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Ricinus communis L.: From Ancient Ethnomedicine to Modern Pharmacological and Industrial Relevance

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Abstract

Ricinus communis L., belonging to the family *Euphorbiaceae*, commonly known as castor, is a multipurpose medicinal and industrial plant extensively used in traditional systems of medicine across tropical and subtropical regions. In *Ayurveda, Unani, Siddha* and folk practices, various parts of the plant, including leaves, roots, seeds and castor oil, have been employed for the management of inflammation, constipation, rheumatism, skin disorders, microbial infections and reproductive ailments. In recent decades, scientific investigations have provided substantial evidence supporting many of these traditional claims. Phytochemical studies reveal the presence of diverse bioactive constituents such as ricinoleic acid, flavonoids, phenolic compounds, alkaloids, terpenoids and ribosome-inactivating proteins, which collectively contribute to its pharmacological potential. Experimental studies demonstrate that *R. communis* exhibits antimicrobial, anti-inflammatory, antioxidant, wound healing, antidiabetic, anticancer and analgesic activities. In addition to its medicinal importance, castor oil holds immense industrial value in pharmaceutical formulations, cosmetics, lubricants, polymers and biodiesel production. However, the presence of toxic constituents, particularly ricin, raises serious safety concerns and necessitates careful processing, detoxification, and dose standardisation. This review critically compiles and analyses available literature on the ethnomedicinal uses, phytochemistry, pharmacological activities, toxicological aspects and industrial relevance of *R. communis*, highlighting its potential as a valuable natural resource for evidence-based phytotherapy and sustainable industrial applications.

Major Findings: *Ricinus communis* is a well-documented medicinal plant with a long history of use in traditional healthcare systems. Integration of traditional knowledge with modern pharmacological validation supports the future development of safe castor-based natural remedies.

Keywords: Castor Oil, Ethnomedicine, Natural Remedies, Phytochemistry, Pharmacological Activity

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1. Introduction

Since ancient times, human societies have relied extensively on plants for food, medicine, and industrial purposes, recognising their immense therapeutic and economic value[1]. This practice remains deeply embedded in traditional healthcare systems across the world, particularly in India, where *Ayurveda, Unani*, and *Siddha* systems continue to utilise medicinal plants for disease prevention and health promotion[2]. These traditional systems not only preserve ancient ethnomedical knowledge but also serve as a foundation for modern pharmacological research through scientific validation[3]. Numerous plant species that were historically used in folk medicine have now been scientifically investigated and incorporated into contemporary drug development programmes[4]. Disciplines such as ethnobotany and ethno-pharmacology play a

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crucial role in bridging indigenous knowledge with modern biomedical sciences[5].In recent years, the global search for plant-based therapeutics has expanded into a multidisciplinary scientific endeavour involving botanical authentication, phytochemical profiling, bioassay-guided fractionation, and molecular characterisation[6]. These approaches have resulted in the identification of several plant-derived bioactive compounds with significant therapeutic potential[7]. Advances in phytochemistry and a better understanding of structure-activity relationships have accelerated the discovery of effective plant-derived molecules for managing chronic, infectious, and degenerative diseases[8]. Medicinal plants have demonstrated promising efficacy against major health challenges, including cancer, viral infections, metabolic disorders, inflammatory conditions, and lifestyle-related diseases[9]. Globally, the commercial significance of phytopharmaceuticals and plant-based industrial products is increasing rapidly[10]. The global herbal and plant-derived products market is estimated to exceed USD 60 billion and is projected to expand substantially in the coming decades due to growing consumer preference for natural, eco-friendly, and sustainable products[11]. Despite the vast diversity of plant secondary metabolites, only a small fraction of the estimated global phytochemical pool has been scientifically explored, indicating immense scope for future discoveries[12]. Natural products continue to contribute substantially to modern medicine, with nearly 25% of currently used drugs being derived directly or indirectly from plants[13]. In developing and low-income countries, nearly 70-80% of the population still depends on plant-based remedies due to their affordability, accessibility, and relatively lower side effects compared to synthetic drugs[14]. *Ricinus communis* L., commonly known as castor, is an important industrial and medicinal plant belonging to the family *Euphorbiaceae*[15]. It is a fast-growing perennial or annual shrub that thrives under a wide range of agro-climatic conditions, from tropical to subtropical regions, and is widely cultivated in India, Africa, China, Brazil and Thailand[16]. In India, castor grows successfully up to an altitude of about 1,500 m and is well adapted to marginal lands, drought-prone areas, and semi-arid ecosystems, reflecting its remarkable resilience and adaptability[17]. Traditionally, different parts of the plant, including seeds, leaves, roots and oil, have been used in indigenous medicine for treating constipation, skin disorders, inflammation, rheumatism and microbial infections[18]. In addition to its traditional medicinal applications, castor has gained immense industrial importance due to the unique properties of castor oil, which is rich in ricinoleic acid[19]. Recent scientific investigations have highlighted the antimicrobial, anti-inflammatory, antioxidant, hepatoprotective and anticancer properties of various phytoconstituents present in *R. communis*[20]. Ongoing research is focused on optimising extraction techniques, standardising dosages, and exploring synergistic effects with conventional drugs to enhance therapeutic efficacy[21]. Castor is primarily grown during the warm season and performs best in hot and semiarid climates[22]. Traditionally, castor seeds have been the major economic part of the plant, while leaves and roots have also been utilised for their pharmacological significance[23]. Phytochemical studies on *R. communis* have revealed the presence of diverse bioactive compounds such as alkaloids, flavonoids, phenolics, terpenoids, fatty acids and glycosides, which exhibit a wide range of biological activities including antioxidant, anti-inflammatory, antimicrobial, and anticancer effects[24]. Several studies have also reported analgesic, wound-healing and immunomodulatory properties of castor plant extracts[25]. However, the presence of toxic proteins such as ricin in the seeds necessitates careful processing and controlled use[26]. A comprehensive understanding of both the therapeutic benefits and toxicological risks is essential to ensure the safe and effective utilisation of castor for medicinal and industrial purposes.

2. Common and Regional Names of Castor

Ricinus communis L., a plant of considerable ethnobotanical, medicinal and industrial importance, is widely recognised by a variety of common and regional names across different cultures and geographical regions[27]. Owing to its long history of cultivation, multipurpose utilisation, and wide ecological adaptability, castor has acquired numerous vernacular names that reflect its cultural relevance, morphological characteristics, and traditional uses[28]. Globally, the plant is commonly referred to as castor

bean plant, castor oil plant, *Palma Christi*, and wonder tree, names that emphasise both its medicinal value and economic significance[29]. In different parts of the world, castor is known by diverse local names. In Southeast Asia, it is referred to as *jarakpagar* or *jarakkepyar* in Indonesia; *pokokjarak* in Malaysia; *tangan-tangan* in Tagalog (Philippines); *maenglak* in Thailand and *thầudầu* in Vietnamese. In Africa, it is commonly known as *kharwa* or *endu* in East African regions, while in Spanish-speaking countries, it is known as *higuerilla* or *ricino*. In Europe, traditional names such as *ricin* (French), *Rizinus* (German) and *olio di ricino* (Italian) are commonly used, largely derived from the Latin botanical nomenclature[30]. In the Indian subcontinent, linguistic diversity has resulted in a rich array of vernacular names for *R. communis*, reflecting its widespread cultivation and traditional use in agriculture, medicine and industry[31].

