

Review

A phytochemical and pharmacological review of *Ricinus communis* L.

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Abstract

Background The *Ricinus* genus consists of herbs with one known species, *Ricinus communis* Linn is commonly referred to as a castor oil plant. This plant is a rapidly developing perennial herb with moderate height, it is also a member of the castor bean family that possesses spiky green fruits. The flowers lack petals and are also monoecious. The fruit has lots of oil with three hard brown shiny seeds. Castor beans (*R. communis* seeds) produce castor oil, widely used as a purgative, lubricant, varnish, and pain killers.

Main body Appropriate literature was accessed from Google Scholar, Scopus, PubMed, and Web of Science for articles about *Ricinus communis*. Many pharmacological properties of *Ricinus communis* reported are analgesic, anti-bacterial, anti-cancer, anti-fungal, anti-diabetic, anti-inflammatory, anti-oxidant, mosquitocidal, anti-nociceptive, and anti-fertility properties. These properties are due to its phytochemicals like; Ricinine, gallic acid, quercetin, Kaempferol-3-O- β -D-xylpyranoside, Quercetin-3-O- β -rutinoside, etc.

Conclusion The pharmacological applications of *Ricinus communis* show promising prospects for wound healing, diabetes control, antioxidant therapy, cancer treatment animal feed composition. Nevertheless, its usage requires caution, especially in therapeutic conditions where its purgative effects are unnecessary.

Keywords *Ricinus communis* · Phytochemical · Pharmacological properties · Pharmacokinetics · Traditional use

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1 Background

The Euphorbiaceae is a very big family of spurge with about 7500 species distributed in five sub-families from over 300 genera [1–3]. The members of these family are flowering plants that is either herbs, shrubs or trees. *Ricinus* is a Greek word referring to “tick” or louse, that infest sheep and dogs. The name was given to the plant because of the seed has resemblance with some tick [1, 4]. *Ricinus* genus herbs have only one known specie, *Ricinus communis* Linn generally called castor oil plant [5, 6]. Castor crop is a hard crop, that is drought-resistant, tolerant to all types of soil, easily grows on the field to produce about 350–900 kg of oil per hectare [7]. It is a leafy plant with spiny fruits of the castor bean family that reproduces yearly. The flowers lack petals and are monoecious. The fruit is a capsule with soft prickles body and three hard brown shinny seeds [8]. Castor oil seed has been relevant in many industries like the agricultural and pharmaceutical among others [7]. Castor oil plant is fast growing with oil-rich seeds or beans used to make castor oil, widely used as purgative, lubricants, varnishes and pains killers [8, 9]. Several folks or traditional medicine around the world use castor oil plant. The primary healthcare in developing countries has over 80% dependence on herbal drug [10]. The numerous phytochemicals found in the seeds of castor oil includes flavonoids, alkaloids, tannins, anthrocyanins, terpenoids, phenolics and vitamins have great pharmacological and physiological benefit to human bodies [11–14]. The word phytochemicals is derived from the Greek term phyto meaning plant while the chemicals in phytochemicals incorporate bioactive and insubstantial chemical compounds that makes the body less susceptible to disease [15–17]. Various reviews have evaluated the phytochemcial composition and pharamacological properties of plants to showcase their potential benefits and drug develoement prospects [18–20].

Extracts from the castor plant have their used in many communities globally in the treatment and/or management of ailments like dermatitis, ringworm, warts, dandruff, rheumatism, headaches, hypoglycemia, and edema. The topical application on the breast of lactating mothers improves breast milk flow also the oil has shown to alleviate labor pain and speeds up of delivery [1, 21–25].

This plant extracts have, laxative, diuretic, anti-inflammatory, antihelmintic, antioxidant, and insecticidal capacities [1].

2 Main text

2.1 Taxonomy/classification

Domain: Eukaryota.

Subkingdom: Tracheobionta.

Kingdom: Plantae.

Phylum: Spermatophyta.

Subphylum: Angiospermae.

Division: Magnoliophyta.

Class: Dicotyledonae.

Subclass: Rosidae.

Order: Euphorbiales.

Family: Euphorbiaceae.

Genus: *Ricinus* L.

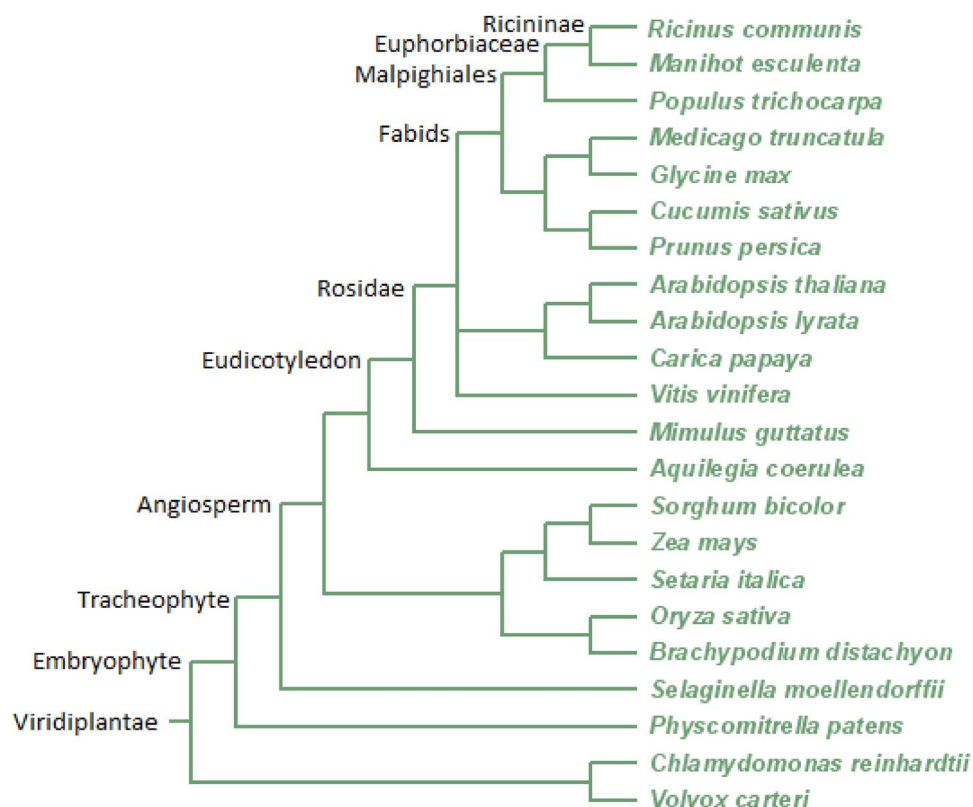
Species: *Ricinus communis* L. [USDA National Plant Database. 2006 [26]. This is shown in Fig. 1 below.

