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Jatropha curcas: A Systemic Review on Pharmacological, Phytochemical, Toxicological Profiles and Commercial Applications

Sumit N Laxane [1], Surendra Swarnkar [1], Mruthunjaya K[2], Sachin B Zanwar [1] and Manjunath Setty M [1]*

[1]Dept of Pharmacognosy, Manipal College of Pharmaceutical Sciences, Manipal University, Manipal-576 104, Karnataka, India
[2] Dept of Pharmacognosy, JSS College of Pharmacy, JSS University, Mysore-570 015, Karnataka, India

ABSTRACT

Jatropha curcas L. Barbados nut, purging nut tree, is a bush or small tree and belongs to euphorbiaceae family. This plant has been used traditionally for medicinal purposes. The plant possesses anti-inflammatory, antimetastatic, antitumor, coagulant and anti-coagulant (dose dependent), disinfectant, antiparasitic, wound healing, insecticidal, pregnancy terminating activity and antidiarrhoeal effect. The main constituents of the plant are curcin, curcusone-B, curcain etc. Apart from this, the plant also contains toxic principle such as tetramethylpyrazine (TMPZ). In this review, effort has been made to compile all the information reported on its pharmacological, phytochemical, toxicological studies and commercial applications. This information will be helpful to create interest towards the plant and may be useful in developing new formulations, which are more effective and having more therapeutic value.
Keywords: Jatropha curcas, Eeuphorbiaceae, curcin, Jatropha Energy System, Bio-fuel.

Corresponding author

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INTRODUCTION

Jatropha curcas is a small tree or shrub belonging to family: Euphorbiaceae. It has many Synonym Curcas purgans Medic. Its vernacular/common names in English are physic nut, purging nut; Other common names: Barbados nut, Black vomit nut, Curcas bean, Kukui haole, Purgeerboontjie. It is a bush or small tree (up to 5 m height). The genus Jatropha contains approximately 170 known species. The genus name Jatropha derived from the Greek jatrós (doctor), trophé (food), which implies medicinal uses. The plant is planted as a hedge (living fence) by farmers all over the world because it is not browsed by animals [1-3] **(Figure 1).**

GEOGRAPHICAL DISTRIBUTION:

Jatropha curcas originated from Central America. From the Caribbean islands it was probably distributed by Portuguese seafarers via the Cape Verde Islands and formerly Portuguese Guinea (now Guinea Bissau) to other countries in Africa and Asia. Today it is cultivated in almost all tropical and subtropical countries as protection hedge around gardens and fields, since it not browsed by cattle [1].

TAXONOMICAL DISTRIBUTION:

It is a small tree or shrub with smooth gray bark, which exudes whitish colored watery latex when cut. Normally it grows between three to five meters in height, but can attain a height of up to eight or ten meters under favourable conditions.

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Leaves: It has large green to pale-green leaves, alternate to sub-opposite, three to five lobed with a spiral phyllotaxis **(Figure 2 and 3).**

Figure 2: Leaf veinature

Figure 3: The leaf

Flowers: The petiole length ranges between 6-23 mm. The inflorescence is formed in the leaf axil. Flowers are formed terminally, individually, with female flowers usually slightly larger and occur in the hot seasons. In conditions where continuous growth occurs, an unbalance of pistillate or staminate flower production results in a higher number of female flowers. More number of female flowers is grown by the plant if bee keeping is done along with. More female flowers give more number of seeds **(Figure 4).**

Fruits: Fruits are produced in winter when the shrub is leafless, or it may produce several crops during the year if soil moisture is good and temperatures are sufficiently high. Each inflorescence yields a bunch of approximately 10 or more ovoid fruits. A three, bi-valved cocci is formed after the seeds mature and the fleshy exocarp dries **(Figure 5).**

Seeds: The seeds become mature when the capsule changes from green to yellow, after two to four months from fertilization. The blackish, thin shelled seeds are oblong and resemble small castor seeds [4] **(Figure 6).**

ETHNOBOTANICAL USES

According to Hartwell, the extracts are used in folk remedies for cancer. Reported to be abortifacient, anodyne, antiseptic, diuretic, emetic, hemostat, lactagogue, narcotic, purgative, rubefacient, stypt and vulnerary; physic nut is a folk remedy for alopecia, ascites, burns, convulsions, cough, dermatitis, diarrhea, dropsy, dysentery, dyspepsia, eczema, fever, gonorrhea, hernia, incontinence, inflammation, jaundice, neuralgia, paralysis, parturition, pneumonia, rash, rheumatism, scabies, sciatica, sores, stomachache, syphilis, tetanus, thrush, tumors, ulcers, uterosis, and yellow fever. Latex applied topically to bee and wasp stings. Mauritians massage ascitic limbs with the oil. Cameroon natives apply the leaf decoction in arthritis [3-7]. Colombians drink the leaf decoction for venereal disease. Bahamans drink the decoction for heartburn. Costa Ricans poultice leaves onto erysipelas and splenosis. Guatemalans place heated leaves on the breast as a lactagogue. Cubans apply the latex to toothache. Colombians and Costa Ricans apply the latex to burns, hemorrhoids, ringworm, and ulcers. Barbadians use the leaf tea for marasmus, Panamanians for jaundice. Venezuelans take the root decoction for dysentery. Seeds are used also for dropsy, gout, paralysis and skin ailments. Leaves are regarded as antiparasitic, applied to scabies; rubefacient for paralysis, rheumatism; also applied to hard tumors. Latex used to dress sores and ulcers and inflamed tongues. Seed is viewed as aperient; the seed oil is emetic, laxative, purgative and for skin ailments; root decoction as a mouthwash for bleeding gums [6].

