Annals of Phytomedicine 13(2): 199-205, 2024

DOI: http://dx.doi.org/10.54085/ap.2024.13.2.19

Annals of Phytomedicine: An International Journal
http://www.ukaazpublications.com/publications/index.php

Print ISSN : 2278-9839 Online ISSN : 2393-9885

Review Article : Open Access

Exploring the medicinal potential of Castor (*Ricinus communis* L.): A comprehensive review

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Article Info

Article history
Received 20 July 2024
Revised 24 September 2024
Accepted 25 September 2024
Published Online 30 December 2024

Keywords
Antimicrobial
Castor
Phytomedical
Ricin
Toxicity

Abstract

Castor (*Ricinus communis* L) holds immense healing potential, particularly in the treatment of cancer and ulcers. This plant has been revered for its disease prevention capabilities and recurrent healing properties, making it a valuable resource across diverse fields, including agriculture, pharmacy, economics, and social health. The pharmacological activities of *R. communis* are well-supported by traditional medicine, where it has been used for centuries. These activities contribute to the development of sustainable synthetic drugs, offering a natural alternative to conventional pharmaceuticals. However, the plant's seeds contain a potent toxin called ricin, which poses serious risks to both humans and animals. Ingestion can lead to severe signs such as fever, vomiting, and nervous depression, underscoring the importance of careful handling and processing. Despite these risks, the plant's rich phytochemical composition continues to attract attention for its potential in wound healing, diabetes management, antioxidant therapies, and especially in the fight against cancer. Current examination and clinical studies are essential to completely harnessing the benefits of *R. communis*. These efforts aim to mitigate its toxic effects while enhancing its medicinal applications, offering promising prospects in both medical and agricultural fields. The plant's multifaceted benefits, if safely and effectively utilised, could revolutionise various industries and improve public health.

1. Introduction

The Castor (*Ricinus communis* L) crop belongs to the family of Euphorbiaceae and is highly adaptable, thriving in various geographical regions. The botanical name *R. communis* was derived by Swedish naturalist Carlous Linnaeus in the eighteenth century. *Ricinus* is the Latin word for Mediterranean sheep tick, which the Castor plant seed has total resemblance to, and *communis* literally means common. Notably, India and China are the leading producers, accounting for approximately ninety per cent of worldwide castor production (Sbihi *et al*., 2018). The active constituents present in the plant determine the medicinal or biological effects of that plant. There are many chemical constituents present in the Castor bean plant (leaf, fruit, seed, stem, oil, *etc*.) among them, the most active ingredient is ricin (Said *et al*., 2016). Traditionally, oil extracted from its seeds was used for laxatives, purgatives, and emollients in various medicinal practices. Seeds are highly toxic due to the presence of ricin, ricinine, and lecithin. Ricin, in particular, is enormously poisonous, with as little as 500 mg potentially being lethal for an adult (Moshiri *et al*., 2016). However, the seed extract of Castor has been used for antitumor (Lin and Liu, 1986), antifertility (Sandhyakumary *et al*., 2003), and pesticide (Sharma *et al*., 1991).

Oil content of castor seeds is between 40% and 60%, with global yearly production reaching approximately 1.8 mt (Perdomo *et al*., 2013). Ricinoleic acid is present in Castor, which includes carboxylic, hydroxylic, and a single point of unsaturation (Mubofu, 2016). These chemical features enhance the oil's structural integrity. The fatty acid composition of Castor oil primarily consists of ricinoleic, oleic, stearic, palmitic, and linolenic acids, among others (Beruk *et al*., 2018). It is a monounsaturated fatty acid and most abundant, making up approximately 75% of the oil's total content (Panhwar *et al*., 2016). Experimental studies have demonstrated that various parts of the plant exhibit *in vivo* anti-inflammatory, antioxidant, and anti-nociceptive activities when extracted with ethanol (Tijjan *et al*., 2015). Oilseeds are rich in bioactive compounds, including phytosterols, phenolic acids, tocopherols, tocotrienols, and carotenoids. Many of these compounds, including phytin, have positive effects on health and can be used to design functional foods. Therefore, phytin plays a crucial role in the nutritional value (Bhuneshwari and Surya Pratap Singh, 2022). Additionally eessential oil nanoparticles having the greater therapeutic effect and targeted effect than the other dosage forms (Nikhita *et al*., 2023).

