REVIEW OF CARBONACEOUS MATERIALS IN CASTOR OIL FOR THIN FILMS DEPOSITION

[1] Vinay Kumar Singh & [2] Hridaya Nand Sah
[1]Department of Physics, Raja Singh College, Siwan, Bihar, India, Pin-841226.
[2]Department of Mathematics, Raja Singh College, Siwan, Bihar, India, Pin-841226.

ABSTRACT: In this research article we provide detailed reviews of carbon precursor-castor oil origin, production, properties and applications of Castor oil, etc. This oil is produced from castor beans. It has long been considered to be of important commercial value primarily for the manufacturing of soaps, lubricants, and coatings, among others. Global castor oil production is concentrated primarily in a small geographic region of Gujarat in Western India. This region is favorable due to its labor-intensive cultivation method and subtropical climate conditions. Entrepreneurs and castor processors in the United States and South America also cultivate castor beans but are faced with the challenge of achieving high castor oil production efficiency, as well as obtaining the desired oil quality.

Keywords: Castor oil, Castor beans, Ricinoleic acid, Non-edible oil, Ricinus communis, ' Eranda', etc.

I. INTRODUCTION

Castor bean oil is obtained from the bean of castor plant (*Ricinus communis L.*) a member of the Spurge family of plants (*Euphorbiaceae).* The botanical name of castor oil is *Ricinus communis* L. The label display name is Castor oil. Other Names are Palma Christi oil, Ricinus oil, Ricinoleum, Tangantangan oil, Triglyceride of ricinus acids, Turkey Red oil (sulfated form), Blown oil (oxidated form), Phorbyol, Venelex, Xeandam, Optase, and *Trypsin* complex. It is natural oil obtained from the seeds of the castor plant. The castor oil plant is a native of India, where it bears several ancient Sanskrit names, the most ancient and most usual being 'ERANDA'. It is also found in France, America, Italy, China, Egupt, Greece, Belgium, Algeria, and Riviera, etc. The name *'Castor'* was indeed originated in the 18th century to this plant in Jamaica, where it seems to have been called *'Agnus Castor',* through it bears no resemblance to the south European plant properly so called. The botanical name is from the Latin Ricinus (a dog-tick), from the form and makings of the seed. Castor is an annual herbaceous plant in our regions but can reach the size of small tree in tropical Africa. Native to Abyssinia, it spread all over the world and acclimatized.

Castor is cultivated around the world because of the commercial importance of its oil. India is the world's largest producer of castor seed and meets most of the global demand for castor oil. India produces 8 to 8.5 lakh tonnes of castor seed annually, and accounting for more than 60% of the entire global production. Because of its unlimited industrial applications, castor oil enjoys tremendous demand world-wide. The current consumption of Castor Oil and its derivatives in the domestic market is estimated at about 300,000 tones. India is also the biggest exporter of castor oil and its derivatives at 87% share of the international trade in this commodity. Castor is an important non-edible oil-seed crop and is grown especially in arid and semi arid region. It is originated in the tropical belt of both India and Africa. It is cultivated in different countries on commercial scale, of which India, China and Brazil is major castor growing countries accounting for 90 per cent of the world's production. Castor seeds contain about 48-50 percent oil by weight. The overall castor oil & derivatives manufacturing process is: Sowing > Cultivation > Harvest > Seed Dehulling & Cleaning > Oil Extraction >Oil Filtration & Purification > Oil Refining > Production of Castor Oil Grades & Derivatives. While castor oil by itself is used in diverse applications, chemical derivatives of castor oil find further uses in industrial applications and their domains of use are increasing. The worldwide increase in the production of castor seeds and castor oil testifies the huge potential as a green bio-resource for chemical transformations because castor oil can be used as the starting material for producing a wide range of end-products. It has been shown that the use of castor oil from renewable materials for carbon thin films for solar cell is technically feasible, eco-friendly, and has a low cost and with high efficiency. Besides that, being composed of agricultural waste, it helps in the reduction of waste generation and gives added value to the waste. The castor plant and its seeds are shown in Figure 1: (a), and (b).

