Chapter 11

Physiological and Medicinal Properties of Castor Oil

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ABSTRACT

Castor plant is a member of the Euphorbiaceae family that spreads throughout the tropical regions of the world. Increasing demand of biodiesel and other medicinal and industrial applications for vegetable oil have increased processing and production of castor oil worldwide. Ricinoleic acid is the most important component of castor oil. It has a variety of effects on the gastrointestinal tract, including inhibition of water and electrolyte absorption, stimulation of water secretion into the intestinal lumen and depression of small bowel contractile activity. Conjugated fatty acids from castor oil have attracted much attention as a novel type of biologically, physiologically and pharmaceutically beneficial functional lipid. Castor oil is well–known for numerous health properties being the most important medicinal oil as a cleansing laxative and purgative. Moreover, root and leaves of castor plant is also useful as an ingredient of different prescriptions for nervous diseases. Recently, FDA has been approved castor oil as a direct food additive for using as a flavoring agent and/or adjuvant. On the obtained reports and versatile application of castor oil in pharmaceuticals, cosmetics, biodiesel, paint, soap and recently in food industry has led to much research being done on castor oil.

Keywords : Castor oil, Physiological, Medicinal, Physicochemical, Ricinoleic acid.

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1. INTRODUCTION

Castor plant (*Ricinus communis L.*) was probably one of the first crops cultivated by early man who used the oil extracted from the seeds for a wide variety of applications including lamp oil (Weiss, 2000). The castor plant (Fig. 1) is a perennial shrub mainly cultivated as an oilseed crop.

Fig. 1: Castor plant (Photo: A. Alirezalu, Tarbiat Modares University)

Castor plant is a member of the Euphorbiaceae family that spread throughout the tropical regions of the world. Early taxonomists tried to classify castor based on phenotypic differences into several subspecies but most botanists now believe all castor belong to the same species. Castor accessions show significant differences in branching, height, growth habit or colour and many of these phenotypic traits are simply inherited (Peat, 1928) and most accessions will readily intercross (Atsmon, 1989).

Castor plant is a coarse perennial, bearing large, alternate, palmately lobed leaves, flowers in huge terminal clusters (Fig. 2). The seeds are also varicolored in prickly or smooth three–membered capsules. In tropical climates the plant heights is commonly of 30 to 40 feet with stems three to six inches in diameter (Fig. 2). In temperate climates it

Fig. 2: (*Contd...*)

behaves as an annual plant, and heights of three to eight feet are more common. Here, a brief review of the most important physiological and medicinal properties of castor oil is given.

Fig. 2: Castor plant and seeds (Photo: A. Alirezalu, Tarbiat Modares University)

2. CASTOR BEAN SEED

There are different varieties of castor bean seeds that contain about 45–55% oil. After the extraction of castor oil, the remaining material is called the castor bean pomace, which has about 36% protein. The castor bean pomace contains also a highly toxic and heat sensitive ricin and albumin and a powerful allergen protein fraction which is more heat resistant (Polit and Sgarbieri, 1976).

The size and external markings of seeds from different cultivated varieties differ but average seeds are of an oval, laterally compressed form. The smaller, annual varieties yield small seeds and the tree forms yields large seeds. They have a shining, marble–grey and brown, thick, leathery outer coat, within which is a dark– coloured, thin, brittle coat (Fig. 3). A large, distinct, leafy embryo lies in the middle of a dense, oily tissue (Weiss, 2000).

Fig. 3: Variation in seeds of castor (*Ricinus communis L.*)

Moisture content, foreign material, leaves and cracked or broken beans are considered for improving of grading the castor seeds. Ideally, castor beans should be stored at less than 7% moisture due to reduction of post contamination during storage period.

3. CASTOR OIL

China, India and Brazil produced the majority of the world's castor oil in 2005 and 2006. Ethiopia, Thailand and Paraguay have also contributed relatively minor amounts for castor oil production. Total world production of castor seed was about 1 million ton/year during the year 2005 (Anonymous, 2005). The changes of castor oil prices and variability in production has made the international market for castor oil very unstable (Roetheli *et al*., 1991). Increasing demand of biodiesel and other medicinal and industrial applications for vegetable oil have increased processing and production of castor oil worldwide.

