinnata* will impact most significantly through the extraction of seed oil that can be used in the manufacture of biodiesel. The potential of *P. pinnata* oil as a source of fuel for the biodiesel industry is well recognized [54, 55]. Moreover, the use of vegetable oils from plants such as *P. pinnata* has the potential to provide an environmentally acceptable fuel, the production of which is greenhouse gas neutral, with reductions in current diesel engine emissions [56]. The seeds of *P. pinnata* contain 30 to 40% oil [57] which can be converted to biodiesel (fatty acid methyl esters; FAMES) by esterification with methanol in the presence of KOH. The predominant fatty acid is oleic acid (C18:1; 45 to 55%) with palmitic acid (C16:0; 5 to 15%), stearic acid (C18:0; 5 to 10%) and linoleic acid (C18:2; 15 to 20%), and to a much lesser extent arachidic acid (C20:0), eicosanoic acid (C20:1), behenic acid (C22:0) and lignoceric acid (C24:0) [57].

CONCLUSION:

The extensive literature survey revealed that *Pongamia Pinnata* L. is important medicinal plant with diverse pharmacological spectrum. The plant shows the presence of many chemical constituents which are responsible for varied pharmacological and medicinal properties. Furthermore, it also represents a milestone in the field of bio fuel industry as one of the most important bio fuel crop. However, evaluation needs to be carried out on *Pongamia Pinnata* L. in order to explore the concealed areas and their practical clinical applications, which can be used for the welfare of the mankind.

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