Common regional names used in India include:

- *Erand* in Hindi, Marathi, and Gujarati
- *Rendi* in Telugu
- *Avanakku* in Tamil
- *Chittamoottilam* and *Avanakku* in Malayalam
- *Haralu* in Kannada
- *Bherenda* in Sanskrit
- *Reri* in Bengali
- *Endi* in Assamese
- *Arandi* in Odia

In classical *Ayurvedic* literature, castor has been described under several Sanskrit synonyms such as *Eranda*, *Bheranda*, *Gandharvahasta* and *Vatari*, each denoting specific morphological traits or therapeutic properties, particularly its well-known laxative and anti-inflammatory effects[32]. The extensive diversity of common and regional names highlights the profound ethnobotanical importance of *R. communis* across different cultures and regions, underscoring its long-standing role in traditional medicine, rural livelihoods and agro-industrial systems[33-35].

3. Methods

In order to present a comprehensive and evidence-based overview of *R. communis* L., a systematic literature search was conducted using a wide range of focused keywords and Boolean operators[36]. The keywords used during the search included "traditional uses", "traditional medicine", "ethnobotany", "phytochemistry", "secondary metabolites", "phytoconstituents", "pharmacological activities", "industrial uses" and "toxicology". To further refine the search and ensure the inclusion of studies with well-defined biological and therapeutic relevance, specific pharmacological terms such as "antioxidant", "antimicrobial", "anti-inflammatory", "anticancer", "hepatoprotective", "analgesic" and "laxative" were combined with the plant name "*Ricinus communis*" during database queries[37]. The literature sources comprised diverse electronic databases and online scientific repositories, including PubMed, Scopus (Elsevier), Web of Science (Clarivate Analytics), Science Direct, Springer Link, Wiley Online Library, Taylor and Francis Online, Google Scholar, ResearchGate, NOPR and MAPA. These platforms were selected due to their extensive indexing of peer-reviewed research articles and their relevance to ethnobotany, pharmacology, medicinal plant research and natural product chemistry[38]. The screening strategy focused on research articles published in the English language between January 2000 and March 2024. After applying predefined inclusion and exclusion criteria, a total of 196 research articles were initially retrieved. The inclusion criteria encompassed original research articles, systematic reviews and ethnobotanical surveys that specifically addressed the traditional uses, phytochemical composition, pharmacological activities and toxicological aspects of *R. communis*. Studies lacking experimental validation, incomplete datasets, or clear methodological descriptions were excluded to maintain scientific rigour. Additionally, duplicate records across databases were carefully identified and removed. Abstracts of the retrieved articles were independently screened to assess relevance, followed by full-text evaluation of selected papers. Emphasis was placed on studies employing standardised experimental protocols, validated analytical techniques and reproducible pharmacological assays. This systematic and multi-stage screening approach ensured the selection of high-quality, reliable literature and facilitated a balanced synthesis of both classical ethnomedicinal knowledge and contemporary scientific evidence related to castor. Subsequent screening involved abstract evaluation, duplication removal and assessment of relevance to castor's ethnomedicinal, phytochemical, pharmacological and toxicological

aspects. Following this rigorous screening process, 142 articles were selected for detailed analysis and inclusion in the present review. This systematic methodology ensured that the selected literature encompassed both classical ethnobotanical knowledge and contemporary scientific evidence, thereby facilitating a holistic understanding of *R. communis* and its medicinal, industrial and toxicological significance[39].

4. Taxonomy and Botanical Identification of Castor

The castor plant (*R. communis* L.) is a fast-growing annual or perennial shrub that typically attains a height ranging from 100 to 400 cm, depending on genotype and environmental conditions (Figure 1)[40]. The plant is erect, robust and extensively branched, with a hollow, glabrousand often glaucous stem exhibiting green to purplish pigmentation. Leaves are large, alternate, palmately lobed with 5-11 deeply cut segments, long petioles and a glossy green to reddish appearance, which serve as a key morphological feature for field identification. The inflorescence is a terminal raceme bearing unisexual flowers, with female flowers located at the upper portion and male flowers at the lower portion of the inflorescence[41]. The flowers are conspicuous but apetalous, with male flowers characterised by numerous branched stamens bearing yellow anthers, while female flowers possess a prominent tricarpellary ovary with red to purplish feathery stigmas. The fruit is a globose, spiny or smooth capsule that dehisces on maturity into three segments, each containing a single seed. Castor seeds are oblong, smooth, and shiny, with distinctive mottled patterns resembling ticks, a characteristic that gives rise to the common name "castor bean"[42]. *Ricinus communis* is believed to have originated in the tropical regions of Africa but is now widely distributed across tropical, subtropical and warm temperate regions of the world, including India, China, Brazil, Thailand, and African countries[43]. The plant thrives well in tropical and semi-arid climates and is commonly found growing along roadsides, wastelands, field bunds, and marginal agricultural lands. Its adaptability to drought, tolerance to poor soil fertility and rapid growth enable it to colonise disturbed habitats efficiently[44]. Due to its distinctive morphological features, wide ecological amplitude and ease of identification, castor holds significant agronomic, medicinal and industrial importance (Table 1).

Table 1. Taxonomic classification of *Ricinus communis*

Taxonomic Rank	Classification
Kingdom	*Plantae*
Subkingdom	*Tracheobionta* (Vascular plants)
Superdivision	*Spermatophyta* (Seed plants)
Division	*Magnoliophyta* (Angiosperms)
Class	*Magnoliopsida* (Dicotyledons)
Subclass	*Rosidae*
Order	*Malpighiales*
Family	*Euphorbiaceae*
Genus	*Ricinus*
Species	*Ricinus communis* L.