Recently, FDA has also been approved castor oil as a direct food additive for use as a flavoring agent and/ or adjuvant. The joint FAO/ WHO expert committee reported that castor oil is safe for use in food as a carrier solvent and/or release agent. The Committee has been established an acceptable daily intake (ADI) of 0–0.7 mg/kg/day (Anonymous, 1979; Burdock, 2006).

Castor seeds accumulate about 45–55% oil in the form of triacylglycerol (TAG) that serves as a major energy reserve for seed germination and seedling growth (Caupin, 1997). Castor is an important oilseed crop that produces an oil rich in ricinoleic acid (18:19c–12OH; about up to 90%), an unusual hydroxy fatty acid with conjugated unsaturation (Lobb, 1992). The hydroxy group imparts unique chemical and physical properties that make castor oil a vital industrial raw material for industrial applications (Caupin, 1997).

Due to the presence of the toxic ricin and potent allergenic 2S albumins in the seed, the general approach is to generate a safe castor crop by blocking expression of the ricin and 2S albumins in seed to produce ricinoleate from temperate oil seeds (Caupin, 1997). Castor oil is obtained from extracting or expressing the seed of a plant. The castor oil is not only a naturally–occurring resource; it is inexpensive and environmentally friendly. Castor oil is viscous, pale yellow non–volatile and non–drying oil with a bland taste and is sometimes used as a purgative. It has a slight characteristic odour while the crude oil tastes slightly acrid with a nauseating after–taste. Relative to other vegetable oils, it has a good shelf life and it does not turn rancid unless subjected to excessive heat. It is noteworthy that the quality of seed oil is hardly affected by the variation in good or poor seeds (Ogunniyi, 2006).

The castor oil and the chemical intermediate prepared are used in pharmacology and in the production of such industrial products as protective coatings, paints, synthetic, textiles, plasticizers, jet engine lubricants, hydraulic fluids, soaps and detergents, resins, waxes, cosmetic, anti–fungal products and a variety of valuable derived products (Caupin, 1997).

In spite of being one of the most important industrial oils in world market, the development of alternative castor oil profiles other than high ricinoleic acid is needed for covering a wider range of market niches, not only in the industrial but also in the food sector. A natural mutant of castor with seed oil characterized by high oleic acid and low ricinoleic acid content has been recently developed (Rojas–Barros *et al*., 2004). The recent isolation of a natural mutant of castor bean with high oleic acid and low ricinoleic acid concentration opens up new potential uses for castor oil.

3.1. Oil Extraction

Production and processing of castor oil consist of: collection of castor seeds when the capsules drying, open and discharging the seeds. The seeds are then cleaned, decorticated, cooked and dried prior to extraction. Cooking is done in order to coagulate protein, which is necessary to permit efficient extraction and to free the oil for efficient pressing. It is done at 80°C, under airtight conditions. After cooking, the material is dried at 100°C, to reach a moisture content of approximately 4% (Fellows, 1996; Ogunniyi, 2006).

The oil is obtained from the seeds by two principal methods: pressing and solvent extraction. The extraction of oil from castor seed is by one or a combination of mechanical pressing and solvent extraction. In mechanical pressing, the seeds are crushed and then adjusted to low moisture content by warming in a steam–jacketed vessel. Thereafter, the crushed seeds are loaded into hydraulic presses and they are pressed by mechanical means to extract oil. Extracted oil is filtered and collected in a settling tank. Material removed from the oil, called foot, is fed back into the stream of fresh material. Material discharged from the press, called cake, contains 8 to 10% oil. However, mechanical pressing will only remove about 40–50% of the oil present and the remaining it can be recovered by solvent extraction (Ogunniyi, 2006).

The oil from mechanical pressing has light colour and low free fatty acids (Kirk–Othmer, 1979). In the solvent extraction method, the crushed seeds are extracted with a solvent in a soxhlet or commercial extractor. Solvents used for extraction include heptane, hexane and petroleum ethers (Ogunniyi, 2006).

