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Review

Ethnobotany, ethnopharmacology and toxicity of *Jatropha curcas* L. (Euphorbiaceae): A review

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ABSTRACT

Jatropha curcas L. (Euphorbiaceae) is a multiple purpose plant with potential for biodiesel production and medicinal uses. It has been used for treatment of a wide spectrum of ailments related to skin, cancer, digestive, respiratory and infectious diseases. This review aims to provide an up-to-date survey of information available on botany, traditional uses, phytochemistry, pharmacology and toxicity of *J. curcas*. Establishing a scientific basis that explains its ethnopharmacological uses in order to facilitate and guide future research. The review covers literature available from 1960 to 2012 collected from scientific journals, books and electronic searches such as Google scholar, Web of Science and ScienceDirect. Ethnomedicinal uses of *J. curcas* have been reported from many countries in Africa, Asia, South America and the Middle East for almost 100 different types of ailments. The phytochemical studies have shown the presence of many secondary metabolites including diterpeniods, sesquiterpenoids, alkaloids, flavonoids, phenols, lignans, coumarins and cyclic peptides. Crude extracts and isolated compounds from *J. curcas* show a wide range of pharmacological activities, such as anti-inflammatory, antioxidant, antimicrobial, antiviral, anticancer, antidiabetic, anticoagulant, hepatoprotective, analgesic and abortifacient effects. *J. curcas* has been a widely used source of medicine for decades in many cultures. The present review reveals that *J. curcas* is a valuable source of medicinally important molecules and provides convincing support for its future use in modern medicine.

Contents

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1. Introduction

Jatropha curcas is a multiple purpose plant with potential for biodiesel production and medicinal uses. In recent years, increased interest in its seed oil for biodiesel production has encouraged cultivation of the plant on large scale. There are predictions that millions of hectares will come under *J. curcas* cultivation (Devappa et al., 2011). This would generate huge quantities of raw materials for biodiesel and other potential uses that could open new routes for sustainable ecofriendly development.

A number of reviews were written on the genus *Jatropha* covering various aspects for example, medicinal properties, phytochemistry and pharmacology (Sabandar et al., 2012; Sharma and Singh, 2012), diterpenes (Devappa et al., 2011), toxicity (Devappa et al., 2010a), nutritional, biochemical, and pharmaceutical potential of proteins and peptides (Devappa et al., 2010b) and chemical constituents (Zhang et al., 2009). Although there are some reviews published recently on medicinal benefits and applications from *J. curcas* species (Prasad et al., 2012; Sharma et al., 2012; Luis et al., 2012; Kamal et al., 2011; Thomas et al., 2008), there is still a crucial need for an inclusive review that covers the therapeutic and toxicological potential of this species. The present review attempts to collate the available information on the botany, traditional uses, phytochemistry, pharmacology and toxicity of *J. curcas*. We hope that this review may provide scientific basis that explain the ethnopharmacological use of *J. curcas* in order to facilitate and guide future research. In particular, we aimed to answer the following questions. (1) What information is available on the traditional uses, botany, phytochemistry and toxicity of *J. curcas*? (2) What pharmacological studies were performed on this plant and how do they validate its traditional uses? and (3) What is the future for *J. curcas*?.

1.1. Taxonomy and botanical description

The genus *Jatropha* belongs to the tribe Jatropheae in the Euphorbiaceae family and contains approximately 170 known species (Carels, 2009; Dehgan and Webster, 1979). The botanical name of the genus *Jatropha* was derived from the Greek word "Jatros" meaning a doctor and "trophe" meaning food (Kumar and Sharma, 2008) which incorporates the historical medicinal uses of this plant. *J. curcas* L. (Fig. 1) is a dense shrub or small tree 3–5 m in height. It can reach up to 10 m under favourable conditions. It is a diploid species with $2n = 22$ chromosomes (Carels, 2009). There are two genotypes found in Mexico classified as toxic and non-toxic (Becker and Makkar, 2008). The life span of the plant is up to 50 years (Achten et al., 2010). It is a deciduous plant with an articulated growth habit with morphological discontinuity (Becker and Makkar, 2008). The root system constitutes a main taproot and four shallow lateral roots (Carels, 2009; Heller, 1996; Neuwinger, 1996). The branches are glabrous with smooth greenish-bronze-coloured bark and translucent latex (Neuwinger, 1996). The leaves are smooth simple, 5-lobed and heart-shaped, 10–15 cm long, dark green, cordate or round, acute at the apex, cordate at the base, alternate and may fall once a year (Dehgan and Webster, 1979; Neuwinger, 1996). The flowers are in axillary clusters with a stalk of 3–5 cm long, bracts entire, lanceolate or linear, densely pubescent, yellowish-green, with prominent glandular discs in the flowers. Male flowers with 5 ovate-elliptic sepals, less than 4 mm long and 5-oblong-obovate petals united in the lower half, densely hairy inside, 6–7 mm long, 8 stamens. Female flowers with free oblong petals and larger sepals, 4 mm long (Abdelgadir et al., 2009; Bhattacharya et al., 2005; Chang-Wei et al., 2007; Raju and Ezradanam, 2002). Fruits are ovoid capsules 3–4 cm long, slightly trilobite, splitting into three cells. The seeds are three per fruit, large, oblong, 2 cm long and sweet tasting (Kochhar et al., 2008; Neuwinger, 1996).

1.2. Habitat, distribution and ecology

The center of origin of *J. curcas* is in the Northeastern part of South America and the dry areas of Mexico (Jongschaap et al., 2007; Makkar et al., 2009). It was reported that the plant was distributed by Portuguese ships via the Cape Verde Islands and Guinea Bissau to other countries in Africa and Asia (Heller, 1996). Currently it is cultivated abundantly in many tropical and sub-tropical regions in Africa and Asia (Schmook and Serralta-Peraza, 1997) as an ornamental tree (Iwu, 1993) or as sturdy hedges (Neuwinger, 1996). *J. curcas* grows under conditions where the temperature ranges between 15 and 40 °C (Kumar and Sharma, 2008). The plant is not sensitive to day length and may flower any time of the year (Heller, 1996). It grows well under a wide range of rainfall from 250 to over 1200 mm per annum. During low rainfall and prolonged dry periods the plant sheds its leaves as a counter to drought. The plant grows well in well drained soils with good aeration and is well adapted to marginal soils with low nutrient content (Openshaw, 2000).

1.3. General uses

J. curcas seed kernels contain 31–35% crude protein and 55–58% lipid (Martínez-Herrera et al., 2006). The oil is composed of 97.6% neutral lipids, 0.95% glycolipids and 1.45% phospholipids (Rao et al., 2009).

Fig. 1. *Jatropha curcas* (A) mature plant; (B) seedling; (C) inflorescence with male and female flowers; (D) fruits at different stages of ripeness; and (E) mature fruit with seeds.

The unsaturated fatty acids dominate the saturated fatty acids in a ratio of 3:1 (Joshi et al., 2011). The main fatty acids found in *J. curcas* oil are oleic (41.5–48.8%), linoleic (34.6–44.4%), palmitic (10.5–13%), stearic (2.3–2.8%) in addition to cis-11-eicosenoic and cis-11,14eicosadienoic acids (Martínez-Herrera et al., 2006). Having a high oil and protein content makes the plant a good candidate for many usages and industries. The history of the commercialization of *J. curcas* was started by the exportation of its seed oil hundreds of years ago from Cape Verde to Portugal for soap production and lamps (Gübitz et al., 1999). The seed oil properties have been sufficiently persuasive to consider it as a substitute for fossil fuels to help reduce greenhouse gas emissions (Abdelgadir et al., 2010). The oil can be used in manufacturing of candles, soaps and cosmetics. The seed cake or kernel meal provides a highly nutritious and economic protein supplement for animal feed if detoxified (Makkar et al., 1998). Recently, Visser et al. (2011) reported the possibility of producing cellulosic methanol from the by-products of *J. curcas* oil extraction. The plant can be used to prevent soil erosion, reclaim land and as a living fence (Heller, 1996).

2. Vernacular names and traditional uses

2.1. Vernacular names

J. curcas L. (Fig. 1) is commonly known as: Barbados nut, termite plant, fig nut, black vomit nut, curcas bean, kukui haole, physic nut, purge nut, purgeerboontjie, purging nut tree, hab el-meluk, bubble-bush, ratanjot (Iwu, 1993; Ram et al., 2008). It is known by various vernacular names in Africa as: tabanani, kidi, bagani in Senegal, Gambia, Guniea, Sierra Leone and Ivory Coast; kpoti in Ghana and Togo; habb el meluk in Sudan; mupfure-donga, mupfure-wa-tshikhuwa, purgeerboontjie in South Africa (Neuwinger, 1996); and botute or omangba in Nigeria (Gbolade, 2009; Igoli et al., 2005).

2.2. Hunting poison

The stem bark or the latex is a fishing poison in some parts of Africa and the Philippines. In Nigeria a mixture of *J. curcas* seeds and the latex of *Euphorbia poisnii* or *E. unispina* mixed with corn is used as bait for hunting guinea-fowl. Some tribes make arrow poison from seed or seed oil of *J. curcas* and *Strophanthus* spp. in Nigeria and Burkina Faso. Seeds grated with palm oil are used to kill rats in Gabon (Neuwinger, 1996). These traditional uses as hunting poison are related to the high toxicity of the seed and latex of *J. curcas*. Table 7 contains a summary of its toxic components and their modes of action.

2.3. Uses in traditional veterinary practices and medicine

Most parts of *J. curcas* have been widely used for veterinary purposes. The seeds are highly effective against *Strongyloides papillosus* infection in goats (Adam and Magzoub, 1975). Uses of various parts of *J. curcas* in folk and traditional medicine worldwide have been summarized in Table 1. However, the majority of these observations have not been tested following scientific principles, and therefore, the use of *J. curcas* plant parts for such applications should be used with caution. All parts of *J. curcas* have been widely used in west and central Africa (Neuwinger, 1996). The dried plant sap rubbed to a powder

Table 1
Uses of different plant parts of *Jatropha curcas* in folk and traditional medicine.

Plant part	Region	Form	Use	Reference
Leaves	West Africa	Decoction	Lactagogue, rubefacient, suppurative	Iwu (1993)
		Decoction + lime juice	Fever, convulsions, anthelmintic	Iwu (1993)
		Ash from burn leaves	To draw out the guinea worm sore	Iwu (1993)
		Infusion of young leaves	Urinary complaints	Iwu (1993)
		Boiled (*Jatropha curcas* + *Azadirachta indica* + *Carica papaya*)	Malaria (drink and bath)	Asase et al. (2005); Wole and Ayanbode (2009)
	Nigeria	Decoction of boiled leaves (*J. curcas* + *Syzygium guineese*) + palm oil	Drink for diabetes	Gbolade (2009)
	Cameroon	Raw leaves	*Arthritis*; against abscess in the stomach	Watt and Breyer-Brandwijk (1962); Sandberg et al. (2005)
	Benin	Leaf decoction	Oedemas and cough (orally and external use)	Neuwinger (1996)
		Decoction of leaves + roots + fruits of *Xylopia ethiopica*	Drepanocytosis (drink)	Neuwinger (1996)
		Fresh leaves + kaolin pounded in water	Haemorrhoids (drink 150 ml once a day)	Neuwinger (1996)
	India	Leaf (paste + crude)	Jaundice and liver troubles	Sharma et al. (2010a)
		Tender leaves	Headache	Udayan et al. (2007)
		Leaves paste	Burn spot; chest inflammation, congestion, headache, hypertension, eczema, galactogogue	Nath and Choudhury (2010); Jain and Srivastava (2005)
		Leaf juice	Amenorrhoea and oligomenorrhoea	Jain and Srivastava (2005)
		Leaf paste of J. curcas and *J. gossypifolia*	Night blindness (eyes are covered with paste for 2–3 days)	Patil and Bhaskar (2006); Dolui et al. (2004)
		Infusion	Diabetes	Jaiswal (2010)
		Leaf poultice	Furuncle, hair loss	Jain and Srivastava (2005)
		Crushed leaves	Haemostatic, styptic when applied on cuts and furuncle, hair loss bleeding wounds, snake bite	Watt and Breyer-Brandwijk (1962); Neuwinger (1996); Osoniyi and Onajobi (2003); Balangcod and Balangcod (2011)
	Colombia	Decoction	Drink for venereal diseases;	Morton (1981)
	Costa Rica	Poultice	Erysipelas and splenosis	Morton (1981)
	Barbados	Tea	Marasmas, jaundice	Ocampo and Balick (2009)
	Panama	leaf poultice	As rubefacient for: paralysis rheumatism and hard tumor	Morton (1981)
	Guatemala	Heated leaves	Lactagogue	Morton (1981)
		Crushed leaves	Haemostasis, styptic when applied on cuts and bleeding wounds, snake bite	Watt and Breyer-Brandwijk (1962); Neuwinger (1996);
Latex		Paste	Dressing wounds, inflamed tongues and ulcer	Osoniyi and Onajobi (2003); Perry (1980)
	West Africa	Latex + salt	Carious teeth and help tooth come out in children, mouthwash	Iwu (1993)
	Benin	Dried latex	Leucorrhagia, urethritis	Neuwinger (1996)
	Mali	Paste	To stop bleeding, against infection	Wole and Ayanbode (2009)
	Cuba	Paste	Toothache	
	Colombia	Paste	Burns, haemorrhiods, ringworm, ulcer	
	Bahamas	Decoction	Heart burn	
	India	Latex + salt	Headache	Rajendran et al. (2008); Tripathi and Srivastava (2010);
			Eczema, scabies, wounds, burn, cancer	Verma and Chauhan (2007); Silja et al (2008);
			Toothache, mouth ulcer, cracked lips	Jain and Srivastava (2005);
			Otorrhoea, cold and cough	Deka et al. (2008); Yesodharan and Sujana (2007);
			Itching of genital organs	Meena and Yadav (2010); Nath and Choudhury (2010);
				Ganesan et al., 2004 (2006); Samuel and Andrews (2010)
Roots	India	Decoction	Mouthwash for bleeding gum and toothache; eczema, ringworm,	Duke and Ayensu (1985)
		Root bark decoction	Mouthwash for toothache and sore throat; abortifacient	Yesodharan and Sujana (2007): Jain and Srivastava (2005)
	Venezuela	Decoction	Dysentery	Iwu (1993)
	West Africa	Decoction	Gonorrhea	Iwu (1993)
		Powdered root bark	Dressing wound and sores	Iwu (1993)
		Infusion of root	Rheumatism, dyspepsia, diarrhea,	Iwu (1993)
		Root pulp + *Xylopia* sp. fruits	Dysentery, incontinence	Iwu (1993)
	Cameroon	Decoction of root 0.5 kg in 5 l water + indigenous salt	Hypertension (100–150 ml) drunk twice a day for 6 d; sexually transmitted disease	Noumi et al. (1999)
Seeds	India	Gargle of fresh stem juice	Arthritis, gout, jaundice, purgative	Kumar and Sharma (2008); Katewa et al. (2008); Jain and Srivastava (2005)
			Toothache; angular stomatitis	Rajendran et al. (2008)
			Constipation	Shiddamallayya et al. (2010)
			Rheumatism, dermatitis, herpes, dropsy	Jain and Srivastava (2005)
			Dysentery, stomach disorders, rheumatism	Jain et al. (2010)
	Mali		Laxative	Wole and Ayanbode (2009)
Stem	West Africa	Roasted seeds + shea butter	Dropsy, gout, paralysis, skin ailments	Watt and Breyer-Brandwijk (1962)
		Preparations containing seeds	Guinea worm infection, tumors, syphilis, skin infestation, abortifacient	Watt and Breyer-Brandwijk (1962)