5. Traditional Uses of *Ricinus communis*

The extensive medicinal legacy of *R. communis* L. (castor) reflects its long-standing importance in traditional healing systems across Asia, Africa and the Americas[31]. Almost all parts of the plant, including roots, seeds, leaves and seed oil, have been utilised for centuries owing to their diverse therapeutic properties[45]. In Indian traditional medicine, particularly *Ayurveda* and folk practices, castor leaves and oil are extensively used for the management of inflammatory disorders, skin ailments and musculoskeletal conditions. Fresh leaves often warmed and applied as poultices are traditionally used to relieve joint pain, swellings, boils and abscesses, while leaf decoctions are administered to alleviate fever and digestive discomfort. Castor oil, although derived from seeds containing the toxic protein ricin, is widely employed in purified and regulated form as a potent laxative and purgative in traditional medicine. It is also externally applied to reduce rheumatic pain, arthritis, sciaticaand muscle stiffness. In rural communities of northern and central India, castor oil massage is a common household remedy for postpartum care, body weakness and infantile ailments such as abdominal colic. Burning or warming of leaves followed by topical application is traditionally practised to relieve headache, chest congestion and inflammation. A wide range of therapeutic applications based on specific plant parts is summarised in Table 2. In Himalayan ethno-medicine, castor leaf juice and decoctions are



Figure 1. Botanical morphology of castor showing leaves, inflorescence, seeds and capsules.

used to support liver function, treat jaundice, and manage splenic enlargement. Tribal communities in Uttarakhand and Himachal Pradesh apply leaf paste and oil externally for wound healing, skin infections and insect bites. In several African countries, including Nigeria, Ethiopia and Kenya, castor leaves and roots are traditionally used for treating fever, malaria-like symptoms and headaches through decoctions and topical applications. In Ethiopia, aqueous root extracts are occasionally used in folk medicine for managing rabies and severe inflammatory conditions. The regional diversity of ethno-medicinal practices involving castor is summarised in Table 3. Beyond its medicinal value, *R. communis* also holds significant agro-ecological importance. In many parts of Africa and Latin America, castor extracts are utilised as bio-insecticides and repellents in organic farming systems. In India, the plant is often grown along field boundaries to deter grazing animals due to the unpalatable nature of its leaves and seeds. In *Ayurveda*, castor (*Eranda*) is a key ingredient in classical formulations such as *Erandataila* and *Gandharvahastadi taila*, valued for their laxative, anti-inflammatory and vāta-pacifying properties[46]. These formulations are traditionally prescribed for constipation, arthritis, gout, neurological disorders and abdominal diseases[47]. In the *Unani* system of medicine, castor oil (*Roghan-e-Bedanjir*) is used for treating paralysis, joint stiffness and chronic skin diseases[48]. Homoeopathic practitioners employ tinctures prepared from castor seeds for the management of gastrointestinal disturbances and certain skin conditions[49]. In Central and South America, traditional beverages and topical preparations made from castor oil and leaves are used to alleviate kidney pain, labour pain and inflammatory conditions[50]. Etymologically, the name *Ricinus* is derived from the Latin word meaning "tick," referring to the tick-like appearance of the seeds, which has been noted in ancient medicinal texts. Traditional uses of castor have also been associated with its mild sedative, analgesic and anti-inflammatory effects, justifying its application in pain management and digestive disorders[51]. Modern scientific investigations corroborate many of these traditional claims, demonstrating the plant's anti-inflammatory, antimicrobial, analgesic, laxative and wound-healing activities (Table 4)[52]. The ethnobotanical significance and pharmacological potential of *R. communis* underscore its value as an important medicinal plant for affordable rural healthcare and sustainable traditional medicine systems, while also highlighting its relevance in contemporary ethno-pharmacological research.

6. Phytochemistry of *Ricinus communis*

Plant-derived bioactive compounds have long played a central role in traditional medicine and human

Table 2. Traditional uses and mode of application based on the plant parts of castor

Plant Part	Traditional Use	Mode of Application
Leaves	Inflammation, rheumatism, headache, fever, and wound healing	Poultice, decoction, topical application
Flowers	Mild laxative, anti-inflammatory, and uterine disorders	Infusion, decoction
Seeds	Constipation, arthritis, paralytic disorders, purgative	Oral use (processed oil), external massage
Root	Rheumatism, abdominal pain, and skin diseases	Aqueous extract, paste
Oil (Seed oil)	Laxative, arthritis, skin disorders, hair growth	Oral use (medicated), topical application
Whole Plant	Anti-inflammatory, antimicrobial, diuretic, and analgesic effects	Decoction, extract

Table 3. Regional ethno-medicinal applications, preparations and uses of castor

Region/Country	Traditional Application	Preparation and Uses
India (Himalayan region)	Rheumatism, joint pain, skin infections	Leaf poultice, warm castor oil application
India (Plains and tribal regions)	Constipation, abdominal pain, inflammation	Castor oil oral use, seed oil massage
Africa (Nigeria, Ethiopia)	Wound healing, headache, and fever	Leaf paste, decoction
Sudan / Kenya	Malaria, digestive disorders	Whole plant or leaf decoction
South America (Brazil, Peru)	Muscle pain, labour pain, inflammation	Oil massage, herbal infusion
China	Laxative, abscesses, swelling	Processed seed oil, topical paste
Ayurveda (India)	Arthritis, sciatica, fever, vāta disorders	*Erandataila, churna*, decoction
Unani system (India)	Paralysis, joint stiffness, skin diseases	*Roghan-e-bedanjir* (castor oil)
Folk medicine (Caribbean)	Intestinal worms, skin ulcers	Oil ingestion (controlled), leaf poultice

Table 4. Common therapeutic properties and their associated traditional uses of castor

Pharmacological Property	Associated Traditional Use
Antimicrobial	Skin infections, boils, abscesses, wound healing
Anti-inflammatory	Joint pain, arthritis, rheumatism, swelling
Expectorant	Chest congestion, cough, bronchial discomfort
Laxative / Purgative	Constipation, digestive detoxification, intestinal cleansing
Analgesic	Headache, muscle pain, sciatica, abdominal pain
Antidote	Snake bites (seed paste in folk medicine)
Antiseptic	Ulcers, eczema, minor wounds, insect bites
Diuretic	Water retention, urinary disorders
Sedative / Relaxant	Mild anxiety, muscle tension, and postpartum care

health. *Ricinus communis* L. is particularly notable for its complex phytochemical composition and broad spectrum of pharmacological properties[53]. The plant contains diverse secondary metabolites such as alkaloids, flavonoids, tannins, glycosides, phenols, terpenoids, saponins, steroids and polysaccharides, which are distributed in its leaves, stems, roots, seeds, and seed oil (Table 5)[54]. Recent quantitative phytochemical studies have revealed that leaf extracts contain significant amounts of phenolics (8-12 mg/g) and flavonoids (10-18 mg/g), while the seeds are a rich source of ricin and other bioactive proteins[55]. Methanolic leaf and stem extracts have demonstrated total phenolic content ranging from 22.5 ± 1.1 to 30.2 ± 1.4 mg GAE/g and total flavonoid content between 35.6 ± 0.8 and 45.2 ± 0.9 mg QE/g, highlighting the concentration of bioactive compounds in aerial plant parts[56]. GC-MS profiling of hexane, chloroform and methanolic extracts has revealed a wide range of compounds, including alkanes, fatty acids, esters, ketones,

aldehydes, amino acids, steroids and heterocyclic compounds[57]. Alkaloids are considered the most pharmacologically active constituents of castor. Seeds contain ricinine, ricin and ricinine N-oxide, while the leaves and stems possess ricinine, ricinine methyl ester and other minor alkaloids (Figure 2)[58]. The seed oil, widely known for its laxative properties, also contains toxic proteins such as ricin and allergenic compounds, along with ricinoleic acid, a unique hydroxy fatty acid contributing to its medicinal and industrial relevance[59]. Aerial parts contain flavonoids such as quercetin, rutin, kaempferoland apigenin, which exhibit antioxidant, anti-inflammatory and antimicrobial activities[60]. GC-MS and HPLC analyses have further identified hydrocarbons (nonacosane, octadecane) and phenolic acids (caffeic acid, ferulic acid) in leaves and stems[61]. Alkaloids isolated from root extracts, including ricinine, ricinoleic acid derivatives and secondary amines, have shown neuroprotective and anti-inflammatory activity[62]. The presence of phytosterols such as β-sitosterol and stigmasterol in seed oil contributes to its lipid-lowering and anti-inflammatory