The Castor plant is prominent for its high nutritional significance, attributed to its substantial content of monounsaturated fatty acids (Sbihi *et al*., 2018) and bioactive compounds, vitamin E, phospholipids, and phenolics (Said *et al*., 2016). Oil composites contribute to the stability and flavour of castor oil, making it versatile for various applications (Sedeek *et al*., 2012). The main tocopherol isomers in oil are found in higher concentrations, with α-tocopherol ranging from 43.1 to 96.62 mg/g and γ-tocopherol from 30.89 to 52.7 mg/g, compared to those in edible oils (Sbihi *et al*., 2018). In this review, we discuss the chemical composition of Castor, its traditional and modern applications, and various phytochemical active compounds. Additionally, we compare the physicochemical

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properties, antioxidants, composition of Castor oil, and toxicity, providing a comprehensive analysis of its characteristics.

2. Chemical composition of *R. communis*

Castor oil is composed of triglycerides that lack glycerin. Each triglyceride molecule features a long 18-carbon chain with a double bond (Patel *et al*., 2016). Its chemical properties are primarily based on the structure of ricinoleic acid, which includes a carboxyl group, a hydroxyl group, and a single point of unsaturation (Mubofu, 2016). The carboxylic group in castor oil enables the production of a wide range of esterification products. The hydroxyl (-OH) group on the 12th carbon can be acetylated or removed through dehydration to increase the degree of unsaturation, resulting in a semi-drying oil (Nezihe *et al*., 2010).

Castor has garnered global recognition due to its rich phytochemical profile and significant commercial value. Key bioactive constituents include castor oil, ricinoleyl sulphate, ricinoleic acid, 11-amino-undecanoic acid, and lithium grease (Anjani, 2014). The oil extracted from Castor is unique because it is the primary source of ricinoleic acid, a hydroxy fatty acid that makes up around 85% of the oil. This extraordinary concentration of ricinoleic acid gives castor oil its distinctive properties, making it essential for various industrial uses. Castor oil is extensively utilised in the production of creams, polishes, lubricants, dyes, and greasepaints (Keera *et al*., 2018).

In contrast, the leaves of *R. communis* are non-toxic and are consumed as cooked vegetables in some cultures, methanol extracts from these leaves have been shown to possess significant antioxidants (Nemudzivhadi and Masoko, 2014). Six bioactive composites identified in Castor leaves that exhibit various pharmacological activities (Singh *et al*., 2009). Rutin has gained significant attention for its potential therapeutic benefits in cancer treatment, primarily due to its strong antioxidant properties reported by Sharma *et al.* (2013). After ingestion, rutin is digested by colonic microbiota into phenolic derivatives, all of which contribute to its health-promoting effects (Pashikanti *et al*., 2010).

The dried leaves of *R. communis* showed the presence of two alkaloids, ricinine (0.55%) and N-demethylricinine (0.016%) and six flavones: glycosides kaempferol-3-O-β-D-xylopyranoside, kaempferol-3-O-β-D-glucopyranoside, quercetin-3-O-β-D-xylopyranoside, quercetin-3-O-β-D-glucopyranoside, kaempferol-3-O-β-rutinoside, and quercetin-3-O-β-rutinoside (Singh *et al*., 2009; Kang *et al*., 1985). The monoterpenoids (1,8-cineole, camphor, and α-pinene) and asesquiterpenoid (β-caryophyllene), gallic acid, quercetin, gentisic acid, rutin, epicatechin, and ellagic acid are the major phenolic compounds isolated from leaves.