Figure 5: Fruit & its different sections

Figure 4: Flower

Figure 6: Seeds

PHARMACOLOGICAL ACTIVITY

Antiinflammatory activity of Jatropha curcas

Antiinflammatory activity of topical application of Jatropha curcas L. root powder in paste form in TPA-induced ear inflammation was confirmed in albino mice and successive solvent extraction of these roots was carried out by ether and methanol. The methanol extract exhibited systemic and significant antiinflammatory activity in acute carrageenan induced rat paw edema. It also showed activity against formalin-induced rat paw edema, turpentine-induced exudative changes and cotton pellet-induced granular tissue formation after oral treatment for 7 days in albino rats. Thus resultant antiinflammatory activity might be due to effects on several mediators and arachidonic acid metabolism involving cyclo-oxygenase pathway resulting in prostaglandin formation; anti-proliferative activity leading to reduction in granular tissue formation and leukocyte migration from the vessels [7].

Antimetastatic effects of curcusone-B, a diterpene

A new approach to cancer therapy in recent years has been to target the metastatic process. The antimetastatic potential of curcusone B, a diterpene isolated from J. curcas Linn., was investigated against 4 human cancer cell lines. Treatment with non-cytotoxic doses of curcusone-B resulted in a strong reduction of invitro invasion, motility and secretion of matrix-metalloproteinases (MMP) of the cancer cells, whereas the ability to adhere to a Matrigel-coated surface was variably sensitive to curcusone B treatment. Curcusone-B, thus, effectively suppresses the metastatic processes at doses that are non-toxic to cells, which may be of therapeutic benefit for the treatment of metastatic cancers [8].

Antitumor effects of curcin from seeds

Antitumor activity of curcin was tested by MTT assay. The N-glycosidase activity of curcin was determined by characterization of R-fragment in gel. A cell-free system, rabbit reticulocyte lysate, was introduced to quantify the inhibitory activity of curcin on protein biosynthesis. The curcin had a powerful inhibitory action upon protein synthesis in reticulocyte lysate with an IC_{50} (95 % confidence limits) value of 0.19 (0.11-0.27) nmol/L. The IC_{50} (95 % confidence limits) of curcin on SGC-7901, Sp2/0, and human hepatoma was 0.23 (0.15-0.32) mg/L, 0.66 (0.35-0.97) mg/L, 3.16 (2.74-3.58) mg/L respectively. Curcin was found to have no toxic to Hela cells and normal cells (MRC) [9].

Coagulant and anticoagulant activities in latex

J. curcas Linn. is traditionally used as a haemostatic. Investigation of the coagulant activity of the latex of J. curcas showed that whole latex significantly ($P<0.01$) reduced the clotting time of human blood. Diluted latex, however, prolonged the clotting time: at high dilutions, the blood did not clot at all. This indicates that J. curcas latex possesses both coagulant and anticoagulant activities. Prothrombin time (PT) and activated partial thromboplastin time (APTT) tests on plasma confirm these observations. Solvent partitioning of the latex with ethyl acetate and butanol led to a partial separation of the two opposing activities: at low concentrations, the ethyl acetate fraction exhibited a procoagulant activity, while the butanol fraction had the highest anticoagulant activity. The residual aqueous fraction had no significant effect on the clotting time of blood and the PT but slightly prolonged the APTT [10].

Disinfectant/antiparasitic activity

Bacteriological and parasitologic tests were carried out on laboratory bench surfaces using the sap and crushed leaves of J. curcas. Observation showed that the sap exhibited germicidal actions on the growth of common bacteria of Staphylococcus, Bacillus and Micrococcus species on contact and retained such effects on treated laboratory bench surface for close to six hours after initial application. Ova of Ascaris lumbricoides and Necator americanus incubated in 50% and 100% concentrations of the sap at room temperature showed either no evidence of embryonation after 21 days in the case of A. lumbricoides, negation of hatchability in hookworm or complete distortion in both. The sap also exhibited strong inhibitory effect on normal larval growth of mosquito, but was highly toxic to mice when administered through oral or intraperitoneal routes. This may conclude that J. curcas would provide a very cheap, readily available disinfectant and malaria vector control agent and should be commercially exploited [11, 12].

