



SUDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY
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Physico-Chemical Characteristics of Castor Oil

(Ricinus communis L)

الخواص الفيزيوكيميائية لزيت الخروع

**A dissertation Submitted to Sudan University of Science and
Technology in partial fulfillment of the degree of B.Sc. (Honours) in
Food Science and Technology**

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الآية

قال تعالى:

(وَعَدَدَهُ مَفَاتِحُ الْغَيْبِ لَا يَعْلَمُهَا إِلَّا هُوَ وَيَعْلَمُ مَا فِي الْبُرِّ وَالْبَحْرِ وَمَا
تَسْقُطُ مِنْ وَرَقَةٍ إِلَّا يَعْلَمُهَا وَلَا حَبَّةٌ فِي ظِلْمَاتِ الْأَرْضِ وَلَا رَطْبٌ وَلَا
يَابِسٌ إِلَّا فِي كِتَابٍ مُبِينٍ 59)

صدق الله العظيم

سوره الانعام الآية (59)

Dedication

To our mothers.....

....To our fathers

To our families.....

.... And friends

And teachers.....

With respects.....

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Prayers and thanks to Allah, who gave us good health and support to accomplish this study.

We are grateful thanks to our supervisor **Dr. Ebrahim Alfaig Alnoor** who was cooperated with us during this study, also for his unlimited assistance and Knowledge.

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ABSTRACT

This study was aimed to analyze castor seed and determine physicochemical characteristic of the castor oil.

The seeds were cleaned and crushed for proximate analysis which include oil, protein, moisture, ash, crude fiber, and total carbohydrate and the obtained results were 46.2, 24.2, 7.25, 3.12, 2.18, and 19.14, respectively.

The oil was extracted by solvents extraction, the physical properties of oil refractive index , moisture content , specific gravity and color were tested And the result were 1.4722 , 0.16 , 0.9589, Respectively, And the result colour were yellow 0.9 red 0.56.

Also the chemical properties of the castor oil which are peroxide value, free fatty acids, saponification value, and iodine value were tested the results were 9.22, 0.5, 159.2, 83.7, respectively.

Castor seed oil contain a good amount of oil with good physical and chemical characteristics. It could be one of the promising source of medicinal oil in Sudan.

المُلخَص

هذه الدراسة هدفت لتحليل بذور الخروع وتحديد الخواص الكيميائية و الفيزوكيميائية لزيت حبوب الخروع.

تم تنظيف الحبوب وكسرها لإجراء التحليل الكيميائي الذي يتضمن محتوى الزيت ، محتوى البروتين ، محتوى الرطوبة ، الرماد الكلي ، الألياف الكلية و الكربوهيدرات . النتائج المتحصل عليها كانت كالتالي 46.2 ، 24.2 ، 7.25 ، 3.12 ، 2.18 ، 19.14 على التوالي.

تم استخلاص الزيت عن طريق المذيبات ، حيث كانت الخواص الفيزيائية كالتالي معامل الانكسار ، رطوبة الزيت ، والكثافة النوعية وتم اجرائها والنتائج المتحصل عليها كالتالي 1.4722 ، 0.16 ، 0.9589 على التوالي ، وكذلك نتائج اللون و كانت النتائج اصفر 0.9 ، احمر 0.56. ايضاً الخواص الكيميائية قيمة البيروكسايد ، الاحماص الدهنية الحرة ، قيمة التصبن والقيمة اليودية كانت نتائجها كالتالي 9.22 ، 0.5 ، 159.2 ، 83.7 على التوالي.

حبوب الخروع تحتوي على نسبة جيدة من الزيت بخواص فيزيائية وكيميائية جيدة ويمكن ان يكون مصدر واعد للزيوت الطبية في السودان.

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CHAPTER ONE

1. INTRODUCTION

Castor oil is a vegetable oil obtained by pressing the seeds of the castor oil plant (*Ricinus communis*). (Weiss *et al.*, 2000). The common name "castor oil", from which the plant gets its name, probably comes from its use as a replacement for castoreum, a perfume base made from the dried perineal glands of the beaver (*castor* in Latin) (Ogunniyi, 2006).

Castor oil is one of the most versatile vegetable oils obtained from the castor bean. Its unique chemical composition makes it useful in a large number of applications. It has found usage in many chemical industries. It is a raw material for paints, coatings, inks, lubricants and a wide variety of other products (Ogunniyi, 2006). It is a triglyceride in which approximately ninety percent of fatty acid chains are ricinoleic acid. Castor oil is fast becoming one of the most sought after plant oils, owing to its rich properties and variety of end-uses in lubricant, pharmaceutical and cosmetic preparations.

Castor oil was one of the world's first medicinal oil because it naturally contains a unique and beneficial mixture of triglycerides or fatty acids (Caupin, 1997). The presence of unusual hydroxy fatty acid ricinoleate (ricinoleic acid) makes this oil very unique by imparting very high density to the oil. Castor oil is a colourless to very pale yellow liquid with mild or no odour or taste. Various attributes of castor oil like unsaturated bonds, low melting point (5°C), very low solidification point (-12°C to -18°C), high boiling point (313°C), high density (961 kg/m³), with the highest and most stable viscosity (9.5–10.0 Pa s⁻¹) make it industrially useful than any other vegetable oil (Miller *et al.*, 2009). Ricinoleic acid (12-hydroxy-9-cis octadecenoic acid) a major component of castor oil is an unsaturated omega 9-fatty acid that naturally occurs in mature castor seeds. Ricinoleic acid is abundant in castor oil (90%) but many common vegetable oils and oil seeds contain lower amounts of this particular fatty acid; its content amounts to 0.27% in cottonseed oil and 0.03% in soybean oil (Yamamoto *et al.*, 2008). Ricinoleic acid was discovered in 1848 (Miller *et al.*, 2009).

The seed oils of *Jatropha gossypifolia* and *Hevea brasiliensis* were also found to contain high content of ricinoleic acid (about 18%). Apart from ricinoleic acid, castor oil also contains saturated fatty acids like palmitic acid and stearic acid (**Weiss *et al.*, 2000**).