Interestingly, the leaves also contain cytotoxic phytochemicals that induce cell death by causing the translocation of phosphatidylserine to the outer parts of the cell membrane, leading to mitochondrial dysfunction. Notable compounds identified include three monoterpenoids-α-pinene, camphor, and 1,8-cineole-as well as a sesquiterpenoid, β-caryophyllene. *R. communis* agglutinin I (RCA I) preferentially binds to tumour endothelial cells, leading to the downregulation of VEGFR-2, apoptosis of endothelial cells, and regression of tumour vessels while leaving normal blood vessels unaffected (You *et al*., 2010).

The seeds of *R. communis* are composed of 65-75% endosperm and 25-35% seed coat. Their chemical composition includes ash (2.5%), water (5.5%), carbohydrates (13%), crude fibre (12.5%), and crude protein (17.9%) (Adel *et al*., 2011). The oil extracted from these seeds is characterised by high density, stable viscosity across a wide temperature range, and a freezing point of -10°C. Seeds containing 45% oil include glycosides such as dihydroxystearic acids, ricinoleic acid, stearic acid, isoricinoleic acid, lipases, and crystalline ricinine (Alugah and Ibraheem, 2014). Indole-3-acetic acid has been extracted from the roots (Darmanin *et al*., 2009). Castor meal is detoxified, and this can be used as a supplement in broiler finisher (Akande *et al*., 2016). Castor residue called pomace with a high amount of nitrogen is used as animal feed and as organic fertiliser without any reported harmful effects (Borja *et al*., 2017).

3. Traditional and modern applications

In ancient times, farmers were aware of the danger and kept their livestock away from the Castor plant to avoid losing them. The seeds have also been used in folk medicine to treat a wide range of ailments (David *et al*., 2007). The proteins from Castor bean seeds have been studied for their potential medical applications since ancient times. Over time, their significant roles in the early days of immunological research and the discovery of fundamental principles of immunology were recognized. In the last three decades, the mechanism of action of these toxins has been elucidated, leading to efforts to target them specifically at malignant cells. Ricin, one of the toxins, has also been used in bioterrorism. More recently, these toxins have served as experimental models to study the intracellular trafficking of endocytosed proteins (Olsnes *et al*., 1974). Although, the Castor bean plant originated in Asia and Africa, it is now found in Europe and America as well (Olsnes *et al*., 1974). Castor oil continues to be produced in large quantities worldwide, and the toxin remaining in the Castor meal after oil extraction with hexane or carbon tetrachloride can be easily removed through a simple salting-out procedure (David *et al*., 2007).

Especially Castor plants are used in modern and old medicine for treating a varied range of diseases long before the development of chemical and synthetic compounds (Anubhav *et al*., 2023; Atanasov *et al*., 2015). In early Rome and Greece, the Castor plant was used as a cathartic for over 2,500 years, highlighting its long-standing therapeutic significance (Scarpa and Guerci, 1982). Castor oil is widely used in traditional and herbal medicine (Kadambi and Dabral, 1955). Around the world, traditional medicine practices frequently incorporate Castor oil plant extracts. In developing countries, over 80% of primary healthcare relies on herbal drugs (Chen *et al*., 2016).

The powdered leaf of Castor has been shown to possess insecticidal properties, effective against sucking pests. The insecticidal properties of the *R. communis* were evaluated for their effectiveness in controlling termites that damage the wood of *Mangifera indica* and *Pinus longifolia*. Comparative trials indicated that the order of insecticidal activity was as follows: DDT = BHC > Castor oil + Castor cake (1:1) > Castor oil > Castor leaves > Castor cake > Neem oil > neem leaves. All treatments significantly reduced the weight loss in wood pieces exposed to termites (Sharma *et al*., 1990). Additionally, in some cultures, cats are served with Castor leaf to increase milk creation (Abdul *et al*., 2018). The oil from the leaf is traditionally given to infants to release flatulence, stomach aches, and eye infections (Abdul *et al*., 2018). Additionally, the leaf extraction is used as an emetic for treating narcotics, poisoning, and the cure of jaundice (Rana, 2012). These various applications underscore the plant's multifaceted role in traditional medicine.