3.2. Oil Refining

If necessary from, it is usual to refine the crude oil obtained from solvent extraction and also mechanical pressing. The main aim of refining is to remove colloidal matter, free fatty acid, colouring matter and other undesirable constituents, making the oil more resistant to deterioration during storage. Main steps of vegetable oil refining includes: (A) removing colloidal matter by settling and filtration, (B) neutralizing the free fatty acid by NaOH, (C) removing coloured components by bleaching agents and (D) deodorizing by treatment with steam at low pressure and high temperature. The common method of refining used for edible oils is applicable to castor oil (Ogunniyi, 2006). Refining of castor oil can be attributed to the fact that some impurities and other components are removed during oil refining. Moreover, the pH value of the crude oil which is found to be 6.11 indicate that the oil is more acidic compared to 6.34 pH obtained for the refined oil. This may be as a result of degumming and neutralization carried out during the oil refining process (Akpan *et al*., 2006).

Table 1. Characteristics of castor oil grades

Properties	Cold pressed oil	Solvent–extracted oil	Dehydrated oil
Specific gravity	0.961–0.963	0.957–0.963	0.926–0.937
Acid value	3	10	6
Iodine value (Wij)	82–88	80–88	125–145
Saponification value	179–185	177–182	185–188

4. CASTOR OIL PROPERTIES

Castor oil physical and chemical properties can vary with the method of extraction. Cold–pressed castor oil has low acid value, low iodine value and a slightly higher saponification value than solvent–extracted oil and it is lighter in colour (Table 1) (Ogunniyi, 2006).

Physicochemical properties of castor oil are centered on high content of ricinoleic acid and the three points of functionality existing in the molecule. These include: (1) the carboxyl group which can provide a wide range of esterifications, (2) the single point of unsaturation which can be changed by hydrogenation or epoxidation or vulcanization, and (3) the hydroxyl group which can be acetylated or alkoxylated, may be removed by dehydration to increase the unsaturation of the compound to give semi–drying oil.

The hydroxyl position is very reactive and the molecule can be split at that point by high–temperature pyrolysis and by caustic fusion to yield useful products of shorter chain length. The presence of hydroxyl group on castor oil gives extra stability to the oil and its derivatives by preventing the formation of hydroperoxides. Results revealed that ricinoleic acid comprises over 85% of the fatty acid of castor oil. According to Ogunniyi (2006), other fatty acids present are linoleic (4.2%), oleic (3.0%), stearic (1%), palmitic (1%), dihydroxystearic acid (0.7%), linolenic acid (0.3%) and eicosanoic acid (0.3%). The oil is characterized by high viscosity although this is unusual for a natural vegetable oil. It can be linked mainly to hydrogen bonding of its hydroxyl groups. It is also soluble in alcohols in any proportion but it has only limited solubility in aliphatic petroleum solvents. Although castor oil is a unique naturally–occurring polyhydroxy compound, a limitation of the oil is the slight reduction of its hydroxyl value and acid value on storage; both values may change by about 10% if stored for about 90 days. The reduction of these values is due to the reaction between hydroxyl and carboxyl groups in the oil molecule to form estolides (Ogunniyi, 2006).

5. CONJUGATED FATTY ACID FROM CASTOR OIL AND ITS HEALTH ASPECTS

Castor oil has only one double bond in each fatty acid chain. Therefore, it is classified as non–drying oil. However, it can be dehydrated to give semi–drying or drying oil which is used extensively in paints and varnishes. As the name implies, dehydration involves the removal of water from the fatty acid portion of the oil. Being a polyhydroxy compound, its hydroxyl functionality can be reduced through dehydration or increased by interesterification with a polyhydric alcohol. The dehydration process is carried out at about 250°C and in the presence of catalysts (*e.g.*, concentrated sulphuric acid, activated earth) and under an inert atmosphere or vacuum. Under this condition of dehydration, the hydroxyl group and an adjacent hydrogen atom from the C–11 or C–13 position of the ricinoleic acid portion of the molecule is removed as water. This yields a mixture of two acids, each containing two double bonds but in one case, they are conjugated. The presence of an acid containing conjugated double bonds results in an oil resembling tung oil in some of its properties. Thus, castor oil, which is non–drying, can be treated and converted into a semi–drying or drying oil known as dehydrated castor oil (Ogunniyi, 2006). Production of conjugated linoleic acid (CLA) isomers from castor bean oil by Villeneuve *et al*. (2005) is studied.