Table 5. Major phytochemicals and their biological activities of *R.communis*

Phytochemical	Plant Parts	Biological Activity / Traditional Use
Ricinine	Seeds, leaves	Anti-inflammatory, antimicrobial, neuroprotective
Ricin	Seeds	Toxic protein, used cautiously for biomedical research
Ricinoleic acid	Seed oil	Laxative, anti-inflammatory, wound healing
Flavonoids (quercetin, rutin, kaempferol)	Leaves, stems	Antioxidant, anti-inflammatory, antimicrobial
Alkaloids (ricinine derivatives)	Leaves, seeds, roots	Analgesic, antipyretic, antimicrobial
Sterols (β-sitosterol, stigmasterol)	Seed oil	Anti-inflammatory, lipid-lowering
Polysaccharides	Seeds, leaves	Immunomodulatory, wound healing
Fatty acids (oleic, linoleic, palmitic)	Seed oil	Anti-inflammatory, skin nourishment
Hydrocarbons (nonacosane, octadecane)	Leaf extract	Antimicrobial, structural bioactivity
Phenolic acids (caffeic acid, ferulic acid)	Leaves, stems	Antioxidant, anti-inflammatory
Tannins	Leaves, stems	Antimicrobial, anti-diarrheal, and wound healing
Saponins	Leaves, stems	Anti-inflammatory, immunomodulatory

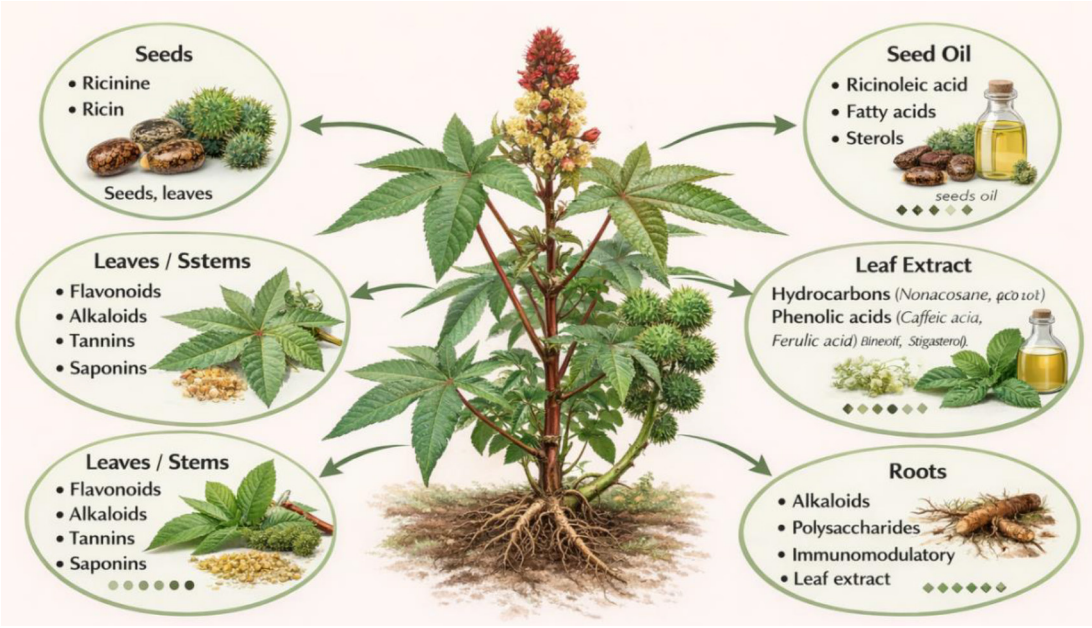


Figure 2. Schematic representation of *Ricinus communis* phytochemicals and their distribution in plant parts.

effects[63]. In addition, polysaccharides extracted from leaves and seeds demonstrate immunomodulatory and wound-healing potential[64]. These findings provide a strong scientific basis for the traditional medicinal applications of *R. communis*, including its use as a laxative, anti-inflammatory, antimicrobial, analgesic and wound-healing agent[65]. Advances in analytical techniques such as high-resolution mass spectrometry, nuclear magnetic resonance and chromatography have greatly enhanced the identification and characterisation of these compounds, reaffirming the ethnomedicinal significance and pharmacological potential of castor in contemporary pharmaceutical research[66-68].

7. Pharmacological Activities

7.1 Antimicrobial Activity of *Ricinus communis*

The rapid emergence of multidrug-resistant microorganisms has intensified interest in medicinal plants such as *R. communis* L., which is well known for its broad-spectrum antimicrobial potential[69,70]. Various plant parts, including seeds, leaves, roots and stem bark, have been extensively investigated, and extracts prepared using polar and non-polar solvents have demonstrated significant antibacterial and antifungal activities. Methanolic and ethanolic extracts of castor leaves and seeds exhibit strong inhibitory effects against both Gram-positive and Gram-negative bacteria. Methanol leaf extracts showed pronounced antibacterial activity against *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Bacillus subtilis*, with inhibition zones ranging from 16 to 24 mm[71]. Seed oil and ethanolic seed extracts have been reported to possess marked antimicrobial activity, primarily attributed to the presence of ricinoleic acid, flavonoids, alkaloids and phenolic compounds[72]. Chloroform and hexane extracts of castor seeds exhibited low minimum inhibitory concentration (MIC) values (1.5-4.0 mg/mL) against *S. aureus*, *E. coli* and *Klebsiella pneumoniae*, indicating strong bactericidal properties[73,74]. Ethanolic extracts were also effective against fungal pathogens such as *Candida albicans*, *Aspergillus niger* and *Penicillium* spp., with MIC values ranging from 5 to 20 mg/mL[75]. Recent advances have highlighted the antimicrobial efficacy of nanoparticles synthesised using *R. communis* extracts. Silver nanoparticles derived from leaf and seed extracts showed enhanced antibacterial and antifungal activity against *E. coli*, *S. aureus*, *P. aeruginosa*, and *C. albicans* by inducing membrane damage and oxidative stress[76]. Similarly, zinc oxide and iron oxide nanoparticles synthesised using castor leaf extracts significantly inhibited the growth of foodborne and clinical pathogens, including *Salmonella typhi* and *Proteus mirabilis*[77]. Furthermore, aqueous and ethanolic stem and root extracts have shown effectiveness against food-spoiling and foodborne microorganisms such as *Listeria monocytogenes* and *Salmonella enterica*, producing inhibition zones up to 22 mm[78]. Among the solvents used, ethanol and methanol have been identified as the most efficient for extracting bioactive antimicrobial constituents from castor. Overall, these findings underscore the considerable potential of *R. communis* as a natural and sustainable source of antimicrobial agents, particularly in combating antibiotic-resistant pathogens and for applications in pharmaceutical and food safety sectors.