Castor oil is a colorless to very pale yellow liquid with a distinct taste and odor once first ingested (**Duke, 1983**).

Castor oil and its derivatives are used in the manufacturing of soaps, lubricants, hydraulic and brake fluids, paints, dyes, coatings, inks, cold resistant plastics, waxes and polishes, nylon, pharmaceuticals and perfumes. (**Mutlu and Meier, 2010**).

Objectives of the study

Since the castor oil is widely used in the industry including the pharmaceutical uses, the main objective of this study was to compare the physicochemical properties of this oil with the vegetables oils used in food.

Specific objectives include

1. To determine the chemical composition of castor seed.
2. To determine physicochemical characteristics of castor oil.

CHAPTER TWO

2. LITREATURE REVIEW

2.1 Introduction

The castor oil plant (*Ricinus communis L*), is a plant species of the family *Euphorbiaceae* and the sole member of the genus *Ricinus* and of the subtribe *Ricininae*. (Wikipedia, 2008). The castor plant is native to the Ethiopian region of east Africa

Castor oil is a vegetable oil obtained by pressing the seeds of the castor oil plant (Weiss *et al.*, 2000).The common name "castor oil", from which the plant gets its name, probably comes from its use as a replacement for castoreum, a perfume base made from the dried perineal glands of the beaver (*castor* in Latin) (Ogunniyi, 2006).

2.2 Botanical classification:

Kingdom: Plantae -Plants

Sub kingdom: Tracheobionta – (Vascular plants)

Super division: Spermatophyta – (Seed plants)

Division: Magnoliophyta – (Flowering plants)

Class: Magnoliopsida – (Dicotyledons)

Subclass: Rosidae

Order: Euphorbiales

Family: Euphorbiaceae – (Spurge family)

Genus: *Ricinus L.* (*Ricinus*)

Species: *Ricinus communis Linn*

Vernacular names

India	:	Tamil	- Amanakku
		Hindi	- Arandi
		Sanskrit	- Eranda
		Kannada	- Haralenne
		Marathi	- Erand
		Telugu	- Aavadam
		Malayalam	- Aavanakku
	Bangla	- Erando	
Brazil	:	Carrapateriro, mamona	
Ethiopia	:	Gulo	
Korean	:	Bibeo	
Mexico	:	Higuerilla	
Arabic name:		Zaytul khirwa	

2.3 Geographical Distribution

Probably native to Africa, Castor bean has been introduced and is cultivated in many tropical and subtropical areas of the world, frequently appearing spontaneously. It is found throughout India, cultivated and found wild up to 2400 meters (**wealth of India, 2008**). It has escaped cultivation and become naturalized as a weed almost everywhere in the world that has a tropical or subtropical climate (**Duke, 1983**).

The essential constituent of the seeds of the *Ricinus communis* is castor oil. Global castor seed production is around 1 million tons per year. Leading producing areas are India (with over 60% of the global yield), China, Brazil, Eastern Africa and Ethiopia. It is wide spread throughout tropical regions (**Duke, 1983**).

2.4 Description

Although monotypic, the castor oil plant can vary greatly in its growth habits and appearance depending upon the climatic, Geographical conditions. It is a fast- growing, suckering perennial shrub which can reach the size of a small tree (around 12 meters /39feet).

Leaves - The glossy leaf is 15-45 centimeters in length, long - stalked, alternate and palmate with 5-12 deep lobes with coarsely toothed segments. Their colour varies from dark green, sometimes with a reddish tinge, to dark reddish purple or bronze. The stems (and the spherical, spiny seed pods) also vary in pigmentation.

Flowers - The flowers borne in terminal panicle - like inflorescences of green monoecious flowers without petals. The male flowers are yellowish- green with prominent creamy stamens and are carried in ovoid spikes up to 15 centimeters long; the female flowers, born at the tips of the spikes, have prominent red stigmas. (Zhang *et al.*, 2013).

2.5 Castor bean toxicity

It grows in tropical and warm temperate regions throughout the world and is becoming an abundant weed in the southwestern United States. *Ricinus communis* is a perennial, erect, branched, herb, typically less than 2 meters in height. (Morton, 1977) The beans are oblong and light brown, mottled with dark brown spots. The seed is only toxic if the outer shell is broken or chewed. Ricin is contained in the bean pulp following the separation of the oil from the beans. No ricin is thought to remain in the oil, and it is inactivated during extraction if done under heated conditions.

Ingested castor beans are generally toxic only if the ricin is released through mastication. Reports on the ricin content of castor beans vary, but it is probably in the range of 1% to 5% (Bradberry *et al.*, 2003). Purified ricin is a white powder that is soluble in water and stable over a wide pH range (Cope *et al.*, 1945).

It is a protein toxin (toxalbumin) (**Parker, and Ramachandran, 1996**). It is a glycoprotein lectin composed of 2 chains, A and B, linked by a disulfide bond (**Ishiguro et al., 1976**). The B chain is a lectin and binds to galactose-containing glycoproteins and glycolipids expressed on the surface of cells, facilitating the entry of ricin into the cytosol (**Sandvig, and van Deurs, 2000**). The A chain inhibits protein synthesis by irreversibly inactivating eukaryotic ribosomes through removal of a single adenine residue from the 28S ribosomal RNA loop contained within the 60S subunit. This process prevents chain elongation of polypeptides and leads to cell death (**Olsnes, 2004**).

Toxicity results from the inhibition of protein synthesis, but other mechanisms are noted including apoptosis pathways, direct cell membrane damage, alteration of membrane structure and function, and release of cytokine inflammatory mediators (**Day et al., 2002**).

The castor bean plant also contains another glycoprotein lectin, the *Ricin communis agglutinin*, which, unlike ricin, is not directly cytotoxic, but does have affinity for the red blood cell, leading to agglutination and subsequent haemolysis. *Ricin communis agglutinin* is not significantly absorbed from the gut and causes clinically significant haemolysis only after intravenous administration. (**Hegde and Podder, 1992**).