3 Morphology

3.1 Castor oil trees, stems and leaves

Castor oil tree or shrub has a sucker and a woody stem that rapidly grows up to over 6 m in height [27]. The woody stem has a sap that can be greyish, greenish or reddish colour. The stem of castor oil is round, with waxy bloom that are sometimes red, green or bluish in appearance. Anytime the castor plant is old the stem becomes grey in colour at the

Fig. 1 Classification of *Ricinus communis*. Source:http://bioweb.uwlax.edu/bio203/2011/beaudrie_nich/classification.htm



base [7]. Also, branches are few, hairless and hollow with finger-like leaf around 5–12 sometimes 7–9 in height. The leaves are usually simple, with large leaf blades and palmate shape (10–70 cm long and 15–60 cm wide). The colour ranges from purple or dark red, green or bluish-green color. When crushed, their leaves have a characteristic odor [7, 27]. The flowers are large and elongated with a length of 8–15 cm found on the branches tip. The flowers in castor plant are seen when the climate is favourable. The flowers are carried on clusters called inflorescences, creating a pyramidal raceme commonly referred to as spikes. These formations occur at the ends of both main and lateral branches. The flowers are inflorescence with a pyramidal raceme look on the branches, may be dioecious or monoecious [7, 28]. The castor plant is sometimes confused with *Jatropha gossypifolium* in the Euphorbiaceae family.

3.2 Castor fruit

The young fruits are egg-shape, rounded with bright red or greenish-red color and covered in soft dulled spines. The mature capsule has three segments around 10–30 mm across. Castor fruit when ripe has rigid and stiff globular spiny capsule. The castor fruit is typically a schizocarp, releasing its seeds explosively. Nevertheless, certain types of castor fruit yield capsules characterized by their simple, soft, and pliable spines, while others produce irritable spiny capsules. The capsule develops within approximately 3–7 days following fertilization [7].

3.3 Castor seeds or beans

The seeds are arranged in the capsule in threes with square, elongated or oval shape covered by a brittle seed coat or testa on the white kernel. The colour of the seed's ranges from white, brown, chocolate, red, reddish brown or black. The length of the seed is around 250 mm with a breadth of 5 to 16 mm. The wart appendage part of the seed is called caruncle. The seed oil is used in traditionally and conventionally therapies [23, 29]. Commercially, the whole castor bean plant can be used as animal feed, biofuel, fertilizer, and in phytoremediation [29].

4 Origin and distribution

Castor bean documentation [*R. communis* L.] from old literature shows that it is common in the tropics of Africa and Ethiopia [4, 29, 30]. It was placed in Euphorbiaceae family and named genus *Ricinus*. L in 1753 by Linnaeus. and J. Mueller Argavoskii [3]. It is both cultivated or seen in the wild as a perennial crop in India arid land. It is called Wonder tree or Castor oil plant [31]. FAO showed that over 20 nations cultivate castor plant, however India is the largest producer followed by China and Brazil. The suitable temperature for Castor plant is 20–25 °C around the dry subtropics and tropics by summer. Large amount of oil is produced during warm atmospheric conditions but high temperatures around 38 °C reduce the viability of the seed while low temperature kills the plant causing frost formation [32]. It has been reported to grow in saline soil with contaminant like arsenate, copper, chromium, manganese and nickel [33, 34]. Castor has been utilized for nutrient cycling, phytoremediation, phytoextraction and phytoremediation of heavy metals like Cadmium, Iron, Copper, Zinc, Mn, lead, Cs¹³⁷ [Cesium] and Boron, [35–40]. *Ricinus communis* works better than mustard [*Brassica juncea*] to Cadmium from polluted soils mainly due to its underground and overground plants or wood [41, 42]. It is common in East India and North-East Africa; however, it has now been prevalent overseas, particularly all over regions of the subtropics and tropics worldwide where they are nowadays naturalized. The seeds are poisonous hence their use in castor oil production while the leaves and roots have therapeutic purposes.

5 Traditional uses

Natural resources like plants have been utilized as conventional and traditional medicine for the treatments of diseases before the discovery of chemical and synthetic compound [43–45]. All the parts like seeds, leaves, fruit, flower, stem, bark, roots of *R. communis* are useful. In the ancient Rome and Greece, it was used as a laxative about 2500 years [43, 46]. The powdered leaves showed insecticidal action against aphids, rust mites, mosquitoes and whiteflies. Also, Cattle are fed with their leaves to increase the production of milk [6]. The leaves oil extract are given to infant to alleviate farting, stomach ache including eye infection [6]. The leaves juice is used as emetic during narcotic and opium poisoning and in treatment of jaundice [23]. The patented leaves extract in the United States is sold under the name is called ‘Spra Kast’. The alkaline and aqueous extract have been reported to have antifungal activity against yeast and mycobacterium [47]. The root extracts are used as treatments for tooth ache and purging [6]. The removal of the seed coat allows the castor or ricinus oil to be extracted [48]. This oil has been employed as arthritic, laxative and cathartic [49]. The oil is one of the safest purgatives because it cleanses the large intestine while holding water, relieving mild and moderate constipation [50, 51]. Traditionally, it is employed in the treatment of corns, moles, warts, breast indurations, inflammations, cyst, sciatica, gout, pile, paralysis and tumors [52, 53]. Some eye conditions like conjunctivitis, styes and skin conditions like eczema and psoriasis have also been treated with this oil [50]. Also, the oil induces labour in some women when given with quinine sulphate or alone through the mouth in pregnancy. The leaves juice is given to increase the secretion of milk in nursing mothers [54]. Other benefits of oil include soap production, fungicides, embalming fluid, fuels of lamp, lubricant, cosmetics composition, plastics, brake fluid, paints, printer’s ink, textile dyes, leather finishes, waxes, fibers, hydraulic fluid, varnishes and adhesives [27, 56].

6 Chemical composition of *R. communis*

Currently, several isolated components of the plant/seeds have been characterized this includes castor oil, homologous *Ricinus communis* agglutinin [RCA120, RCAI], poisonous ricin [ricin D, RCA60, RCA-II], alkaloids ricinine and nudiflorin and several allergenic compounds shown in Fig. 2 below [56].

Castor has gained global attention due to its valuable phytochemicals and commercial significance. Notable bioactive constituents include castor oil, ricinoleyl-sulfate, ricinoleic acid (Fig. 3), 11-amino-undecanoic acid and lithium grease (lithium hydroxystearate) [57].

R. communis dried leaves contain two alkaloids, Ricinine (0.55%) and N-Demethylricinine (0.016%) and along with six flavones Kaempferol-3-O- β -D-xylopyranoside, Quercetin-3-O- β -D-xylopyranoside, Kaempferol-3-O- β -D-glucopyranoside, Quercetin-3-O- β -D-glucopyranoside, Quercetin-3-O- β -rutinoside and Kaempferol-3-O- β -rutinoside that are glycosides

Fig. 2 Diagrammatic representation of the main components of *Ricinus communis* L. [6]