(continued on next page)

Table 1 (*continued*)

Plant part	Region	Form	Use	Reference
		Leafy twigs pounded in water	Glass of the filtrate is drunk once a day for malaria	Neuwinger (1996)
		Young twigs paste + black pepper	White discharge (given twice a day)	Verma and Chauhan (2007); Mairh et al. (2010); Silja et al. (2008);
		Twigs	Chewing for: pyorrhea, gum and teeth problems; as tooth brush	Jain and Srivastava (2005); Dolui et al. (2004)
		Juice	Dysentery (taken orally 3 times a day) Sores, haemostatic, wound	Jain and Srivastava (2005)
		Crushed stem heated with oil	As massage for muscles pain, hematoma	Balangcod and Balangcod (2011)
Bark	India	Infusion + salt	Diarrhea, dysentery	Borah et al. (2006); Purkayastha et al. (2007)
		Water extract mixed with milk	Diabetes (given for two weeks	Jayakumar et al. (2010)
		Bark powder paste	Muscular pain	Kamble et al. (2010)
		Bark juice	Scabies	Jeeva et al. (2006)
		Bark	Mouth sore (chewing)	Jeeva et al. (2006)
	India	Gargle of fresh stem juice	Toothache; angular stomatitis	Rajendran et al. (2008)
Oil	West Africa		Itch, herpes, as rubefacient	Iwu (1993)
			Eczema, skin diseases, rheumatism	Heller (1996)
	India		Leukoderma, sores and pimple	Tripathi and Srivastava (2010); Pawar and Patil (2006);
			Massage for arthritis, rheumatism, paralytic affections, leprosy	Jeeva et al. (2006); Shiddamallayya et al. (2010);
Fruit	India	Fruit powder	Constipation	Sharma et al. (2010a)
			On fracture, swelling, headache	Jain and Srivastava (2005)
	Nigeria	Fruit burnt into ashes And taken with pap	Diabetes	Jain and Srivastava (2005) Gbolade (2009)
	Benin	Fruit powder	Constipation	Neuwinger (1996)
			Dysentery, stomach disorders, rheumatism	Jain et al. (2010)
	Mali		Laxative	Wole and Ayanbode (2009)

between the hands and applied to wounds is regarded as "penicillin" in The Congo. In Senegal, Nigeria, Congo and East Africa, the leaf, stem sap or the dried powdered plant is spread on flesh wounds as a haemostatic. In Ivory Coast grilled leaves are crushed together with saliva and the paste is applied to abscesses and wounds. A few drops of diluted water solution of twig sap are given by mouth to new-born babies affected by tetanus. The leaf has been used as haemostatic agent when applied to cuts and bleeding wounds (Neuwinger, 1996). The seeds have been used for treating ascites, gout, paralysis, skin diseases and as a purgative, anthelminthic and abortifacient. In some parts of Africa seeds are chewed when in need of a laxative (Wole and Ayanbode, 2009). The seed oil has been used as ingredient in the treatment of rheumatism (Heller, 1996; Iwu, 1993).

3. Phytochemical analysis

Jatropha species are rich sources of phytochemicals such as terpenes, cyclic peptides alkaloids and lignans (Devappa et al., 2010a). Numerous papers (El Diwani et al., 2009; Igbinosa et al., 2011; Makkar et al., 2009; Manpong et al., 2009; Namuli et al., 2011; Oskoueian et al., 2011a) have reported the presence of secondary metabolites in different parts of *J. curcas*. The biological activities of the secondary metabolites isolated from *J. curcas* are presented in Table 2.

3.1. Diterpenes

Diterpenes have been dominating the research area in *J. curcas* for their novel chemical structures and medicinal values. Diterpenes have a range of *in vitro* biological activities such as antihypertensive, anticancer, antiretroviral, anti-inflammatory, analgesic, antimicrobial, insecticidal and molluscicidal activities (Devappa et al., 2011). This review collates 37 diterpenes isolated from *J. curcas* with various biological activities (Table 2). Based on their skeletal structure the diterpenes isolated from *J. curcas* fall into six groups as: 1) phorbol esters; 2) rhamnofolane; 3) lathyrane; 4) pimarane; 5) dinorditerpenes; and 6) deoxypreussomerins.

3.1.1. Phorbol esters

Phorbol esters are diterpenes with a tigliane skeletal structure and are believed to be the most toxic molecules in *Jatropha* species. Phorbol esters cause skin-irritation and tumor promotion by stimulating protein kinase C (PKC). This suggests a variety of biological activities over a range of organisms as PKC is involved in signal transduction and developmental processes of most cells and tissues. Phorbol esters promote tumor growth following exposure to subcarcinogenic doses of carcinogens (Goel et al., 2007). Among the phorbol esters isolated from *J. curcas* Hirota et al. (1988) isolated 12-Deoxy-l 6-hydroxyphorbol which has a macrocyclic dicarboxylic acid diester structure. Zhang et al. (2009) reported the identification of a compound named riolozatrione, whereas Naengchomnong et al. (1994) isolated jatrophol ($C_{20}H_{24}O_3$). Hass et al. (2002) isolated six phorbol ester compounds from *J. curcas* seed oil characterized as Jatropha factors C1–C6 with the molecular formula $C_{44}H_{54}O_8Na$. Pertino et al. (2007) isolated other phorbol esters from *J. curcas* named jatropholones A and B, whereas recently, Chianese et al. (2011) isolated acetoxyjatropholone from root bark of *J. curcas*.

3.1.2. Dinorditerpenes, deoxypreussomerins and pimarane

Naengchomnong et al. (1986a) isolated dinorditerpene compounds named curcusones ($C_{20}H_{24}O_2$) from the roots of *J. curcas*. They identified four compounds as curcusone A, curcusone B ($C_{20}H_{24}O_2$), curcusone C ($C_{20}H_{24}O_3$) and curcusone D. Recently, Chianese et al. (2011) isolated curcusone E and spirocurcasone from root bark of *J. curcas*. Zhang et al. (2009) reported the isolation of 16-hydroxyphorbol whereas, Hass et al. (2002) found another compound with the same diterpene skeleton named as 12-deoxy-16-hydroxyphorbol. A rare dinorditerpene compound named heudolotione ($C_{18}H_{20}O_2$) was isolated by Ravindranath et al. (2003) from aerial parts of *J. curcas*. Ravindranath et al. (2004a) isolated palmarumycins from the stems of *J. curcas* and three compounds were identified as palmarumycin CP1 ($C_{20}H_{12}O_4$), palmarumycin JC1 ($C_{20}H_{14}O_5$) and palmarumycin JC2 ($C_{20}H_{14}O_5$). Wang et al. (2009) isolated lactam diterpenoid jatrophalactam ($C_{20}H_{29}NO_3$) from the roots of *J. curcas*. Jing et al. (2005) isolated three deoxypreussomerin diterpenes named jatropherol 1, 2 and 3 from *J. curcas* seed. Ravindranath et al. (2004a) found two pimarane diterpenes from *J. curcas* roots named as

Table 2
Phytochemicals isolated from *Jatropha curcas*.

No.	Compound class, name and derivatives	Biological activity	Part	References
	(1) Diterpenes			
	1.1 Phorbol esters			
1	12-Deoxy-16-hydroxyphorbol (DHPB)	Tumor promoter	Seed	Hirota et al. (1988)
2	Jatrophol	Cytotoxic activity	Roots	Naengchomnong et al. (1994)
3	Jatropha factor C1	Antimicrobial, antitumor, molluscicidal, insecticidal and cytotoxic activity	Oil	Hass et al. (2002)
4	Jatropha factor C2		Oil	Hass et al. (2002)
5	Jatropha factor C3		Oil	Hass et al. (2002)
6	Jatropha factor C4		Oil	Hass et al. (2002)
7	Jatropha factor C5		Oil	Hass et al. (2002)
8	Jatropha factor C6		Oil	Hass et al. (2002)
9	Jatropholones A	Antiplasmodial, gastroprotective		Pertino et al. (2007)
10	Jatropholones B	Cytotoxic and molluscicidal activities		Pertino et al. (2007)
11	Riolozatrione	NA	Roots	Zhang et al. (2009)
12	acetoxyjatropholone	Cytotoxic activity	Roots	Chianese et al. (2011)
	1.2 Rhamnofolane diterpenes			
13	Caniojane	Antiplasmodial and cytotoxic activities	Roots	Sutthivaiyakit et al. (2009)
	1.3 Lathyrane diterpenes			
14	Jatrogrossidione	Leshmanicidal, trypanocidal	Roots	Schmeda-Hirschmann et al. (1992)
15	Curculathyranes A	NA	Roots	Naengchomnong et al. (1986a)
26	Curculathyranes B	NA	Roots	Naengchomnong et al. (1986a)
17	15-*O*-Acetyl-15-epi-(4*E*)-jatrogrossidentadione	NA	Roots	Ravindranath et al. (2004b)
18	(14*E*)-14-*O*-acetyl-5,6-epijatrogrossidentadione	NA	Roots	Ravindranath et al. (2004b)
19	(4*E*)-15-epijatrogrossidentadione	NA	Roots	Ravindranath et al. (2004b)
20	Epijatrogrossidentadione	NA	Roots	Ravindranath et al. (2004b)
	1.4 Pimarane diterpenes			
21	3β-Acetoxy-12-methoxy-13-methyl-podcarpa-8,11,13-trien-7one	NA	Roots	Ravindranath et al. (2004b)
22	3β,12-Dihydroxy-13 methylpodoacrpane-8,10,13-triene	NA	Roots	Ravindranath et al. (2004b)
	1.5 Dinorditerpenes			
23	Heudolotione	Cytotoxic activity	Aerial	Ravindranath et al. (2003); Xu et al. (2011)
24	16-Hydroxyphorbol	NA		Zhang et al. (2009)
25	12-Deoxy-16-hydroxyphorbol	NA		Hass et al. (2002)
26	Curcusones A	Anti-invasive effects in tumor cells	Roots	Naengchomnong et al. (1986b)
27	Curcusones B	Anti-invasive effects in tumor cells	Roots	Naengchomnong et al. (1986b)
28	Curcusones C	Anti-invasive effects in tumor cells	Roots	Naengchomnong et al. (1986b)
29	Curcusones D	Anti-invasive effects in tumor cells	Roots	Naengchomnong et al. (1986b)
30	Curcusone E	Antiproliferative		Chianese et al. (2011)
31	Spirocurcasone	Antiproliferative		Chianese et al. (2011)
	1.6 Deoxypreussomerins			
32	Palmarumycin CP1	NA	Stems	Ravindranath et al. (2004a)
33	Palmarumycin JC1	Antibacterial	Stems	Ravindranath et al. (2004a)
34	Palmarumycin JC2	Antibacterial	Stems	Ravindranath et al. (2004a)
35	Jatrophalactam	Anticancer	Roots	Wang et al. (2009)
36	Jatrophalactone	Cytotoxic activity	Root	Liu et al. (2012)
37	Jatrophalone	Cytotoxic activity	Root	Liu et al. (2012)
38	Jatrophadiketone	Cytotoxic activity	Root	Liu et al. (2012)
	(2) Sesquiterpenoids and triterpenes			
39	Friedelin	NA		Ravindranath et al. (2004a)
40	Taraxasterol	Antimicrobial		Mitra et al. (1970)
41	(Z)-3-*O*-Coumaroyloleanolic	Cytotoxic activity	Latex	Goulart et al. (1993)
42	β-Amyrin	Cytotoxic activity	Stem	Mitra et al. (1970)
43	β-Sitosterol	Cytotoxic activity	Stem	Mitra et al. (1970); Ling-yi et al. (1996)
44	Stigmasterol	Cytotoxic activity	Root	Ling-yi et al. (1996)
45	Daucasterol	Cytotoxic activity	Root	Ling-yi et al. (1996)
	(3) Alkaloids			
46	Pyrrolidine (5-Hydroxypyrrolidin-2-one)	Anticancer	Leaf	Staubmann et al. (1999a)
47	Pyrimidine-2,4-dione	Anticancer	Leaf	Staubmann et al. (1999a)
48	Diamide (curcamide)	Anticancer	Seed cake	
49	Imidazole (4-Butyl-2-chloro-5-formyl-1H-imidazole)	Anticancer	Root	
	(4) Flavonoids			
50	Flavonoid glycoside I	Anticancer		Khafagy et al. (1977)
51	Flavonoid glycoside II	Anticancer		Khafagy et al. (1977)
52	Nobiletin	Anticancer	Root	Ling-yi et al. (1996)
53	Tomentin	Anticancer	Aerial	Ravindranath et al. (2004a)
	(5) Phenolics			
54	3-Hydroxy-4-methoxybenzaldehyde	Anti-inflammatory	Root	Ling-yi et al. (1996)
55	3-Methoxy-4-hydroxybenzoate acid	Anti-inflammatory	Root	Ling-yi et al. (1996)
56	Caffeoylaldehyde	Anti-inflammatory	Seed cake	Yao et al. (2012)

