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Processing of cashew nut shell and feasibility of its oil as bio fuel in compression ignition engine

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ABSTRACT

Cashew nut shell (CNS) is the byproduct obtained from cashew (*Anacardium occidentale L.*) processing industries and it is a soft honey comb structure containing a dark brown liquid known as Cashew nut shell liquid (CNSL). CNSL mainly consists of Anacardic acid, cardol, cardanol and small amount of other phenols and less polar substances. The composition percentage varies with many parameters like, nature of origin, climatic condition, method of extraction, etc. In this article, method of processing of CNS, yielding percentage of CNSL, variation in their composition with respect to type of processing, use of different constituents and their separation are listed. In addition to that, methods for separation of cardanol (a major constituent of technical CNSL) from oil, and feasibility of its use in diesel engine as a biofuel were discussed along with the physiochemical properties. Presence of long carbon linear chain gives excellent solubility in diesel. The calorific value of cardanol is high and is closer to diesel. The corrosiveness of it also very mild due to nature of phenolic compounds present in it. Higher viscosity is the only drawback of every vegetable oil and this can be lowered while blending with diesel and ethanol if necessary. From these studies, the cardanol have the properties much closer to the conventional diesel and which can be used as a biofuel in addition with diesel fuel.

Key Words: Cashew, Nut, CNSL oil, Cardanol oil, properties of CNSL oil,

INTRODUCTION

The cashew tree, belongs to the family of *anacardiaceae*, has a native of north east Brazil with a name of "acajou". India has the largest area harvested under the raw cashew nuts in the world. India is the second largest producer of cashew with an average total area of 8,68,000 hectare of land, producing 6,65,000 tons of raw cashew nuts with an average productivity of 860 kg per hectare. Processing of cashew and its products are carried out by 3799 processing units which includes 1850 small scale cottage industries spread over India, which leads India to become the first processor of cashew among world.

The byproducts obtained from the cashew processing industries are incorporated for many industrial applications like manufacturing of polymers, friction lining, paints, adhesives, etc. The present paper reports the studies on the feasibility of cardanol oil as an alternative biofuel in compression ignition engine in blend with diesel.

Plantation of tree, flowering, fruit and nut: Cashew tree is a fast growing, hardy and drought resistant multipurpose tree that can be cultivated in many tropical climatic conditions. Trees are also suitable for use in reforestation in barren, slash and burned farmland, degraded land and coastal sandy land. In India, cashew trees were often used as a reforestation and to fix dunes. The cashew tree gum that has been proposed as an aqueous two phase extract and substitute for fractioned dextran (Sarrubo 2000), cashew tree wood can be used as termite resistant and useful for boat building.

A fruit fully grows in two to three months normally at the end of the dry season and high temperature leads to earlier flowering. The nut develops initially and the apple develops latter and enlarges before fruit fall. The fruit (pseudo fruit) was hardly edible because of its "unripe" taste, but a juice can be made from it and the nuts can be eatable if cooked. Besides that, the apple is also used to make jelly, jam, wine and syrup (MacLeod 1981, Maia 2000, Da Silva 2000).

The nut consists of kernel 20-25%, kernel liquid 20-30%, testa 3% and other being the shell by the weight of nut. Nut is on the outside of the fruit, it is covered with reddish brown skin known as shell and a testa. The shell and kernel consists of honeycomb structure containing dark colored, high viscous phenolic material known as Cashew Nut Shell Liquid.

The simple and cheapest method for processing of Cashew Nuts is to expose the nuts in the intense of sun light. Well dried nuts are then hand shelled to remove kernel from cashew nut. Dried kernels are easy to peel off the seed coat from it by manually. Peeled off nuts are graded as per their quality either they whole, broken, butts, splits, pieces and small pieces

Cashew nut shell liquid: The cashew processing industries generates huge quantity of shell, which is about 67% percentage of raw seeds. The cashew nut shell is about 1/8 inch thickness, with a soft honeycomb structure inside, containing a dark reddish brown viscous liquid known as cashew nut shell liquid oil and is pericarp fluid. CNSL is a valuable raw material obtained as a byproduct from industry. It is reported to be 25 - 30% by weight of the unshelled nut in India which is higher than African based nuts. It is recognized as a valuable commodity because of its high concentration of unsaturated long chain phenols such as cardanol (1), cardol (2), 2-methylcardol (3) and anacardic acid (4) as shown in figure 1.