Esterase and lipase activity in seeds

Two new esterases (JEA and JEB) and a lipase (JL) were extracted from the seeds of J .curas. Lipase activity was only found during germination of the seeds and increased to a maximum after 4 days of germination. All enzymes were found to be most active in the alkaline range at around pH 8 and the purified (fractionated precipitation with ethanol and gel filtration) esterases were very stable at high temperatures. The molecular weight (SDS-PAGE: sodium dodecyl sulfate polyacrylamide gel electrophoresis) of both esterases was determined to be 21.6-23.5 kDa (JEA) and 30.2 kDa (JEB) and the isoelectric point was 5.7-6.1 for esterase JEA and 9.0 for esterase JEB. Most ions caused a negative influence on the activity of both esterases. Both esterases hydrolyzed tributyrin, nitrophenyl esters up to a chain length of C4 and naphtylesters up to a chain length C6. In transesterification reactions, JL was found to be most active at very low water activities (0.2) and in high water activities, the lipase hydrolysed triglycerides into conversions above 80%. JL is a potentially useful biocatalyst in the hydrolysis of triglycerides in organic solvents [13].

Wound healing activities of bark extract in albino rats

J. curcas accelerates the healing process by increasing the skin breaking strength, granulation tissue breaking strength, wound contraction, dry granulation tissue weight and hydroxyproline levels. A significant decrease in epithelization period was also observed. The histopathological examination of granulation tissue showed much advanced phase of healing, with more collagen, which has organized to form bundles [14].

Insecticidal properties

Jatropha seed oil at various serial dilutions ranging from 0% to 2% (v/w) at 0.5% intervals were evaluated for anti-ovipositional activity and long-term protective ability of treated cowpeas against the seed beetle Callosobruchus maculatus. The oil significantly (P< 0.05) reduced oviposition by C. maculatus in no-choice test in all the concentrations tested. Oviposition was significantly reduced at all the oil concentration evaluated. J. curcas oil also offers a 12-week protection for treated seeds since there was neither seed damage nor adult emergency in treated cowpea seeds. The results of this study suggest J. curcas has antioviposition and ovicidal effects on C. maculatus therefore making it a viable candidate for incorporation into pest control program of gain legumes [15].

Pregnancy terminating effect

The fertility regulatory effect of the fruit of J. curcas was investigated by oral administration of different extracts to pregnant rats for varying periods of time. Foetal resorption was observed with methanol, petroleum ether and dichloromethane extracts indicating the abortifacient properties of the fruit. The results also suggest that the interruption of pregnancy occurred at an early stage after implantation. This effect could be accomplished even when the extracts were given from the 6th to the 8th day of pregnancy. Loss of body weight during the dosing period, ranging from slight to severe was seen in the treated animals [16].

Antidiarrhoeal activity of root extract

Use of Jatropha roots in the treatment of diarrhoea is a common ethnobotanical practice in Konkan, a part of the Western coastal area of India. Roots of this species were undertaken for pharmacognostic studies and evaluation of antidiarrhoeal activity in albino mice. The methanol fraction after successive extraction showed activity against castor oil induced diarrhoea and intraluminal accumulation of fluid. It also reduced gastrointestinal motility after charcoal meal administration in albino mice. The results indicate that action of J. curcus root methanol extract could be through a combination of inhibition of elevated prostaglandin biosynthesis and reduced propulsive movement of the small intestine [17].

PHYTOCONSTITUENTS

The seed which is black and oval in shape is rich in fixed oil. The oil content of the seed is high (66.4%) [18] (**Table 1 and 2).**

Table 1: Lipid composition of Jatropa curcus

Percentage oil composition and lipid classes		Fatty acid composition		Triacylglycerols	
Composition	**Percentage**	**Composition**	**Percentage**	**Composition**	**Percentage**
Oil	66.4	Palmitic acid (C16:0)	11.3	PPO/POP	2.7
Unsaponifiable	3.8	Stearic acid (C18:0)	17.0	PLP	1.5
Hydrocarbons/ sytereo esters	4.8	Oleic acid (C18:1)	12.8	SOP	2.0
Triacycerols	88.2	Linoleic acid (C18:2)	47.3	OPO/POO	12.5
Free fatty acids	3.4	Arachidic acid (C20:0)	4.7	POL	10.0
Diacyglycerols	2.5	Arachidoleic acid (C20:1)	1.8	SOO/OSO	3.3
Sterols	2.2	Beheric acid (C22:0)	0.6	OOO	0.4
Monoacyglycerols	1.7	C24:0	44	OOL	31.2
Polar lipids	2.0			LLO	19.8
				LLL	10.7
				BOO	3.5
				Unidentified	2.4

Table 2: Physicochemical parameter of Jatropha curcas oil [19]

Colour	Golden yellow
Specific gravity	0.8601
Refractive index	1.4735
Free fatty acids (%)	4.54
Acid value (mg. $KOH.g^{-1}$)	4.24
Saponification value (mg. $KOH.g^{-1}$)	169.9
Iodine value (mg. I_2. g^{-1})	111.6
Peroxide value (mg reac. O_2 g^{-1})	3.5

manure for improving physical and chemical properties of the soil [20].