(continued on next page)

Table 2 (*continued*)

No.	Compound class, name and derivatives	Biological activity	Part	References
57	Syringaldehyde	Anti-inflammatory	Seed cake	Yao et al. (2012)
	(6) Liganans, neoliganans, coumarins and Coumarino-lignoids			
58	Isoamericanin	Anticancer	Seed cake	Yao et al. (2012)
59	Isoprincepin	Anticancer	Seed cake	Yao et al. (2012)
60	6-Methoxy-7-hydroxycoumarin	Anticancer		Zhang et al. (2009)
61	2,3,7-Trimethoxy-8-O-β-D-glucoside ellagic acid	Anticancer		Zhang et al. (2009)
62	5-Hydroxy-6,7-dimethoxycoumarin	Anticancer	Root	Ling-yi et al. (1996)
63	Scopaletin	Anticancer	Aerial	Ravindranath et al. (2004a)
64	Marmesin	Anticancer	Root	Naengchomnong et al. (1994)
65	Propacin	Anticancer	Root	Naengchomnong et al. (1994)
66	Jatrophin	NA	Root	Naengchomnong et al. (1994)
	(7) Phytosterols			
67	5α-stigmasta-3,6-diene	NA	Roots	Kong et al. (1996)
68	4-Butyl-2-chloro-5-formly-1*H*-imidazole	NA	Roots	Kong et al. (1996)
	(8) Proteins			
	7.1 Functional proteins			
69	Aquaporins	Drought resistance		Maurel and Maarten (2001)
70	Betaine aldehyde dehydrogenase	Drought resistance		Zhang et al. (2009)
71	Esterases (JEA)	Hydrolysis of triglycerides		Staubmann et al. (1999b)
72	Esterases (JEB)	Hydrolysis of triglycerides		Staubmann et al. (1999b)
73	Lipase (JL)	Hydrolysis of triglycerides		Staubmann et al. (1999b) Abigor et
74	Curcain	Wound healing	Latex	Abigor et al. (1997, 2002); Nath and Duta (1997)
75	Curcin	Immunotoxins and protein synthesis inhibitor		Stripe et al. (1976); Lin et al. (2002); Weike et al. (2006)
76	β-glucanase	Antifungal activity		Wei et al. (2005); Jin-xia et al. (2005)
77	Jatrophidin	Antifungal activity		Devappa et al. (2010b)
78	Curcacycline A	Antimalarial activity, cell proliferation and human complement inhibitor	Latex	Van den Berg et al. (1995)
79	Curcacycline B		Latex	Auvin et al. (1997)

3β-acetoxy-12-methoxy-13-methyl-podcarpa-8,11,13-trien-7one and 3β,12-dihydroxy-13 methylpodoacrpane-8,10,13-triene (Table 2).

3.1.3. Lathyrane and rhamnofolane

Naengchomnong et al. (1986b) isolated two lathyrane compounds named curculathyranes A and B. The lathyrane diterpene jatrogrossidione ($C_{20}H_{26}O_3$) was isolated from roots of *J. grossidentata* by Schmeda-Hirschmann et al. (1992). Four jatrogrossidione derivatives from dried parts of *J. curcas* were isolated by Ravindranath et al. (2004b) as: (I) 15-*O*-acetyl-15-epi-(4*E*)-jatrogrossidentadione ($C_{22}H_{30}O_5$); (II) (14*E*)-14-*O*-acetyl-5,6-epijatrogrossidentadione ($C_{22}H_{30}O_4$); (III) 3β-acetoxy-12-methoxy-13-methyl-podcarpa-8,11,13-trien-7one ($C_{21}H_{28}O_4$); and (IV) 3β,12-dihydroxy-13-methylpodoacrpane-8,10,13-triene ($C_{18}H_{26}O_2$). Rhamnofolane diterpene named caniojane ($C_{20}H_{24}O_5$) was isolated from *J. curcas* roots (Sutthivaiyakit et al., 2009). Recently, Liu et al. (2012) isolated three compounds from roots of *J. curcas* named as jatrophalactone, jatrophalone and jatrophadiketone (Table 2).

3.2. Sesquiterpenoids and triterpenes

A number sesquiterpenoids and triterpene compounds were isolated from *J. curcas* (Table 2) such as taraxasterol, β-amyrin and β-sitosterol (Mitra et al., 1970), (Z)-3-*O*-coumaroyloleanolic (Goulart et al., 1993), stigmasterol and daucasterol (Ling-yi et al., 1996) and friedelin (Ravindranath et al., 2004b).

3.3. Alkaloids

Alkaloids are a large group of nitrogen-containing compounds with important medicinal uses. They are known as compounds with powerful narcotic analgesic, antimalarial, antibacterial, antineoplastic, anticancer and many other pharmacological activities. Two alkaloids were isolated from *J. curcas* leaves by Staubmann et al. (1999a) pyrrolidine (5-hydroxypyrrolidin-2-one) and pyrimidine-2,4-dione (uracil). Das et al. (2005) isolated imidazole (4-Butyl-2-chloro-5-formyl-1H-imidazole). Recently, Yao et al. (2012) isolated the compound diamide (curcamide) from the seed cake of *J. curcas* (Table 2).

3.4. Flavonoids

Flavonoids are secondary metabolites with many pharmacological activities such as anticancer, antiviral, antitoxic, and hepatoprotective activities. Two flavonoids were isolated from *J. curcas* by Khafagy et al. (1977) named flavonoid glycoside I and flavonoid glycoside II, whereas Ling-yi et al. (1996) reported the isolation of nobiletin. Ravindranath et al. (2004a) reported isolation of tomentin (Table 2).

3.5. Phenolics

Phenolic compounds are present in all plants and are considered to be biologically active constituents. These compounds have antithrombotic and anti-inflammatory actions because they inhibit or antagonize the platelet activating factor (PAF) which is a potent inflammatory phospholipid mediator (Fragopoulou et al., 2007). A number of phenolic compounds were isolated from different parts of *J. curcas* (Table 2) such as 3-hydroxy-4-methoxybenzaldehyde and 3-methoxy-4-hydroxybenzoate acid from the root (Ling-yi et al., 1996), caffeoylaldehyde and syringaldehyde from the seed cake (Yao et al., 2012).

3.6. Lignans, neolignans, coumarins, coumarino-lignoids and phytosterols

Coumarins are secondary metabolites that occur in seed coats, fruits, flowers, roots, leaves, and stems. Coumarins are used to treat various skin disorders such as eczema, psoriasis by means of a combination

of oral ingestion and UV-A treatment. Four compounds were identified from *J. curcas* as tomentin, 5-hydroxy-6,7-dimethoxycoumarin, 6-methoxy-7-hydroxycoumarin and 2,3,7-trimethoxy-8-*O*-β-D-glucoside ellagic acid (Zhang et al., 2009). Isolation of one phytosterol compound named 5α-stigmasta-3,6-diene was reported (Zhang et al., 2009; see Table 2).

3.7. Proteins

J. curcas proteins and peptides have been studied for their roles in plant metabolic activities, defense against predators and biological activities. Functional proteins such as aquaporins were isolated from different parts of *J. curcas*. These proteins play essential roles in plant adaptation to drought stress by controlling the transmembrane water movement. In *J. curcas* aquaporins play an important role in the rapid growth by the plant during dry weather conditions (Devappa et al., 2010b). Other functional proteins isolated from the plant are: curcin, a lectin Stripe et al. (1976); two esterases (JEA and JEB) and a lipase (JL) (Staubmann et al., 1999b); curcain, a protease from the latex of *J. curcas* (Nath and Duta, 1997); phytate and a trypsine inhibitor (Makkar and Becker, 1997). Van den Berg et al. (1995) isolated the cyclic peptide curcacyclin A and Auvin et al. (1997) isolated curcacyclin B (Table 2).

4. Pharmacological information

4.1. Anti-inflammatory effects

The anti-inflammatory activities of different extracts from *J. curcas* are outlined in Table 3. Anti-inflammatory activity for fractions from ethyl acetate extracts of *J. curcas* leaves was reported earlier by Staubmann et al. (1999c). Topical application of *J. curcas* root powder paste on TPA-induced ear inflammation in albino mice (Mujumdar and Misar, 2004). The methanolic extract of *J. curcas* leaves showed anti-inflammatory effects on Wister albino rats (Uche and Aprioku, 2008). Water extracts from *J. curcas* bark and leaves showed significant anti-inflammatory activity using the formalin-induced paw edema method in rats (Sanjeetha et al., 2009). The alcoholic extract of roots, stems and leaves of *J. curcas* exhibited systemic and significant anti-inflammatory activity in acute carrageenan-induced rat paw edema (Nayak and Patel, 2010a). The anti-inflammatory effects of *J. curcas* extracts of leaf, stem bark, root and latex is attributed to their strong iNOS inhibition (Oskoueian et al. (2011b).

4.2. Antioxidant activity

The antioxidant activities of different extracts from *J. curcas* are listed in Table 4. The aqueous, ethanol and methanol extracts besides methanolic extract fractions from nodes, leaves, stems and roots of *J. curcas* exhibited antioxidant activity (El Diwani et al., 2009; Igbinosa et al., 2011; Oskoueian et al., 2011b).

4.3. Antimicrobial activity

The antimicrobial activity of various extracts from different parts of *J. curcas* is outlined in Table 5, including the information on the methods used, inhibition zone, minimal inhibitory concentration, minimal bacterial concentration and the standards used. Some of the studies included different parts of the plant such as Namuli et al. (2011) who reported antimicrobial activity of the crude aqueous, methanolic and hexane extracts of various plant parts of *J. curcas*. Antimicrobial activity of alcoholic extracts from *J. curcas* leaves was reported by Akinpelu et al. (2009) and Irene and Cariño (2011) for methanol extracts, whereas Sharma et al. (2010b) used ethanol extracts. Antimicrobial activity of *J. curcas* stem bark was reported in a number of papers. Igbinosa et al. (2009) reported antimicrobial activity of crude ethanolic, methanolic and water extracts of the stem bark of *J. curcas*. Gupta et al. (2010) found antimicrobial activity for crude petroleum ether, ethyl acetate and methanol extracts beside two other purified compounds JC-1 and JC-2 isolated from the stem bark of *J. curcas*. Recently, Obasi et al. (2011) reported antimicrobial activity of the methanolic extract in addition to methanolic extract fractions (Chloroform, ethyl acetate and methanol) from stem bark of *J. curcas*. *J. curcas* root extracts showed antimicrobial activities against a wide range of microorganism specially those responsible for sexually transmitted diseases. Hexane, ethyl acetate and methanol extracts of *J. curcas* roots displayed strong antimicrobial activity. However, the methanol extract of the root bark showed potent broad spectrum activity (Aiyelaagbe et al., 2007). The antimicrobial activity of *J. curcas* latex from stems and leaves was reported by Oyi et al. (2007). The seeds and seed cake of the plant exhibited antimicrobial activities as reported in several papers. Sriprang et al. (2010) reported antibacterial activity for hexane, dichloromethane, acetone and methanol extracts from *J. curcas* seed cake against Gram-negative and Gram-positive bacteria. Donlaporn and Suntornsuk (2010) showed that ethanol extract from *J. curcas* seed cake exhibited antifungal activity. Later, Daniyan et al. (2011) found antimicrobial activity for methanol, ethyl acetate and hexane extracts from *J. curcas* seed. Numerous studies

Table 3
Anti-inflammatory activity from different extracts of different parts of the *Jatropha curcas* plant.

Part used	Extract	Activity observed	References
Leaf	Ethyl acetate	Anti-infammatory activity using a carrageenan-induced rat paw edema	Staubmann et al. (1999c)
	Methanol	Inhibition on the egg albumin-induced oedema in Wister albino rats at 10–80 mg kg^{-1}	Uche and Aprioku (2008)
	Water	100% inhibition of formalin-induced rat paw oedema for leaf water extract (300 mg kg^{-1})	Sanjeetha et al. (2009)
Root	Root powder paste	Topical application on TPA-induced ear inflammation in albino mice resulted in 1) dose-dependent inhibitory activity in carrageenan-induced paw inflammation. 2) Inhibition of formalin-induced rat paw oedema. 3) Reduction in leukocyte count in exudative fluid	Mujumdar and Misar (2004)
Leaf, stem, root and	Alcohol	Significant reduction in percentage of acute carrageenan-induced rat paw edema inflammation	(Nayak and Patel, 2010a)
Leaf, stem, root and latex		1). Inhibition of NO production from macrophages RAW 264.7 cells, induced by LPS (*Escherichia coli* lipopolysaccharide) and IFN- (recombinant mouse interferon-gamma). 2) At 200 μg ml^{-1} the methanolic extract inhibited the NO as leaf (80.8%) and stem bark (80.6%). 3) Latex extract at concentrations between 3.1 and 200 μg ml^{-1} were not toxic to the raw 264.7 cell. 4) At 200 μg/ml, the value of NO inhibition was 93.9% indicating the strong ability of latex extract to inhibit the iNOS while maintaining cell viability comparable to L-NAME. 5) Root methanolic extract at concentrations between (3.1–200 μg ml^{-1}) inhibited NO production (93.6–95.8%) similar to L-NAME while, concentrations between 6.2 and 200 μg ml^{-1}) were toxic to the raw 264.7 cell.	Oskoueian et al. (2011b)

Table 4
Antioxidant activity of different extracts from different parts of the *Jatropha curcas* plant.