7.2 Anti-inflammatory Activity of *Ricinus communis*

Ricinus communis L. exhibits pronounced anti-inflammatory activity, primarily attributed to its rich profile of bioactive constituents such as ricinoleic acid, flavonoids, alkaloids, terpenoids and phenolic compounds[79]. The plant has a long history of traditional use in treating inflammation, pain, arthritis and skin disorders, and recent pharmacological investigations strongly support these ethnomedicinal claims. Various *in vivo* and *in vitro* studies have demonstrated that extracts obtained from castor leaves, seeds and roots using methanol, ethanol and aqueous solvents possess significant anti-inflammatory potential. Ethanolic and methanolic leaf extracts of *R. communis* showed remarkable inhibition of inflammation in carrageenan-induced rat paw oedema models, with percentage inhibition comparable to standard anti-inflammatory drugs such as diclofenac sodium and indomethacin[80]. The reduction in oedema volume is mainly associated with the suppression of inflammatory mediators released during the acute phase of inflammation. Seed oil rich in ricinoleic acid has been reported to exert potent topical and systemic anti-inflammatory effects by reducing swelling, erythema and pain in

experimental animal models[81]. Mechanistic studies suggest that the anti-inflammatory action of *R. communis* involves inhibition of key pro-inflammatory mediators, including nitric oxide, prostaglandins, tumour necrosis factor-α (TNF-α) and interleukins. Bioactive compounds such as flavonoids and phenolic acids modulate inflammation by inhibiting Cyclooxygenase and Lipoxygenase pathways, which play a central role in prostaglandin and leukotriene synthesis[82]. Additionally, the strong antioxidant activity of castor phytochemicals scavenges reactive oxygen species, thereby attenuating oxidative stress-induced inflammatory responses[83]. Recent studies have also highlighted the efficacy of castor leaf and root extracts in chronic inflammation models, including cotton pellet-induced granuloma and adjuvant-induced arthritis, indicating their role in both acute and chronic inflammatory conditions[84]. Furthermore, nano-formulations and topical preparations derived from *R. communis* oil have shown enhanced anti-inflammatory efficacy and improved bioavailability[85]. Overall, these findings confirm that *Ricinus communis* possesses substantial anti-inflammatory activity, validating its traditional applications and highlighting its potential for development into plant-based anti-inflammatory and anti-arthritic therapeutic agents.

7.3 Analgesic and Antioxidant Activity of *Ricinus communis*

Ricinus communis L. exhibits noteworthy analgesic and antioxidant activities, which are primarily attributed to its diverse array of bioactive constituents such as ricinoleic acid, flavonoids, phenolic acids, tocopherols and alkaloids[86]. Traditionally, castor leaves and seed oil have been widely used in folk medicine for relieving pain, inflammation, headaches, rheumatism, and muscular disorders, and modern pharmacological investigations strongly substantiate these traditional claims. Extracts obtained from leaves, seeds and roots using methanol, ethanol and aqueous solvents have demonstrated significant analgesic and antioxidant efficacy in experimental models. Analgesic activity of *R. communis* has been confirmed through various *in vivo* pain models, including acetic acid-induced writhing, hot plate and tail-flick tests. Ethanolic and methanolic leaf extracts showed significant reduction in writhing responses in mice, indicating strong peripheral analgesic activity comparable to standard drugs such as aspirin and diclofenac sodium[87]. Seed oil rich in ricinoleic acid has also been reported to exert potent analgesic effects by modulating nociceptive pathways and reducing pain perception through inhibition of prostaglandin synthesis[88]. The central analgesic action observed in hot plate assays suggests possible interaction with opioid receptors or modulation of central pain pathways[89].In addition to analgesic properties, *R. communis* exhibits substantial antioxidant activity, which plays a crucial role in mitigating oxidative stress-associated pain and tissue damage. Methanolic and ethanolic leaf extracts demonstrated strong free radical scavenging activity against DPPH, ABTS and superoxide radicals, along with significant ferric reducing antioxidant power (FRAP)[90]. The high antioxidant potential is mainly due to flavonoids, phenolic compounds and vitamin E derivatives present in castor, which neutralise reactive oxygen species and inhibit lipid peroxidation[91]. Oxidative stress is closely linked to inflammatory pain and neurodegenerative disorders, and the antioxidant activity of *R. communis* contributes to its analgesic efficacy by protecting cellular membranes and reducing oxidative damage. Recent studies have also shown that flavonoid-rich fractions of castor leaves enhance endogenous antioxidant enzymes such as superoxide dismutase (SOD), catalase and glutathione peroxidase, thereby strengthening cellular defence mechanisms[92]. Overall, the combined analgesic and antioxidant properties of *R. communis* validate its traditional medicinal use and highlight its potential as a natural source for the development of plant-based analgesic and antioxidant therapeutics.

7.4 Wound Healing Activity of *Ricinus communis*

Ricinus communis L. exhibits remarkable wound healing activity, which is primarily attributed to its rich content of ricinoleic acid, flavonoids, tannins, alkaloids, terpenoids and phenolic compounds[93]. Traditionally, castor leaves and seed oil have been extensively used for the treatment of wounds, burns, ulcers and skin infections in various indigenous systems of medicine. Contemporary experimental studies strongly validate these traditional applications, highlighting the plant's ability to accelerate wound contraction, enhance epithelialization and improve collagen synthesis.