The shell of the seeds composed mainly of fiber (> 83% neutral detergent fiber) and very little crude protein (CP < 6%). The kernels were rich in CP (22.2-27.7%) and lipid (53.9-58.5%).(19) The seed cake produced after oil expulsion is rich in nitrogen (> 5 %), phosphorus (>2.5% P_2O_5) and potassium (1% K_2O) and can be converted into valuable organic

TOXICITY

The plant poisoning is irritating, with acute abdominal pain and nausea about 1/2 hour following ingestion. Diarrhea and nausea continue but are not usually serious. Depression and collapse may occur, especially in children. Two seeds are strong purgative, four to five seed are said to have caused death, but the roasted seed is said to be nearly innocuous. Bark, fruit, leaf, root, and wood are all reported to contain HCN [37]. Seeds contain the dangerous toxalbumin curcin, rendering them potentially fatally toxic [29]

Routes of entry:

Oral-All cases of systemic poisoning have resulted from ingestion of plant material (in most cases the seeds).

Main risks and target organs

Main risks are dehydration and cardiovascular collapse as a result of haemorrhagic gastro-enteritis and central nervous system depression.

Poisonous parts-All parts are considered toxic but in particular the seeds.

Acute poisoning:

Ingestion: Symptoms of poisoning are likely to be similar for all species of Jatropha. There is usually a delay of an hour or more between consumption of the plant and the occurrence of symptoms. Symptoms are largely those associated with gastro-intestinal irritation.

There is acute abdominal pain and a burning sensation in the throat about half an hour after ingestion of the seeds followed by nausea, vomiting and profuse watery diarrhoea. In severe poisoning, these symptoms progress to haemorrhagic gastroenteritis and dehydration. Polydypsia can be extreme. Salivation and sweating may occur. There may be skeletal muscle spasm. Intense hyperpnoea or a quick panting respiration is seen together with hypotension and electrocardiographic abnormalities. There may be CNS and cardiovascular depression, children are more susceptible; this may be either a direct effect of toxins or secondary to dehydration.

In one report, gastrointestinal symptoms as well as atropine-like effects developed eight hours after ingestion of Jatropha multifida [38]. Symptoms included sweating, dry skin and mouth, slight mydriasis, mild tachycardia, and flushing of facial skin and persisted for four hours.
Skin exposure: Primary chemical irritation from mechanical and/or chemical injury [39].
Eye contact: Primary chemical irritation from mechanical and/or chemical injury.

Systematic description of clinical effects:

a. Cardiovascular- Hypotension with a fast weak pulse. Shock due to fluid and electrolyte loss may occur. Electrocardiographic abnormalities.
b. Respiratory- Hyperpnoea.
c. Neurological

1. CNS- There may be CNS depression either as a direct result of toxins or secondary to hypotension. Seizures have been mentioned in association with toxalbumin poisoning, but generally in animal cases or in symptom summaries rather than actual case reports (Micromedex-software database, 1974-1994).

2. Autonomic nervous system-There have been reports of salivation, sweating and abdominal cramping occurring in human intoxications of Jatropha macrorhiza root [40].This suggests some cholinergic activity. Contrary to this, atropine-like effects have been reported [38]; thus diminished cholinergic stimulation may be evident- mydriasis, dry mouth, flushed hot dry skin, tachycardia, etc.

d. Skeletal and smooth muscle- The muscles and extremities may be contracted by spasms. Intestinal spasm can be severe.
e. Gastrointestinal- Acute abdominal pain and a burning sensation in the throat about half an hour after ingestion of the seeds. This is followed by nausea, vomiting and profuse watery diarrhoea. The vomitus and faeces may contain blood. Lesions are those of haemorrhagic gastro-intestinal inflammation.
f. Hepatic- Liver damage may occur in serious cases of toxalbumin poisoning. There may be increases ALT, total bilirubin, and AST. (Micromedex, 1974-1994)
g. Urinary: Renal-Oliguria, probably secondary to hypotension rather than direct renal toxicity. Urinalysis may reveal haemoglobinuria and albuminuria.
h. Dermatological- Dermatitis because of primary chemical irritation possibly in conjunction with mechanical injury can occur in most, if not all, individuals. Reactions occur soon after exposure. The severity of the reaction is dependent on the extent and duration of contact. Hypersensitisation may also be developed.
i. Eye, ears, nose, and throat: Local effects-retinal haemorrhages, optic nerve injury have been reported in toxalbumin poisoning (Micromedex, 1974-1994).
j. Hematological: Haemoconcentration secondary to fluid loss. Toxalbumins are haemagluttinating. Effects in poisoning are minimal even though the effect is prominent invitro. (Micromedex, 1974-1994)
k. Allergic reactions- Stated as being a primary chemical irritant [39], but hypersensitivity reactions may occur in susceptible individuals. The inflammation resulting from primary chemical irritant effects of Jatropha is a predisposing factor to the development of contact allergy.
l. Other clinical effects-Toxalbumin poisoning may produce fever (Micromedex, 1974-1994) and oedematous swelling of several organs.