Fig. 1 Castor plant (**a**) and castor seeds (**b**)

Figure 1: (a) Castor Plant, and (b) Castor Seeds

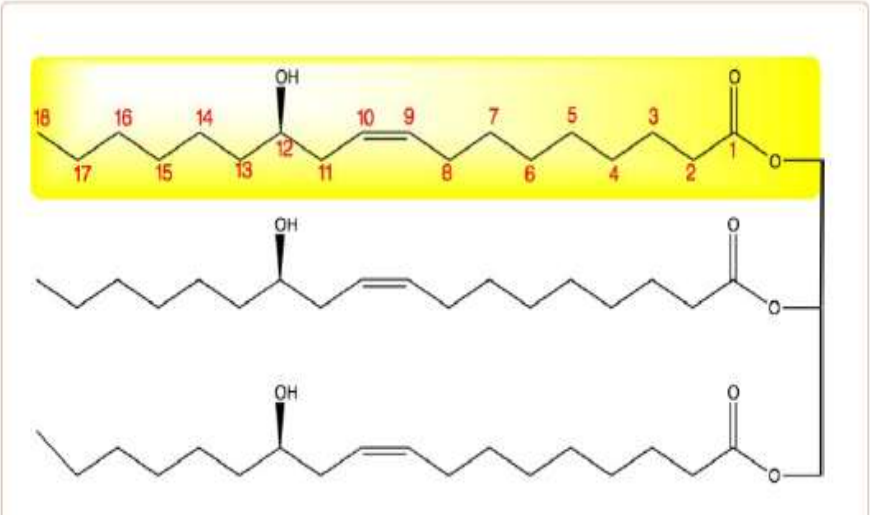

Figure 2: Chemical structure of ricinoleic acid, the primary component of castor oil.

II. COMPOSITION AND STRUCTURE OF THE CASTOR OIL

The unique structure of castor oil offers interesting properties, making it appropriate for various industrial applications. Castor oil is known to consist of up to 90% *ricinoleic*, 4% *linoleic*, 3% oleic, 1% *stearic*, and less than 1% *linolenic* fatty acids. Castor oil is valuable due to the high content of *ricinoleic* acid (RA), which is used in a variety of applications in the chemical industry. The hydroxyl functionality of RA makes the castor oil a natural *polyol* providing oxidative stability to the oil, and a relatively high shelf life compared to other oils by preventing peroxide formation. The presence of the hydroxyl group in RA and RA derivatives provides a functional group location for performing a variety of chemical reactions including halogenations, dehydration, alkoxylation, esterification, and sulfation. As a result, this unique functionality allows the castor oil to be used in industrial applications such as paints, coatings, inks, and lubricants. The chemical structure of castor oil is shown in Fig. [2], and summary list of key derivatives of castor oil is shown in Table: [1].

III. CASTOR OIL CHEMISTRY AND COMPOSITION

[a] Castor oil is unique among all fats and oils in that.
[b] It is the only source of an 18-carbon hydroxylated fatty acid with one double bond.
[c] Ricinoleic acid (12-Hydroxyoleic Acid) comprises approximately 87% of the fatty acid composition.
[d] Product uniformity and consistency are relatively high for a naturally occurring material.
[e] It is a toxic, biodegradable, renewable resource.

Table [1]: Summary List of Key Derivatives of Castor Oil

Commercial Castor Oil	First Pressed Degummed Grade Castor Oil
Refined Castor Oil – F.S.G./B.S.S.	Refined Castor Oil – Extra Pale Grade
Refined Castor Oil – Pale Pressed Grade	Castor Oil Pharmaceutical (I.P/B.P./U.S.P.)
Sulfonated Castor Oil – Turkey Red Oil	Blown Castor Oil
Ricinoleic Acid	Hydrogenated Castor Oil
12-Hydroxy Stearic Acid (12-H.S.A.)	Methyl-12-Hydroxy Stearate
Methyl Ricinoleate	Urethane Modified Castor Oil
Dehydrated Castor Oil (DCO)	Glycerine
Urethane Grade	Ethoxylated Castor Oil
Sebacic Acid	Heptaldehyde
2-Heptanol	Undecylenic Aldehyde
Methyl Undecylenate	2-Octanol
Undecanoic Acid	Undecylenic Acid
Calcium Undecylenate	Zinc Undecylenate
Zinc Ricinoleate	Heptanoic Acid