Topical application of castor oil and leaf extracts has demonstrated significant wound healing efficacy in excision, incision and burn wound models. Ethanolic and aqueous leaf extracts of *R. communis* significantly enhanced the rate of wound contraction and reduced the epithelialization period in excision wound models, showing effects comparable to standard wound healing agents such as povidone-iodine and nitrofurazone[94]. Increased tensile strength observed in incision wound models further confirms the role of castor extracts in promoting collagen maturation and fibroblast proliferation[95]. The wound healing potential of *R. communis* is closely associated with its antimicrobial and anti-inflammatory properties, which prevent secondary infections and reduce prolonged inflammatory responses at the wound site. Ricinoleic acid present in castor oil plays a pivotal role by maintaining a moist wound environment, enhancing angiogenesis and facilitating granulation tissue formation[96]. Additionally, flavonoids and tannins contribute by scavenging free radicals, reducing lipid peroxidation and protecting newly formed tissues from oxidative damage[97]. Histopathological studies of castor-treated wounds have revealed well-organised collagen fibres, increased fibroblast density and enhanced neovascularisation, indicating accelerated tissue regeneration[98]. Recent advancements have also focused on castor oil-based formulations, hydrogels and biopolymer dressings, which have shown superior wound healing efficacy, improved biocompatibility and sustained release of bioactive compounds[99]. Overall, these findings establish *R. communis* as a promising natural therapeutic agent for wound management, supporting its traditional use and offering substantial potential for development into modern wound care products.

7.5 Anti-fertility Activity of *Ricinus communis*

Ricinus communis L. has been traditionally used in certain indigenous and folk medicinal systems for regulating fertility and reproductive health. In recent years, scientific investigations have substantiated its potential anti-fertility effects in both male and female experimental models, drawing attention to its possible application in plant-based contraceptive development[100]. Various extracts prepared from seeds, roots and leaves using ethanol, methanol and aqueous solvents have been reported to influence reproductive physiology significantly. Experimental studies have demonstrated that administration of ethanolic and methanolic seed extracts of *R. communis* in female rats leads to a marked reduction in fertility indices, including decreased implantation rates and altered oestrous cycle patterns[101]. The observed anti-implantation and anti-ovulatory effects are primarily attributed to hormonal imbalance induced by bioactive constituents present in the plant. Histopathological examination of reproductive organs revealed thinning of the endometrium, reduced uterine glandular activity and follicular atresia in the ovaries, indicating suppression of normal reproductive function[102].In male reproductive models, seed and root extracts of *R. communis* have shown pronounced antifertility effects by significantly reducing sperm count, motility and viability, along with a decrease in serum testosterone levels[103]. Testicular histopathological studies revealed degeneration of seminiferous tubules, reduction in spermatogenic cell layers, and impairment of Leydig cell function, suggesting direct gonadotoxic effects of castor phytochemicals[104]. These changes collectively contribute to reduced spermatogenesis and impaired male fertility. The antifertility activity of *R. communis* is mainly associated with its bioactive compounds such as alkaloids, flavonoids, phenolics and certain glycosides. These compounds are believed to interfere with the hypothalamic - pituitary -gonadal axis, disrupt steroidogenesis and exert cytotoxic effects on germ cells[105]. Flavonoids and phenolic constituents may further contribute by modulating prostaglandin synthesis and altering uterine contractility, thereby affecting implantation and maintenance of pregnancy[106]. *In vitro* studies have also suggested that castor seed extracts can impair fertilisation by affecting sperm membrane integrity and reducing sperm-oocyte interaction efficiency[107]. Although these findings highlight the promising potential of *R. communis* as a natural antifertility agent, comprehensive toxicity, reversibility, and safety evaluations are essential before considering its application in human contraceptive formulations.

7.6 Anticancer and Cytotoxic Activity of *Ricinus communis*

Ricinus communis L. has been investigated for anticancer and cytotoxic potentials owing to its rich array of bioactive phytochemicals, including ricin, ricinine, ricinoleic acid, phenolics, flavonoids and lectins, which

exhibit cell-growth inhibitory actions and pro-apoptotic effects in cancer models (Figure 3)[108]. Although many traditional uses of castor have centred on digestive and topical medicinal applications, recent research has expanded into oncological contexts, demonstrating promising cytotoxic and anticancer properties of various castor extracts and compounds *in vitro* and *in vivo*. A key study demonstrated that methanolic extracts from different parts of *R. communis* (including seeds, stems, leaves, fruit and roots) exhibited cytotoxic effects in brine shrimp lethality assays, indicating the presence of components capable of disrupting cellular integrity and viability. The LC_{50} values ranged from 0.22-3.70 µg/mL in brine shrimp models depending on extraction methods, suggesting potent cytotoxicity at low concentrations[109]. These data underscore the potential of castor phytoconstituents for further anticancer exploration. More explicitly, fruit extracts from *R. communis* showed significant anticancer efficacy against human breast cancer cell lines (MCF-7 and MDA-MB-231). Treatment with castor fruit extract (RCFE) resulted in dose and time-dependent inhibition of cancer cell proliferation, reduced metastatic behaviour (migration, adhesion, invasion) and induction of apoptosis characterised by increased pro-apoptotic markers (Bax, caspase-7), PARP cleavage and down-regulation of anti-apoptotic Bcl-2. In syngeneic mouse tumour models, RCFE significantly reduced tumour volume, further supporting its potential as an anticancer agent[110]. Similarly, purified ricin protein isolated from castor seeds exhibited potent cytotoxicity against melanoma cells *in vitro*. Ricin treatment decreased colony formation, reduced expression of ERK signalling proteins, and induced apoptosis preferentially in melanoma cells compared with non-tumorigenic control cells, indicating a selective cytotoxic mechanism linked to disruption of key survival pathways[111]. Cytotoxic activity has also been measured in crude protein fractions from castor seed against Ehrlich Ascites Carcinoma (EAC) cells, where administration of seed protein showed ~54% inhibition of cancer cell growth at 100 µg/mL, and hallmark apoptotic features such as nuclear condensation and fragmentation were observed[112]. Additionally, studies involving essential oil from castor leaves demonstrated cytotoxic effects on HeLa (human cervical cancer) cells, further validating the broad cytotoxic profile of castor phytochemicals across diverse cancer cell types[113]. Collectively, these results highlight that *R. communis* contains multiple bioactive constituents capable of exerting cytotoxic and anticancer effects via pro-apoptotic induction, inhibition of proliferation and suppression of metastatic phenotypes. While the toxic nature of certain components (e.g., ricin) necessitates careful safety evaluation, the anticancer and cytotoxic properties emerging from these studies provide compelling impetus for future drug discovery and development from castor-derived compounds.

7.7 Antidiabetic Activity of *Ricinus communis*

Diabetes mellitus is a chronic metabolic disorder characterised by persistent hyperglycemia, dysregulated glucose metabolism, and associated complications affecting multiple organs. Traditional medicinal systems have long employed *R. communis* L. for managing metabolic ailments, including diabetes, and contemporary research has validated significant antidiabetic activity of various castor plant extracts in experimental models[114]. The hypoglycemic potential of castor is largely attributable to its diverse array of bioactive phytochemicals such as flavonoids, phenolic acids, sterols and ricinoleic acid, which can modulate glucose metabolism, enhance insulin sensitivity and impact key enzyme pathways involved in carbohydrate digestion and glucose homeostasis. Studies in streptozotocin (STZ) induced diabetic rats have demonstrated that ethanolic and aqueous ethanolic leaf extracts of *R. communis* significantly reduce fasting blood glucose levels and attenuate the body weight loss typically observed in diabetic animals, with efficacy that, in some doses, approaches that of standard antidiabetic drugs such as glibenclamide. The extracts not only lowered serum glucose but also ameliorated diabetes associated alterations in liver enzyme levels (ALT, AST, ALP), lipid profiles and markers of renal function, indicating a broader protective effect on metabolic health. In addition to *in vivo* animal data, root extracts of *R. communis* prepared with 50 % ethanol have shown significant antihyperglycemic effects in both normal and experimentally diabetic models, demonstrating sustained hypoglycemic action over extended periods and improving overall glucose homeostasis without observable toxicity at high doses, suggesting a favourable safety profile[115].