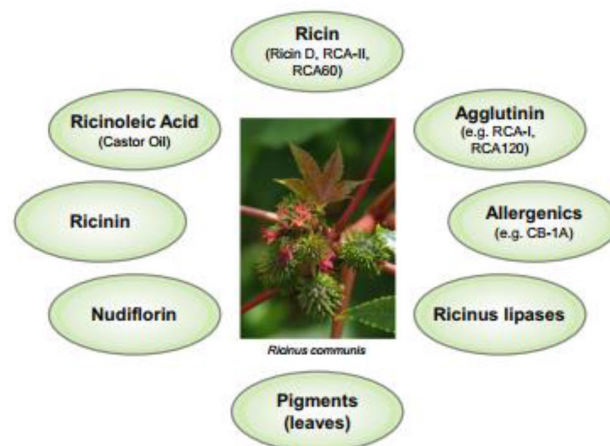
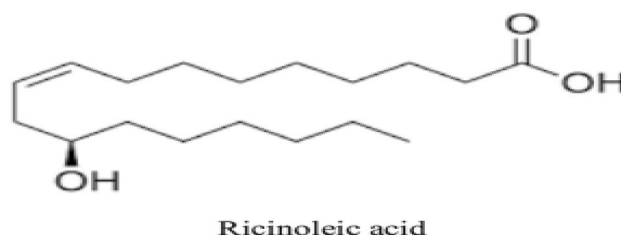


Fig. 3 Structure of Ricinolenic Acid [31]



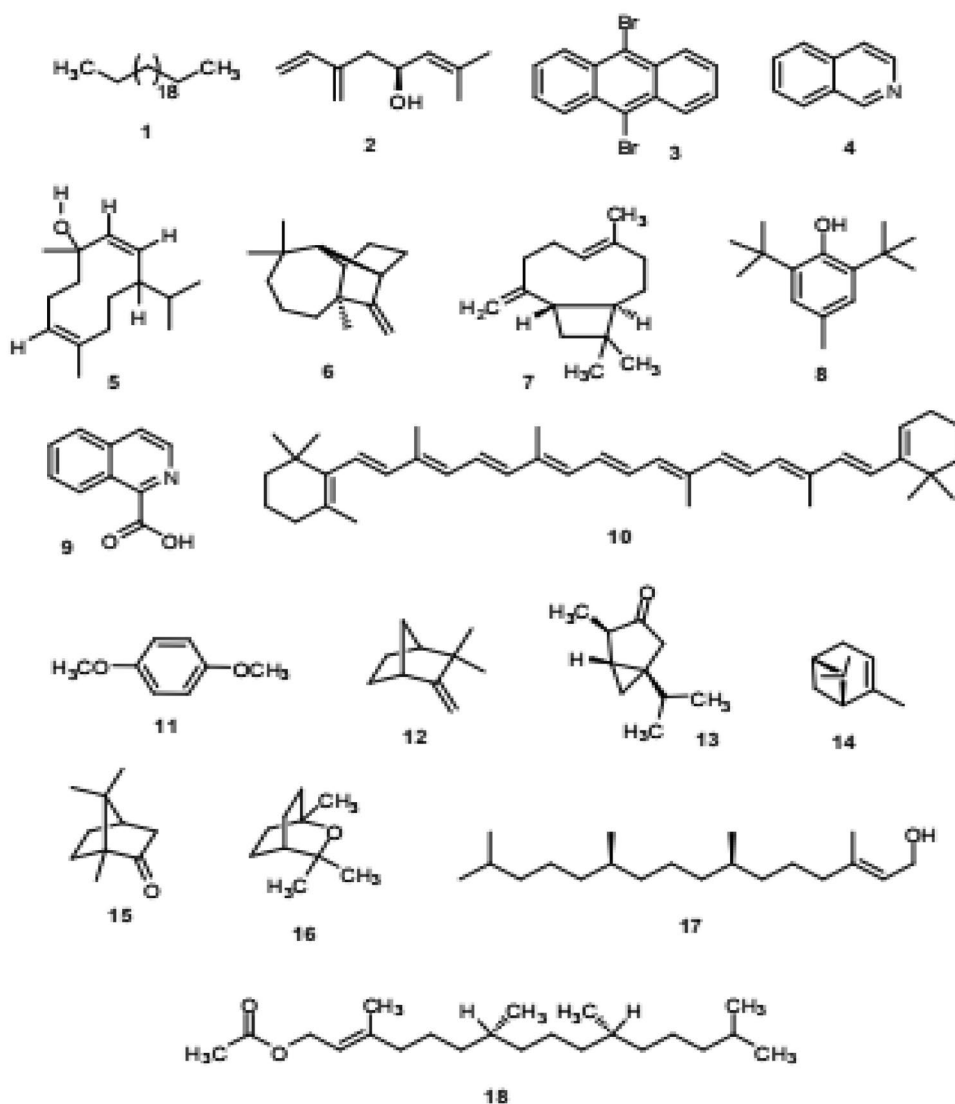
[58]. Leaves main phenolic compounds include monoterpenoids (1,8-Cineole, α -Pinene, and Camphor), a sesquiterpenoid (β -caryophyllene), Gallic acid, Epicatechin, Quercetin, Rutin, Gentisic acid and Ellagic acid [59, 60]. Roots of the plant contain Indole-3-acetic acid [59, 60]. Gas Chromatography analysis for castor oil reveals the presence of ester forms of many fatty acids, having more of Ricinoleic acid in its component while the stem tissues contain more ricinine [61]. The seeds of *R. communis* consist of 65–75% endosperm and 25–35% seed coat, while the chemical composition is ash (2.5%), water (5.5%), carbohydrates (13%), crude fiber (12.5%), and crude protein (17.9%) [62]. The seeds oil exhibits characteristics such as high density, stable viscosity over a broad range of temperature and -10°C as its freezing point [63]. The seeds with 45% oil consist of glycosides like Dihydroxystearic acids, Ricinoleic, Stearic, Isoricinoleic, lipases and crystalline Ricinine [64]. *Ricinus communis* is rich in various phytochemicals, including flavonoids and tannins [65]. Report from several research pointed out phytochemicals like quercetin-3-O- β monoterpenoids and kaempferol-3-O- β -D-glucopyranoside [66, 67], triterpenoids (α -amyirin, β -amyirin and lupeol) [68], gallic acid and quercetin [69], camphor α -thujone, beta-thujone [70], ricin [71], epicatechin [72], catechin [73], ricinoleic acid and linoleic acid, [74], Ingenol [75]. This is shown in Fig. 4 and expanded in groups in Fig. 5 below.

1-Docosane, 2-Ipsdienol, 3-9,10-Dibromo anthracene, 4-Isoquinoline, 5-Germacra-1[10],5-dien-4-ol, 6-Longifolene, 7- β -Caryophyllene, 8-2,6-bis-(1,1-Dimethyl-propyl)-4-methyl-phenol (DPMP), 9-1-Isoquinoline carbonitrile 10- β -Carotene, 11-2-Bromo-1,4-dimethoxybenzene, 12- α -Camphene, 13- α -Thujone, 14- α -Pinene, 15- α -Camphor, 16- α -1,8-Cineole, 17-Phytol, 18-Phytol acetate.

7 Pharmacological activity

The plant exhibits hepatoprotective, antifilarial properties [77], antioxidant effects [59], antiasthmatic activity [78] and antimicrobial actions [79]. Additionally, the plant's roots are incorporated into various formulations for treating nervous disorders and rheumatic conditions like pleurodynia, lumbago, and sciatica, as documented in wealth of India [80]. The roots also demonstrate scavenging of free radicals and antiinflammatory properties [81], anti-fertility effects [82], and anti-diabetic properties [83]. The presence of phytochemical compounds in the castor oil like saponin, cyanogenic glycoside, flavonoid, oxalate, phytate, alkaloid and tannin may be responsible for the oil's antimicrobial activity [55]. In the stem phytochemicals that brings about antioxidant activity includes Methyl ricinoleate, Ricinoleic acid, 12 octadecadienoic

Fig. 4 Structure of the identified volatile compounds or secondary metabolites present in two cultivars; RH 21 and GH 12 of *Ricinus communis* L. using GC/MS analysis [76]



acid and methyl ester stem and while in the leaves flavonoid is responsible [31]. The pharmacological properties of *R. communis*, the phytochemicals and plant parts is summarized in Table 1 below.