IV. PROPERTIES & CHEMICAL COMPOSITION OF CASTOR OIL

It is a fatty acid with 18 carbon atoms, a double bond between the ninth and tenth carbons, and is hence also known as dodecahydroxyoleic Acid. No other vegetable oil contains such a diverse and high proportion of fatty hydroxyacids. Uniqueness of castor oil is that regardless of

where the beans are grown, the chemical composition remains constant. It is this consistency that has allowed castor oil to be used as the absolute standard for viscosity by the Bureau of Standards. Castor oil has a molecular weight of 298; a low melting point (5°C) and a low solidification point (12°C to -18°C). It is a monounsaturated fatty acid, soluble in pure alcohol, insoluble in water and has some miscibility in petroleum aliphatic solvents. It resists heat and leaves virtually no residue. The Physical and chemical properties of castor oil are shown in Table: [2], and Chemical composition of castor oil are shown in Table: [3].

Table [2]: Physical and chemical properties of castor oil

S.N.	Characteristics	Standard value
1.	Density at 20^0C	0.950-0.970
2.	Solubolity in ethanol/alcohal	Soluble
3.	Refractive index it 20^0c	1.4750-1.4850
4.	Acid index	<5.0
5.	Iodin index peroxide	82-90
6.	Peroxide value	<5.0
7.	Colour	Pale-yellow
8.	Odour	Specific/mild
9.	Specific gravity at 15^0C	0.950-0.970
10	Cooled upto 0^0C	Becomes turbid
11.	Melting point(M.P)	50^0C
12.	Boiling point(B.P)	188^0C

Table [3]: Chemial composition of castor oil

S.N.	Constituent of average composition	Percentage (%)
1.	Ricinoleic acid	90(%)
2.	Oleic tearic acid	3 to 4(%)
3.	Stearic acid	1.0(%)
4.	Linoleic acid	3 to 4(%)
5.	Unsaponifiables acid	0.5 to 1(%)
6.	Palmitric acid	1.0(%)
7.	Dihydroxy stearic acid	0.7(%)
8.	Lenolenic acid	0.3(%)
9.	Eicosenoic acid	0.3(%)

V. MOLECULAR /CHEMICAL FORMULA OF CASTOR OIL

$$CH_3\text{-}(CH_2)_5\text{-}CH\ (OH)\text{-}CH_2\text{-}CH{=}CH\text{-}(CH_2)_7\text{-}COOH$$

VI. TOXICITY

Castor is one of the most poisonous plants in the world due to ricin contained in the bean, stem and leaves. Ricin is not found in the expressed oil but remains in the press cake. Just 4 to 8 beans can kill an adult person, a horse or an ox. However, cases of poisoning are rare. Animals sense the toxicity and avoid it.

During processing care should be taken to keep dust levels low and/or wear protective gear to avoid inhaling resin laden dust. Care should be taken to avoid situations where Castor seeds 5 could accidentally enter the food chain, e.g. through inter-cropping with food crops, shared storage or processing facilities. The toxins also protect castor against some insects. Table: [4] Factsheet physical properties of castor oil in relation to diesel and other oils.