As people increasingly turn to herbal products over synthetic chemicals due to concerns about long-term residual effects, the medicinal value of Castor has gained renewed attention (Das *et al*., 2010). Historically, castor beans were incorporated into the pharmacopoeia of the ancient eastern region. In traditional medicine of China, seeds of Castor were used for their anthelmintic properties, and poultices made from the seeds, along with leaf juice, were applied externally to treat chronic wounds. Additionally, Castor sap is used to alleviate rhinitis by being administered into the ear (Scarpa and Guerci, 1982).

Castor plant extracts are used globally for a variety of treatments and ailments. They possess essential and beneficial biological properties, including antioxidant (Obumselu *et al*., 2011), antimicrobial (Nath *et al*., 2011), antihelmintic, insecticidal, diuretic, anti-inflammatory, and laxative things (Rana *et al*., 2012). These extracts are used for conditions such as nuisance, asthma, dermatitis, ringworm, warts, and dandruff (Sibi *et al*., 2012). Additionally, external application of Castor oil on the breasts of nursing mothers has been exposed to increase milk movement, and castor oil is also used to relieve labour pain and aid delivery (Friedman *et al*., 2013).

For regulation of purgatives and to treat skin diseases in Unani medicine, the Castor root was used. The plant is also employed to stimulate breast milk production and applied topically to treat burns. Castor seeds and oil act as purgatives and are used to address various conditions, including liver problems, pain, asthma, and dropsy (Ladda and Kamthane, 2014). Castor seeds or leaves are utilised to treat sprains, swelling, and wounds in veterinary medicine (Quattrocchi, 2012). Castor oil is utilised in medicine for treating bone diseases such as acute osteomyelitis, bone deformities, and articular pains. Research involving mice and bucks demonstrated that Castor can regenerate bones without scarring, promote fibroblast neoformation, and support the formation of polyurethane resin (Beloti, 2007). Historically, *R. communis* was used for similar bone-related conditions, and the combination of Castor polyurethane with $Ca_3(PO_4)_2$ was found to improve matrix mineralisation (Scarpa and Guerci, 1982). They potentially inhibit the biochemical barriers involved in the development of calcium oxalate, along with its antioxidant effects, which is accompanying its practice in the therapy of kidney disease (KSD) (Pradeep Singh *et al*., 2022). The steroidal compounds (phytosterols) found in the methanol extract of *R. communis* seeds have been shown to produce antifertility effects (Sani *et al*., 2007). Seed extract of *R. communis* possesses antifertility activity. The ether-soluble portion of the methanol extract, when administered subcutaneously to adult female rats and rabbits, exhibited anti-implantation and contraceptive effects.

4. Phytochemical composition

The numerous phytochemicals found in the seeds of Castor oil, including flavonoids, alkaloids, tannins, anthrocyanins, terpenoids, phenolics, and vitamins, have great pharmacological and physiological benefit to human bodies (Kang *et al*., 1985). *R. communis* has garnered worldwide consideration due to its rich phytochemical profile and significant profitable value. Additionally, the roots of the plant are a source of indole-3-acetic acid, which contributes to its diverse phytochemical profile (Singh *et al*., 2009). This rich array of compounds highlights the plant's broad medicinal and industrial applications, underscoring the significance of *R. communis* as a valuable natural resource.

Ergost-5-en-3-ol, stigmasterol, β-sitosterol, and one probucol have been isolated from Castor stem, while lupeol and 30-Norlupan-3β-ol-20-one are obtained from the seed coat (Malcolm *et al*., 1968). Tannins in the castor have been shown to significantly enhance the phagocytic function of human neutrophils, suggesting a potential immunomodulatory effect (Kumar *et al*., 2007). The seeds of the Castor oil plant contain numerous phytochemicals, including anthocyanins, vitamins that offer significant physiological benefits (Chouhan *et al*., 2021; Jaime *et al*., 2010; Gulcin *et al*., 2012).