7.1 Antibacterial activity

The rise in infectious diseases that are resistant to antibiotics has become a threat to life, making it a necessity for new and diverse treatment to be discovered from natural products [84]. *Ricinus communis* contains phytochemicals that have microbicidal properties against many microorganisms. The crude extract of *R. communis* showed activity antibacterial like *Staphylococcus aureus*, *Escherichia coli*, *Streptococcus mutans* including *Staphylococcus aureus* resistant to methicillin with ethanolic extract shows are the maximum activity against staphylococcus at MIC of 5 mg/mL. Testing various aqueous and solvent-based extracts evaluated the activity of *Ricinus communis* against *Enterococcus faecalis* [85]. The assessment included aqueous, ethanolic and butanolic extracts [86]. In another research with *Bacillus subtilis* and *Escherichia coli*, the methanolic extract exhibited low and high action respectively [87]. The *R. communis* aqueous extract was highly effective against staphylococcus and moderately effective against *Klebsiella pneumonia* [88]. *Ricinus communis* oil tested positive when accessed for bacteriocidal actions in a random clinical trial. The ability to cause cytoplasmic cell death and disruption of the cell wall inhibited the formation of biofilm because sodium ricinoleate is present [89]. The results from these experiments show that *R. communis* has good antibacterial drug properties against all kinds of bacteria.

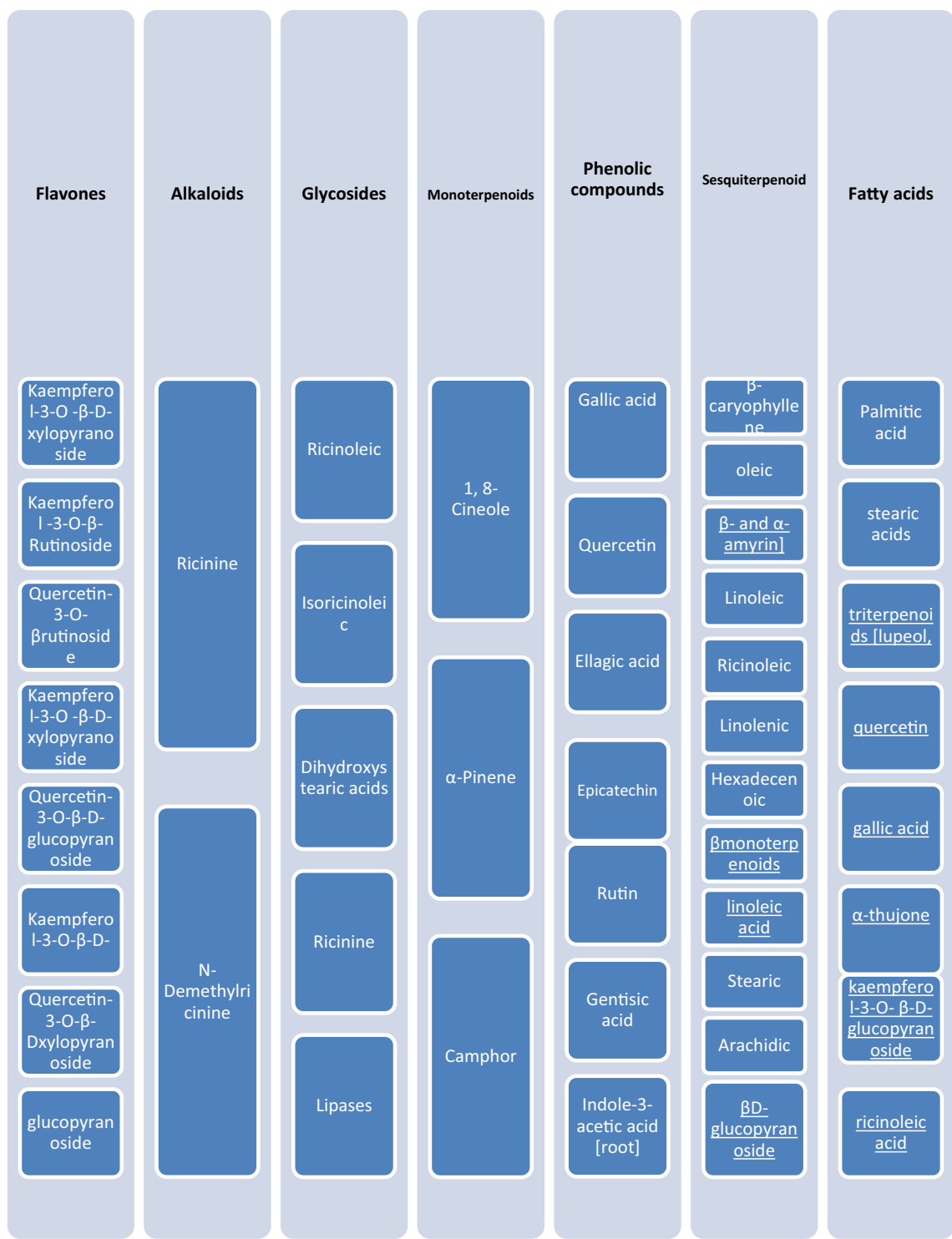


Fig. 5 Phytochemical Profile of *R. communis*

7.2 Antifungal activity

R. communis aqueous and methanolic extracts shows fungicidal actions against different fungi. The findings from an experiment conducted on various fungi indicated that the *R. communis* extract exhibited its highest activity against *Candida albicans*, while its least activity was observed against *Alternaria solani* [47]. Another examination using the

Table 1 Pharmacological properties of *R. communis*, the phytochemical players and plant parts

	Pharmacological Properties	Phytochemical players and <i>R. communis</i> plant parts
1	Anti-bacterial	Alkaloids like Ricinine; aqueous, ethanolic and butanolic extracts and <i>R. communis</i> oil
2	Antifungal	Aqueous and methanolic extracts of <i>R. communis</i>
3	Anti-diabetic	Ethanolic root extract of <i>R. communis</i>
4	Anti-cancer	Aqueous, methanol and ethanol extract of <i>R. communis</i> , lectins, pyridine
5	Anti-inflammatory	Aqueous, ethanol and methanol extract of <i>R. communis</i> , ricinolein, ricinoleic acid
6	Anti-oxidant	Ricinoleic acid, Methyl ricinoleate, methyl ester stem and 12 octadecadienoic acid Flavonoids: epicatechin, gallic acid, gentisic acid, rutin and quercetin and ellagic acid
7	Mosquitocidal	Seed extract, 3-carboxy-4methoxyN-methyl-2-pyridone and ricinine
8	Analgesic	Ricinine, root and bark aqueous and methanolic extract
9	Anticonvulsant and Antinociceptive activity	Seed extract, leaves methanolic extract and oil
10	Anti-hepatotoxicity	Ethanolic and butanolic extract of leaves, N-demethylricinine and ricinine, flavonoids and tannins
11	Anti-helminthic	Aqueous and ethanolic extract
12	Wound healing	Castor oil rich in Flavonoids, tannins, sesquiterpenes and triterpenoids
13	Anti-fertility	Ethanolic and methanolic extracts, seed extract
14	Laxative and uterine contracting	Castor oil and ricinoleic acid
15	Antiulcer and Antiasthmatic	Flavonoids and saponin
16	Bone regeneration	Castor oil

methanolic extract demonstrated strong inhibitory effects on *Aspergillus fumigatus* and *Aspergillus niger*, with comparatively lower activity against *Aspergillus flavus* [86]. Conversely, of *R. communis* leaves aqueous extract exhibited reduced activity against *Aspergillus flavus* and *Aspergillus fumigatus* [87].