There are no literature reports of poisoning from ingesting purified ricin. All clinical reports with regard to poisoning refer to castor bean ingestion. Documented mild to lethal clinical symptoms may result from ingesting one half to 30 beans. (**Challoner and McCarron, 1990**) Two castor oil beans were the minimum number found to be associated with death. (**Rauber and Heard, 1985**).

2.6 Symptoms of castor bean consumption

Symptom onset after ingestion is usually within 4 to 6 hours but may be as late as 10 hours. Initial symptoms are nonspecific and may include colicky abdominal pain, vomiting, diarrhoea, heartburn, and oropharyngeal pain. Haematemesis and melena are reported less commonly (**Malizia, et al., 1977**). Fluid losses may lead to electrolyte imbalances, dehydration, hypotension, and circulatory collapse (**Koch and Caplan, 1942**). Laboratory abnormalities may

include leukocytosis, elevated transaminases and creatinine kinase, hyperbilirubinemia, renal insufficiency, and anaemia, Information on allergic reactions to ricin is primarily from persons working in or living near castor bean processing plants, Allergy patch testing reveals an (IgE) (immunoglobulin E) are antibodies produced by immune system-mediated inflammatory reaction to ricin although other allergens may be present in the castor bean dust (**Metz and Bocher, 2001**).

Generally, independent of the uptake route (oral or parenteral injection) the symptoms induced by ricin were quite similar, and the severity of symptoms increases with the amount of toxin incorporated. Symptoms arose after 3 to 20 h after ingestion or injection. Physical symptoms were abdominal pain, emesis, and diarrhea with or without blood, muscular pain, cramps in the limbs, circulatory collapse, dyspnoea and dehydration. Muscular pain and circulatory collapse were more commonly observed with injected ricin, as well as pain at the injection site. Biochemical analyses often revealed increase in white blood cells, blood urea nitrogen (BUN), aspartate aminotransferase (AST) and alanine aminotransferase (ALT), indicating dysfunction of liver and kidneys. Autopsy in fatal cases showed hemorrhagic necrosis in intestines and heart and oedema in lungs (**Poli et al., 2007**).

A comprehensive review from a Sri Lankan hospital records local child poisoning cases between 1984 and 2001, reporting 46 cases of accidental *Ricinus communis* intoxications (and further cases caused by intoxication with *Abrus precatorius*, *Jatropha curcas*, *Manihot utilissima*, and others), all of them not fatal; all patients experienced vomiting and some dehydration and abdominal pain (**Worbs et al., 2011**).

A very recent review on the American Association of Poison Control Centers reports 45 fatalities out of more than 2 million plant poisonings between 1983 and 2009, of these, only one fatal case was attributed to *Ricinus communis*, while the majority (16 deaths) was caused by *Datura* and *Cicuta* species (**Ogunniyi, 2006**).

2.7 Castor beans uses

Castor beans have been used traditionally by women in many countries for birth control (**Salhab and Issa, 1997**). The use of castor seed oil in India has been documented since 2000 BC for use in lamps and in local medicine as a laxative, purgative, and cathartic in Unani, Ayurvedic and other ethno medical systems. Castor seed and urine have also been used in China for centuries, mainly prescribed in local medicine for internal use or use in dressings (**Wikipedia, 2008**).

Castor beans have been found in ancient Egyptian tombs dating back to 4000 B.C. According to the *Ebers Papyrus*, an Egyptian medical text from 1500 BC, Egyptian doctors used castor oil to protect the eyes from irritation. The oil from the bean was used thousands of years ago in facial oils and in wick lamps for lighting (**Ogunniyi, 2006**). In Oman, this is the first patient we have received in the last 10 years who used castor beans as a traditional treatment for a cough.

2.8 Castor cake usages

Castor cake is known as a high source of protein and has numerous usages.

The castor bean contains nitrogen (up to 5%) phosphorus (2%) and potassium (around 1%) which makes it suitable as a fertilizer as an organic manure. (**Worbs et al., 2011; Gubta et al., 2004**) it has found its utility as organic fertilizer in various crops e.g. sugarcane, grapes, cotton, rice, wheat, potato, tomato, tea, coffee, horticulture, lawns.

The castor cake is also used as a fungicide and in plant-parasitic nematode control (**Archana and Prasad, 2014**).

The castor cake has also been referenced for use as a filler to obtain composite materials in various polymers, such as polystyrene, low density polyethylene, polypropylene, poly (hydroxyalkanoates), etc. The inclusion of castor cake is reported to elevate the mechanical properties and biodegradable characteristics in low density polyethylene (**Gustavo et al., 2014; Guimarães et al., 2006**).

The protein isolated from the castor cake also has potential to serve as a premium raw material to manufacture surfactants, fibers, plastics, etc.

There are also reports that, after a proper detoxification, in a mix with other feed materials at 10-20% level, it has been used as a supplement feed, particularly for sheep, cattle, dogs chicken, fish, etc (**Robb *et al.*, 1974 ;Gubta *et al.*, 2004**). Infact, the detoxified castor cake presents a better animal feed owing to its high protein value.

The calorific value of deoiled castor cake is around 4000kcal per kg and it is useful as a substitute of fossil fuels e.g. coal for generating energy. It is a clean fuel and generates very little ash.

2.9 Technologies to destroy the ricin in the Castor cake

Due to the it's high protein content and multifarious applications, the castor cake remains the center of research among the scientific community. The prime limiting factor in restricting the use of castor cake and even the cultivation of castor plant is the occurrence of toxic ricin.

Ricin has several ways for its inactivation. Following are the summary of options developed for the detoxification of the castor cake.

Heating the castor cake in autoclave for 1 h in steam at 15 psi can destroy the ricin and remove the allergen (**Jenkins, 1963**).

Heating the castor cake in autoclave at 125oC for 15 min, completely eliminates the ricin with minimum changes in the cake (**kodras *et al.*, 1949**).

Ethanol has also been used to detoxify the castor cake. The repeated extraction of castor cake with ethanol has resulted in the detoxification of castor cake (**Rao, 1970**).