Carcinogenicity:

The seed oil of J. curcas was found to contain skin tumour promoters in a two-stage mouse carcinogenesis experiment. The "irritant fraction" present in the methanol extract of the seed oil when partially purified induced ornithine decarboxylase in mouse skin and inhibited the specific binding of 3H-12-O-tetradecanoylphorbol-13-acetate(TPA) to a particulate fraction of mouse skin. After initiation with 7, 12-dimethylbenz[a]anthracene (DMBA), this "irritant fraction" induced tumours in the skin of 36% of the mice tested in 30 weeks [41].

Main toxins: Curcin: Phytotoxins or toxalbumins are large, complex protein molecules of high toxicity. Curcin is said to be irritant and remains in the seed after the oil has been expressed and found in the fruit and sap.

It has been suggested that invivo phytotoxins act as proteolytic enzymes, owing their toxicity to the breakdown of critical proteins and the accumulation of ammonia [42].

Purgative oil - The seed yields 40% oil, known as hell oil, pinheon oil, oleum infernale or oleum ricini majoris, which contains small amounts of an irritant curcanoleic acid, which is related to ricinoleic acid and crotonoleic acid, the principle active ingredients of castor oil and croton oil respectively [43].

Other toxins:

- There may be a dermatitis producing resin [39].
- There may be an alkaloid, and a glycoside which produce cardiovascular and respiratory depression.
- Tetramethylpyrazine (TMPZ), an amide alkaloid has been obtained from the stem of J. podagrica. It has been found to possess a non-specific spasmolytic and vasodilator activity [44]. These actions may account, at least in part, for the reported hypotensive (depressor) effects of the amide alkaloid in experimental animals. TMPZ has also been found to possess neuromuscular-blocking effects similar to d-tubocurarine [45].

MANAGEMENT

General principles

1. The management of Jatropha poisoning is similar to that for the castor bean (Ricinis). Decontamination is indicated for all known or suspected poisonings. There is no antidote.
2. Rehydration, either voluntary water ingestion or i.v. fluid administration, to counteract fluid lost due to vomiting and diarrhoea is critical. Treatment is essentially symptomatic and supportive. The more critical analyses and investigations are fluid and electrolytes, acid-base status, full blood count, and renal and hepatic function.
3. Monitor level of consciousness.
4. Specific therapy may be indicated for haemorrhagic gastrointestinal damage, skeletal muscle and gastrointesinal spasm, excessive salivary secretions and haemoglobinuria.
5. After substantial exposures to toxalbumin containing plants, an observation period of up to 8 hours is advised.

First-aid measures and management principles

Ingestion: Unless the patient is unconscious, convulsing, or unable to swallow give fluids (milk or water) to dilute.

1. Seek medical assistance. In hospital or a health care facility
2. Induce vomiting unless the patient has already vomited, or perform gastric lavage.
3. Administer activated charcoal and a cathartic to hasten elimination, although in the presence of diarrhoea this is unnecessary.

Skin: Wash the affected area well with plenty of water and use a mild soap.
Eye: Flush the eye with copious amounts of water for at least 15 minutes.

If irritation persists seek medical assistance.
Relevant laboratory analyses and other investigations
Other investigations-Monitor hepatic, renal, pancreatic, and red blood cell function.

Life supportive procedures and symptomatic treatment

Fluid and electrolyte status may deteriorate suddenly and severely. Give i.v. fluids and electrolyte as necessary to restore and maintain fluid and electrolyte balance. Monitor renal function and alkalinize urine to minimize effects of haemoglobinuria. Treat haemorrhagic gastro-intestinal damage as for peptic ulceration. Observe for signs of CNS depression and initiate assisted ventilation, if necessary.

Decontamination

In all cases of ingestion or suspected ingestion, if the patient is seen sufficiently soon (within 1-2 hours of ingestion), induce emesis with Ipecac Syrup or perform gastric lavage unless vomiting has been extensive.

Elimination

Administer activated charcoal and a cathartic to enhance and hasten elimination, although severe diarrhoea may make this unnecessary. Cathartic administration must be cautious due to the risk of exacerbating purgation and fluid loss.

Phytotoxins are non dialysable. However, methods for eliminating the toxins from the blood (haemodialysis, peritoneal dialysis, charcoal haemoperfusion etc.) have been suggested as useful, whether this removes plant toxins other than phytotoxins from the blood and therefore improves the prognosis and hastens the recovery, is yet to be demonstrated. A possible indication for this would be life threatening CNS or respiratory depression (not secondary to hypovolaemia) which is unresponsive to other supportive measures.