Part used	Extract	Activity observed	References
Nodes, leaves, stems and roots	Ethanol	Antioxidant activity using DPPH (1,1-diphenyl-2-picrylhydrazyl hydrate) assay. The crude extract from roots has the higher free radical scavenging activity with maximum inhibition of 0.521 mg ml^{-1}	El Diwani et al. (2009)
Latex, leaf, root and stem bark	Methanol	Antioxidant activity using DPPH and nitric oxide (NO) scavenging activity assays. The IC_{50} values for DPPH scavenging activity for latex, leaf extracts, quercetin and vitamin C were 6.8, 5.9, 4.2 and 10.6 μg ml^{-1}, respectively. Good NO scavenging activity was shown by latex IC_{50} 29.7 and leaf IC_{50} 93.5 μg m l^{-1}. The root and stem bark showed moderate and weak activities (IC_{50} 57.9 and >200 μg ml^{-1}), respectively. All samples exhibited NO scavenging activity in a dose-dependent manner	Oskoueian et al. (2011b)
Stem bark	Methanol, ethanol and water	Antioxidant activity using DPPH, 2,2′-azino-bis-(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS), ferric reducing, nitric oxide (NO), superoxide anion, (O_2-) and hydrogen peroxide (H_2O_2) assays. Butylated hydroxyl toluene (BHT) and ascorbic acid were used as standards. The higher the concentration the higher DPPH scavenging activity. The methanolic extract showed the highest DPPH scavenging activity followed by aqueous and ethanolic extract but possess high DPPH scavenging activity compared with the standard BHT. The inhibition of ABTS radical by the extracts was also concentration dependant. The scavenging activity of $ABTS^+$ for the three extracts was high. All extracts exhibited higher superoxide radical scavenging activity when compared with BHT	Igbinosa et al. (2011)

reported on antimicrobial activities by diterpenes and other compounds isolated from *J. curcas*. Achenbach and Benirschke (1997) reported antifungal and antibacterial activity for curcusones C and D. Ravindranath et al. (2004a) reported antibacterial activity for palmarumycins. Xiao et al. (2011) isolated and identified cationic antimicrobial peptide (KVFLGK, JCpep7) from *J. curcas*. In a recent study, Devappa et al. (2012a) evaluated the antibacterial activity of the phorbol ester-rich fraction isolated from *J. curcas* oil (Table 5). However, a number of constraints were highlighted by Devappa et al. (2011) mainly that some phytochemicals from the genus *Jatropha* were not characterized and checked appropriately for bioactivity. Less sensitive, non-specific, or broad spectrum assays have been used for the antimicrobial activities. Besides, most of the studies did not clearly mention the conditions under which the tests were undertaken such as location, climate, harvest and healthy or diseased states. In some studies the phytochemicals were evaluated to determine their bioactivity using microbial susceptibility assays at impractical and inapplicable doses or they lack comparison with the standard active compounds. Further, in some studies the information about selection criteria of microbes used in the experiments were not mentioned.

4.4. Anticancer activity

A survey on plant species from the Mexican flora revealed that *J. curcas* is one of the species that is used for cancer treatments in Mexico (Alonso-Castro et al., 2011). Diterpenes are the major secondary metabolites synthesized by *J. curcas*. These compounds are proven to be cytotoxic and tumor-inhibitors (Devappa et al., 2011). The anticancer activities of different extracts from *J. curcas* are presented in Table 6. The methanolic extract fraction from *J. curcas* leaves showed antimetastatic activity (Balaji et al., 2009a). Extracts from leaf, root and stem bark of *J. curcas* showed cytotoxic activity on an HT-29 cell line. The root extract was more active compared to leaf and stem bark suggesting its candidacy as a source of an anticancer therapeutic agent (Oskoueian et al., 2011b). Anticancer activities by diterpenes isolated from *J. curcas* plant have been reported in several papers. Goel et al. (2007) stated that phorbol esters are co-carcinogens which themselves do not induce but promote tumours. Antimetastatic activity of curcusone B against 4 human cancer cell lines was reported by Mungman et al. (2005), whereas Devappa et al. (2011) reported antimetastatic activity against a cholangiocarcinoma cell line (KKU-100 cells). Pertino et al. (2007) reported gastro-protective activity from jatropholone (A and B) in an HCl/EtOH-induced gastric lesion model in mice. Sutthivaiyakit et al. (2009) reported cytotoxicity for caniojane against African green monkey kidney fibroblasts and antituberculosis effects against *Mycobacterium tuberculosis* H37Ra. Theoduloz et al. (2009) reported anti-proliferative activity of jatropholone B against fibroblasts CCL-171, AGS CRL-1739, lung HTB-58, bladder HTB-1 and leukemia CCL-240. In contrast, Wang et al., 2009 reported no significant inhibitory activity *in vitro* for jatrophalactam against a human lung cancer cell line A549, colon cancer HT-29, and epidermal squamous cell carcinoma A431. Recently, Liu et al. (2012) reported cytotoxic activity for jatrophalactone. Anticancer activities of proteins isolated from *J. curcas* have been studied for a number of decades. Stripe et al. (1976) isolated the Ribosome-Inactivating Proteins (RIPs) curcins from *J. curcas* seeds. These proteins are considered as cell-killing agents that can inhibit cell-free protein synthesis. Luo et al. (2007) reported antitumor activity of curcin in *Escherichia coli* strain M15. The protein synthesis was inhibited in the cell-free translation system. Regarding the cytotoxicity studies on the genus *Jatropha* Devappa et al. (2011) stated that phytochemicals studied for cytotoxicity and antitumor activities using cell lines lack the proper reference compounds. Cell-based activities are less sensitive, more variable and the cytotoxicity of the interested compounds may mask a more specific activity.

4.5. Antiviral activity

Muanza et al. (1995) reported a moderate cycloprotective activity against HIV in cultured human lymphoblastoid CEM-SS cells for the methanol extract from *J. curcas*. Matsuse et al. (1999) investigated the effects of aqueous and methanolic extracts from *J. curcas* branches for the inhibition of HIV-induced cytopathic effects in cultured cells, HIV-reverse transcriptase and HIV-protease enzymes. The water extract of *J. curcas* branches showed potent inhibition (IC_{50} 24 μg ml^{-1}) of the HIV-induced cytopathic effects with low cytotoxicity (CC_{50} > 1000) and selectivity index CC_{50}/IC_{50} (>41.7). Recently, Wender et al. (2008) reported the possibility of synthesizing prostratin and DPP from phorbol esters from *J. curcas*. This synthesis facilitates the identification of superior clinical candidates that could be used in the treatment of HIV.

4.6. Antidiabetic activity

Traditionally leaf infusion (Jaiswal, 2010), decoctions of boiled leaves or fruit burnt into ashes (Gbolade, 2009), water extract of the bark (Jayakumar et al., 2010) are used to control blood sugar levels. However, the scientific information available regarding human models is very scarce and research is needed to cover this aspect in the near future. Mishra et al. (2010) reported antihyperglycemic effects of 50% ethanolic extract from *J. curcas* leaves by oral administration in allaxon-induced diabetic rats. The extract at doses of 250 and 500 mg ml^{-1} bw respectively, showed potent antihyperglycemic activity LD_{50} 2500 mg kg^{-1}. Reduction in glucose level in treated rats was 219.5–116.5 and 237–98.8 for the doses of 250 and 500 mg kg^{-1}, respectively. The results were comparable to reduction in rats treated with the standard glibenclamide 232–94.5 at 600 μg kg^{-1}.

Table 5
Antimicrobial activities of extracts from different parts of the *Jatropha curcas* plant.

Part used	Extract	Activity observed	Reference
Leaf	Methanol	Antibacterial activity against *Escherichia coli*, *Staphyllococcus aureus* and *Pseudomonas aeruginosa*	Akinpelu et al. (2009)
	Ethanol	Activity against *E. coli*, *P. aeruginosa*, *P. fluorescens* and *S. aureus*. MIC values ranged between 6 and 11 mm. Filter paper disc method was used	Sharma et al. (2010b)
	Methanol	Activity against *S. aureus*, *Bacillus subtilis*, *Mycobacterium phlei*, *Candida albicans* and *Trychphyton mentagropytes*	Villaseñor and Cariño (2011)
Stem bark	Ethanol, methanol and water	Activity against *E. coli*, *S. aureus*, *Klebsiella pneumonia*, *Proteus mirabills*, *P. aeruginosa*, *C. albican*, *S. epidermis*, *Shigella dysenteriae*, *Micrococcus Kristinae*, *B. cereus*, *Bacillus subtillis*, *Proteous vulgaris*, *and Serratia marcescens* with zones of inhibition ranges as 5–12, 8–20 and 0–8 mm for ethanol, methanol and water extract, respectively. MBC ranged between 2.0 and 12.5 mg ml^{-1} for ethanol and 2.0–20.0 mg ml^{-1} for the methanol extract Antifungal activities against *Trichophyton longifusis*, *Candida glaberata*, *Fusarium solani*, *Microsporium canis*, *Aspergillus flavus*, *C. albicans*, *Aspergillus niger* and *Penicillium notatum*. Zones of inhibition for the extracts were 15–18, 15–20, and 5–10 mm respectively	Igbinosa et al. (2009)
	Petroleum ether,ethyl acetate, methanol & JC-1 & JC-2	Activity against Gram-positive *B. subtilis*, *B. megaterium*, *B. cereus*, *Sarcina lutea* and *S.* aureus and Gram-negative *Escherichia coli*, *Salmonella Typhi*, *S. paratyphi*, *Shigella boydii*, *Sh. Dysenteriae*, *P. aeruginosa*, *Vibrio mimicus and V. parahemolyticus* Antifungal activity against *C. albicans*, *C. oryzae*, *A. niger* and *Saccharomyces cerevisiae*	Gupta et al. (2010)
	Fractions of (Chloroform, ethyl acetate and methanol)	Activity against Gram-positive bacteria *B. subtilis*, *S. aureus*, *E. coli*. MIC ranged between 0.625 and 20 μg ml^{-1}. Gentamicin sulphate (10 μg ml^{-1}) was used as standard	Obasi et al. (2011)
Roots	Hexane, ethyl acetate and methanol	Activity at 200 mg ml^{-1} against *Gardnerella vaginalis*, *Neisseria gonorrhea*, *E. coli*, *S. aureus*, *Klebsiella aerogenes*, *Proteus mirabills*, *P. aeruginosa* and *C. albicans* MIC 0.75 μg ml^{-1}. The root methanol extract showed broad spectrum activity against all the microorganisms except *Candida albicana*. Gentamycin and ticonazole used as standards	Aiyelaagbe et al. (2007)
Latex		Antimicrobiall activity against *B. subtilis*, *E. coli*, *P. aeruginosa*, *S. aureus*, *Streptococcus pyogenes*, *C. albicans* and *Trychophyton* sp. Inhibition zone ranged between 20 and 26 mm. Agar and broth dilution methods were used for the test	Oyi et al. (2007)
Seed	methanol, ethyl acetate and hexane	Activity against *S. aureus*, *C. albicans*, *E. coli and S. typhi.* Inhibition zone ranges 10–25, 10–25, 8–23, 10–20 and 12–21 mg ml^{-1}, respectively. Agar diffusion method was used	Daniyan et al. (2011)
Seed-cake	Ethanol	Antifungal activity against *Fusarium oxysporum*, *F. semitectum*, *Pythium aphanidermatum*, *Lasiodiplodia theobromae*, *Curvularia lunata*, *Colletotrichum capsici*, *and C. gloeosporioides.*	Donlaporn and Suntornsuk (2010)
	Hexane, dichloromethane, acetone and methanol	Antibacterial activity against Gram-negative bacteria (*E. coli*, *P. aeruginosa*, and *S. typhi*) and the Gram-positive bacteria, (*S.s aureus*, *B. cereus*, and *B. megaterium*). Agar diffusion method was used and ampicillin streptomycin were refered as positive controls	Sriprang et al. (2010)
Various plant parts	Aqueous, methanol and hexane	Antibacterial activity against Gram-positive bacteria (*S. aureus*, *B. cereus*, *B. subtilis*) and Gram-negative bacteria (*E. coli*, *K. pneumonia*, *P. aeruginosa*). The methanol extract from all parts of the plant was effective against the entire microorganisms with inhibition zone ranged from 8.0 to 17.7 mm, MIC 1.2 to 2.3 mg ml^{-1} and MBC 0.4 to 6.33 mg ml^{-1}. Paper disc diffusion method was used for the test	Namuli et al. (2011)
Oil	Curcusones C and D	Antifungal and antibacterial activity against *Botrytis cinerea*, *Rhizoctonia solani* and *B. subtilis*	Achenbach and Benirschke (1997)
	Palmarumyc ins	Antibacterial activity against *S. aureus* at concentration of 30 μg ml^{-1} with a range of inhibition zone of 10–13 mm	Ravindranath et al. (2004b)
	Cationic peptide (KVFLGK, JCpep7)	Activity against gram positive bacteria (*Salmonella typhimurium*, *P. aeruginosa*, *Sh. dysenteriaei*) and Gram-negative bacteria (*S. aureus*, *K. pneumonia and B. subtilis*).	Xiao et al. (2011)
	Phorbol ester rich fraction	Antibacterial activity against *B. subtilis*, *Pseudomonas putida*, *Proteus mirabilis*, *S. aureus*, *S. pyogenes* and *E. coli*. Zone of inhibition ranged between 12 and 19 mm and MIC values between 12 and 19 mm and MBC values between 215 and 537 μg ml^{-1}. Antifungal activity against *A. niger*, *A. flavus*, *Botrytis cinerea*, *F. oxysporium*, *F. moniliforme*, *Curvularia lunata* and *P. notatum*	Devappa et al. (2012a)
	Caniojane	Antituberculosis effect against *Mycobacterium tuberculosis* H37Ra with MIC 25 μg ml^{-1} and test reference as IC_{50} 2.5 μg ml^{-1}. Kanamycin was used as test reference	Sutthivaiyakit et al. (2009)

In addition, the extract significantly reduced the cholesterol and triglyceride levels in the rats.