The alkali treatment is one of the most efficient treatments found to inactivate the ricin in castor cake. The use of alkali reagents such as Ca(OH)₂ (0.5%), NaHCO₃ (0.5%) and autoclaving reduces ricin to non-detectable limits (**Srinivas and Nagaraj ,1999**).

2.10 Recent detoxification techniques

The effective methods include autoclaving, boiling for 2 h and alkali treatment with sodium or calcium hydroxide (**Anandan *et al.*, 2005**).

In another method, the reactive seed crushing using alkaline methanol is reported as an efficient way to detoxify the castor cake. The seeds were flattened and treated with alkaline methanol to get esters directly and the amount of ricin in the remaining cake was less than 0.01% as analyzed by Immuno affinity and liquid chromatography-tandem mass spectrometry (IALCTMS) method (**Dubois *et al.*, 2013**).

According to a recent study, where the relation of castor cake detoxification in reference to the pH has been studied, it is said that the cytotoxic activity of ricin when heated under basic condition lowers dramatically (The measured half-life for ricin added to yogurt fruit drink at 90°C was only 0.24 ± 0.04 min at pH 6.5 but it increased 30-fold to 7.3 ± 1.1 min when tested at pH 4.5) (**Zhang *et al.*, 2013**). It is further mentioned that, the half-life for the ricin inactivation at 75°C is high in lactose-rich foods (**Zhang *et al.*, 2013**).

2.11 Castor seeds contain a powerful allergen: CB1A

Castor bean allergen-1 (CB1A) is the principal allergen of the castor bean. It is virtually non-toxic, does not cause death though may cause allergic reactions. It is a polysaccharidic protein factor. While the ricin is heat-labile, the CB1A is a very stable allergen and a point of concern for the castor bean industry (**Kim, 2006**). CB1A is among one of the most heat-stable proteins found. In most normal heating conditions, the CB1A is known to retain its native antigenic structure, immune precipitating and allergenic properties (**Layton *et al.*, 1961**).

In general, CB1A is a group of low molecular weight micro heterogeneous proteins (**Spies *et al.*, 1964**). It consist of low molecular weight albumin storage proteins from the castor endosperm (**Youle and Huang, 1978**).

The CB1A component compares physiochemically with the 2S storage protein of seeds.

The amino acid composition of CB1A consists of relatively high arginine, cysteine and glutamic acid content. It doesn't contain tryptophan (**Coulson *et al.*,**

1950). The CB1A is considered as a nontoxic fraction (**Jenknis 1963**). however, it has capacity to sensitize the people who have hypersensitivity (**Brandle *et al.*, 1983; Yoshikawa *et al.*, 1986**).

The potent allergen CB1A in castor seed and cake has been a matter of concern and as a result deallergenation of castor cake has been proposed by many researchers (**Jenknis 1963**). The work carried out by the Food Protein Research and Development Center, concluded that in the order of preference, sodium hydroxide-sodium hypochlorite mixture, calcium hydroxide, sodium bicarbonate, sodium hydroxide and sodium hypochlorite are very effective in destroying CB-1A when used in combination with proper heat treatment (**Weiss *et al.*, 2000**).

Further, it was concluded that the detoxified and deallergenated castor meal is safe for use as animal feeds as demonstrated by chick and swine feeding studies.

2.12 Medicinal use of castor oil

The castor oil plant *Ricinus communis*, also known as Palma(e) Christi or wonder tree, is a perennial scrub of the spurge family Euphorbiaceae. *Ricinus communis* is probably native to eastern Africa and was used in ancient Egypt and by the Romans and Greeks (**Caupin, 1997**). Nowadays the plant grows wild in many tropical and subtropical regions and is found as an ornamental plant virtually all around the world.

A companion to the British Pharmacopoeia 3rd edition, published in 1866 describes castor oil properties as "a mild and speedy cathartic. Particularly applicable to constipation from indurate faeces, or after swallowing acrid substances, or on the accumulation of acrid secretions. Used in diseases attended with irritation or inflammation of the bowels, as colic, diarrhoea, dysentery, and enteritis". According to the author, the dose administered corresponds 1/2 to 1 oz. for adults, 1 to 3 drms. (Meaning ml) for infants. The oil is administered floating on some aromatic water, or mixed in a cup of hot sweetened coffee (**Squire, 1866**).

According to Potter's Herbal Cyclopaedia, castor oil has been used since ancient times as a laxative and purgative. The authors do not recommend regular use and for long periods because the oil is believed to cause histological abnormalities in the intestine. Castor oil is reported also as an emollient and soothing to the skin and eye and is an ingredient of many cosmetic and ophthalmic

preparations. The dosage indicated for oral intake corresponds to 5-20 ml (**Williamson, 2003**).

Some old medical journals described castor oil as a very potent agent producing catharsis by irritation. Because of this property, the author recommended not to use the oil for the treatment of functional constipation (**McKenna, 1964**). Other journal described the use of castor oil for the induction of labor (**Holmes, 1934**).

WHO monograph describes for *Oleum Ricini* traditional medicinal uses as emenagogue, to induce labor, for the treatment of burns, haemorrhoids, pneumonia, rheumatism and sprains and well-established medicinal uses as short-term treatment (3-5 days) for acute constipation when other dietary methods of bulk-forming laxatives have not provided adequate relief. As a cathartic for use in bowel evaluation prior to surgery or for external use for topical dermatoses and dermatitis. The dose indicated as laxative is 1-10 ml, as single daily dose, while for induction of labour: 4-60 ml as maximum single dose, under medical supervision is indicated (**WHO, 2009**).

The Extra Pharmacopoeia (**Ogunniyi, 2006**) indicates that castor oil is a purgative, acting on the small intestines, the latency until the effect varies between 2 and 8 hours. It is also given at a dose of 15 ml to empty the bowel before X-ray examination. Externally it is also described as an emollient, used in preparations such as Zinc and castor oil ointment (**Reynolds and Martindale, 1982**).