Recently, CLA especially its isomers has attracted much attention because of its beneficial effects, including reduction of carcinogenesis, arteriosclerosis and body fats (Chin *et al*., 1992; Nicolosi *et al*., 1997). Conjugated fatty acids from castor oil have attracted much attention as a novel type of biologically and physiologically beneficial functional lipid.

The unique activities of CLA have been intensively studied and CLA expected to be an important potential material for pharmaceuticals and dietary supplements. According to results, CLA inhibits the initiation of mouse skin carcinogenesis (Ha *et al*., 1987; Pariza and Hargraves, 1985), mouse forestomach (Ha *et al*., 1990) and rat mammary tumorigenesis (Ip *et al*., 1991). Moreover, CLA has been reported to be effective in preventing the catabolic effects of immune stimulation (Cook *et al*., 1993; Miller *et al*., 1994) and to change the low–density lipoprotein/high–density lipoprotein cholesterol ratio in rabbits (Lee *et al*., 1994). In addition, the effects of CLA on human's body composition such as fat loss and lean gain are attracting increasing attention (West *et al*., 1998; Keim, 2003). In recent years, CLA, as a dietary supplement, is produced through chemical isomerization of linoleic acid, which results in the by–production of unexpected isomers. However, recent studies have revealed that each isomer can have different effects on metabolism and cell functions, and acts through different cell signaling pathways (Wahle *et al*., 2004).

Today, complex mixtures of isomers which are produced through alkaline isomerization of linoleic acid are used for production CLA commercial isomers (Ando *et al*., 2004). It is appeared that in production of CLA for pharmacological or nutraceutical purposes, an isomer–selective and safe process is required. The introduction of biological reactions to CLA production will solve these problems. As well known, only the free form of ricinoleic acid can be acted as a substrate for CLA production by lactic acid bacteria, *e.g*., the triacylglycerol and ester of ricinoleic acid did not. Ando *et al*. (2004) studied conjugated linoleic acid production from castor oil by *Lactobacillus plantarum* JCM 1551. They reported that in the presence of lipase, castor oil became an effective substrate for CLA production by the bacterium.

6. MEDICINAL ASPECTS

Castor seeds are well–known for numerous health properties which is most important medicinal oil as a cleansing laxative and purgative. The pharmacodynamics of the constituent, derivative elements and versatile application of the castor bean is of great interest and still the object of very detailed research (Scarpa and Guerci, 1982; Burdock *et al*., 2006).

Historical documents reveal that castor oil was used medicinally in Egypt, India, and China as well as Iran, Africa, Greece and Rome. Traditional medicines derived mainly from plants play major role in the management of diseases. The use of different parts of castor plant for the treatment of different diseases in traditional or folk remedies has been searched in worldwide (Scarpa and Guerci, 1982).

Ricinoleic acid, the major fatty acid present in castor oil, has a variety of effects on the gastrointestinal tract, including inhibition of water and electrolyte absorption (Donowitz, 1979), Stimulation of water secretion into the intestinal lumen (Ammon and Phillips, 1974) and depression of small bowel contractile activity (Ammon *et al.*, 1974).

The cathartic action of orally ingested castor oil traditionally has been attributed to irritant or stimulatory effects of ricinoleic acid on the gastrointestinal smooth muscle; the ricinoleic acid is liberated in the small intestine by the action of pancreatic lipase (Stewart and Bass, 1976). Moreover, absorption of ricinoleic acid occurs incompletely; substantial quantities remain in the gastrointestinal tract after oral administration (Stewart and Bass, 1976). Since diet palatability are not affected by the presence of castor oil, the poor absorption of ricinoleic acid and its potential to reduce absorption of other fatty acids could be responsible for the absence of more substantial body weight gains by rats and mice consuming castor oil containing diets.