4.7. Analgesic activity

Uche and Aprioku (2008) reported analgesic activity of methanolic extract from *J. curcas* leaves in mice using the acetic acid-induced writhing test. The methanolic extract caused significant reduction in the number of acetic acid-induced writhing in mice compared to the analgesic effect obtained from the reference drug paracetamol. In another study Yusuf and Maxwell (2010) studied the analgesic activity *in vivo* of the methanolic leaf extract from *J. curcas* using hot plate and acetic acid-induced writhing reflex in mice and tail flick or immersion method in rats. In the hot plate and tail flick models, oral administration of the leaf extract at doses of 100, 200 and 400 mg kg^{-1} and the reference drug acetylsalicylic 400 mg kg^{-1} showed a potent analgesic effect by increasing the pain time dose dependant in mice and rats. In the acetic acid-induced writhing reflex model, the extract decreased the number of abdominal contortions. Nayak and Patel (2010b) reported that alcoholic extract from stem and roots of *J. curcas* showed significant activity and produced significant reduction in yeast-induced pyrexia compared to the standard drugs pantazocine and paracetamol, respectively.

4.8. Hepatoprotective activity

Balaji et al. (2009b) evaluated the methanolic fractions from *J. curcas* leaves against hepatocellular carcinoma induced by aflatoxin B_1 by oral administration in rats at doses of 100 and 200 mg kg^{-1}. The methanolic fractions decreased the levels of elevated serum enzymes, lipid levels and bilirubin and increased the protein and uric acid levels. The liver histopathology showed that the methanolic fractions reduced incidence of liver lesions, lymphocytic infiltrations and hepatic necrosis induced by aflatoxins.

4.9. Wound healing activity

The traditional use of different parts of *J. curcas* for wound healing is documented in many parts of the world (Neuwinger, 1996; Osoniyi and

Table 6
Anticancer activities of extracts from different parts of the *Jatropha curcas* plant.

Part used	Extract	Activity observed	References
Leaf	Methanol fraction	Antimetastatic activity using $B_{16}F_{10}$ melanoma cells in C57BL/6 mice. Administration of the methanolic fraction at the dose of 100 and 200 mg kg^{-1} inhibited the metastatic colony formation of the melanoma in lungs by 47.5 and 69.5% respectively. The methanolic fraction was *in vitro* cytotoxic against $B_{16}F_{10}$ melanoma IC_{50} 24.8 μg ml^{-1} and reduced the levels of lung collagen hydroxyproline, hexoxamine, uronic acid contents, levels of serum aialic acid in the treated animals	Balaji et al. (2009a)
Leaf, stem bark and root		Cytotoxic activity by leaf extract IC_{50} 199.1 μg ml^{-1}, stem bark IC_{50} > 200 μg ml^{-1} in HT-29 cell line. The root extract at 25 μg m l^{-1} decreased the HT-29 cell viability to 28.8%. Increase in extracts concentration up to 200 μg ml^{-1} reduced the cell viability significantly in a dose-dependent manner.	Oskoueian et al. (2011a)
Roots	Jatrophalactone	Cytotoxic activity against the human myeloid leukemia HL-60, hepatocellular carcinoma SMMC-7721, lung cancer A-549, breast cancer MCF-7, and colon cancer SW480 cell lines with IC_{50} value 8.5, 20.6, 19.7, 20.1, and 19.2 μM, respectively	Liu et al. (2012)
	Jatrophalone	No cytotoxic activity against the above cell lines IC_{50} (>40 μM)	
	Jatrophadiketone	No cytotoxic activity against the above cell lines IC_{50} (>40 μM)	
Seed	Curcin	Antitumor activity by inserting curcin into *Eschericia coli* strain M15. At concentration of 50 μg ml^{-1} the curcin inhibited the growth of tumor cells of cellule pulmonary cancer and gastric cancer in a a concentration-dependant mode	Luo et al. (2007)
	Curcusone A	Antimetastatic activity against 4 human cancer cell lines. At non-cytotoxic doses reduced the *in vitro* invasion motility and secretion of matrix- metalloproteinases of the cancer cell	Mungman et al. (2005)
	Curcusone B	Antimetastatic activity against cholangiocarcinoma cell line KKU-100. At nontoxic doses of 10 Mm suppressed *in vitro* invasion of KKU-100 cells by 90%, by suppressing cell motility and matrix metalloproteinase-2 (MMP-2) activities in the medium. The IC_{50} values (μM) on KKU 100 cells were as, survival (25.1), adhesion (31.7), invasion (5.7), motility (7.9) and MMP-2 secretion (4.7)	Devappa et al. (2011)
	Caniojane	Cytotoxicity against aginst African green monkey kidney fibroblasts IC_{50} 12.9 μg ml^{-1} and test reference ellipticine as IC_{50} 0.7 μg ml^{-1}	Sutthivaiyakit et al. (2009)
	Jatropholone (A and B)	Gastro-protective activity in HCl/EtOH-induced gastric lesions model in mice. Jatropholone A reduced the lesion by 54% in a dose-related manner at the highest dose of 100 mg kg^{-1} while, jatropholone B reduced the lesions by 83–91% at all the doses. The cytotoxicity of jatropholones was evaluated against fibroblasts and AGS cells. Jatropholone B was non-cytotoxic to both AGS cells and fibroblasts (>1000 μM), while jatropholone A showed a selective effect against AGS cells (IC_{50}, 49 μM) and non-toxic towards fibroblasts (>1000 μM). The test reference compound, lansoprazole exhibited a gastro -protective effect of 73% at 9.4 mg kg^{-1}, cytotoxic to AGS cells and fibroblasts at 162 and 306 (IC50, μM)	Pertino et al. (2007)
		Anti-proliferative activity against fibroblasts CCL-171 (IC_{50} 0.29 μM), AGS CRL-1739 (IC_{50} 0.51 μM), lung HTB-58 (IC_{50} 1.8 μM), bladder HTB-1 (IC_{50} 1.7 μM) and leukemia CCL-240 (IC_{50} 5.1 μM). The reference compound etoposide exhibited activity at 3.9, 0.36, 2.5, 2.8 and 0.80 (IC_{50} in μM), respectively.	Theoduloz et al. (2009)
		Anti-proliferative effects (IC_{50} in μM) at a concentration of >100 (μM) against the above cell lines	
	Jatrophalactam	No significant inhibitory activity *in vitro* against human lung cancer cell lines A549, colon cancer HT-29, and epidermal squamous cell carcinoma A431	Wang et al., 2009

Onajobi, 2003; Balangcod and Balangcod, 2011. However, scientific research relevant to the human model is lacking. Villegas et al. (1997) reported positive cicatrizant activity by *J. curcas* extract in mice. Shetty et al. (2006) evaluated the wound healing activity of crude bark extract from *J. curcas* in Wistar albino rats. The extract accelerated the healing processes by increasing the skin breaking strength, granulation tissue breaking strength, wound contraction, dry granulation tissue weight and hydroxyproline levels. Esimone et al. (2009) tested the wound healing activity of herbal ointment containing methanolic extract from *J. curcas* leaves incorporated into 10 g of simple ointment base. Ointment was applied topically to the wound at intervals of 3 days until complete wound closure. Blank ointment and gentamicin ointment (1%) served as standard and control respectively. The methanol extract incorporated into an ointment base caused higher rates of wound healing and reduced the epithelialisation period in a dose-related manner.

4.10. Anticoagulant and procoagulant activity

Traditionally the leaf, stem sap or the dried powdered plant of *J. curcas* is spread on flesh wounds as haemostatic (Neuwinger, 1996; Watt and Breyer-Brandwijk, 1962). Osoniyi and Onajobi (2003) reported that *J. curcas* possess both procoagulant and anticoagulant activities as the latex from *J. curcas* significantly reduced the clotting time of human blood. However, diluted latex, prolonged the clotting time. They attributed the occurrence of these two opposing activities to the solvent partitioning of the latex with acetyl acetate and butanol. At low concentration, the acetyl acetate fraction showed procoagulant activity, while the butanol fraction had the highest anticoagulant activity.

4.11. Antifertility activity (abortifacient activity)

Goonasekera et al. (1995) reported antifertility activity by oral administration of methanol, petroleum ether and dichloromethane extracts from *J. curcas* fruits to pregnant rats. The fruit extracts caused foetal resorption by interrupting pregnancy occurrence at an early stage after implantation. Makonnen et al. (1997) reported anti-implantation and antifertility effects of crude seed extract of *J. curcas* when administrated orally to female albino pigs. Odusote et al. (2002) reported inhibition of pup birth by *J. curcas* oil at a dose of 2 ml kg^{-1} BW.

5. Toxicity

5.1. Toxic and antinutritional components

The major toxic and antinutritional components from *J. curcas* and their molecular mechanisms are summarized in Table 7. Phorbol esters and curcin are the most toxic phytochemicals of *J. curcas* (Devappa et al., 2010a). The seeds contain major toxic components as the phorbol esters, the antinutritional phytate and the trypsin inhibitor factors. In the study by Devappa et al. (2012b) *J. curcas* kernels were separated into cotyledons, hypocotyls, kernel coat and endosperm to determine the location of the antinutrients. Their results showed that majority of phytate (96.5%), trypsin inhibitor (95.3%) and phorbol esters (85.7%) were localised in the endosperm.

5.2. Toxicological effects in the in vitro and in vivo models

J. curcas exhibited toxicity to a wide variety of species *i.e.* microorganisms, animals including humans. All parts of *J. curcas* are toxic and

Table 7
Toxic and antinutritional components of *J. curcas*.

Component	Class	Plant part and range	Mode of action	References
Phorbol esters	Diterpene esters	Oil	Affects cell differentiation, platelet aggregation and metabolic activity. Promotes tumor as they mimic the action of diacyl glycerol stimulator of the protein kinase C (PKC)	Devappa et al. (2010a); Baldini et al. (2012); Goel et al. (2007)
Tannins	Phenols	Seed (2.0–2.9%) of the seed shell	Reduce food intake, growth retardation, and impaired nutrient absorption	Devappa et al. (2010a)
Protease inhibitors	Peptides	Seed (18.4–27.5) mg of trypsin inhibited/g of DM	Binding and inactivate the pancreatic proteolytic enzymes (trypsin and chymotrypsin). Interfere with the physiological process of proteins digestion, causing disorders of the pancreas, reduction in the digestibility of proteins in the diet and growth decrease	Baldini et al. (2012)
Lectins	Carbohydrate-binding (glyco)proteins	Seed (0.85–6.85) using haemagglutination assay and (51.3–204) using latex agglutination test	Agglutination of erythrocytes in animals, binding specific carbohydrates, mainly in cells of the duodenum and jejunum, causing serious damage to the intestinal wall - affect the turnover and loss of gut epithelial cells – interfere with nutrient digestion and absorption – damaging the luminal membranes of the epithelium – modulate the immunological status of the digestive tract.	Devappa et al. (2010a)
Curcin	Toxalbumin ribosome-inactivating proteins (RIP)	Seed	Inhibit prokaryotic and eukaryotic ribosome by specific modification of the larger rRNA. Protein translation inhibitory activity or N-glycosidase activity like other type	Devappa et al. (2010a) Stripe et al. (1976) Lin et al. (2002).
Saponins	Glycosides or steroids	Seed (1.8%–3.4%) as diosgenin equivalent	Has ability to form foam in aqueous solutions, causing haemolytic disorder and complex changing in steroids. Causes changes in the permeability of the intestinal mucosa, inhibiting nutrients transport	Devappa et al. (2010a)
Phytate	Principle storage form of phosphorus	Seed (6.2%–10.1%) as phytic acid equivalent	Prevent the absorption of minerals (Zn, Fe, Ca and Mn in the gastrointestinal tract and affecting protein digestibility by the formation of the complex protein-phytic acid	Devappa et al. (2010a)

the degree of toxicity varies with the extract types, nature of test substances, dose, mode of administration, and sensitivity of the animals (Devappa et al., 2010a). The seeds are toxic to humans (Heller, 1996; Gandhi et al., 1995) with symptoms of giddiness, vomiting, delirium, muscle shock, decrease of visual capacity, high pulse rate and diarrhoea (Becker and Makkar, 1998; Rai and Lakhanpal, 2008; Singh et al., 2010). In animals toxic symptoms were reported when raw or defatted seeds were force-fed to chicks (El-Badawi et al., 1995; Makkar et al., 2009), pigs (Chivandi et al., 2000, 2006), sheep and goats (Adam and Magzoub, 1975; Ahmed and Adam, 1979), rabbits (Gandhi et al., 1995), mice and rats (Liberalino et al., 1988; Abdel Gadir et al., 2003; Adam, 1974), carp *Cyprinus carpio* (Becker and Makkar, 1998). In rabbits, Gandhi et al. (1995) observed symptoms of diarrhoea, haemorrhagic eyes and inflammation of the g-intestinal tract at 6, 9 and 13.5 ml kg^{-1} BW. In mice, Horiuchi et al. (1988) reported induction of tumors by topical application of a methanol fraction from *J. curcas* oil with 36% of the animals having skin tumors in 30 weeks. Jing et al. (2005) reported toxicity for jatropherol-I (LD_{50} 82.2 mg kg^{-1} BW) when administrated orally. Li et al. (2010) reported toxic activity for phorbol esters (LD_{50} 27.34 mg kg^{-1} BW) given by intragastric administration to Swiss Hauschka mice. The histopathological studies on the organs from the dead mice showed prominent lesions mainly found in lungs and kidneys, with diffused haemorrhages in lung, and glomerular sclerosis and atrophy in kidney at doses 32.40 mg kg^{-1} BW. In rats, Adolf et al. (1984) reported irritant activity from *J. curcas* seed oil (LD_{50} 25 μg/ear), hydrophilic fraction (LD_{50}1.8 μg/ear) and the neutral fraction (LD_{50}1.5 μg/ear). Sutthivaiyakit et al. (2009) reported antiplasmodial activity for caniojane against *Plasmodium falciparum*.