Table: [4] Factsheet physical properties of castor oil in relation to diesel and other oils

Type of fuel/oil	Specific gravity 20° C	Viscosity 20° C(Cst) (T in °C)	Pour point (°C)	Cloud point (°C)	Flash point (°C)	Iodine Number	Oil contents (% mass)	Conradson (% on total)	Cetane Number	LCV (MJ/Kg)
Diesel fuel	0.81-0.84	4.6	-33	-15	52-102			0.01	43-52	42-53
RME	0.87-0.89									
coprah						10				
palm	0.92	60	22		280	45			39	36.9
cotton seed	0.92	50 (27)	-15.0	1.7	234	106		0,24	42-48	39.6
Jatropha	0.92	78.2	8	16	236	105	28-40	0.47	23-45	38-39
Ground nut	0.92	42 (37)	-7	13	282	93			42	
rape seed	0.91	78	-32	-4	285	105			37.6	37.6
castor	0.95-0.97[1]	78 (30 0C)	-12-18 [3]		260	85	35-55		42 [1]	37-39 [1]
soya	0.91	61	-12	-4	330	130			38	39.6
sunflower	0.92	58	-16	7	316	125			37.1	39.5

VII. VARIOUS USES OF CASTOR OIL

(1) Combined with citron ointment, it is used in common leprosy.
(2 It is used in clean, light-colored soap, cheap soap, and transparent soap, etc.
(3) It is used in dressing of fabrics, lighting, lacquers, adhesives, rubbers, urethanes, sealants, caulks, pigments, dyes, coatings, hydraulic and brake fluid, lubricants, liquid dielectrics, inks, waxes and polishes, textiles, plastics, cosmetic items, polishing high class furniture and carriage bodies, varnishes, water-proof materials, etc.
(4) It is used in hair conditioner, hair stimulant, products for normal, damaged and delicate hair, product for the scalp, body product like-sun oils & bath oils, face product for normal combination and dry skin, lip balms, etc.
(5) It is medicinally used as medicined like to remove constipation, in diarrhea due to undigested material, dysentery ophthalmic surgery, dropped into eye to remove the after-irritation caused by the removal of foreign bodies, etc.
(6) It is used as lubricating, burning and for leather dressing, etc.

VIII. APPLICATIONS OF THE CASTOR DERIVATIVES

Castor oil's application range is very wide. From the attractive uses such as cosmetics to the areas of national security involving engineering plastics, jet engine lubricants and polymers for electronics and telecommunications, castor oil plays an important role in today's industry. The Table [5]: below provides an overview of the applications in which castor oil and its derivatives are used.

Table [5]: Overview of applications of castor oil and its derivatives

Agriculture Organic Fertilizers	**Plastics and Rubber** Polyamide 11 (Nylon 11) ,Plastic Films, Adhesives, Coupling Agents, Polyols, Synthetic Resins, Plasticizers
Food Surfactants, Viscosity Reducing Additives, Flavourings, Food Packaging	**Cosmetics and Perfumeries** Perfumery Products, Lipsticks, Hair Tonics, Shampoos, Polishes, Emulsifiers, Deodorants
Paper Flypapers, Defoamer, Water Proofing Additive	**Pharmaceuticals** Antihelmintic, Antidandruff, Cathartic,Emollient,Emulsifiers, Deodorants
Electronics and Telecommunications Polymers for Electronics and Telecommunications, Polyurethanes, Insulation Materials	**Paints, Inks and Additives** Inks, Plasticizer for Coatings, Varnishes, Lacquers, Paint Strippers, Adhesive Removers, Wetting and Dispersing Additives
Textile Chemicals Textile Finishing Materials, Dyeing Aids, Nylon, Synthetic Fibers and Resins, Synthetic Detergents, Surfactants, Pigment Wetting Agents	**Lubricants** Hydraulic Fluids, Heavy Duty Automotive, Greases, Fuel Additives, Corrosion Inhibitors, Lubricating Grease, Aircraft Lubricants, Jet Engine Lubricants, Racing Car Lubricants