Stimulant laxatives generally function by increasing accumulation of electrolytes and water, as well as by increasing colonic motility in the colonic lumen. The recommended dose of castor oil for cathartic in adult humans is 15–60 ml of the oil. However, as little as 4 ml may produce laxative effects. Evacuation of the bowel with 'one or two copious, semi–fluid stools', are cathartic doses of castor oil that will cause usually within 1–6 hours following ingestion (Gaginella and Phillips, 1975; Barbezat, 1983; Schiller, 2001). In general, laxative or purgative effects are evident at castor oil doses of 10 g or higher (Watson *et al.*, 1963; CIR, 1988). The proposed mechanism of castor oil action are included intestine remains elusive, inhibition of Na^{+}/K^{+}–ATPase, stimulation of prostaglandins, activation of adenylate cyclase and biosynthesis of platelet activating factor (Izzo, 1996; Gaginella *et al.*, 1998). Results from studies in rats showed that nitric oxide may play an important role in the 'diarrhoea effect' of castor oil (Capasso *et al.*, 1994).

Castor oil is regulated by the United State food and drug administration as a laxative drug and there have been reports of investigations of polymerized ricinoleate so potential inert matrix for sustained drug delivery (Teomim *et al.*, 1999).

Purgative doses in rodents are 40 fold higher than the noted in humans. The reason for this apparent discrepancy is almost unclear, but maybe relate to differing gastrointestinal effects of undiluted castor oil compared to castor oil admixed with the diet. For example, castor oil has been noted to be an adulterant of cooking oil in India (Burdock *et al.*, 2006).

Castor oil has a long history of use as a folk remedy, primarily as a purgative, but is now predominantly employed as a cream base and an emollient applied to the skin. Topical dermatological uses include elimination of surface genital warts, cysts, bunions, corns and eye formulations to relieve discomfort from mechanical injury to the cornea (Briggs and Briggs, 1996). This oil is used also for the treatment of skin infections and it is reported to have wound healing properties. Ricinoleic acid inhibits the growth of many bacteria, viruses, molds and yeasts.

Some studies suggest that castor oil can be effective on bacterial (*Streptococcus mutans*) growth and/or plaque formation on artificial dental enamel (Merkle and Higuchi, 1980). Pre–treatment of the artificial dental surfaces with solutions of sodium ricinoleate inhibited bacterial growth and material deposition for approximately 6–8 h after treatment. Other reports showed that castor oil could only inhibit of bacteria proliferation in suspension and not in intact plaque (Mordenti *et al*., 1982). However, Mordenti *et al*. (1982) also reported that ricinoleate treatment has significant effect on decrease of plaque acid production and probably retardation of gum and tooth disease processes. Jombo and Enenebeaku (2008) has been reported that extract and oil from fermented castor seed are antibacterial effects against *Klebsiella pneumoniae, Escherichia coli, Proteus vulgaris, and Staphylococcus aureus* on agar medium. They described also those active antibacterial ingredients in castor oil should be identified while its medicinal value to humans properly investigated.

Shokeen *et al*. (2008) reported that root of this plant is also useful as an ingredient of different prescriptions for nervous diseases and rheumatic affections such as pleurodynia, lumbago and sciatica. In the traditional medicine of Indian, the leaf, root and seed oil of castor plant have been used for the treatment of inflammation and liver disorders (Kirtikar and Basu, 1991), as laxative (Capasso *et al*., 1994), hypoglycemic (Dhar *et al*., 1968), hepatoprotective (Yanfg *et al*., 1987; Visen *et al*., 1992), diuretic (Abraham *et al*., 1986) and antibacterial (Verpoorte and Dihal, 1987). Castor oil has been shown to influence several metabolic and histochemical activities in the human body. According to Fakhri (1989), its extracts were found to cause proportional increase in mean wheal diameter in skin tests in castor bean allergic workers. Ilavarasan *et al*. (2006) also showed that castor oil has anti–inflammatory and free radical scavenging activity. There are many research on antifertility properties have well been proven among humans (Isichei *et al.*, 2000; Das *et al.*, 2000; Sandhya-kumary *et al.*, 2003). Roots and aerial parts have also been shown to be useful in the treatment of diabetes (Pullaiah and Naidu, 2003).