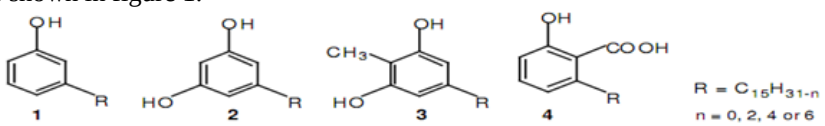

Figure.1.Chemical constituents of cashew nut shell liquid

MATERIALS AND METHODS

Extraction of CNSL oil: Extraction of CNSL oil from cashew nut shell includes open pan roasting, drum roasting, hot oil roasting, cold extraction, solvent extraction, super critical fluid extraction (Rajesh N. Patel 2006), pyrolysis process (Das 2004, Tsamba 2004), Soxhlet extraction method (Castro 1998, Tyman 1989) and research have been carried out to improve the percentage of yield from raw cashew nut by using new extraction methods like Sub Critical Water extraction and two-step extraction methods (Maria Yuliana 2011).The percentage yield of oil varies with the type of extraction process.

As the extraction method varies, the quantity and quality of oil varies with the composition percentage of Anacardic acid, Cardanol and cardol. There are two types of CNSL oils and are known as natural or immature oil (iCNSL) and technical oil (tCNSL). The compositions of iCNSL are anacardic acid 70%, cardol 18%, Cardanol 5%, and remaining are the other phenols and less polar substances. The tCNSL oil have the composition of cardanol 83-84%, cardol 8-11%, polymeric material 10% and traces of methyl-cardol (Kumar 2002, De Lima 2008).

Thermal Extraction Process: The shelled nuts can be processed by open pan roasting in small scale industries. Open pan roasting method removes the oil by charring/degradation, there by wasting the liquid which is the valuable source of natural phenol (Senthilkumar P 2009).

Mechanical Extraction Process: Screw press method is a type of extraction method, in which the nuts are placed in the hydraulic press on screw pressing machine and then exert high pressure to extract oil from shell. In the Expeller type extraction the nuts are crushed in the crusher along with a stream of steam at a temperature of 180 -185^{0}C, with a pressure of 7.5 – 8 kg/cm^2 to collect the oil. Extracted oil can be reheated in order to remove the moisture content.

Solvent Extraction Process: Solvent extraction can be carried out by using soxhlet extractor, ultrasonication, Supercritical Fluid Extraction and pyrolysis. New extraction processes like Sub Critical Water extraction (SCW) and two – step extraction methods are in progress to improve the yielding of oil.(Subbarao 2011).Some authors use ethanol as a solvent for extraction of oil in soxhlet extractor.Two – step extraction comprise a soxhlet extraction followed by a SCW extraction. The solvent was evaporated from the extract to obtain the analyte and residue from the soxhlet extraction was dried to remove the solvent. The dried residue was then subjected to SCW.

Properties of CNSL oil: CNSL oil is amber-colored, poisonous, viscous oil and it is often considered as the better and cheaper source of unsaturated phenols. This oil is toxic and corrosive to the skin (Akinhanmi T F 2008). Dark colors formed during the polymerization and are attributable to the presence of polyhydric phenols, primary cardanol, and the di hydric component accounts for oil a vesicant activity.

Applications of CNSL oil: CNSL has many biological and industrial applications due to the fact that it can easily react forming various derivatives, including polymers and resins (Patel R N 2006). It can replace phenol in any applications with equivalent or better result.