7.3 Anti-diabetic activity

Ricinus communis ethanolic root extract were administered in the treatment of hyperglycemic rats, exhibited antidiabetic properties. The outcomes of a study involving alloxan-treated diabetic rats, with a body weight of 500 mg/kg given single dose daily for 3 weeks and 2 days, revealed a decline significantly in their lipid profile on days one, ten and twentieth of the experiment. This reduction contributed to the normalization of fasting blood glucose levels. Furthermore, there was an elevated level of insulin, better lipid profiles, resulting in decreased levels of glucose with a range of (379 ± 72) mg/dL (in diabetic rats) and [149 ± 11] mg/dL [in control rats] [83]. An in vivo investigation conducted with alloxan-treated diabetic rats demonstrated a notable reduction in the level of glucose in blood from 390.0 mg/dL to 148.5 the administration of Ricinus extract, indicating a 62% decrease in levels of glucose following one week treatment [90]. *Ricinus communis* roots ethanolic extract (RCRE) tested with bioassay-guided purification. The administration 500 mg/kg of root ethanolic extract of *Ricinus communis* to the diabetic rats for 3 weeks and two days showed favorable effects on fasting blood glucose, kidney and liver also on total lipid profile [31].

7.4 Anti-cancer activity

The aqueous, ethanol and methanol extract of *R. communis* plant parts, used on some types of cancer cervical cancer, MCF 7 (Breast cancer), melanoma, PC 3 (Pancreatic cancer), Hep G2 (Hepatic cancer) pointed its anti-cancer activity both on in vivo and in vitro studies [91–93]. *Ricinus communis* lectins showed cytotoxic action on HeLa cells, human erythrocytes, sarcoma [94]. The life span of the mice was seen to increase after the administration of ricin A [95].

In another study, *R. communis* aqueous extracts effects on A375 cell line were cytotoxic in action with 48 µg/mL as the IC 50 [96]. The administration of Ricinus was associated with accelerated apoptotic activity in tumor blood cells also in vascular endothelial growth factor-2 (VEGFR-2) down regulation, attributed to the presence of agglutinin 1 [97]. An analysis involving alkaloid pyridine and the β-catenin (WNT) signaling pathway which are crucial in cancer development, differentiation, and proliferation was conducted [98]. Furthermore, additional in vitro studies revealed *R. communis* extracts cytotoxic effect on many cancer cell lines, including breast, colon, liver, cervix, skin melanoma (B16F10), ovarian

(OVCAR-5), and prostate cancers. Notably, at 100 µg/mL concentration, *R. communis* extract was showed good effect against the above-mentioned cancer cell lines [91]. *Ricinus communis* fruit extract showed good potency for breast cancer treatment and management. Also, *Ricinus communis* fruit extract is effective against ferocious triple-negative breast cancer cells [MDA-MB-231 cell line] and estrogens-positive MCF-7 [31].

7.5 Anti-inflammatory activity

R. communis was assessed for antiinflammatory action using ethanolic, methanolic or hexane and acetone fractions. Flavonoids presence is the reason why the methanolic extract showed a remarkable activity. A study, where macrophage cell lines were tested with the methanolic extract showed 95% scavenging activity pointing its anti-inflammatory action [99]. The result of a different research pointed out ricinolein pro-inflammatory and anti-inflammatory activity [100]. The *in-vivo* studies using two animal models, i.e., carrageenan-induced paw edema and cotton pellet granuloma model.

Administering *Ricinus* methanolic extract of 100 mg/kg showed 26.47% reduction in edema in the carrageenan model. The reduction in edema was more pronounced at 43.28% when administered at doses of 250 and 500 µg/kg for cotton pellet granuloma models. These effects were attributed to the leucine-rich protein (NALP3) inflammasome and nucleotide-binding domain activation [101, 102]. Other *in vivo study*, where *R. communis* anti-inflammatory action was carried out against histamine or carrageenan-induced edema in guinea pigs or mice respectively. Edema was reduced by 58% after *R. communis* extract ricinoleic acid administered topically for 8 d (0.9 mg/mouse). The result confirms the anti-inflammatory potential of ricinoleic acid (new capsaicin-like substance) [103].

7.6 Antioxidant activity

R. communis methanolic extracts and leaves showed antioxidant action during an *in vitro study* using DPPH (1,1-diphenyl-2-picrylhydrazyl) were attributed to the following isolates: ellagic acid, epicatechin, gallic acid, rutin, gentisic acid and quercetin [104]. Another study, that suggesting *R. communis* antioxidant properties noticed its free radicals scavenging activity on 2,2-diphenyl-1-picrylhydrazyl (DPPH) NO, superoxide and 2,2'-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid (ABTS) [59, 104]. *Ricinus communis* fractions of ethyl acetate and butanol extracts both pointed out great antioxidant action most likely because of flavonoids and tannins [59, 105, 106]. The anti-inflammatory action of the methanolic extract of *R. communis* in rats carrageenan-induced paw edema resulted from flavonoids because of their protective effect [31].

7.7 Mosquitocidal activity

R. communis showed cytotoxicity on numerous mosquito larvae species like *Culex quinquefasciatus*, *Anopheles albopictus*, *Anopheles stephensi*, *Anopheles gambiae* were studied and the death rate was close almost total. The extract of *R. communis* seeds showed a lethal concentration (16.84 µg/mL; 11.64 µg/mL; 7.10 µg/mL) on the larval species of *Anopheles albopictus*, *Anopheles stephensi*, *Culex quinque fasciatus* respectively [107, 108]. Malaria is still a worldwide epidemic because of the millions of people that die yearly from the bite of infected anopheles' mosquitoes. According to WHO world wide estimation in 2012, malaria caused 627,000 deaths in 2012 out of the 2.7 million infected individuals [109]. *Plasmodium falciparum* has developed a resistance against most malaria drugs. However, *R. communis* inhibited the both male and female *Anopheles gambiae* greatly. This inhibitory activity was due to the presence of two compounds 3-carboxy-4-methoxy-N-methyl-2-pyridone and ricinine [108]. Various extract shows increasing larvicidal activity on their exposure to different larva. *Ricinus communis* extracts shows very high mortality at (0.18 mg/m) lethal concentration 50 [LC50] [108]. *Ricinus* shows strong action against both *Culex quinque fasciatus* and *Anopheles arabiensis* [110]. Another study based on *Ricinus communis* leaves and stems pointed out their ability to reduce mosquito bites fever and infection in European countries. The stored extracted juice extracted after neutralization is useful in the treatment of redness and rashes from mosquito bites [31].