6.1. Toxicological Studies

The leaves, seeds and extracted oil of the plant contain the toxic protein ricin, highly allergenic storage proteins and the alkaloid ricinine which can inhibit protein synthesis in body (Khvostova, 1986). Ricin is a 66 kilodalton (KDa) glycoprotein cytotoxin present in the seeds and oil extracted from castor plant. The presence of ricin in the high protein meal of castor remaining after oil extraction can be affected on its value as an animal feed (Roetheli *et al*., 1991).

Ricinine is a bitter white crystalline alkaloid extracted from the seeds of the castor–oil plant. It appears to be a naturally occurring insecticide in castor bean which has a relatively low human toxicity. The researchers mentioned a negative correlation between the concentration of ricinine and oil in castor seeds. It was also reported that environmental factors such as high temperature enhance the concentration of ricinine during seed maturation (Auld *et al*., 2009).

A decrease in ileal water absorption can be concluded with ricinoleic acid in intestinal elution resulted in at intraluminal ricinoleate concentrations of 0.5 mm or higher. It has been reported that at 2.0 mm or higher, there was net water secretion in the jejunum (Anonymous, 1979, 1988). The absorption rate of ricinoleate was approximately half that of oleic acid.

As is well approved, the fresh castor seeds are very poisonous for humans. There is no agreement about the lethal rate of castor seed and it can be varying in humans, for example, from the possible previous protracted ingestion of oil (Kingsbury, 1964). If castor seed is accidentally ingested, it can lead to abdominal pain, diarrhea and vomiting. Therefore, as little as 1 mg of ricin can kill an adult (Burdock *et al*., 2006).

The symptoms of poisoning are nausea, diarrhea, fever, cyanosis, vomiting, perspiration (Watt and Breyer–Brandwijk, 1962; Kingsbury, 1964; Scarpa and Guerc, 1982). Oliver, (1960) revealed that oil injected in high doses can induce vasodilatation and lymphangitis. The pulp of the seeds contains allergens (glycoproteins) which in particularly sensitive persons can promote strong allergic reactions such as coryza, conjunctivitis, dermatitis, eczema and bronchial asthma (Watt and Breyer–Brandwijk, 1962; Scarpa and Guerc, 1982).

6.2. Absorption

Results revealed that castor oil absorption is approximately low. According to Burdock *et al*. (2006), castor oil is hydrolyzed in the small intestine by pancreatic lipases to yield glycerol and ricinoleic acid after orally ingested. As well known, ricinoleic acid like other anionic surfactants, reduces net absorption of fluid and electrolytes, stimulates intestinal peristalsis, and increases intestinal motility (Brunton, 1990). Therefore, gross morphological damage to the intestinal mucosa arising due to the potency of this surfactant action may explain, in part, the changed permeability and mobility caused by castor oil (Cline *et al*., 1976).

7. CONCLUSION

There is no doubt that castor oil is a valuable plant. This is evident from the researches that much has been carried out about the oil and its component. In the present chapter, the physicochemical, physiological, medicinal and toxicological properties of castor oil have been outlined. Generally, it is considered that non–edible vegetable oils should be exploited as far as it is possible so that edible oils can be used for human's consumption. This is especially very important in developing countries where food safety and security poses a challenge. Safety data especially to castor oil/ricinoleic acid are limited. However, ricinoleic acid constitutes up to 90% of the fatty acid content of castor oil. Therefore, available results on castor oil component are relevant and have been discussed. These data indicate bolus doses of 10–15 g or higher of undiluted castor oil to have pharmacological effects on the human gastrointestinal tract. Castor plant is one of the most important medicinal plants which are used in pharmaceuticals, cosmetics and hygienic industries in developed countries. It is approved that conjugated fatty acids from castor oil have attracted much attention as a novel type of biologically and physiologically beneficial functional lipid. The versatile application of castor oil in pharmaceuticals, different industries and recently in food industry has led to much research being done on castor oil.

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