6. Conclusions

J. curcas is a multiple purpose plant with potential for biodiesel production and medicinal uses. The plant has a long history of usage in treatments of a wide range of ailments in many countries. The present review attempted to provide information available on botany, traditional uses, phytochemistry, pharmacology and toxicity of *J. curcas* covering literature available from 1960 to 2012. The review has shown diverse traditional uses of *J. curcas* that differ from one country to another. However, the treatments of gastric problems, inflammatory disorders, sexual diseases, jaundice, diabetes, dysentery, fever, and skin diseases are most common. Reports on the use of *J. curcas* for the same ailments in different continents clearly indicate its strong potential for biological activities. The pharmacological studies on the extracts and metabolites from this plant have mostly been performed *in vitro* and *in vivo* with animals. These studies have demonstrated various pharmacological activities such as antiviral, anti-inflammatory, antimicrobial, anticancer, antidiabetic, hepatoprotective and anticoagulant. In relation to the constituents contributing to medicinal values, the findings indicated that diterpenes are mainly responsible for anti-inflammatory, cytotoxicity and antimicrobial activities. Phenolics, flavonoids and saponins are responsible for antimicrobial and antioxidant activities. Sesquiterpenoids are responsible for antimicrobial and analgesic effects, proteins such as curcain are responsible for wound healing. Lignans and steroids are responsible for the cytotoxicity and antidiabetic activities, respectively. The detailed pharmacological studies presented in this review provides pragmatic documentation for J. curcas traditional uses, and reveals that this plant may be considered as potential source for medicinal molecules. However, there are challenges for the reproducibility of biological activities in relevance to the practical significance. Thus, analytical and standardization protocols of plant materials should be developed for *J. curcas*, since these are the bases for reproducible pharmacological studies. Further research is needed to study the physiological and biochemical functions demonstrated by *J. curcas*, identify the individual bioactive natural products, and illustrate their mechanism of action. Caution is to be taken when using the different parts of *J. curcas* in traditional medicine. The antagonistic properties of the phytochemical such as antitumor and tumor promotion properties in *J. curcas* plant extracts suggest caution in the traditional uses and applications. Further studies are required to determine the mechanism and conditions that control these controverting properties. The therapeutic utilization may be ideal when the active compounds are used in purified form.

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References

Abdel Gadir, W.S., Onsa, T.O., Ali, W.E.M., El-Badwi, S.M.A., Adam, S.E.I., 2003. Comparative toxicity of *Croton macrostachys*, *Jatropha curcas* and *Piper abyssinica* seeds in Nubian goats. Small Ruminant Research 48, 61–67.

Abdelgadir, H.A., Johnson, S.D., Van Staden, J., 2009. Pollinator effectiveness, breeding system, and tests for inbreeding depression in the biofuel seed crop, *Jatropha curcas*. The Journal of Horticultural Science and Biotechnology 84, 319–324.

Abdelgadir, H.A., Jäger, A.K., Johnson, S.D., Van Staden, J., 2010. Influence of plant growth regulators on flowering, fruiting, seed oil content, and oil quality of *Jatropha curcas*. South African Journal of Botany 76, 440–446.

Abigor, R.D., Okpefa, E., Bafor, M.E., Uadia, P.O., Osagie, A.U., 1997. The physico-chemical properties of the seed and seed oil of *Jatropha curcas* L. Rivista Italiana delle Sostanze Grasse 74, 405–466.

Achenbach, H., Benirschke, G., 1997. Joannesialactone and other compounds from *Joannesia princeps*. Phytochemistry 45, 149–157.

Achten, W.M.J., Nielsen, L.R., Aerts, R., Lengkeek, A.G., Kjaer, E.D., Trabucco, A., Hansen, J.K., Maes, W.H., Gradual, L., Akinnifesi, F.K., Muys, B., 2010. Towards domestication of *Jatropha curcas*. Biofuels 1, 91–107.

Adam, S.E.I., 1974. Toxic effects of *Jatropha curcas* in mice. Toxicology 2, 67–76.

Adam, S.E.I., Magzoub, M., 1975. Toxicity of *Jatropha curcas* for goats. Toxicology 4, 347–354.

Adolf, W., Opferkuch, H.J., Hecker, E., 1984. Irritant phorbol derivatives from *Jatropha* species. Phytochemistry 23, 129–132.

Ahmed, O.M., Adam, S.E., 1979. Toxicity of *Jatropha curcas* in sheep and goats. Research in Veterinary Science 27, 89–96.

Aiyelaagbe, O.O., Adeniyi, B.A., Fatunsi, O.F., Armish, B.D., 2007. In vitro antimicrobial activity and phytochemical analysis of *Jatropha curcas* roots. International Journal of Pharmacology 3, 106–110.

Akinpelu, D.A., Aiyegoro, O.A., Okoh, A.I., 2009. The bioactive potentials of two medicinal plants commonly used as folklore remedies among some tribes in West Africa. African Journal of Biotechnology 8, 1660–1664.

Alonso-Castro, A.J., Villarreal, M.L., Salazar-Olivo, L.A., Gomez-Sanchez, M., Dominguez, F., Garcia-Carranca, A., 2011. Mexican medicinal plants used for cancer treatment: pharmacological, phytochemical and ethnobotanical studies. Journal of Ethnopharmacology 133, 945–972.

Asase, A., Oteng-Yeboah, A.A., Odamtten, G.T., Simmonds, M.S.J., 2005. Ethnobotanical study of some Ghanaian anti-malarial plants. Journal of Ethnopharmacology 99, 273–279.

Auvin, C., Baraguey, C., Blond, A., Lezenven, F., Pousset, J.L., Bodo, B., 1997. Curcacycline B, a cyclic nonapeptide from *Jatropha curcas* enhancing rotamase activity of cyclophilin. Tetrahedron Letters 38, 2845–2848.

Balaji, R., Rekha, N., Deecarman, M., Manikandan, L., 2009a. Antimetastatic and antiproliferative activity of methanolic fraction of *Jatropha curcas* against B16F10 melanoma induced lung metastasis in C57BL/6 mice. African Journal of Pharmacy and Pharmacology 3, 547–555.

Balaji, R., Suba, V., Rekha, N., Deecarman, M., 2009b. Hepatoprotective activity of methanolic fraction of *Jatropha curcas* on aflatoxin B1 hepatic carcinoma. International Journal of Pharmaceutical Sciences 1, 287–296.

Balangcod, T.D., Balangcod, A.K.D., 2011. Ethnomedical knowledge of plants and healthcare practices among the Kalanguya tribe in Tinoc, Ifugao, Luzon, Philippines. Indian Journal of Traditional Knowledge 10, 227–238.

Baldini, M., Raranciuc, S., Vischi, M., 2012. Toxicity of *Jatropha curcas* L. as a biofuel crop and options for management. CAB Reviews 7, 1–13.

Becker, K., Makkar, H.P.S., 1998. Toxic effects of phorbol esters in carp (*Cyprinus carpio* L.). Veterinary and Human Toxicology 40, 82–86.

Becker, K., Makkar, H.P.S., 2008. *Jatropha curcas*: a potential source for tomorrow's oil and biodiesel. Lipid Technology 20, 104–107.

Bhattacharya, A.A., Datta, K., Datta, S.K., 2005. Floral biology floral resource constraints and pollination limitations in *Jatropha curcas* L. Pakistan Journal of Biological Sciences 8, 456–460.

Borah, P.K., Gogoi, P., Phukan, A.C., Mahanta, J., 2006. Traditional medicine in the treatment of gastrointestinal diseases in Upper Assam. Indian Journal for Traditional Knowledge 5, 510–512.

Carels, N., 2009. *Jatropha curcas*: a review. In: Kader, J.C., Delseny, M. (Eds.), Advances in Botanical Research, 50, pp. 39–86.

Chang-Wei, L., Kun, L., You, C., Yong-Yu, S., 2007. Floral display and breeding system of *Jatropha curcas* L. Forestry Studies in China 9, 114–119.

Chianese, G., Fattorusso, E., Aiyelaagbe, O.O., Luciano, P., Schröder, H.C., Müller, W.E.G., Taglialatela-Scafati, O., 2011. Spirocurcasone, a diterpenoid with a novel carbon skeleton from *Jatropha curcas*. Organic Letters 13, 316–319.

Chivandi, E., Makuza, S.M., Erlanger, K.H., Mtimum, J.P., Read, J.S., Tivapasi, M., 2000. Effects of dietry *Jatropha curcas* on the haematology of weaned pigs. Zimbabwe Veterinary Journal 31, 83–91.

Chivandi, E., Erlwanger, K.H., Makuza, S.M., Read, J.S., Mtimuni, J.P., 2006. Effects of dietary *Jatropha curcas* meal on percent packed cell volume, serum glucose, cholesterol and triglyceride concentration and alpha-amylase activity of weaned fattening pigs. Research Journal of Animal and Veterinary Sciences 1, 18–24.

Daniyan, S.Y., Abalaka, M.E., Elemba, O.M., Aransiola, S.A., 2011. In vitro antimicrobial activity and phytochemical screening of *Jatropha curcas* seed extract. International Research Journal of Pharmacy 2, 60–64.

Das, B., Reddy, K.R., Ravindranath, N., Kishore, K.H., Murthy, U.S.N., 2005. A substituted imidazole derivative from *Jatropha curcas*. Indian Journal of Chemistry 44B, 1119–1120.

Dehgan, B., Webster, G.L., 1979. Morphology and infrageneric relationships of genus *Jatropha* (Euphorbiaceae). University of California Publications in Botany 74, 11–27.

Deka, P., Nath, K.K., Borthakur, S.K., 2008. Ethioatrical uses of *Euphorbia antiqourum* L. and *E. ligularia* Roxb. in Assam. Indian Journal of Traditional Knowledge 7, 466–488.

Devappa, R.K., Makkar, H.P.S., Becker, K., 2010a. *Jatropha* toxicity — a review. Journal of Toxicology and Environmental Health, Part B 13, 476–507.

Devappa, R.K., Makkar, H.P.S., Becker, K., 2010b. Nutritional, biochemical, and pharmaceutical potential of proteins and peptides from Jatropha: review. Journal of Agriculture and Food Chemistry 58, 6543–6555.

Devappa, R.K., Makkar, H.P.S., Becker, K., 2011. *Jatropha* diterpenes—a review. Journal of American Oil Chemistry Society 88, 301–322.

Devappa, R.K., Rajesh, S.K., Kumar, V., Makkar, H.P.S., Becker, K., 2012a. Activities of *Jatropha curcas* phorbol esters in various bioassays. Ecotoxicology and Environmental Safety 78, 57–62.

Devappa, R.K., Rajesh, S.K., Kumar, V., Makkar, H.P.S., Becker, K., 2012b. Localisation of antinutrients and qualitative identification of toxic components in *Jatropha curcas* seed. Journal of the Science of Food and Agriculture 92, 1519–1525.

Dolui, A.K., Sharma, H.K., Marein, T.B., Lalhriatpuii, T.C., 2004. Folk herbal remedies from Meghalaya. Indian Journal of Traditional Knowledge 3, 358–364.

Donlaporn, S., Suntornsuk, W., 2010. Antifungal activities of ethanolic extract from *Jatropha curcas* seed cake. Journal of Microbiology and Biotechnology 20, 319–324.

Duke, J.A., Ayensu, E.S., 1985. Medicinal Plants of China, 14. Reference Publication Inc, Algonac, Michigan 52–361.

El Diwani, G., El Rafie, Sh., Hawash, S., 2009. Antioxidant activity of extracts obtained from residues of nodes leaves stem and root of Egyptian *Jatropha curcas*. African Journal of Pharmacy and Pharmacology 3, 521–530.

El-Badawi, S.M., Adam, S.E., Hapke, H.J., 1995. Comparative toxicity of *Ricinus communis* and *Jatropha curcas* in Brown Hisex chicks. Deutsche Tierarztliche Wochenschrift 102, 75–77.

Esimone, C.O., Nworu, C.S., Jackson, C., 2009. Cutaneous wound healing activity of a herbal ointment containing the leaf extract of *Jatropha curcas* L. (Euphorbiaceae). International Journal of Applied Research in Natural Products 1, 1–4.

Fragopoulou, E., Nomikos, T., Karantonis, H.C., Apostolakis, C., Pliakis, E., Samiotaki, M., Panayotou, G., Antonopoulou, S., 2007. Biological activity of acetylated phenolic compounds. Journal of Agricultural and Food Chemistry 55, 80–89.

Gandhi, V.M., Cherian, K.M., Mulky, M.J., 1995. Toxicology studies on Ratanjyot oil. Food Chemistry and Toxicology 33, 39–42.

Ganesan, S., Suresh, N., Kesaven, L., 2004. Ethnomedicinal survey of lower Palani Hills of Tamil Nadu. Indian Journal of Traditional Knowledge 3, 299–304.

Ganesan, S., Venkateshan, G., Banumathy, N., 2006. Medicinal plants used by ethnic group Thottianaickans of Semmalai hills (reserved forest), Tiruchirappalli district, Tamil Nadu. Indian Journal of Traditional Knowledge 5, 245–252.

Gbolade, A.A., 2009. Inventory of antidiabetic plants in selected district of Lagos State, Nigeria. Journal of Ethnopharmacology 121, 135–139.

Goel, G., Makkar, H.P.S., Francis, G., Becker, K., 2007. Phorbol esters: structure, biological activity and toxicity in animals. International Journal of Toxicology 26, 279–288.

Goonasekera, M.M., Gunawardana, V.K., Jayasena, K., Mohammed, S.G., Balasubramaniam, S., 1995. Pregnancy terminating effect of *Jatropha curcas* in rats. Journal of Ethnopharmacology 47, 117–123.

Goulart, M.O.F., Santàna, A.E.G., de Lima, R.A., Cavalcante, S.H., 1993. Fitoconstituintes químicos isolados de *Jatropha Elliptica*, Atribuição dos deslocamentos químicos dos átomos de carbono e hidrogênio dos diterpenos Jatrofolonas A e B. Química Nova 16, 95–100.

Gübitz, G.M., Mittelbach, M., Trabi, M., 1999. Exploitation of the tropical oil seed plant *Jatropha curcas* L. Bioresource Technology 67, 73–82.

Gupta, D.D., Haque, E., Islam, N., Mondal, S.I., Shibib, B.A., 2010. Antimicrobial and cytotoxic activities of *Jatropha curcas* (Euphorbiaceae). Dhaka University Journal of Pharmaceutical Science 9, 139–142.

Hass, W., Sterk, H., Mittelbach, M., 2002. Novel 12-deoxy-16-hydroxyphorbol diesters isolated from the seed oil of *Jatropha curcas*. Journal of Natural Products 65, 1334–1440.

Heller, J., 1996. Physic nut *Jatropha curcas* L., promoting the conservation and use of underutilized and neglected crops, 1st edn. International Plant Genetics and Crop Plant Research Institute, Gartersleben (IPGRI), Rome, Italy.