7.8 Analgesic activity

R. communis extracts contains alkaloid ricinine responsible for the potent central analgesic activity according to the results of different studies, it acts as a stimulant for central nervous system, memory improvement, hyperreactivity, clonic seizures and neuroleptic effects. Ricinine does not reduce the explorational brain behaviour hence it is a non-anxiogenic [111]. *Ricinus communis* root and bark aqueous extract was assessed with 100 and 200 mg/kg doses, with positive control

being 50 mg/kg of diclofenac in albino mice. The tail immersion and Eddy's hot plate methods were used to determine the analgesic activity [111, 112]. Another study on Ricinus leaves methanolic extract showed great antinociceptive activity and analgesic action. The mice treated with ricinus showed high analgesic activity against the tail flick experiment at the dose of 150 mg/kg (2.900 ± 0.194) as compared to control (6.30 ± 0.110) [78].

7.9 Anticonvulsant and antinociceptive activity

The extract from *R. communis* were accessed for anticonvulsant activity proving to be a potent epileptic. The animals convulsed, after treating them with electric shock. The animals been treated with *R. communis* seed extract at 60 mg/kg dose, had around 82% lower amount of seizure when compared with a standard drug having high seizure with inhibition rate of only 8.89% [113]. In physiology, Nociception is used to explain processes of noxious stimuli perception and encoding [114]. The leaves methanolic extract is antinociceptive when administered to mice induced with formalin paw licking, tail immersion and acetic acid writhing tests [78]. The analgesic activity of extract at 150 mg/kg was seen in inflammatory and neurogenic pains induced by formalin [78]. There were increases latent time following the administration of drug after 90 min' treatment in the model of tail immersion [78]. *Ricinus communis* has been considered to be effective against epileptic attacks, seizures, neurological problems such as headaches from migraine and due to sinusitis. Some researcher from India pointed to the fact that a mixture of warm water and castor oil treats confusion state, water eyes, epilepsy and headaches [31].

7.10 Anti-hepatotoxicity

In the world today liver damage is a very serious problem hence the need for herbs and plant products that are hepatoprotective against the liver damages induced by drugs or cirrhosis [115, 116]. The ethanolic extract of leaves is seen to be protective against the liver damage induced by galactosamine [117]. The butanolic extract of ethanol showed the most potent action because of bioactive compounds N-demethylricinine and ricinine. Another experiment carried on the leaf ethanolic extract against the liver damage induced by ketoconazole (Phytoral) showed significant decrease in hepatic enzymes confirming its hepatoprotective nature on applying 100 mg/kg body weight [118]. An albino rats and mice model study where hepatosuppression was induced with carbon tetrachloride (CCl₄) and the leaves powder were used as treatment the result pointed out healing capacity and regeneration of the hepatic cells [119, 120]. Another report on the pharmacology of the cold aqueous extract, whole leaves extract and glycoside proved its protection against necrosis of hepatic cells, cell necrosis and fatty changes respectively. The leaves had significant both sympathetic and parasympathetic activity that increases the liver protection and blood supply [120]. The flavonoids in *R. communis* ethanolic extract showed antiperoxidative and membrane stabilizing effects. Hence, *R. communis* accelerates liver repairs and regenerative abilities because of tannins and flavonoid [31].

7.11 Anti-helminthic activity

The antihelminthic activity of *R. communis* was studied by inducing paralysis and killing the worms. Ricinus aqueous and ethanolic extract of at 100 mg/mL caused paralysis and death at different time, however the ethanolic extract activity 31.50 ± 1.25 showed lesser action when compared to aqueous extract 8.50 ± 0.64 [121].

7.12 Wound healing activity

The *R. communis* castor oil contains bioactive components like flavonoids, tannins, sesquiterpenes and triterpenoids produces antioxidant, antimicrobial and astringent activity needed for its wound healing capacity. The excision wound healing model was studied by accessing % closure of scar area, scar area, and epithelialization [110]. The result of excision wound model pointed out wound healing action of castor oil by epithelialization time and the area of the scar. The castor oil concentrations of 5% w/w and 10% w/w proved that 10% w/w showed excellent wound-healing property [110]. The *R. communis* wound healing activity in castor oil was believed to be caused by its ability to reduced lipid peroxidation and its antioxidant action like increase collagen fibrils viability, collagen fibres strength, elevated blood circulation, DNA synthesis, prevention of cell damage [31].

7.13 Anti-fertility activity

R. communis ethanolic extracts were studied in male rats for antifertility activity, the result revealed decrease in sperm count of the epididymis, alteration in the morphology and motility of sperm including testicular function suppression [106, 122]. However, a reversible anti-fertility effect is noticed on administration of 50% root alcohol extract to male rats. There is decrease in the levels of testosterone and fructose pointing to decline in the reproductive performance [123].

Female rats and rabbit were administered with the ether and methanolic seed extract, the result shows abortifacient, contraceptive and anti-implantation for one year [123, 124]. The seed extract was seen to prolong guinea pigs' oestrus cycle, dioestrus phase and can weight reduction in the uterus after administering the extract [125]. *Ricinus communis* methanol extract contains steroids hence, the reason for its anti-fertility effects [31].

7.14 Laxative and uterine contracting

Castor oil and ricinoleic acid can be used as laxative because it induces prostaglandin receptors 2. Smooth muscle contraction is activated by castor oil in the intestinal walls. Most Prostaglandin receptors 2 are proven potential laxatives [126]. Some doctors advise patients suffering from constipation to a mixture of *R. communis* juice extract and warm water. *Ricinus communis* leaf extract have remarkable contraction ability on uterine movements. The drug containing *R. communis* are used to inducing labor in pregnant women this is related to the effect of oxytocin [31].

7.15 Antiulcer and antiasthmatic activity

R. communis at 500 mg/kg possesses antiulcer properties. The mechanism of action for mucosa defense is by strengthening and protecting the cells of the mucosa layer because it contains flavonoids and saponin [127]. The ethanolic extract of *R. communis* reduces milk induced eosinophilia and leucocytosis pointing to antiasthmatic activity of flavonoids or saponins presence [31].

7.16 Bone regeneration

R. communis oil has been applied in traditional medicine to treat bone diseases related like acute osteomyelitis, afflicted limbs and other bone deformities [46]. In research done on rats and rabbits, *R. communis* regenerated bones without the formation of scar, promote neoformation of fibroblast, promote formation of polyurethane resin, delay inflammatory response in their skulls [128]. The mixture of calcium phosphate with *R. communis* polyurethane promotes mineralization of bone matrix when looking into biocompatible materials and bone that lacks minerals. There is slower reabsorption of *R. communis* polyurethane making it useful in the treatment of osteoarthritis in rats for 2 weeks devoid of any harmful effects [129]. *Ricinus communis* oil in ancient times has used to treat many bone-related diseases. Bone diseases treated with *R. communis* includes like acute osteomyelitis, bone deformities, articular pains and afflicted limbs. The mixture of *R. communis* polyurethane and Calcium phosphate could be used to increase matrix mineralization [31].