IX. CARBON THIN FILMS FROM CASTOR OIL

As besides the crystalline forms, an amorphous form of carbon has been found to be having a lot of technological applications. There is a growing interest in amorphous carbon (α- C) hydrogenated amorphous carbon (α-C:H) thin film because of their well-known outstanding properties and especially due to the feasibility of band gap engineering over a wide range from insulating diamond (5.5 eV) to that of metallic graphite (0eV). The properties of these amorphous carbons sensitivity depend upon the relative concentration of sp2 and sp3 hybridized carbons. The resulting amorphous materials are variously referred to as tetrahedral amorphous carbon conducting (ta-C), amorphous conducting carbon (α-C), hydrogenated amorphous carbon (α-C: H), amorphous conducting Carbon (α-CC). Recently M. Sharon et al have reported that organic material possessing C-atoms with sp^2 and sp^3 both configurations can be most suitable precursors for producing carbonaceous thin films for their application in solar cells. They synthesized various forms of carbon by simple paralysis' of camphor ($C_{10}H_{16}O$) and kerosene in completely inert atmosphere (absent of H_2), and without using any catalyst. Along the same line we have thought that castor oil might be useful precursors for preparing thin films of carbon. This research topic reports the results our efforts made in the direction and describes the structural, optical and electrical properties of of conducting carbon thin films prepared from the paralysis of oil of turpentine, a natural α –carbon precursors. Amorphous quartz substrates were used as they are convenient for the mentioned studies. The paralysis technique has been used in present investigations due to simplicity, affordable cost, and feasibility of the mass production process.

X. CONCLUSIONS

Castor oil is one of the most versatile plant oils of the world. The various grades of the oil and its derivatives are used in over a dozen diverse industries already. In future, castor oil and castor oil oleo chemicals have the potential to be used in newer industries, with the rising environmental concerns, and the increasing need for bio-based products to replace synthetic feedstock. This oil can be used as a good candidate in thin films preparation for the applications in the fabrication of carbon solar cell in future, also other products of industrial applications. The diversity of chemicals and products produced from castor oil has proven that castor is an important and potential non-edible oilseed crop. The great utilitarian value in industry, agriculture, cosmetics and pharmaceutical sectors is a direct proof that castor oil is a potential bio-based starting material. The presence of a hydroxyl group, carboxylate and double bonds in the ricinoleic acid, imparts unique properties for the derivatization of castor oil into vital industrial raw materials. It has been shown how castor oil can be used as a renewable bio-based raw material for the production a multitude of functional materials. It is equally noted that the diverse possibilities of castor oil transformation mainly depend on the presence of the three functional groups. This review has further shown that castor oil is a potential alternative to petroleum-based starting materials for the production of wide range of industrial materials. It can also be seen that apart from the oil's unique chemical structure and environmental considerations, the worldwide growth in castor oil demand is due to its easy availability, low cost, non-food competition. It has been observed in the discussion that castor oil is more than just a bio-based raw material in great demand by the chemical industries but its use as a fuel is also seen when transesterification is done.

ACKNOWLEDGMENTS

One of the authors, DR. VINAY KUMAR SINGH takes this opportunity to thank Prof. M.K. Sharan, Ex-Principle and HOD, Department of Physics, Rajendra College, J.P. University, Chapra, for numerous discussions, valuable suggestion and help in preparing the present research paper for publication. I also feel indebted to some scientific spiritualists who provided us the enthusiasm to undertake scientific studies with a wholesome attitude.

REFERENCES

[1] V.K. Singh, M. K. Sharan, & K.P. Srivastava, 2006, Amorphous Semiconducting Carbon Thin Films from Castor Oil, *Material Science Research India* (MSRI), Bhopal Vol. 03, No. (2a), pp 263-266.

[2] V.K. Singh, M. K. Sharan, & K.P. Srivastava, 2008, Amorphous Semiconducting Carbon Thin Films for Carbon PV-Cells, *International Journal of Acta Ciencia Indica of Chemistry*, Vol. XXXIVC, No. 1, 27, pp 127-132.

[3] V.K. Singh, M. K. Sharan, & K.P. Srivastava, 2006, Spray Paralyzed Semi-Conducting Carbon Thin Films from Turpentine Oil, *International Journal of Chemical Sciences*,Vol. 4, No. 3, pp 660-664.