PDR for Herbal Medicine also included castor oil as a drug used internally in folk medicine for acute constipation, in intestinal inflammation, for removal of worms, and as a form of birth control. The oil is used externally for inflammatory skin disorders, furuncles, carbuncles, abscesses, inflammation of the middle ear and headaches (poultice). Recommended oral daily dose for acute constipation or as laxative against worms is, at least 10 grams divided into 1 or 5 doses, while for external use, a paste made of grounded seeds is applied to the affected skin areas twice daily, up to 15 days (**Gruenwald et al., 2004**).

The medicinal use of castor oil (virgin and refined) is documented in several medicinal handbooks throughout a period of at least 30 years, including at least 15 years within the EU.

Castor oil is authorised in the European Union for cleaning of the bowels since 1959 and as a laxative since 1968. Based on this longstanding use and

available clinical data just one well-established use indication is proposed in the monograph.

2.13 Industrial uses of castor oil

Although castor oil is not edible it is more versatile than other vegetable oils as it is widely used as starting material for many industrial chemical products because of its unique structure. It is one of those vegetable oils that has found usage in many chemical industries. It is raw material of paints, coatings, inks, lubricants, and a wide variety of other products. **(Ogunniyi et al., 1996).**

Because of its hydroxyl functionality, the oil is suitable for use in isocyanate reaction to make poly-urethane elastomers **(Quipeng et al., 1990)**, polyurethane millable **(Kirk-othmer, 1979; Yeganeh and Mehdi-zadeh, 2004)**, castables **(Heiss, 1960; Lyon and Garret, 1973)**, adhesives and coatings **(Yeadon et al., 1959; Trevino and Trumbo, 2002; Somani et al., 2003)**, interpenetrating polymer network from castor oil – based poly-urethane **(Patel and Suthar, 1988; Xie and Guo, 2002)** and polyurethane foam **(Ehrlich et al., 1959; Ogunniyi et al., 1996)**. Some semi-rigid foams that have potential uses in thermal insulation when produced when castor oil / polyether mixture was reacted with toluene diisocyanate **(Ogunniyi et al., 1996)**.

Sebacic acid, a 10- carbon dicarboxylic acid, is manufactured by heating castor oil to high temperatures (about 250 C°) with alkali. This treatment results in saponification of the castor oil to ricinoleic acid that is then cleaved to give capryl alcohol (2-octanol) and sebacic acid. The preparation of sebacic acid 2-octanol from castor oil has been reported **(Vasishtha et al., 1990)**.

Castor oil has been used as a plasticizer of celluloid and in lacquers but the blown oil has been discovered to perform better. Blown or oxidized castor oil is prepared by blowing air or oxygen in to at temperatures of 80-130 C°, with or without catalyst to obtain oils of varying viscosity. The blown oil is used widely as a plasticizer in lacquers, artificial leathers, hydraulic fluids and adhesives **(Kirk- Othmer, 1979; Weiss, 1971)**.

Castor oil also can be modified by reduction with hydrogen to produce hydrogenated castor oil (HCO), which is a wax-like material with melting point of 86 C°. Hydrogenated castor oil is used in cosmetics, hair, dressing, ointments, preparation of hydrostearic acid and derivatives; and in certain cases as wax

substitutes and for polishes. Sometimes HCO is used as paint additives, solid lubricant, pressure mould release agent in the manufacture of formed plastics and rubber goods (**Kirk- othmer, 1979; Weiss, 1971**).

Another product formed from the modification of castor oil is sulphated castor oil (also known as “turkey red oil”). Sulphated castor oil is prepared by added concentrated sulphuric acid to castor oil at 25-30 C° for several hours, following by washing and neutralizing with sodium hydroxide solution. It is an active wet agent. As such, it is used extensively in dyeing and in finishing of cotton and linen. Generally, the ability of castor oil and of it is derivatives to wet surfaces make them useful as excellent carriers of pigments and dyes. Also the action of sulphuric acid on castor oil produces a useful emulsifier for certain insecticidal oils (**Kirk- othmer, 1979; Weiss, 1971**).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 MATERIAL

Castor seeds (*Ricinus communis*) were collected from Omdurman market in Khartoum state in May (2016). The seeds keeps in a plastic container and transported to laboratory for physical and chemical analysis. The chemical and apparatus used for oil extraction and determination of chemical components were found in the department of food science of food science and technology – Sudan University.

3.2 METHODS

3.2.1 Castor seeds approximate chemical analysis

The moisture, ash and crude fiber contents were analyzed according to standard methods described in AOAC (1997).

Nitrogen was assayed using Kjeldahl method and the nitrogen content was converted to protein by a multiplication factor of 6.25 (AOAC, 1997) Total Carbohydrates were determined by difference using a standard method of (AOAC 1997). All the proximate analyses were carried out in triplicate and the results expressed as percentage of the sample analyzed.

3.2.1.1 Moisture content

The dry seed (5g) was weighed into a clean dry aluminum dish with a known weight. The sample was dried in an oven at a temperature of 105 °C for 16 hours, cooled in desiccators and weighed. And weighing was repeated twice until there was no difference in the two successive weights.

The moisture content was calculated following the method of AOAC, (1997).

$$\text{Moisture content \%} = \frac{(w_2 - w_1) - (w_3 - w_1)}{(w_2 - w_1)} \times 100$$

Where:

W1= weight of empty dish.

W2= weight of dish with the sample.

W3= weight after drying the dish.