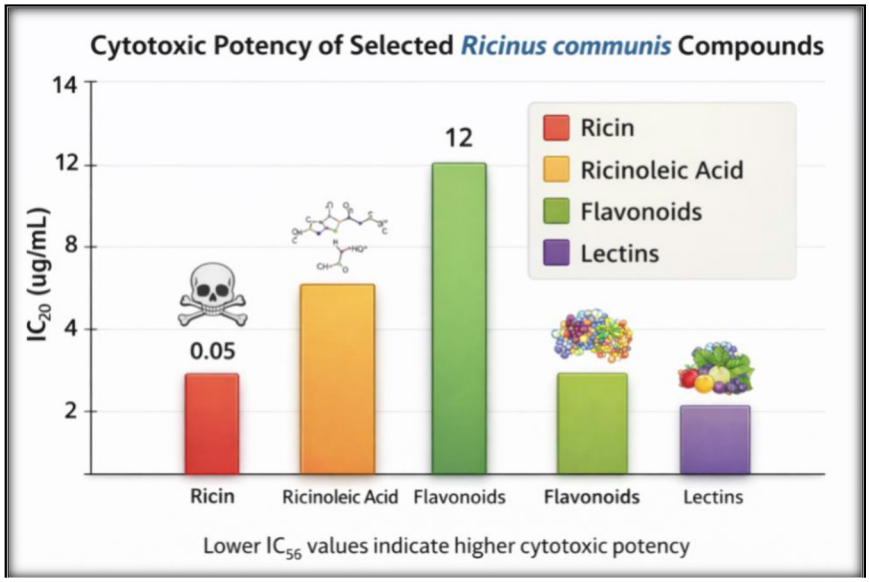


Figure 3. IC_{50} values of certain *R. communis* compounds show their cytotoxic potency.

Mechanistically, castor's antidiabetic potential may involve inhibition of carbohydrate-digesting enzymes such as α-amylase and α-glucosidase, thereby slowing glucose absorption in the gut, as well as modulation of insulin signalling pathways and improvement of glucose uptake in peripheral tissues[116]. Network pharmacology studies further indicate that multiple castor phytochemicals such as quercetin, kaempferol, stigmasterol and β-sitosterol interact with key targets associated with insulin resistance and inflammation, including NF-κB, GSK3B and TNF pathways, which are intimately involved in diabetic pathophysiology[117]. Overall, *R. communis* exhibits promising antidiabetic activity through multi-faceted mechanisms including glucose lowering, metabolic regulation, enzyme inhibition and amelioration of diabetes induced biochemical disruptions. These findings support its traditional use and highlight its potential for development as a complementary or adjunctive natural therapeutic for diabetes management, although further isolation of active constituents and clinical evaluation are warranted.

8. Toxicological Profile of *Ricinus communis*

While *R. communis* possesses a wide spectrum of therapeutic properties, its toxicological potential is significant and must be carefully considered in both traditional use and modern applications. The plant synthesises one of the most potent natural toxins known as ricin, a ribosomeinactivating protein primarily concentrated in the seeds but present in lower amounts throughout the plant. Another toxic constituent is ricinine, a piperidine alkaloid in seeds and leaves that serves as a biomarker for ricin exposure and adds to castor's adverse profile[118].

8.1 Principal Toxic Compounds and Mechanisms

The most dangerous toxic principle in castor is *ricin*, a glycoprotein toxalbumin composed of two polypeptide chains linked by a disulfide bond. Chain B facilitates binding and cellular entry, while Chain A irreversibly inhibits ribosomal protein synthesis in eukaryotic cells, triggering apoptosis and widespread cellular dysfunction[119]. Ricin is water-soluble and does not partition into the lipid phase during oil extraction, meaning properly processed castor oil is free of ricin and generally safe for intended uses[120]. However, unprocessed seed mash, crushed seeds or extracts can contain active ricin and cause severe toxicity when ingested, inhaled or injected.

8.2 Clinical Manifestations of Ricin Poisoning

The clinical picture of ricin toxicity varies with dose and route of exposure. Ingestion of castor seeds (especially if chewed or crushed) represents a common

accidental exposure pathway. Early symptoms typically include burning pain in the mouth and throat, nausea, vomiting, colicky abdominal pain and bloody diarrhoea, which may emerge several hours after exposure[121]. Gastrointestinal irritation is followed by dehydration, hypovolemia and hemorrhagic gastroenteritis, with potential progression to multiorgan dysfunction involving the liver, kidneys, and central nervous system over 2-5 days[122]. Fatal outcomes have been documented in severe cases, particularly when supportive care is delayed. Respiratory exposure to ricin (as a powder or aerosol) produces respiratory distress, cough, chest tightness, pulmonary edema and noncardiogenic lung injury, with rapid progression to respiratory failure in high dose exposures[118]. When ricin enters the bloodstream via injection, it can induce hemolysis and multiorgan failure, leading to death within hours to days, as seen in case reports of intentional injection exposures[123].

8.3 Dose Response, Lethality and Toxicity Modulators

Toxicity is highly dose-dependent. Ingestion of as few as 5-10 castor seeds (crushed) has been estimated to be lethal in humans, with fatalities occurring within 36-72 hours of exposure in severe cases. The LD_{50} of purified ricin by inhalation or parenteral exposure is in the range of 5-10 µg/kg body weight, underscoring its extreme potency (Figure 4). Intact seeds are often less toxic since the hard outer coat can pass through the digestive tract without releasing ricin; toxicity is principally a concern when the seed's integrity is compromised.

8.4 Other Toxicological Considerations

In addition to ricin's acute toxicity, castor plant exposure can trigger skin irritation, allergic dermatitis and respiratory allergies due to airborne pollen and contact with sap[124]. Ricinine can exert additional toxic effects and is used for exposure monitoring. Experimental studies in nonmammalian models such as *Drosophila melanogaster* have confirmed dose-dependent toxicity of ethanol extracts, reinforcing the need for caution in extract preparation and use.