Phenolic Applications: CNSL reduces the corrosion on carbon steel surface due to electrochemical process. Its performance decreases with increasing temperature. CNSL and its derivatives have anti-oxidative characters. Poly films additivated with new thiophosphate esters antioxidants derived from tCNSL have increased thermal stability of films in the presence of thiophosphate ester additive (Diego Lomonac 2011). Cardanol based polyhydrins were used as sensitizers for importing the photo-catalytic activity of bare TiO_2. The porphyrins are brown-red sticky solids, very soluble in $CHCl_2$ or CH_2Cl_2.

Industrial Applications: In industry, CNSL polymers and resins are widely used as friction materials, surface coating, adhesives, laminates, rubber compounding, flame retardants, and anti corrosive paints. CNSL and cardanol found extensive use in automobile break lining applications. Cardanol polysulfide (CPS) was used as vulcanizing agent for natural rubber and optimum cure time of rubber containing this was reduced and the mechanical properties were improved. Cardanol based nonvolac type phenolic resins, capable to form thermo set polymers when blended to commercial epoxy or isocyanate monomers.

Biological Applications: The iCNSL have an important in protecting DNA against damage induced by reactive oxygen species, as well as hydrogen peroxide, generated by intra and extra cellular mechanisms. The high vitro antibacterial activity of cashew nut shell liquid has been attributed to its Anacardic acid content. The biological activities of CNSL such as antitumor, gastro protective, antibiotic have been reported.

Separation of cardanol from CNSL oil: Anacardic acid is thermolabile and easily degraded into cardanol by the decarboxylation process at high temperature. During decarboxylation, anacardic acid, will convert into cardanol. This change can be detected based on the pH changes of the CNSL from acidic to alkaline. In general, the decarboxylation process is carried out at the temperature of 200 – 240°C under reduced pressure not exceeding 666 Pa. The oil obtained by this process is also known as double refined CNSL oil (DR - CNSL). The lower inter molecular energy also had an impact on the decrease of viscosity and hence molecular weight reduces drastically.

Feasibility of cardanol for biofuel: Some properties are to be considered as important for the selection of biofuel and are namely, viscosity, flash point, fire point, density, calorific value, corrosive nature, miscibility, sulphur content, molecular weight, cetane number, etc. It was very interesting that most of the properties were very closer to the conventional diesel fuel.

The viscosity, though on the higher side at room temperature, reduces drastically at higher temperature. Observed viscosity at 30˚C for cardanol was 31.97 cSt, and at 60˚C it was 15.96 cSt. The flash point and fire point of the cardanol was registered at 208˚C and 220˚C respectively. The density value was 0.92 gm/cc. The calorific value shows that 9845 Kcal/kg. Corrosive nature of cardanol is very mild on copper and stainless steel. Cardanol is completely miscible in alcohol and diesel and they are insoluble in water. There is no sulphur present in it. The molecular weight of cardanol is 298.5 g/mol.

SUMMARY

Viscosity is the major drawback for every biomass and this can be reduced while blending with diesel or in addition to the ethanol as similar to the conventional biodiesel in different blends. The flash and fire points were higher than diesel, which indicates that the oil is well suited for storage, handling and transportation. Calorific value of cardanol is very closer to diesel and which enables higher quantity of heat liberation during combustion process and performs good combustion inside the chamber. All the biodiesels are completely miscible with diesel and alcohol group. Absence of sulphur in cardanol possesses good feasibility of it as a biofuel. As the molecular weight of cardanol is closer to diesel, there is no need for the transesterification process.

Fig 1. Constituents of CNSL oil

CONCLUSION AND FURTHER STUDIES

More plantation of cashew tree can lead to increase the forestation against deforestation with minimum care to the plantation, in context of today's land use pressure and trading practices of economics value of cashew tree and its by-product.

From the above discussed properties of cardanol, it can be concluded that, the oil has most of the properties similar to the diesel fuel, and it is well suited as an alternative fuel in the compression ignition engine in blend with diesel. This will reduce the dependence of India on organization of petroleum exporting countries (OPEC) and will leads to the supporting of partial fulfillment of requirements of diesel in India. Further studies can be carried out to improve some of lagging properties like viscosity, corrosive nature by adding some additives to the cardanol oil.

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