[4] Volkhard Scholz, & Jadir Nogueira da Silva (2008), Prospects and risks of the use of castor oil as a fuel, (2008*), Biomass and Bioenergy*, 32, pp. 95–100.

[5] Ch .S. Naga Prasad, K. Vijaya Kumar Reddy, B.S.P. Kumar, E. Ramjee1, O.D. Hebbel and M.C.Nivendgi, Dept. of Mech. Engg., JNTU College of Engg., Hyderabad-85; PDA College of Engg., Gulburga, Karnataka, India.

[6] Wolter Elbersen, Leo Oyen, with contributions from: Rob Bakker and Rolf Blaauw "Nieuwe Grondstoffen voor Biobrandstoffen. Alternatieve 1e Generatie Energiegewassen" Report GAVE-09- 01, Senter Novem.

[7] Allan G, Williams A, Rabinowicz PD, Ravel J, Keim P, 2008, Worldwide genotyping of castor bean germplasm (*Ricinus communis* L) using AFLPs and SSRs. Genetic Resources and Crop Evolution 55: 365-378.

[8] Weiss EA, (2000), Castor, Sesame and Safflower. Leonard Hill London, p: 901

[9] Ogunniyi DS, (2006), Castor Oil: A Vital industrial raw material, *Bioresource Technology*, 97: 1086- 1091.

[10] FAO, (2008), The State of Food and Agriculture. United Nations, Rome p: 240

[11] Duke JA, (1998), *Ricinus communis* from Purdue University New Crop Resource online Program.

[12] Akintayo ET, (2004), Characteristics and composition of Parkia biaglobbosa and Jatropha curcas oil and seeds. *Bioresource Technology*, 92: 307-310.

[13] Esther UI, Anthony EA, Okoli P, Macdonald I, (2008), Characteristics and Composition of African Oil Bean Seed, *Pentaclethra macrophylla Benth*. J Appl Sci Res, 8: 1337-1339.

[14] Akpan UG, Jimoh A, Mohammed AD, (2007), Extraction, Characterization and Modification of castor seed oil, *Leonardo Journal of Science*, 8: 43-52.

[15] Jumat S, Dina AMN, Nazrizawati AT, Mohd Firdaus MY, Noraishah A, (2010). Fatty Acid Composition and Physicochemical properties of Malaysian Castor Bean Ricinus communis L. Seed Oil. Sains Malaysiana, 39: 761-764.

[16] AOAC, (1997), Association of Official Analytical Chemists. (17th Ed), *Official* methods of analysis,Washington, D.C

[17] British Standards, (2002), Methods of analysis of oils and fats.

[18] Abitogun AS, Alademeyin OJ, Oloye DA, (2009), Extraction and Characterization of Castor Seed Oil. *Internet J Nutr Wellness*, 8: 1937-8297.

[19] Mensah B, Ochran R, (2005), Physiochemical characteristics of castor oil from local wild castor plant in Ghana. , *Ghana Journal of Science*, 45:41-44

[20] Bello, E.I. and Makanju, A. (2011) Production Characterization and Evaluation of Castor Oil Biodiesel as Alternative Fuel for Diesel Engines, *Journal of Emerging Trends in Engineering and Applied Science*, 2, 525-530.

[21] Nielsen, F., Hill, B. and Jongh, J., (2011), FACT Arrakis FACT Project No. 146/W/W/001, Castor (*Ricinus cummunis*): Potential of Castor for Bio-Fuel Production. 2nd Edition.

[22] Mutlu, H. and Meier, M.A.R., (2010), Castor Oil as a Renewable Resource for the Chemical Industry *of Lipid Science and Technology*, 112, 10-30.

[23] Alizeralu, A.F.N., Shirzad, H. and Harzati, S. , (2011) , The Effect of Climatic Factors on the Production and Quality of Castor Oil. *Natural Science*, 9, 15-19.

[24] Sharon M., Carbon Nanomaterials, , one chapter *"Encyclopedia of Nanotechnology" Ed.H.S. Nalwa, American Scientific Publishers (2003).*