Hirota, M., Suttajit, M., Suguri, H., Endo, Y., Shudo, K., Wongchai, V., Erich, H., Fujiki, H., 1988. A new tumor promoter from the seed oil of *Jatropha curcas* L., an intramolecular diester of 12-deoxy-l6-hydroxyphorbol[1]. Cancer Research 48, 5800–5804.

Horiuchi, T., Suttajit, M., Suguri, H., Endo, Y., Shudo, K., Wongchai, V., Hecker, E., Fujiki, H., 1988. A new tumor promoter from the seed oil of *Jatropha curcas* L., an intermolecular diester of 12-deoxy-16-hydroxyphorbol. Cancer Research 48, 5800–5804.

Igbinosa, O.O., Igbinosa, E.O., Aiyegoro, O.A., 2009. Antimicrobial activity and phytochemical screening of stem bark extracts from *Jatropha curcas* (Linn). African Journal of Pharmacy and Pharmacology 3, 58–62.

Igbinosa, O.O., Igbinosa, I.H., Chigor, V.N., Uzunuigbe, O.E., Oyedemi, S.O., Odjadjare, E.E., Okoh, A.I., Igbinosa, E.O., 2011. Polyphenolic contents and antioxidant potential of stem bark extract from *Jatropha curcas* (Linn). International Journal of Molecular Sciences 12, 2958–2971.

Igoli, J.O., Ogaji, O.G., Tor-Anyiin, T.A., Igoli, N.P., 2005. Traditional medicine practice amongst the Igede people of Nigeria. Part II. African Journal of Traditional, Complementary and Alternative Medicine 2, 134–152.

Irene, M.V., Cariño, F.A., 2011. Antimicrobial activity of new phorbins from *Jatropha curcas* Linn. (Euphorbiaceae) leaves. Zeitschrift für Naturforschung 66c, 441–446.

Iwu, M.M., 1993. Handbook of African Medicinal Plants. CRC Press, Florida, USA 24–33.

Jain, S.K., Srivastava, S., 2005. Traditional use of some Indian plants among islanders of the Indian Ocean. Indian Journal of Traditional Knowledge 4, 345–357.

Jain, D.L., Baheti, A.M., Jain, S.R., Khandelwal, K.R., 2010. Use of medicinal plants among tribes in Satpuda region of Dhule and Jalgaon districts of Maharashtra—an ethnobotanical survey. Indian Journal of Traditional Knowledge 9, 152–157.

Jaiswal, V., 2010. Culture and ethnobotany of Jaintia tribal community of Meghalaya, Northeast India — a mini review. Indian Journal of Traditional Knowledge 9, 38–44.

Jayakumar, G., Ajithabai, M.D., Sreedevi, S., Viswanathan, P.K., Remeshkumar, B., 2010. Ethnobotanical survey of the plants used in treatment of diabetes. Indian Journal of Traditional Knowledge 9, 100–104.

Jeeva, S., Kiruba, S., Mishra, B.P., Venugopal, N., Dhas, S.S.M., Reini, G.S., Kingston, C., Kavitha, A., Sukumaran, S., Raj, A.D.S., Laloo, R.C., 2006. Weeds of Kanyakumari district and their value in rural life. Indian Journal of Traditional Knowledge 5, 501–509.

Jing, L., Fang, Y., Ying, X., Wenxing, H., Meng, X., Sayed, M.N., Fang, C., 2005. Toxic impact of ingested jatrophol-1 on selected enzymatic activities and ultrastructure of midgut cells in silkworm, *Bomboxy mori* L. Journal of Applied Entomology 129, 98–104.

Jin-xia, Z., Qin, W., Li-jun, Z., Guo-jin, L., Yu, C., Lin, T., Fang, C., 2005. The extraction of β-1,3-glucanase and analysis of partial characteristics in *Jatropha curcas*. Southwest China Journal of Agricultural Science 18, 328–333.

Jongschaap, R.E.E., Corre, W.J., Bindraban, P.S., Brandenburg, W.A., 2007. Claims and Facts on *Jatropha curcas* L. Global *Jatropha curcas* Evaluation, Breeding and Propagation Programme. Plant Research International B.V., Wageningen, The Netherlands 1–4.

Joshi, A., Singhal, P., Bachheti, R.K., 2011. Physicochemical characterization of seed oil of *Jatropha curcas* L. collected from Dehradun (Uttarakhand) India. International Journal of Applied and Pharmaceutical Technology 2, 123–127.

Kamal, S., Manmohan, S., Birendra, S., 2011. A review on chemical and medicobiological applications of *Jatropha curcas*. International Research Journal of Pharmacy 4, 61–66.

Kamble, S.Y., Patil, S.R., Sawant, P.S., Sawant, S., Pawar, S.G., Singh, E.A., 2010. Studies on plants used in traditional medicine by Bhilla tribe of Maharashtra. Indian Journal of Traditional Knowledge 9, 591–598.

Katewa, S.S., Galav, P.K., Nag, A., Jain, A., 2008. Poisonous plants of the southern Aravalli hills of Rajasthan. Indian Journal of Traditional Knowledge 7, 269–272.

Khafagy, S.M., Mohamed, Y.A., Abdel, N.A., Mahmoud, Z.F., 1977. Phytochemical study of *Jatropha curcas*. Plant Medicine 31, 274–277.

Kochhar, S., Singh, S.P., Kochhar, V.K., 2008. Effect of auxins and associated biochemical changes during colonal propagation of the biofuel plant — *Jatropha curcas*. Biomass and Bioenergy 32, 1136–1143.

Kong, L., Min, Z., Jainixia, S., 1996. Chemical constituents from roots of *Jatropha curcas*. Acta Botanica Sinica 38, 161–166.

Kumar, A., Sharma, S., 2008. An evaluation of multipurpose oil seed crop for industrial uses (*Jatropha curcas* L.): a review. Industrial Crops and Products 28, 1–10.

Li, C., Devappa, R.K., Liu, J., Lv, J., Makkar, H.P.S., Becker, K., 2010. Toxicity of *Jatropha curcas* phorbol ester in mice. Food and Chemical Toxicology 48, 620–625.

Liberalino, A.A.A., Bambirra, E.A., Moreaes-Santos, T., Viera, C.E., 1988. *Jatropha curcas* L. seeds: chemical analysis and toxicity. Brazilian Archives of Biology and Technology 31, 539–550.

Lin, J., Yan, F., Tang, L., Chen, F., 2002. Isolation, purification and functional investigation on the N-glycosidase activity of curcin from the seeds of *Jatropha curcas*. High Technology Letters 11, 36–40.

Ling-yi, K., Zhi-da, M., Jian-xia, S., Rui, F., 1996. Chemical constituents from roots of *Jatropha curcas*. Acta Botanica Sinica 38 (2), 161–166.

Liu, J., Yang, Y., Wang, C., Li, Y., Qiu, M., 2012. Three new diterpenes from *Jatropha curcas*. Tetrahedron 68, 972–976.

Luis, C.P., Mo, ChengLin, Janalee, M., Luciene, I., Edjacy, L., Sandra, R., Leticia, B., Eduardo, A., William, G., Marco, B., 2012. *Jatropha curcas*: from biodiesel generation to medicinal applications. Recent Patents on Biotechnology 6, 192–199.

Luo, M.J., Liu, W.X., Yang, X.Y., Xu, Y., Yan, F., Huang, P., Chen, F., 2007. Cloning, expression and antitumor activity of recombinant protein of curcin. Russian Journal of Plant Physiology 54, 202–206.

Mairh, A.K., Kishra, P.K., Kumar, J., Mairh, A., 2010. Traditional botanical wisdom of Birhore tribes of Jharkhand. Indian Journal of Traditional Knowledge 9, 467–470.

Makkar, H.P.S., Becker, K., 1997. Potential of *J. curcas* seed meal as a protein supplement to livestock feed; constraints to its utilization and possible strategies to overcome constraints. In: Giibitz, G.M., Mittelbach, M., Trabi, M. (Eds.), Biofuels and Industrial Products from *Jatropha curcas*. DBV Graz, pp. 190–205.

Makkar, H.P.S., Aderibigbe, A.O., Becker, K., 1998. Comparative evaluation of non-toxic and toxic varieties of *Jatropha curcas* for chemical composition, digestibility, protein degradability and toxic factors. Food Chemistry 62, 207–215.

Makkar, H.P.S., Francis, G., Becker, K., 2009. *Jatropha curcas*, a promising crop for the generation of biodiesel and value-added coproducts. European Journal of Lipid Science and Technology 111, 773–787.

Makonnen, E., Rostom, A.A.H., Assefa, G., Zerihun, L., 1997. Antifertility effect of *Jatropha curcas* L. seed in guinea pigs. The Ethiopian Journal of Health Development 11, 145–148.

Manpong, P., Douglas, S., Douglas, P.L., Pongamphai, S., Teppaitoon, W., Kaewprakaisangkul, O., 2009. Reponses surface methodology applied to the extraction of phenolic compounds from *Jatropha curcas* Linn. Leaves using supercritical CO_2 with a methanol co-solvent. Journal of Food Process Engineering 34, 1661–1681.

Martínez-Herrera, J., Siddhuraju, P., Francis, G., Dávila-Ortíz, G., Becker, K., 2006. Chemical composition, toxic/antimetabolic constituents, and effects of different treatments on their levels, in four provenances of *Jatropha curcas* L. from Mexico. Food Chemistry 96, 80–89.

Matsuse, I.T., Lim, Y.A., Hattori, M., Correa, M., Gupta, M.P., 1999. A search for anti-viral properties in Panamanian medicinal plants: the effects on HIV and its essential enzymes. Journal of Ethnopharmacology 64, 15–22.

Maurel, C., Maarten, J., 2001. Aquaporins. A molecular entry into plant water relations. Plant Physiology 125, 135–138.

Meena, K.L., Yadav, B.L., 2010. Some traditional ethnomedicinal plants of southern Rajasthan. Indian Journal of Traditional Knowledge 9, 471–474.

Mishra, S.B., Vijayakumar, M., Ojha, S.K., Verma, A., 2010. Antidiabetic effect of *Jatropha curcas* L. levels extract in normal and alloxan-induced diabetic rats. International Journal of Pharmaceutical Sciences 12, 482–487.

Mitra, C.R., Bhatnagar, S.C., Sinha, M.K., 1970. Chemical examination of *Jatropha curcas*. Indian Journal of Chemistry 8, 1047.

Morton, J.F., 1981. Atlas of Medicinal Plants of Middle America. Bahamas to Yucatan. C.C. Thomas, Springfield, Illinois 1–1420.

Muanza, D.N., Euler, K.L., Williams, L., Newman, D.J., 1995. Screening of antitumor and anti-HIV activities of nine medicinal plants from Zaire. International Journal of Pharmacognosy 33, 98–106.

Mujumdar, A.M., Misar, A.V., 2004. Anti-inflammatory activity of *Jatropha curcas* roots in mice and rats. Journal of Ethnopharmacology 90, 11–15.

Mungman, S., Thippornwong, M., Tohtong, R., 2005. Anti-metastatic effect of curcusone B, a deterpene from *Jatropha curcas*. *In Vivo* 19, 265–268.

Naengchomnong, W., Thebtaranonth, Y., Wiriyachitra, P., Okamoto, K.T., Clardy, J., 1986a. Isolation and structure determination of four novel diterpenes of *Jatropha curcas*. Tetrahedron Letters 27, 2439–2442.

Naengchomnong, W., Thebtaranonth, Y., Wiriyachitra, P., Okamoto, K.T., Clardy, J., 1986b. Isolation and structure determination of two novel lathyranes from *Jatropha curcas*. Tetrahedron Letters 27, 5675–5678.

Naengchomnong, W., Tarnchompoo, B., Thebtaranonth, Y., 1994. (+)-Jatrophol, (+)-marmesin, propacin and jatrophin from the roots of *Jatropha curcas* (Euphorbiaceae. Journal of the Science Society of Thailand 20, 73–83.

Namuli, A., Abdullah, N., Sieo, C.C., Zuhainis, S.W., Oskoueian, E., 2011. Phytochemical compounds and antibacterial activity of *Jatropha curcas* Linn. extracts. Journal of Medicinal Plants Research 5, 3982–3990.

Nath, M., Choudhury, M.D., 2010. Ethno-medico-botanical aspects of Hmar tribe of Cachar district, Assam (Part 1). Indian Journal of Traditional Knowledge 9, 760–764.

Nath, L.K., Duta, S.K., 1997. Extraction and purification of curcain, a protease from the latex of *Jatropha curcas* L. Pharmacy and Pharmacology 43, 111–114.

Nayak, B.S., Patel, K.N., 2010a. Anti-inflammatory screening of *Jatropha curcas* root, stem and leaf in albino rats. Romanian Journal of Biology Plant-Biology 55, 9–13.

Nayak, B.S., Patel, K.N., 2010b. Screening of different parts of *Jatropha curcas* for antinociceptive and antipyretic activity on rats. Malaysian Journal of Pharmaceutical Sciences 8, 23–28.

Neuwinger, H.D., 1996. African Ethnobotany: Poisons and Drugs: Chemistry, Pharmacology, Toxicology. Chapman and Hall, New York 500–509.

Noumi, E., Houngue, F., Lontsi, D., 1999. Traditional medicine in primary health care: plants used for the treatment of hypertension in Bafia, Cameroon. Fitoterapia 70, 234–239.

Obasi, N.L., Ejikeme, M.P., Egbunu, C.A.C., 2011. Antimicrobial and phytochemical activity of methanolic extract and its fractions of *Jatropha curcas* Linn. (Euphorbiaceae) stem bark. African Journal of Pure and Applied Chemistry 5, 92–96.

Ocampo, R., Balick, M.J., 2009. In: Goldstein, R., Herrera, K. (Eds.), Plants of Semillas Sagradas: An Ethnomedicinal Gadrden in Costa Rica. Finca Luna Nueva Extractos de Costa Rica, S.A, pp. 58–60.