Detoxification of seed oil

The seed oil contains phorbol esters, a family of compounds known to cause a large number of biological effects such as tumor promotion and inflammation. Therefore, it is necessary to find feasible routes for detoxification of the oil. J. curcas seed oil was treated by traditional oil refining processes examining the effect on the content of phorbol esters. Parameters of several refining steps were varied to optimize the grade of detoxification. Almost no effect could be observed with degumming and deodorization, whereas the steps of deacidification and bleaching could reduce the content of phorbol esters up to 55% [46]

Commercial Application

In the last few years the potential of the drought resistant tropical tree J. curcas for the production of bio-fuels and industrial products has been assessed by several groups. Various novel methods for the cultivation and genetic improvement of J. curcas have been presented. A trans-esterification process of the seed oil for its use as a bio-fuel was evaluated on an industrial scale (1500 t/a).

Various biologically active substances have been isolated and characterized from all parts of the plant. Their mechanisms of action have been studied in relation to a great number of applications of J. curcas in traditional medicine.

Substances such as phorbol esters, responsible for the toxicity of J. curcas to animals and humans, have been isolated and their molluscicidal, insecticidal and fungicidal properties have been demonstrated in lab-scale experiments and field trials.

Newly developed biotechnological processes related to the exploitation of J. curcas include the genetic improvement of the plant, biological pest control, enzyme-supported oil extraction, anaerobic fermentation of the press cake and the isolation of antiinflammatory substances and wound-healing enzymes [47]

1. Oil production: Seeds of J. curcas are used for the production of oil. Several methods for oil extraction have been developed. In all processes, about 50% of the weight of the seeds remains as a press cake containing mainly protein and carbohydrates. Investigations have shown that this residue contains toxic compounds and cannot be used as animal feed without further processing. Preliminary experiments have shown that the residue is a good substrate for biogas production [48].
2. Schistosomiasis control: This plant could become an affordable and effective component of an integrated approach to schistosomiasis control [49].
3. Disinfection and prevention of malaria: J. curcas would provide a very cheap, readily available disinfectant and malaria vector control agent and should be commercially exploited [11].
4. Fertilizer: The seed cake produced after oil expulsion is rich in nitrogen (> 5 %), phosphorus (>2.5% P_2O_5) and potassium (1% K_2O) and can be converted into valuable organic manure for improving physical and chemical properties of the soil.
5. Rehabilitating degraded areas and protecting the land from wind erosion: Preliminary studies have shown that it could prove a very promising species for rehabilitating degraded

areas and protecting the land from wind erosion when introduced in dry areas within the framework of watershed management [50].

6. The Jatropha System: as mean of rural development: The Jatropha System is an integrated rural development approach. By planting Jatropha hedge to protect gardens and fields against roaming animals, the oil from the seeds can be used for soap production, for lighting and cooking and as fuel in special diesel engines. In this way the Jatropha System covers 4 main aspects of rural development:

- promotion of women (local soap production)
- poverty reduction (protecting crops and selling seeds, oil and soap)
- erosion control (planting hedges)
- energy supply for the household and stationary engines in the rural area.

The obvious advantage of this system is that all the processing procedure, and thus all added value, can be kept within the rural area or even within one village. No centralised processing (like in the cotton industry) is necessary.

a) medicinal applications
   - The seeds against constipation
   - The sap for wound healing
   - The leaves as tea against malaria etc.
b) Jatropha is planted in the form of hedges around gardens or fields:
   - to protect the crops against roaming animals like cattle or goats
   - Jatropha plants are used as a source of shade for coffee plants in Cuba
   - In Comore islands, in Papua New Guinea and in Uganda Jatropha plants are used as a support plant for vanilla plants.
c) Soap production: The economy of soap production is positive in all the cases where data were available. Economy of soap production shows impressing profit. The profit changes within the different steps of the processing chain.
d) Jatropha oil as fuel: Jatropha oil in Tanzania (Arusha, Engaruka, Mto Wa Mbu) is traded in small quantities for 2 USD per litre. This is 3-times the price of Diesel fuel at the filling station. This means, it is economically not interesting to use Jatropha oil as diesel substitute. If somebody has Jatropha oil, he sells it to soap makers or produces soap himself and buys diesel with the profit.
e) This is the reason, why KAKUTE offers lamps and cookers for the use of Jatropha oil, but this seems to be an alibi and there is not much interest by the population. Petrol for lighting and cooking is cheaper, if it is available.