3.2.1.2 Crude fat

The dry seed (50g) was extracted with Petroleum ether solvent using Soxhlet apparatus for 6 hours. The crude oil extracted in the flask then and dried by heating in a oven at 105°C for one hour. The Percentage crude oil content was then determined gravimetrically (AOAC, 1997).

$$\text{Crude oil content \%} = \frac{\text{weight of extracted oil}}{\text{weight of dry sample}} \times 100$$

3.2.1.3 Ash

The dry seed sample (5g) was placed in a dry clean porcelain crucible and heated progressively for 6 hours at 550°C until, grey -reddish ash was obtained according to (AOAC, 1997). The sample was cooled in a dessicator, weighed and total ash calculated using the following formula.

$$\text{Total ash \%} = \frac{(\text{weight of crucible+ash})-(\text{weight of crucible})}{\text{weight of sample}} \times 100$$

3.2.1.4 Crude fiber

About 2 g of Castor seed powder was transferred into a 200 ml Labeled beaker after which 1.25 % Sulphuric acid (50 ml) and distilled water (150 ml) were added. The sample mixture was then boiled for 30 minutes under reflux flask and later treated with 1.33% potassium hydroxide (50 ml) and 150 ml water the solution was re-boiled again for 30 minutes and registered using vacuum crucible filtrate on system. The sample in the crucible was rinsed with water followed by acetone. The samples was put into a pre-weighed crucible and transferred to the oven to dry for 4 hours, cooled in desiccators and weighed .The

weighed sample was used in the furnace set at 660 °C for 5 hours until it became grey ash which was cooled in the desiccator and weighed (AOAC, 1997). The weight of ash was then calculated as follows:

$$CF \% = \frac{(w_1 - w_2)}{W_s} \times 100$$

Where:

CF= crude fiber.

W1= weight of crucible with sample before ashing.

W2= weight of crucible with sample after ashing.

Ws= weight of sample.

3.2.1.5 Crude protein

Protein can be determined through the following stages:

Digestion stage:

The dry castor seed powder (2 g) was placed in kjeldahl tube and a 4g mixture (catalyst; sodium sulphate and copper sulphate) was added, the mixture was digested with concentrated sulphuric acid (25 ml) for 2 hours in fume hood until the solution became clear to light green.

Distillation stage:

Distilled water (120ml) was added to the solution and allowed to cool. Sodium hydroxide (45%) was also added without agitation. The flask was then connected to the distillation bulb with the tip of the condenser immersed in a standard acid solution (boric acid 2%) Containing 5 drops of the indicator. The flask was then heated to release ammonia into the indicator solution.

Titration stage

The excess standard acid in the distillate was titrated with 0.1N standard HCL The conversion factor of 6.25 was used (AOAC, 1997) and % of Nitrogen calculated as Below:

$$Cp \% = \frac{(T-B) \times N \times 14 \times 100 \times 6.25}{WS \times 1000}$$

Where:

CP= crude protein.

T= Titration reading.

B= Blank titration reading.

N= HCl normality.

Ws= sample weight.

3.2.1.6 Total carbohydrates

Total carbohydrates were determined by difference using the method in (AOAC, 1997).

$$\text{Total carbohydrates \%} = 100 - (MC+AC+FC+CF+CP)$$

Where:

MC= moisture content.

AC= Ash content.

FC= fat content.

CF= crude fiber.

CP= crude proteins.

3.3 Castor oil extraction and physicochemical properties determination

- Preparation of the Seed for oil Extraction

The seeds were decupled, cleaned and crushed and later dried in the oven for three hours at 50 °C to ensure that moisture content was reduced to the bears minimum.

Oil extraction

The prepared seed were oven dried at 70°C until a constant weight was obtained, then grinded into equal sizes. The extractor used was Soxlet apparatus with petroleum ether as solvent. After extraction, the mixture of the solvent and extract was allowed to cool and then filtered to remove solid particles. The filtrate was concentrated under vacuum in a rotary Evaporator (Akpan *et al.*, 2005). The results obtained were noted. The extracted oil was analyzed for the physical and chemical properties. All reagents used were of analytical grade.

3.4 Physical and Chemical characteristics of the extracted castor seeds

3.4.1 Moisture content determination

Five grams (5 g) of the cleaned sample was weighed and dried in an oven at 80 °C. After every 2 hours, the sample was removed from the oven and placed in the desiccators for 30 minutes to cool. It was then removed and weighed (Akpan *et al.*, 2005). The percentage moisture in the seed was then calculated from:

$$\text{Moisture content \%} = \frac{(w_2 - w_1)}{w_1} \times 100$$

Where:

W1 = Original weight of sample before drying (g).

W2 = Weight of sample after drying (g).

3.4.2 Specific gravity determination

The specific gravity bottle was cleaned with acetone, ether and dried in an oven at 60 °C. The weight of the empty bottle was taken, after which the bottle was filled with the oil sample and properly covered. The weight was then recorded using a weighing balance, after which the sample was removed from the bottle. The bottle was properly washed and filled with distilled water, after which the weight was taken and finally, the specific gravity was computed using the relationship below (Akpan *et al.*, 2005).

$$\text{Specific gravity \%} = \frac{W_o - W}{W_1 - W}$$

Where:

W = Weight of empty bottle (g).

W_o = Weight of the bottle and oil content (g).

W₁ = Weight of bottle and water content (g).

3.4.3 Saponification value determination

0.5M KOH was prepared in 95 % ethanol, 5 g of oil sample was weighed and 50 ml of KOH was added, 50 ml of the blank solution was also measured into a conical flask. The two samples were then connected to a reflux apparatus and allowed to boil for an hour until the reflux is completed, 1 ml of phenolphthalein was added to the mixture and the resulting mixture was titrated while hot against 0.5 M HCL acid solution. The volume of the acid used to attain the end point was recorded, the blank determination was carried out using the same procedure described above until the color changes from blue to transparent white, then the volume of acid used was noted, the Saponification value was determined using the formula below (Akpan *et al.*, 2005).

$$\text{Saponification value \%} = \frac{56.1 \times T \times (V_0 - V_1)}{M}$$

Where:

T= Morality of the standard KOH solution used (M),

V_o = Volume of acid used for the first titration with oil sample (cm³),

V₁ = Volume of acid used for the second titration blank solution (cm³),

M = Mass of the oil sample used (g).