Odusote, O.M., Abioye, A.O., Rotib, M.O., 2002. *Jatropha curcas* seed oil Linn (Euphorbiaceae) contraceptive activity and an oral formulation. Nigerian Quarterly Journal of Hospital Medicine 12, 44–47.

Openshaw, K., 2000. A review of *Jatropha curcas*: an oil plant of unfulfilled promise. Biomass and Bioenergy 19, 1–15.

Oskoueian, E., Abullah, N., Saad, W.Z., Omar, A., Ahmed, S., Kuan, W.B., Zolkifli, N.A., Hendra, R., Ho, Y.W., 2011a. Bioactive compounds and biological activities of *Jatropha curcas* L. kernel meal extract. International Journal of Molecular Sciences 12, 5955–5970.

Oskoueian, E., Abullah, N., Saad, W.Z., Omar, A., Ahmed, S., Kuan, W.B., Zolkifli, N.A., Hendra, R., Ho, Y.W., 2011b. Antioxidant, anti-inflammatory and anticancer activities of methanolic extracts from *Jatropha curcas* Linn. Journal of Medicinal Plant Research 5, 49–57.

Osoniyi, O., Onajobi, F., 2003. Coagulant and anticoagulant activities in *Jatropha curcas* latex. Journal of Ethnopharmacology 89, 101–105.

Oyi, A.R., Onaolapo, J.A., Haruna, A.K., Morah, C.O., 2007. Antimicrobial screening and stability studies of the crude extract of *Jatropha curcas* Linn latex (Euphorbiacese). Nigerian Journal of Pharmaceutical Science 6, 14–20.

Patil, H.M., Bhaskar, V.V., 2006. Medicinal knowledge system of Nandurbar district, Maharashtra. Indian Journal of Traditional Knowledge 5, 327–330.

Pawar, S., Patil, D.A., 2006. Folk remedies against rheumatic disorders in Jalgaon district, Maharashtra. Indian Journal of Traditional Knowledge 5, 314–316.

Perry, L.M., 1980. Medicinal Plants of East and South East Asia. MIT Press, Cambridge 620.

Pertino, M., Schmeda-Hirschmann, G., Rodriguez, J.A., Theoduloz, C., 2007. Gastroprotective effect and cytotoxicity of semisynthetic jatropholone derivatives. Planta Medica 73, 1095–1100.

Prasad, D.M.R., Izam, A., Khan, M.M.R., 2012. *Jatropha curcas*: plant of medical benefits. Journal of Medicinal Plants Research 6, 2691–2699.

Purkayastha, J., Dutta, M., Nath, S.C., 2007. Ethnomedicinal plants from Dibru–Saikhowa biosphere reserve, Assam. Indian Journal of Traditional Knowledge 6, 477–480.

Rai, D.K., Lakhanpal, P., 2008. *Jatropha curcas* poisoning in pediatric patients, Mauritius. The Internet Journal of Pediatrics and Neonatology 8, 1–6.

Rajendran, K., Balaji, P., Basu, M.J., 2008. Medicinal plants and their utilization by villagers in southern districts of Tamil Nadu. Indian Journal of Traditional Knowledge 7, 417–420.

Raju, A.J.S., Ezradanam, V., 2002. Pollination ecology and fruiting behaviour in a monoecious species, *Jatropha curcas* L. (Euphorbiaceae). Current Science 83, 1395–1398.

Ram, S.G., Parthiban, K.T., Kumar, R.S., Thiruvengadam, V., Paramathma, M., 2008. Genetic diversity among *Jatropha* species as revealed by RAPD markers. Genetic Resources and Crop Evolution 55, 803–809.
Rao, K.S., Chakrabarti, P.P., Rao, B.V.S.K., Prasad, R.B.N., 2009. Phospholipid composition of *Jatropha curcas* seed lipids. Journal of the American Oil Chemists' Society 86, 197–200.
Ravindranath, N., Ramesh, C., Das, B., 2003. A rare dinorditerpene from *Jatropha curcas*. Biochemical Systematic and Ecology 31, 431–432.
Ravindranath, N., Reddy, M.R., Mahender, G., Ramu, R., Kumar, K.R., Das, B., 2004a. Deoxypreussomerins from *Jatropha curcas*: are they also plant metabolites? Phytochemistry 65, 2387–2390.
Ravindranath, N., Reddy, M.R., Ramesh, C., Ramu, R., Prabhakar, A., Jagadeesh, B., Das, B., 2004b. New lathyrane and podocarpane diterpenoids from *Jatropha curcas*. Chemical and Pharmaceutical Bulletin 52, 608–611.
Sabandar, C.W., Ahmat, N., Jaafar, F.M., Sahidin, I., 2012. Medicinal property, phytochemistry and pharmacology of several *Jatropha* species (Euphorbiaceae): a review. Phytochemistry. http://dx.doi.org/10.1016/j.phytochem.2012.10.009.
Samuel, J.K., Andrews, B., 2010. Traditional medicinal plant wealth of Pachalur and Periyur hamlets dindigul district, Tamil Nadu. Indian Journal of Traditional Knowledge 9, 264–270.
Sandberg, F., Perera-Ivarsson, P., El-Seedi, H.R., 2005. A Swedish collection of medicinal plants from Cameroon. Journal of Ethnopharmacology 102, 336–343.
Sanjeetha, J., Divya, K., Prashanth, M.V., Vamsikrishna, A., Rani, G.L., 2009. Anti-inflammatory and antibacterial activity of *Jatropha curcas* Linn. Journal of Pharmaceutical Research and Health Care 2, 258–262.
Schmeda-Hirschmann, G., Tsichritzis, F., Jakupovic, J., 1992. Diterpenes and a lignan from *Jatropha grossidentata*. Phytochemistry 31, 1731–1735.
Schmook, B., Serralta-Peraza, L., 1997. *Jatropha curcas*: distribution and uses in Yucatan Peninsula of Mexico. In: Gubitz, G.M., Mittelbach, M., Trabi, M. (Eds.), Biofuels and Industrial Products from *Jatropha curcas*. DBV Graz, pp. 53–57.
Sharma, S.K., Singh, H., 2012. A review on pharmacological significance of genus *Jatropha* (Euphorbiaceae). Chinese Journal of Integrative Medicine 18, 868–880.
Sharma, A., Saxena, S., Rani, U., Rajor, S., Batra, A., 2010a. Broad-spectrum antimicrobial properties of medicinally important plant *Jatropha curcas*. International Journal of Pharmaceutical Science Review and Research 4, 11–14.
Sharma, J., Painuli, R.M., Gaur, R.D., 2010b. Plants used by the rural communities of district Shahjahanpur, Uttar Pradesh. Indian Journal of Traditional Knowledge 9, 798–803.
Sharma, S., Dhamija, H.K., Parashar, B., 2012. *Jatropha curcas*: a review. Asian Journal of Pharmaceutical Science 2, 107–111.
Shetty, S., Uupa, S.L., Udupa, A.L., Vollala, V.R., 2006. Wound healing activities of bark extract of *Jatropha curcas* Linn in albino rats. Saudi Medical Journal 27, 1473–1476.
Shiddamallayya, N., Yasmeen, A., Gopakumar, K., 2010. Hundred common forest medicinal plants of Karnataka in primary healthcare. Indian Journal of Traditional Knowledge 9, 90–95.
Silja, V.P., Varma, K.S., Mohanan, K.V., 2008. Ethnomedicinal plant knowledge of the Mullu kuruma tribe of Wayanad district, Kerala. Indian Journal of Traditional Knowledge 7, 604–612.
Singh, R.K., Singh, D., Mahendrakar, A.G., 2010. *Jatropha* poisoning in children. Medical Journal Armed Forces India 66, 80–81.
Sriprang, S., Sriprang, N., Sumpradit, T., Shimbhu, D., 2010. Antibacterial activities of crude extracts from physic nut (*Jatropha curcas*) seed residues. Science Asia 36, 346–348.
Staubmann, R., Ncube, I., Gubitz, G.M., Steiner, W., Read, J.S., 1999a. Esterase and lipase activity in *Jatropha curcas* L. seeds. Journal of Biotechnology 75, 117–126.
Staubmann, R., Schubert-Zsilavecz, M., Hiermann, A., Kartnig, T., 1999b. A complex of 5-hydroxypyrrolidin-2-one and pyrimidine-2,4-dione isolated from *Jatropha curcas*. Phytochemistry 50, 337–338.
Staubmann, R., Schubert-Zsilavecz, M., Hiermann, A., Karting, T., 1999c. The anti-inflammatory effect of *J. curcas* leaves. In: Gübitz, G.M., Mittelbach, M., Trabi, M. (Eds.), Biofuels and Industrial Products from *Jatropha curcas*. Dbv-Verlag Für die Technische Universität Graz, Graz, Austria, pp. 60–87.
Stripe, F., Brizzi, P.A., Lorenzoni, E., Strochi, P., Montanaro, L., Sperti, S., 1976. Studies on the protein from the seeds of *Croton tigilium* and *Jatropha curcas*. Biochemistry Journal 156, 1–6.
Sutthivaiyakit, S., Mongkolvisut, W., Prabpai, S., Kongsaeree, P., 2009. Diterpenes, sesquiterpenes, and a sesquiterpene—coumarin conjugate from *Jatropha integerrima*. Journal of Natural Products 72, 2024–2027.
Theoduloz, C., Rodríguez, J.A., Pertino, M., Schmeda-Hirschmann, G., 2009. Antitumor activity of jatrophone and jatropholone derivatives. Planta Medica 75, 1520–1522.
Thomas, R., Sah, N.K., Sharma, P.B., 2008. Therapeutic biology of *Jatropha curcas*: a mini review. Current Pharmaceutical Biotechnology 9, 315–324.
Tripathi, S.C., Srivastava, M., 2010. Ethnomedicinal flora of Euphorbiaceae used in dermatological problems. Indian Journal of Traditional Knowledge 9, 318–320.
Uche, F.I., Aprioku, J.S., 2008. The phytochemical constituents, analgesic and anti-inflammatory effects of methanol extract of *Jatropha curcas* leaves in mice and Wister lbino rats. Journal of Applied Science and Environmental Management 12, 99–102.
Udayan, P.S., Tushar, K.V., George, S., Balachandran, I., 2007. Ethnomedicinal information from Kattunayakas tribes of Mudumalai Wildlife Sanctuary, Nilgiris district, Tamil Nadu. Indian Journal of Traditional Knowledge 6, 574–578.
Van den Berg, A.J., Horsten, S.F., Kettenes van den Bosch, J.J., Kores, B.H., Beukelman, C.J., Loeflang, B.R., Labadie, R.P., 1995. Curcacycline A: a novel cyclic octapeptide isolated from the latex of *Jatropha curcas* Linn. FEBS Letters 358, 215–218.
Verma, S., Chauhan, N.S., 2007. Indigenous medicinal plants knowledge of Kunihar forest division, district Solan. Indian Journal of Traditional Knowledge 6, 494–497.
Villaseñor, I.M., Cariño, F.A., 2011. Antimicrobial activity of new phorbins from Jatropha curcas Linn. (Euphorbiaceae) leaves. Z Naturfosch C 66, 441–446.
Villegas, L.F., Fernández, I.D., Maldonado, H., Torres, R., Zavaleta, A., Vaisberg, A.J., Hammond, G.B., 1997. Evaluation of the wound-healing activity of selected traditional medicinal plants from Perú. Journal of Ethnopharmacology 55, 193–200.
Visser, E.M., Filho, D.O., Martins, M.A., Steward, B.L., 2011. Bioethanol production potential from Brazilian biodiesel co-products. Biomass and Bioenergy 35, 489–494.
Wang, X.C., Zheng, Z.P., Gan, X.W., Hu, L.H., 2009. Jatrophalactam, a novel diterpenoid lactam isolated from *Jatropha curcas*. Organic Letters 11, 5522–5524.
Watt, J.M., Breyer-Brandwijk, M.G., 1962. The Medicinal and Poisonous Plants of Southern and Eastern Africa, 2nd ed. E and S. Livingstone, Ltd., Edinburgh and London 420–422.
Wei, Q., Liao, Y., Chen, Y., Wang, S.H., Xu, Y., Tang, L., Chen, F., 2005. Isolation, characterisation and antifungal activity of β-1,3-glucanase from seeds of *Jatropha curcas*. South African Journal of Botany 71, 95–99.
Weike, C., Qi, Z., Xingchun, C., Kexiu, W., Ying, X., Lin, T., Shenghua, W., Jie, B., Fang, C., 2006. Chemical modification of *Jatropha curcas* RIPs (curcin) and effect of the modification on relative activity of curcin. Chinese Journal of Applied Environmental Biology 12, 329–333.
Wender, P.A., Kee, J., Warrington, J.M., 2008. Practical synthesis of prostratin, DPP, and their analogs, adjuvant leads against latent HIV. Science 320, 649–652.
Wole, O.M., Ayanbode, O.F., 2009. Use of indigenous knowledge by women in a Nigerian rural community. Indian Journal of Traditional Knowledge 8, 287–295.
Xiao, J., Zhang, H., Niu, L., Wang, X., 2011. Efficient screening of a novel antimicrobial peptide from *Jatropha curcas* by cell membrane affinity chromatography. Journal of Agricultural and Food Chemistry 59, 1145–1151.
Xu, J., Zeng, G., Tan, N., 2011. A new tetracyclic diterpene from *Jatropha curcas*. Helvetica Chemica Acta 94, 842–846.
Yao, L., Han, C., Chen, G., Song, X., Chang, Y., Zang, W., 2012. A new asymmetric diamide from the seed cake of *Jatropha curcas* L. Fitoterapia 83, 1318–1321.
Yesodharan, K., Sujana, K.A., 2007. Ethnomedicinal knowledge among Malamalasar tribe of Parambikulam wildlife sanctuary, Kerala. Indian Journal of Traditional Knowledge 6, 481–485.
Yusuf, O.S., Maxwell, E.I., 2010. Analgesic activity of the methanolic leaf extract of *Jatropha curcas* (Linn). African Journal of Biomedical Research 13, 149–152.
Zhang, X., Zhang, M., Su, X., Huo, C., Gu, Y., Shi, Q., 2009. Chemical constituents of the plants from genus *Jatropha*. Chemistry and Biodiversity 6, 2166–2183.