7. The role of Jatropha in carbon sequestration (1)

Description of the Jatropha Energy System (JES)

The JES is based on several sub-systems, each with associated activities which allow for different implementation options, and where each module can be operated independently, offering its own potential economic benefits. When these activities are integrated into one system, more value is added**.**

The JES offers a decentralized and localized energy option. This mere fact empowers rural communities: it reduces their dependence on imported fuels, prices of which are highly volatile, given irregular supplies, bad infrastructure and the remoteness of the communities from urban centres. Given the likelihood of oil prices reaching ever higher levels in the future, a localized bio-fuels production system becomes increasingly attractive. Moreover, the system diminishes their reliance on State actors and the culture of political promises which are rarely realised. Unlike other decentralized energy systems, the JES is sustainable in the true sense of the word, for it relies on local knowledge and skills. The transfer of knowledge needed to introduce the system is very limited, whereas the introduction of solar, micro-hydro or wind power systems to small communities requires outside and continuous technical expertise. It moreover offers ecological advantages (retroactively or proactively combating erosion and desertification) and allows local communities to gain full ownership of the technology, in such a way that they can easily make decisions about the expansion and replication of the module, according to their own needs. This "bottom-up" approach has the potential to actively engage communities in producing their own energy (which is less likely with more "static" technologies such as wind power and hydro-electric power). Finally, as a CO_2 neutral system, the JES offers a renewable source of energy, based on simple plantations of the energy crop, which can be fully integrated in the village's existing practices.

Implementation strategies

The first step in the introduction of a Jatropha Energy System consists of building a reliable source of Jatropha seeds. Producing Jatropha seedlings at the village level could become a highly profitable activity in itself.

Seedlings can be sold to plantation owners, or they may be used as natural hedge to protect other crops. Several micro-entrepreneurial activities surrounding the cultivation and trade of these mere seedlings have proved to be successful. Jatropha also makes for a suitable base crop for intercropping systems.

Even though Jatropha is well known in many tropical countries, at the first stage of the introduction of a JES, a constant and reliable source of seeds must be assured, creating the need for a dedicated Jatropha-plantation. Jatropha seeds from hedges could be collected by households once the JES is well established, after which they could be exchanged in a kind of simple "seeds

For the system to power more (community) services and machines, a configuration with local plantations can easily be implemented. In order to support a single power unit with a diesel engine running around 5 hours at day, an average of 4 hectares are needed. In itself, the cultivation of mature Jatropha trees becomes a profitable activity. After 3 years Jatropha plants start to yield, reaching maturity in the 5^{th} year. The seeds from Jatropha will be bought either directly by engine owners or by independent millers who process them into bio-fuel until the cost of Jatropha oil will be lower than diesel.

Low labour and investment costs make the JES a low risk system, which allows communities to save money on fuel. As diesel or gasoline tends to be a big cost factor in local village life, with those fuels making up even the biggest cost in marketing agricultural produce, the JES offers an attractive opportunity to generate income (through the sail of oil) and savings (on operating costs of local production processes). When a cooperative approach is taken, these extra-savings can be used to lower milling charges, to support social services or to be invested in extensions of the system.

The JES represents an excellent commercial opportunity for private individuals and entrepreneurs. When introduced, the system creates a competitive environment in the local economy, whereby those who are involved in operations based on the use of diesel fuel (mill operators and others), will naturally have to switch to using the cheaper Jatropha oil. This in turn creates a situation where the introduction of a renewable energy source by one player, forces others to adopt it too, in order to compete [51].

40–50% of Jatropha oil can be substituted for diesel without any engine modification and preheating of the blends [52] **(Table 4).**

Table 3: Chemical constituents of Jatropha curcas

Constituent	Nature	Part from which obtained	Application
Curcin [9]	Toxic protein- a kind of toxalbumin Type-I rip, a single chain protein	Seeds Fruits and sap	Anticancer and construction of immunotoxins
13,16-diester of 12-deoxy-16-hydroxyphorbol, 12-deoxy-16-hydroxyphorbol-4'-[12',14'-butadienyl]-6'-[16',18',20' - nonatrienyl]-bicyclo[3.1.0]hexane-(13-O)-2'-[carboxylate]-(16-O)-3 '-[8'-butenoic-10']ate (DHPB) [21]	New phorbol ester which has macrocyclic dicarboxylic acid diester structure	Seed oil	Tumor promoter
Curcusone B [8]	Diterpene		Anti-metastatic potential
Campesterol, Stigmasterol, β-Sitosterol, δ-5-Avenasterol and δ-7 Stigmasterol [22]		Seed oil	
Ethyl acetate fraction of latex [10]		Latex	Procoagulant activity
Butanol fraction		Latex	Anticoagulant activity
Curcacycline A [23]	A novel cyclic octapeptide-	Latex	Inhibition of (i) classical pathway