In the stem phytochemicals that bring about antioxidant activity include methyl ricinoleate, ricinoleic acid, 12 octadecadienoic acid, and methyl ester stem, while in the leaves flavonoid is responsible. *R. communis* roots have demonstrated antidiabetic properties in hyperglycaemic rats. A daily dose of 500 mg/kg of root extract for three weeks and two days occasioned improvements of lipid profiles and alongside improved insulin levels and reduced glucose levels in rats (Shokeen, 2008). Bioassay-guided purification of *R. communis* root extract further confirmed favourable properties on blood glucose and lipid profiles (Anil and Krishanu, 2023).

5. Antimicrobial properties

Castor oil has identified the presence of flavonoids, cyanogenic glycosides, saponins, oxalates, phytates, alkaloids, and tannins in ascending order of concentration (Momoh *et al*., 2012). Naturally active compounds in Castor oilseeds through an *in vitro* antimicrobial screening against 7 bacterial strains (Udegbunam *et al*., 2015). Flavonoids in Castor oil contribute to its antimicrobial, antioxidant, and anti-inflammatory properties, among other medicinal benefits (Gutiérrez-Grijalva *et al*., 2017). Tannins are known for their toxicity to bacteria, fungi, and yeast (Udegbunam *et al*., 2015). Castor oil is potentially linked toward phytochemicals such as saponins, cyanogenic glycosides, flavonoids, oxalates, phytates, alkaloids, and tannins in antimicrobial activity. The coadministration of *R. communis* with immunosuppressant drugs has shown significant results in preventing infections in patients undergoing oral cancer treatment (Panghal *et al*., 2011).

6. Antioxidant properties

R. communis exhibits a range of beneficial properties, including hepatoprotective, antifilarial (Shanmugapriya, 2012), antioxidant (Singh, 2009), antiasthmatic (Taur *et al*., 2011), and antimicrobial effects (Jombo and Enenebeaku, 2008). Additionally, the plant's shows free radical scavenging, anti-inflammatory effects (Ilavarasan *et al*., 2006), anti-fertility (Sandhyakumary, 2003), and antidiabetic properties (Shokeen, 2008). Diversity and claims of natural oils are unique, such as essential oils are rich in antifungal and antioxidant properties which can be used as natural edible coating materials to horticulture produce from microbial and fungal attacks (Fahim *et al.*, 2017).

Furthermore, *R. communis* have demonstrated anticancer activity against various cancer types, including cervical, breast, pancreatic, and hepatic cancer (Prakash and Gupta, 2014). Castor lectins exhibit cytotoxic effects on cells, human erythrocytes, and administration of ricin A has been shown to extend the lifespan of mice (Endo and Tsurugi, 1986). Anticancer potential is significantly attributed to its zinc oxide content, characterised by a crystalline hexagonal structure in the plant extracts. This hexagonal Wurtzite form of zinc oxide provides a high surface area that enhances anticancer activity. The plant's antioxidant properties and free radical scavenging further contribute to its cancer-fighting abilities (Shobha *et al*., 2019).

Ricin is a heterodimeric protein derived from the seeds of *R. communis*. It exhibits potent cytotoxic activity by fatally disrupting protein synthesis. The cell entry process of ricin is hypothesised to involve a 10-step mechanism, ultimately leading to this disruption. Remarkably, a single ricin molecule reaching the cytosol is sufficient to kill a cell. Therapeutically, ricin has potential applications in targeting and destroying cancer cells.

Rutin, a flavonoid with strong antioxidant properties, is known for its ability to mitigate oxidative stress. It is composed of quercetin and rutinose, although rutin's antioxidant activity is slightly less potent compared to quercetin due to the presence of a catechol group on the B-ring (Burda and Oleszek, 2001; Plumb *et al*., 1999; Mora *et al*., 1990; Kessler *et al*., 2010). Rutin quinone oxidised from rutin, which upregulates the Nrf2-mediated endogenous antioxidant response to enhance mitochondrial biogenesis (Chang *et al*., 2021; Kim *et al*., 2015). It similarly reduces oxidative stress and mitochondrial respiration in C_2C_{12} cells and attenuates inflammatory responses (Liu *et al*., 2019; Servais *et al*., 2007; Khor *et al*., 2014). A lectin isolated from *R. communis* is ricin A, possesses antitumour activity that was more toxic to tumour cells than to non-transformed cells, judged from the ED_{50} of the lectin towards tumour cells and non-transformed cells (Lin and Liu 1986).