8.5 Safety in Medicinal and Industrial Use

Despite these toxic principles, castor oil (ricinoleic acid-rich triglyceride) processed by proper coldpressing and heat treatment does not contain active ricin and is widely regarded as safe for therapeutic, cosmetic and industrial applications. Toxicological evaluations up to high dietary concentrations in rodent models have not demonstrated significant genotoxicity or adverse systemic effects from castor oil itself, though localised irritation and

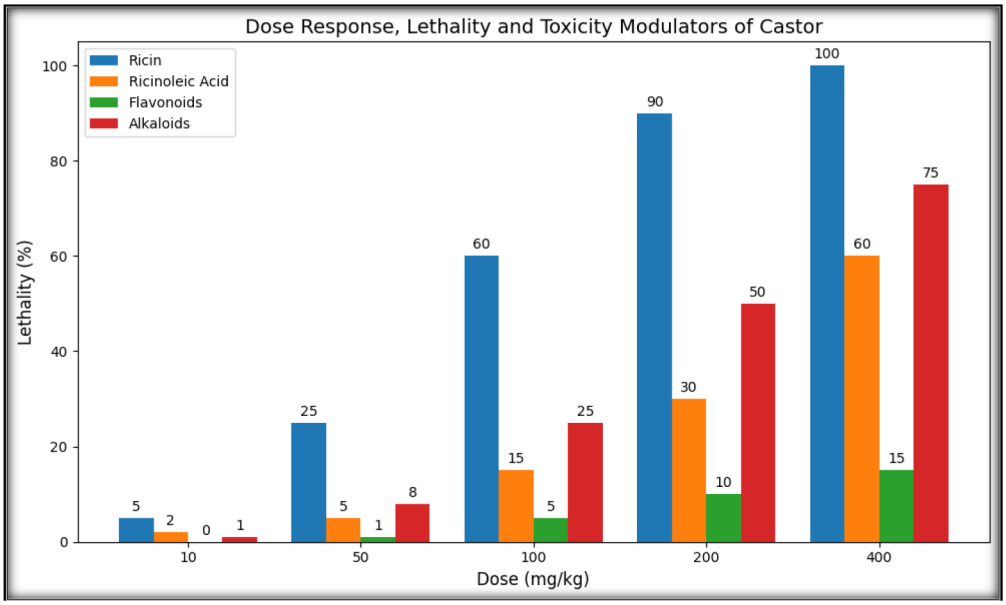


Figure 4. Dose-dependent lethality of *R. communis* constituents showing the contribution of ricin, ricinoleic acid, flavonoids and alkaloids to toxicity.

sensitisation reactions are documented in some dermal exposure studies. Overall, the toxicological profile of *R. communis* reflects a dual potential, a valuable medicinal resource when properly processed and a hazardous plant if toxic components, especially ricin, are ingested or improperly handled. This underscores the importance of rigorous extraction protocols, dosage control and public awareness to minimise risk.

9. Industrial Applications of *Ricinus communis*

Ricinus communis L. is a versatile plant with a rich spectrum of industrial and pharmaceutical applications due to its high oil content, bioactive phytochemicals and unique chemical composition. Castor seeds are primarily valued for castor oil, which contains up to 90 % ricinoleic acid, a monounsaturated fatty acid responsible for its distinctive physicochemical and pharmacological properties[125]. Castor oil and its derivatives have wide-ranging industrial applications. The high hydroxyl content of ricinoleic acid makes castor oil a key raw material in:

9.1 Lubricants and Greases

Castor oil and its esters serve as biodegradable, highviscosity lubricants with excellent thermal stability[126].

9.2 Polyurethanes and Polymers

Castor oil is used to produce polyurethane foams, elastomers and coatings due to its hydroxyl functionality, which reacts with isocyanates[127].

9.3 Cosmetics and Personal Care

It is utilised in soaps, creams, lipsticks and hair care formulations for moisturising and emollient effects[128].

9.4 Biofuels

Trans esterified castor oil can be converted to biodiesel, providing a renewable, non-edible feedstock suitable for sustainable energy applications[129].

9.5 Textile and Paint Industries

Castor oil derivatives serve as plasticisers, surfactants and stabilisers in textile finishing and industrial paints[130]. The industrial significance of castor oil is further enhanced by its biodegradability and low environmental toxicity, making it a preferred green alternative in several chemical processes[131].

10. Safe Use Considerations

Despite its broad therapeutic potential, *R. communis* should be used with caution due to its toxic constituents, particularly ricin in seeds and high-concentration seed oil. Topical and external applications of castor oil are generally considered safer when controlled concentrations are applied, but oral intake of unprocessed seeds or crude oil must be strictly avoided unless standardised formulations have been developed under clinical supervision[132]. Its medicinal use must be aligned with international regulatory frameworks, such as the World Health Organisation guidelines on safe herbal medicine use, to ensure public health protection and promote evidence-based phytotherapeutic development[133-136]. Standardisation of dose, method of extraction and route of administration is critical to minimise adverse effects while preserving therapeutic benefits. Emerging strategies, including nanoparticle encapsulation and targeted delivery, are being investigated to reduce systemic toxicity while maximising pharmacological efficacy[137-140].

11. Conclusion

Ricinus communis L. is a multifunctional plant of immense ethnobotanical, medicinal and industrial significance. Across centuries, it has been valued in traditional medicine systems for treating inflammation, pain, gastrointestinal disorders, skin diseases and reproductive health issues. Modern scientific investigations have validated many of these traditional claims, confirming the plant's broad pharmacological spectrum, including antimicrobial, anti-inflammatory, analgesic, antioxidant, antidiabetic, wound healing, anticancer, cytotoxic and anti-fertility activities. The bioactive compounds, primarily ricin, ricinoleic acid, flavonoids, alkaloids, sterols and phenolicsare distributed across seeds, leaves, roots and oil, each contributing to distinct therapeutic effects. Despite its medicinal potential, the presence of toxic proteins like ricin and alkaloids necessitates careful handling, dosage standardization and adherence to safety protocols. The delicate balance between therapeutic benefits and

toxic risk underscores the need for rigorous preclinical and clinical evaluation before wider pharmacological application. Advances in formulation technologies, such as nanoparticle encapsulation and controlled delivery systems, offer promising avenues to maximise therapeutic efficacy while minimising toxicity. Overall, *R. communis* exemplifies the convergence of ancient medicinal wisdom and modern pharmacological research. It represents a versatile natural resource capable of addressing chronic, infectious and lifestyle-associated diseases while offering sustainable industrial applications. Future research should focus on detailed mechanistic studies, *in vivo* validations, and clinical trials to fully harness its therapeutic potential, ensuring safe, effective and evidence-based use in modern phytomedicine.

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Author Contribution

All authors contributed substantially to the conceptualisation, literature review, drafting and critical revision of the manuscript. S.S.conceptualised the research focus on *Ricinus communis* L., compiled the literature on pharmacological and industrial applications, and prepared the initial manuscript draft. Co-author provided input on toxicology, industrial uses and pharmaceutical applications as well as oversight on formatting, references and manuscript finalisation. All authors have read and agreed to the published version of the manuscript.