3.4.4 Peroxide value determination

A known weight (5g) of sample was weighed into cleaned dried boiling tube 1 gram of potassium iodine (KI) powder was added to the oil and 20 cm³ of the solvent mixture (i.e, glacial acetic acid and chloroform in the ratio 2:1). Then the boiling tube was placed in boiling water bath so that the liquid mixture boils within 30 seconds and allowed to boil vigorously for not more than 30 seconds, the content after boiling was quickly poured into a flask containing 20 cm³ of 5

% potassium iodine (KI) solution and the tube was washed out twice with 25 cm³ of water. Then the mixture was titrated with 0.002 M sodium sulphate using fresh 1 % starch solution, a blank titration was carried out at the sample time, the peroxide value was calculated using the relationship below (Akpan *et al.*, 2005).

$$\text{Peroxide value} = \frac{T \times M \times 1000}{W}$$

Where:

T = titer value of Na₂S₂O₃ = (Sample titer – Blank titer,)

M = Morality of Na₂S₂O₃

W = Weight of sample / (g).

3.4.5 Refractive index determination

The refractive index was determined using Abbey refractometers. The glass prism of the refractometer was thoroughly cleaned with alcohol to ensure that it is free from dust, a drop of oil sample was placed on the lower prism and smeared, then closed with the other covering prism and the light source of the refractometers was switched on, while viewing through the telescope.

The coarse adjustment knob was rotated until the black shadow appears central in the cross wire indicator and while still viewing through the telescope, the fine knob adjustment was made until the rainbow-colored fringe which appeared on the black dividing line disappeared, the coarse knob was rotated to give fine adjustment and make the black shadow appear exactly central in the cross wire indicator. The reading under the telescope and that of the fine adjustment knob were noted and divided by 10,000, this value was then added to the value obtained through the telescope to give the value of the refractive index of the oil at room temperature (Akpan *et al.*, 2005).

3.4.6 Free fatty acids

Free fatty acids content was carried out according to the (British Standard Institute Method 1958). About (5g) of the oil was weighed accurately into 250 ml conical flask. 50 ml mixture of 95% alcohol and ether solvent (1:1) were added.

The solution was neutralized after addition of one ml of phenolphthalein indicator. The contents of the flask were then heated with caution until the oil was completely dissolved. The contents of the flask were then titrated with 0.01N KOH with constant shaking until a pink colour persisted for 15 seconds. The number of ml of 0.1 N KOH recorded as %.

$$\text{Free fatty acid as oleic acid} = \frac{V \times N \times 56.1}{W}$$

Where:

V: Volume of titration (ml).

N: Normality of KOH.

W: weight of sample.

3.4.7 Iodine value

The iodine value (IV) of the oils which quantifies their unsaturation level was determined according to (AOAC 2000). Approximately (0.2g) of oil was accurately weighed and placed in a dry and clean flask specially offered for the test. A 10 ml of chloroform was used for dissolving the oil. A 25 ml of pyridine sulphate dibromide solutions was added and finally 20 ml of KI (0.1 N) were added to the contents of the flask was then stoppered and the mixture was allowed to stand for 10 minutes in a dark place. The stopper and the side of the flask were rinsed with enough amount of distilled water, the contents of the flask was then stoppered and the mixture was allowed to stand for 10 minutes in a dark place. The stopper and the side of the flask were then shaken and titrated against 0.1N sodium thiosulphate solution using starch liquid as indicator. A blank determination was carried out simultaneously.

Calculations:

$$\text{Iodine value (IV)} = (B-A) \times 0.01269 \times 100/S$$

Where:

B: Volume (ml) of sodium thiosulphate in blank solution.

A: Volume (ml) of sodium thiosulphate in test active solution.

S: Weight (gm) of the oil sample.

Iodine factor = 0.01269.

3.4.8 Color

The color intensity of oils was recorded using Lovibond Tintometer as units of red, yellow and blue according to the **(AOCS 2005)**. Samples of oils were filtered through filter paper immediately before testing. An appropriate cell (2" cell) was filled with oil and placed in the tintometer near-by window for light. The instrument was switched on and looked through the eye piece. The yellow color was adjusted to 35, then slides were adjusted until a color match was obtained from combination of red and blue. The values obtained by matching were recorded as red, yellow and blue.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Chemical Compositions of Castor Seed

Moisture content

From the table (1) the moisture content of castor seed was (7.25%) this result was higher than that recorded by (**Akinyemi *et al.*, 2016**) who reported that moisture content of castor seed was (6.39%), while it was similar to that of the cotton seed (7.21%) (**Orhevba and Efomah, 2012**) also it was lower than that of roselle seed (9.2%) (**Nady, 2014**) and it was higher than that of sun flower seed (4.2%) (**Elsadig, 2009**).

Protein

From the Table (1) the protein of castor seed was (24.26%) this result was lower than that reported by (**Akinyemi *et al.*, 2016**) who reported that the protein of castor seed was (26.6), while it was higher than that of cotton seed (15.4%) (**Orhevba and Efomah, 2012**), also it was lower than that of roselle seed (33.4%), (**Haindia *et al.*, 2008**), and it was higher than that of sunflower (18.6%). (**Elsadig, 2009**).

Fat

From the table (1) the fat of castor oil was 46.22% this result was lower than that who recorded by (**Akinyemi *et al.*, 2016**) who reported that the fat content of castor seed was (59.4%), while it was higher than that of cotton seed (13.3%), (**Orhevba and Efomah, 2012**), while it was higher than that of roselle seed (21.6%), (**Nady, 2014**), and it was higher than that of sun flower seed (18.72%) (**Srivastava and verma, 2014**).

Fiber

From the table (1) the fiber of castor seed was 2.18% this result was lower than that who reported by (**Akinyemi *et al.*, 2016**) who reported that the fiber of castor seed was (12.7%), while it was higher than that of cotton seed (0.5%) (**Orhevba and Efomah, 2012**), while it was lower than that of roselle seed (16.4%) (**Nzikou**

et al., 2011), and it was lower than that of sunflower seed (16.51%) (**Elsadig, 2009**).

Ash

From the table (1) the ash of castor seed was 3.12%, this result was similar to (**Akinyemi et al., 2016**) who reported that the ash of castor seed was (3.17%), while it was higher than that of cotton seed (1.5%) (**Orhevba and Efomah, 2012**), while it was lower than that of roselle seed (6.8%) (**Nady, 2014**), and it was lower than that of sunflower seed (3.55%) (**Elsadig, 2009**).