Constituent	Nature	Part from which obtained	Application
	contain one threonine, one valine, two glycine, and four leucine residues - Gly1-Leu2-Leu3-Gly4-Thr5-Val6-Leu7-Leu8-Gly1+ ++.		activity of human complement and (ii) proliferation of human t-cells
Curcain [24]	A proteolytic enzyme. Mw 22,000 daltons	Latex	Proteolytic
Two new esterases (JEA and JEB) [25]	Hydrolyzed tributyrin, nitrophenyl esters up to a chain length of =C4 and naphthylesters up to a chain length =C6.	Seeds	Esterase
A lipase (JL)	Hydrolysed triglycerides into conversions above 80% even in organic solvents	Seeds	Lipase-biocatalyst
Complex of 5-hydroxypyrrolidin-2-one and pyrimidine-2,4-dione [25]		Leaves	
A β-1,3-glucanase [26]	Molecular weight of 65-66kd-protein		Antifungal activity
cyanic acid [27]			Toxic properties
tetradecyl-(E)-ferulate, 3-O-(Z)-coumaroyl oleanolic acid, heudelotinone, epi-isojatrogrossidione, 2alpha-hydroxy-epi-isojatrogrossidione and 2-methyanthraquinon [28]			
7-Keto-β-Sitosterol [29]		Seed	No activity reported
α- Amyrin [29]		Leaf	Analgesic ; antiedemic antiinflammatory; antinociceptive; antitumor ; antiulcer ; cytotoxic; gastroprotective ; hepatoprotective ; insectifuge
Arabinose [29]		Seed	No activity reported.
β- Amyrin [29]		Bark	Analgesic antiedemic antiinflammatory antinociceptive; antiulcer ; gastroprotective ; hepatoprotective ; larvicide mosquitocide
β-Sitosterol-3-O-β-D-glucoside [29]		Leaf	No activity reported
β-Sitosterol-β-D-glucoside [29]		Seed	Antileukemic antispasmodic antitumor hypoglycemic
Campesterol [29]		Leaf	Antioxidant hypocholesterolemic
Curcin [29]		Seed	No activity reported.

Constituent	Nature	Part from which obtained	Application
Curcusones [29]		Plant	No activity reported
Dulcitol [29]		Seed	Antitumor sweetener
Isovitexin [29]		Leaf	Ace-inhibitor antioxidant cancer-preventive
N-1-Triacontanol [29]		Leaf	No activity reported
Raffinose [29]		Seed	Flatugenic
Stachyose [29]		Seed	Flatugenic
Stigmast-5-ene-3-β-7-α-diol [29]		Leaf	Antifertility
Stigmast-5-ene-3-β-7-β-diol [29]		Leaf	Antifertility
Taraxasterol [29]		Bark	Antiedemic, antiinflammatory
Vitexin [29-34]		Leaf	Ace-inhibitor, Aldose-reductase-inhibitor, antiarrhythmic, antibradiquinic, antidermatitic, antihistaminic, antiinflammatory, antioxidant, antiserotoninic, antithyroid, aphidifuge, Camp-phosphodiesterase-inhibitor , Cancer-preventive goitrogenic hypotensive thyroid-peroxidase-inhibitor
Complex of 5-hydroxypyrrolidin-2-1 and pyrimidine-2,4-dione [25]		Leaves	
Curcacycline B (1) [35]	Cyclic nonapeptide	Latex	Enhancing rotamase activity of cyclophilin
CP1, JC1 and JC2 [36]	Deoxypreussomerins, palmarumycins		JC1 and JC2 are antibacterial

Table 4: Jatropha oil in Comparison with Diesel fuel [53]

Parameter	Diesel	Jatropha Oil
Energy content (MJ/kg)	42.6 - 45.0	39.6 - 41.8
Spec. weight (15/40 °C)	0.84 - 0.85	0.91 - 0.92
Solidifying point (°C)	-14.0	2.0
Flash point (°C)	80	110 – 240
Cetane value	47.8	51.0
Sulphur (%)	1.0 - 1.2	0.13

Energy:

The clear oil expressed from the seed has been used for illumination and lubricating, and more recently has been suggested for energetic purposes, one ton of nuts yielding 70 kg refined petroleum, 40 kg "gasoil leger" (light fuel oil), 40 kg regular fuel oil, 34 kg dry tar/pitch/rosin, 270 kg coke-like char, and 200 kg ammonical water, natural gas, creosote, etc.

Government of India has selected the plant for National Program compared to others due to followings: -

- Low cost seeds
- High oil content
- Small gestation period
- Growth on good and degraded soil
- Growth in low and high rainfall areas
- Seeds can be harvested in non-rainy season

Plant size is making collection of seeds more convenient of all the above prospective plant candidates as bio-diesel yielding sources, Jatropha curcas is standing "at the top” [3].

CONCLUSION

Jatropha curcas is a quick-growing and popular tree. It is a traditionally important medicinal plant and having various commercial applications.

1. Jatropha curcas having anti-inflammatory, anti-metastatics, anti-tumor, coagulant and anti-coagulant, disinfectant / anti-parasitic, wound healing, insecticidal, pregnancy terminating activity and anti-diarrhoeal effect.
2. The main constituents are curcin, curcusone B, curcain, campesterol and curcacycline-A.
3. The plant having toxic potential, toxicity is due to curcin and tetramethylpyrazine. The seed oil contains phorbol esters, known to cause a large number of biological effects. However, the toxicity can be managed by deacidification and bleaching of phorbol esters.
4. Now a day’s plant has been used for various commercial applications such as oil production, schistosomiasis control, disinfection, prevention of malaria and fertilizer.

These properties make this plant as a highly commercial one and as an alternative energy source to local as well as to world community.

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