8 Pharmacokinetics

An experiment was carried out on 131 patients with hypertension to access how castor oil is absorbed and excreted. Castor oil contained palmitic acid (1%), palmitoleic acid (0.1%), oleic acid (3.2%), linoleic acid (4.7%), ricinoleic acid (90%), and stearic acid (1%). The doses were from 4 g to about 60 g (each dose is approximately 6 μ C of radioactivity). After the administration of oil in small doses to three patients that served as control, stool and urine samples were analysed on day 1 and day 3, the result of the experiment showed better reabsorption at smaller doses.

The pancreatic enzymes in the small intestine hydrolyses castor oil to give anionic surfactants, ricinoleic acid and glycerol. It also stimulates peristalsis process in the intestine and decrease the total absorption of electrolyte and fluid [130]. Ricinoleic acid undergo metabolism systemically to a few metabolites before excretion. castor oil administered orally to an anorexic woman produced three metabolites of epoxydicarboxylic acids in the urine samples. They are 3,6-epoxydecanedioic acid, 3,6-epoxyoctanedioic acid, 3,6 epoxydodecanedioic acid. The jejunum lining absorbs oleic

and ricinoleic acids as shown by research on six healthy human subjects using steady-state jejunal perfusions. The result of the experiment pointed out that oleic acid gets absorbed faster than ricinoleic acid. The absorption of ricinoleic acid is much slower in all perfusates showing higher mean segment concentrations [131, 132]. The digestion and delipidation of CBs (castor beans) produce Ricin Toxin from the bean matrix. The unripe castor beans produce more toxin than the ripe ones [133, 134].

The results from animal studies showed that the gavage administration produces higher toxicity than oral administration. The reason for this is the terminal galactose residue attached to the carbohydrate structure as seen in the gut microflora, gastrointestinal and salivary glands. The glycoproteins, glycolipids and carbohydrate compete for the same binding site ricin toxin [134]. It takes about an hour before the ricin toxin becomes absorbed in the lymphatic vessel and blood and its toxicity is seen in the liver and spleen [135]. According to the result from animal studies, after two hours of consumption the faeces can be tested for ricin toxin and about 45% is unchanged [136]. An intramuscular or subcutaneous injection will be excreted more in urine after 1 day and little in the faeces [137].

9 Other applications of *castor* oil and seed products

9.1 *Castor* oil in medicine and cosmetics

In some animal research, castor oil is used to cause diarrhea especially in rats due to the action of RA [Ricinoleic acid] on the intestinal walls [138, 139]. This examination promoted quick and effective ways of screening phytochemicals in pilot studies especially when looking out for prospective drug isolate from plant. In contemporary medicine, castor oil could be utilized as vehicles for drug delivery. One sample is a drug formerly called Cremophor EL now Kolliphor EL confirmed by BASF Corp product. The castor oil product is polyethoxylated, the combination is prepared in a ratio 35–1 mol of ethylene oxide and castor oil respectively. This formulation is used as a drug additive, excipient and stable emulsion for aqueous non-polar material. Anticancer drugs like docetaxel and paclitaxel are non-polar drug delivery vehicle [140, 141]. Castor oil is natural products used for against several diseases. It contains bioactive constituents highly important in the manufacture of cosmetic and medicinal products [142]. Castor oil has high saponification value that explains their application in manufacture of soaps and other cosmetic products [55].

9.2 *Castor* oil on skin diseases/disorders

Castor oil has been used in the treatments and prevention of skin problems like acne, wrinkles, stretch marks, sunburn including dry skin, boils, athlete's foot, warts, chronic itching as wound disinfectant and skin moisturizer.

9.3 *Castor* oil in hair treatments

For the growth of eyebrows, eyelashes and hair oils like coconut or almond and castor oil are mixed together. The oil contains omega-6 essential fatty acids known to hasten hair growth, correct bald patches and darken hair and boost the circulation of blood.

9.4 *Castor* oil medicinal use

Castor oil has been utilized as potent laxative and additive in treatment of ailments like age spots, cerebral palsy, gastrointestinal problems, migraines, inflammation, multiple sclerosis, menstrual disorders, rheumatic pains, skin abrasions and Parkinson's disease.

9.5 *Castor* in agriculture

9.5.1 *Castor* husk and meal use in animal feed

In formulating feed for ruminant animals, detoxified castor meal can be employed [143]. This detoxification process involves boiling or autoclaving and adding broilers' finisher's diet or soybean meal to sheep foods devoid of causing

any detrimental effects [144, 145]. Castor husks contains a significant number of seed fragments and are suitable for preparing goat feed. The replacement of hay with castor husk caused 27% milk production reduction and a 28% increase lipid concentration. Importantly, toxicity was not caused by the husk, even in the absence of detoxification agent [146].

9.5.2 Castor diet use in organic fertilizer

Castor diet can serve as organic fertilizer due to its anti-nematode effect, rapid mineralization and high nitrogen content. Castor diet showed a mineralization rate seven times faster than that of bovine manure and fifteen times faster than sugar cane bagasse. Castor meal has been used to increase growth in castor and wheat plant [147, 148]. The reason for castor husk as organic fertilizer for plant growth is because it contains N-rich organic material [148, 149].

9.6 Castor oil use as biodiesel

R. communis is used for production of biodiesel, bioethanol and industrial crop [150–152]. Castor oil generated biodiesel has a high lubricity hence, the reason for good fuel and energy generation properties [153–155]. Research looked into castor oil chemical modification by extracting castor oil with petroleum ether and n-Hexane, it showed good physicochemical properties however sulphonated castor oil showed better standard value especially decreased viscosity which increases the potential of being used extensively as biodiesel and fuel [55].

9.7 Industrial uses of castor oil

In polyurethane industry, castor oil has its use as bio-based polyol. In the food industry uses castor oil to inhibit mold, flavor foods and candy [156]. The oil prevents rotting in pulses rice and wheat. The nylon and paint industries use castor oil and its wax for solid lubricant, carbon paper, polish as well as electrical condensers [157]. Also, natural hydroxylated fatty acids from castor beans oil have huge applications coatings, cosmetics, grease, lubricants, soaps, polymers, paints, linoleum, printing inks, plastics and polyurethane industries [158–161].

9.8 Castor seed is a source of food condiment

White castor seed can be used to make ogiri, an essential food condiment in Nigeria South-East. Ogiri improves eye vision the mode of preparation is by first deshelling the seed, boiling the cotyledons for 8–10 h, after which the seed are allowed to cool for 12–14 h before grounding into paste *Ogiri*. The condiment is very special in Igboland because the oil prevents the growth of microorganism so it lasts for several months [143]. Castor oil seed possess high level of monounsaturated fatty acid similar to some vegetable oils. The triglycerides and fatty acids profile shows that triricinolein and ricinoleic acid are the oil main components while the bioactive constituent includes polyphenols, tocopherols and phytosterols all these are responsible for its antioxidant and anti-inflammatory properties and prolonged shelf life. Castor oil stability is due to its low acid content [55].