Carbohydrates

From the table (1) the carbohydrates of castor seed was 19.14%, this result was higher than that who reported by (**Akinyemi et al., 2016**) who reported that the carbohydrates of castor seed was (4.36%), while it was lower than that of cotton seed (57.06%) (**Orhevba and Efomah, 2012**), while it was lower than that of roselle seed (21.2%) (**Nzikou et al., 2011**), and it was similar than that of sunflower seed (18.72%) (**Srivastava and verma, 2014**).

Table (1) Chemical compositions of castor seeds

Composition	Mean \pm SD (%)
	g/100 g oil
	n = 3
Moisture content	7.25 \pm 0.070
Crude protein	24.26 \pm 0.35
Crude oil	46.22 \pm 0.06
Crude fiber	2.183 \pm 0.025
Ash	3.126 \pm 0.040
Carbohydrates	19.14 \pm 0.01

SD= Standard deviation

n= Number of independent determinations

4.2 Physical Characteristics of Castor Oil

Refractive index

From the table (2) the refractive index of castor oil was 1.47, this result was equal to **(Yusuf, et al., 2015)** who reported that the refractive index of castor oil seed was (1.47), while it was similar to that of cotton oil seed (1.464) **(Orhevba and Efomah, 2012)**, and it was similar that of roselle seed oil (1.469) **(Bligh and Dyer, 1959)** and it was equal to sun flower seed oil (1.47) **(Eckey and Lawrence, 1954)**.

Specific gravity

From the Table (2) the specific gravity of castor oil was 0.95, this result was equal to **(Yusuf, et al., 2015)** who reported that the specific gravity of castor oil seed was (0.95), while it was lower than that of cotton seed oil (0.96) **(Roy, et al., 2012)**, also it was higher than that of roselle seed oil (0.89) **(Nady, 2014)**, and it was higher than that of sunflower seed oil (0.92) **(Mohammed, 1966)**.

Table (2) Physical characteristics of castor oil

Physical characteristics	Mean \pm SD
	n = 3
Color Yellow Red Blue	0.9667 Y \pm 0.11547 0.5667 R \pm 0.05774 0.0
Refractive index	1.4722 \pm 0.00064
Specific gravity	0.9589 \pm 0.00616

SD= Standard deviation

n= Number of independent determinations

4.3 Chemical Characteristics of Castor Oil

Acid value

From the table (3) the acid value of castor oil was **1** this result was lower than that who recorded by **(Yusuf, et al., 2015)** who reported that the acid value of castor oil seed was (2.07), while it was lower than that of cotton seed oil (11.5).**(Orhevba and Efomah, 2012)**, while it was lower than that of roselle seed oil (1.76) **(Bligh and Dyer, 1959)**, and it was higher than that of sun flower seed oil(0.70) **(Izzo et al., 1974)**.

Free fatty acid

From the table (3) the free fatty acid of castor oil was 0.5, this result was lower than that who recorded by **(Yusuf, et al., 2015)** who reported that the free fatty acid of castor oil seed was (1.03), while it was lower than that of cotton oil seed (5.7) **(Orhevba and Efomah, 2012)** and it was lower than that of roselle seed oil(2.24) **(Nzikou et al ., 2011)** and it was higher that than of sun flower seed(0.35) **(Izzo et al., 1974)**.

Peroxide value

From the table (3) the peroxide value of castor oil was 9.22, this result was lower than that who reported by **(Yusuf, et al., 2015)** who reported that the peroxide value of castor oil seed was (38.00), while it was similar to that of cotton seed oil (9.25) **(Orhevba and Efomah, 2012)**, while it was higher than that of roselle seed oil (6.5) **(Nady, 2014)**, also this result was higher than that of sun flower seed oil was (0.21) **(Robertson, 1972)**.

Saponification value

From the table (3) the saponification value of castor oil was 159, this result was lower than that who reported by **(Yusuf, et al., 2015)** who reported that saponification value of castor oil seed was (175.3), while it was lower than that of cotton seed oil (189) **(Orhevba and Efomah,2012)** while it was lower than

that of roselle seed oil (197) (**Nady, 2014**), and it was lower than that of flower seed oil (189.6) (**Jar- Elnabi, 2011**).

Iodine number

From the table (3) the iodine number of castor oil was 83.7, this result was similar to (**Yusuf, et al., 2015**) who reported that the iodine number of castor oil seed was (84.1), while it was lower than that of cotton seed oil (94.7) (**Orhevba and Efomah, 2012**) while it was higher than that of roselle seed oil (81.4) (**Nzikou et al., 2011**), while it was lower than that of sun flower seed oil (104.7) (**Rosa et al., 2009**).

Table (3) Chemical Characteristics of Castor Oil

Chemical characteristics	Mean \pm SD
	n = 3
Acid value (mg /g)	1 \pm 0.1
Free fatty acids (as oleic acid) %	0.5 \pm 0.05
Peroxide value (meq /g)	9.22 \pm 1.06
Saponification value (mg KOH/g oil)	159.26 \pm 2.26954
Iodine number (g I ₂ /100g oil)	83.7 \pm 0.152

SD= Standard deviation

n= Number of independent determinations

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

According to the obtained results it can be concluded that the castor seeds chemical composition similar to cotton seeds and sunflower seed.

While the physical characteristics of castor oil comparable to that of cotton oil seed and sun flower seed.

It is well known that the castor is toxic, but there are many techniques that can be adopted for the detoxification of the ricin.

5.2 Recommendations

By the end of this study, it can be recommended that:

1. More attentions and studies are recommended regarding castor plant, as it is considered as wild weed in many places in Sudan.
2. More researches regarding the detoxification of the oil are recommended.
3. More researches are recommended regarding the physicochemical characteristics of castor oil.

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Appendices:

Figure (1) castor seeds



Figure (2) castor seed oil