R. communis exhibits cytotoxic effects on various mosquitoes, including stephensi and anopheles, with near-total mortality rates observed. The seed extract demonstrates lethal concentrations (16.84 g/m*L* for *Anopheles albopictus*, 11.64 g/ml for *Anopheles stephensi*, and 7.10 g/ml for *Culex quinquefasciatus*) (Mandal, 2010). The liquid, after deactivation, is used to treat redness and rashes caused by mosquito bites (Wachira *et al*., 2014).

7. Toxicity properties

The castor toxic component could be removed with water and precipitated using alcohol. However, it vanished its toxicity when heated, treated with strong acids, or subjected to repeated precipitation. The toxicity was due to an albumen-like substance (Dixson, 1887). The true nature of the toxicity, whether a protein or glycoside, wherever an enormously poisonous protein was moderately cleaned from Castor seed and named ricin (Stillmark, 1888). He also observed that ricin exhibited agglutinating activity on red blood cells, which was initially believed to be the cause of its toxicity. However, it was discovered that the agglutinin was separate from the toxin (Takahashi, 1962).

Ricin poisoning, although rare in humans, can be severe (Rauber and Heard, 1985). While Castor beans are allergenic, Castor oil, when processed and refined, is free from allergens due to its biological effects in higher organisms (Balint, 1974). The potent toxin of ricin inhibits protein synthesis, deactivates ribosomes, and induces apoptosis (Lewis, 2015). Ricin poisoning occurs when unprocessed seeds are consumed. Castor seed oil is used to make protein-rich cakes added to animal feed and soil (Robb, 1974; Balogun, 2004). The sternness of toxicity depends on the exposure way, with breath being more toxic (Balali-Mood and Moshiri, 2015). *R. communis* seeds contain poisons that disturb insects, livestock, and people, with ricin being an influential cytotoxin and RCA being a potent hemagglutinin, and ingesting masticated seeds can cause nausea, diarrhoea, and high morbidity (Mouser *et al*., 2007).

Animal studies show that gavage administration of ricin results in higher toxicity compared to oral administration. This is due to the terminal galactose residue in the carbohydrate structure, which competes for binding sites with glycoproteins, glycolipids, and other carbohydrates (Pincus *et al*., 2011). Ricin toxin is absorbed into the lymphatic system and blood within an hour, with toxicity affecting the liver and spleen (Balali-Mood and Moshiri, 2015). Faecal testing can detect ricin toxin up to two hours after consumption, with about 45% remaining unchanged (He *et al*., 2010). Intramuscular or subcutaneous injections result in ricin being excreted more in urine and less in faeces after one day (Audi *et al*., 2005).

8. Conclusion

The medicinal properties examined in this review underscore the significant therapeutic potential of *R. communis*. This plant plays a crucial role in medicine and has notable effects on cancer and ulcers, as well as on various microbes, bacteria, insects, and parasites that can affect health and immunity. The extensive literature indicates that *R. communis* is highly valuable for disease prevention and treatment, offering numerous alternative solutions across medical, agricultural, pharmaceutical, economic, and social domains. Its pharmacological activities support its traditional use as a medicinal plant and highlight its potential for developing viable synthetic drugs. The plant's abilities present promising prospects for the medicinal field and open opportunities for further research to discover new compounds effective against life-threatening diseases. However, it is significant to note that the seeds of *R. communis* are extremely toxic to both animals and humans, potentially causing severe health issues such as illness and central nervous system depression. Notwithstanding the toxicity of the seeds, the rest of the plant offers numerous benefits.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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Citation **P. Veeramani, K. Subrahmaniyan, C. Harisudan, R. Vijayan, PA, Saravanan, M. Velmurugan and V. Ravichandran (2024). Exploring the medicinal potential of Castor (*Ricinus communis* L.): A comprehensive review. Ann. Phytomed., 13(2):199-205. http://dx.doi.org/10.54085/ap.2024.13.2.19.**