10 Toxicity

Ricinus communis contains toxic substances like alkaloid ricinine, haemagglutinin RCA120 and type II RIP ricin while beneficial compounds like saponins, flavonoids and fatty acids are deleted in microorganism and higher animals [162, 163]. The studies carried out on the toxicity showed that there are harmful substances in the seed [136]. Ricin poisoning has been dated for a long time but it rarely occurs in humans with level low mortality [164]. Castor beans contains allergens but when processed and refined to castor oil it becomes free from allergens. This can be ascribed to series of biological effects in higher organisms [137, 165]. Castor seed endosperm contains Ricin is categorized under type 2 ribosome-inactivating protein [166, 167]. Ricin is a strong toxin in plant of the Type 2 ribosome-inactivating proteins called lectins they inhibit the synthesis of protein, deactivate the ribosomes and induce apoptosis [168]. Ricin poisoning can only occur when unprocessed seeds are eaten. The extract of oil from castor seed are used to make cakes that are rich in protein, added to animal feed and soil [148, 169, 170]. The toxicity severity depends on the exposure route and mode, for instance inhalation is a more toxic route of exposure [135]. *Ricinus communis* seed contains two poisonous toxins that affect insect, animals and humans severely [171]. Ricin is a powerful cytotoxin but friable hemagglutinin while RCA (*Ricinus communis*

agglutinin) is a friable cytotoxin but potent hemagglutinin [58]. When the seeds are masticated, it results to nausea, diarrhea and high morbidity. The more the seed gets ingested the more the resulting complications in people [171]. A puppy that was understudied and given supportive therapy died a few hours after having nausea, diarrhea and fatigue [171]. Histopathologic evaluation of liver and jejunum showed necrosis. Ricin toxic effect was established using mass spectrometry and liquid chromatography with the marker ricinine. A study carried out on suicidal death of 49-year-old man after the consumption of castor bean extract intravenously and subcutaneously showed diarrhea, nausea, vomiting, dyspnoea, muscular pain and vertigo after injection. Though he received intensive care, but multiorgan failure was diagnosed as the cause of his death. This experiment emphasized that ricin is the cause of food poisoning in castor bean. Based on the clinical and toxicological analysis, assertion was made that patient died from toxins in the plant [172]. Ricin is a protein isolated from the seed with a heterodimeric shape. It has a cytotoxic action because it interrupts synthesis of protein. Therapeutically, it is utilized in identifying and destroying cells that are cancerous [173]. Interestingly, leaves also contains cytotoxic phytochemicals that cause cell death by translocating phosphatidyl serine to peripheral parts of cell membrane thereby causing loss of the mitochondria. Identified compounds include three monoterpenoids: α -pinene, camphor, 1,8-cineole, and β -caryophyllene (a sesquiterpenoid). *Ricinus communis* agglutinin I (RCA I) is preferentially binded to tumor endothelial cells causing VEGFR-2 downward regulation, the apoptosis of endothelial cells and regression of tumor vessel after all of these the normal blood vessels remained unaffected [97]. A volatile leaf extract showed cytotoxic action against numerous tumor cell lines in humans in a dose-dependent manner [58]. SK-MEL-28 human melanoma cells undergo apoptosis at a concentration of $20 \mu\text{g mL}^{-1}$ of the extract. The extract administration induces translocation of phosphatidylserine to the cell membrane peripheral leading loss of membrane potential in the mitochondria [58]. The leaf extract exhibited cytotoxicity against HeLa cells, with 2.63 mg/mL as the IC 50 value [174, 175]. *Ricinus communis* lectin demonstrates antitumor activity against both tumor and normal cells [95]. Enzyme-linked immunosorbent assays (ELISA) are utilized to detect the toxin in the fluids and tissues of animals. Individuals with conditions such as appendicitis, Crohn's disease, intestinal obstruction, atony, stenosis, ulcerative colitis, idiopathic abdominal pain, excess water and electrolyte depletion leading to serious dehydration exhibited hypersensitivity to castor oil [176]. Pregnant and breastfeeding mothers are advised against the use of castor oil. Castor oil use should not be prolonged because it reduces nutrients absorption [130]. Overdosage causes gastric irritation with nausea, colic, vomiting, chronic diarrhoea, water and electrolyte [177]. Ricin is one of the most impressive compounds with extreme toxicity and therapeutic applications. Interestingly the emerging nanomedicines field can look into improving its pharmacokinetics for it to become an excellent candidate for targeted drug delivery while controlling its undesirable side effects [56].

10.1 Signs of animal toxicity

RT intramuscular administration in mice leads to myoglobinuria, hypoglycemia, metabolic abnormalities, renal insufficiency elevated amylase, creatinine kinase and liver transaminase [178]. In rat model, the intravenous RT injection causes Kupffer hepatic and renal cell injuries in a space of 4 h resulting in endothelial cell damage, liver vascular thrombi, liver necrosis and disseminated intravascular coagulation [137, 173]. The lungs inflammatory biomarkers like total protein and broncho-alveolar fluid inflammatory cells were elevated before the end of two days. Also, air-blood barrier permeability increases causing non-cardiogenic pulmonary edema and alveolar flooding. All these elevation leads to acidotic hypoxic respiratory failure and death in animals. The histological findings of the animals administered with RT shows inflammation and flooding in the alveolar, edema, and necrotizing pneumonia [179]. There is also release of cytokines and chemokines leading to fever and arthralgias in the Aerosolized RT absorbed pulmonary tracts [134]. RT Ocular administrations of 1:1000 to 1:10,000 dilutions cause pseudomembranous conjunctivitis and conjunctiva irritation [137]. Though, Ricin toxin is not specific to any cell but it causes death in animals with RT intoxication [135]. Death result from oral administration of RT in animals with initial presentation of renal hemorrhagia, liver failure, hypotension and vascular collapse secondary to GI while RT inhalation exposure in animals brings about hypoxia induced lung damage [135].

10.2 Signs of human toxicity

About 4–6 h after the administration of CB extract through the mouth, the patients were presented to have the following abdominal pain, oropharyngeal irritation, diarrhea vomiting, and all kinds of GI bleeding, like melena, hematemesis, hematochezia including secondary GI necrosis [172]. The symptoms could delay until 5 days after ingestion in asymptomatic patient but some patients could have hemolysis and hypoglycemia [134, 135]. A young man case reported in 2002, with a subcutaneous administration of CB extract had anuria, chest and back pain, fatigue, nausea, dizziness, headache,

hematochezia as well as metabolic acidosis. After all these manifestations the patient developed vasoconstrictor-resistant hypotension, kidney and liver failures. The hemorrhage caused resistant to recovery after heart attack. His autopsy showed pleura hemorrhagic foci in brain and head [180].

11 Conclusion

To sum up, the pharmacological applications of *Ricinus communis* indicate promising prospects in wound healing, diabetes control, antioxidant therapy, cancer treatment including animal feed composition. This is due to rich composition of phytochemicals such as Ricinine, Quercetin-3-O- β -rutinoside, quercetin, Kaempferol-3-O- β -D-xylopyranoside, gallic acid etc. Further research and clinical studies are crucial to enhance its potential applications in medical and agricultural fields. As this will enhance drug development and elucidation of its active phytochemicals that will exhibit potent pharmacological activities in biological systems.

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