A REVIEW ON BIODIESEL PRODUCTION FROM CASHEW NUT SHELL OIL AS AN ALTERNATIVE FUEL

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Abstract- Currently, the higher Greenhouse gas (GHG) emissions from fossil fuels has made the policy makers, investors and researchers to think more of the substitution of fossil fuels to save the planet. As an alternative to conventional Petro-diesel fuel, biodiesel has shown great potential due to lower emissions of harmful gases.There are four primary ways to make biodiesel, direct use and blending, micro-emulsions, thermal cracking (pyrolysis) and transesterification. The utilization of liquid fuels such as biodiesel produced from Cashew Nut Shell Oil by transesterification process represents one of the most promising options as an alternative to conventional fossil fuels. In this review, the study of extraction of oil from Cashew Nut Shells which are agro-waste from the Cashew Nut processing factories was done. Also, study of the extracted oil for further processes by transesterification to extract biodiesel from it using methanol (CH_3OH) and potassium hydro-oxide (KOH) was done.Oil content in Cashew Nut shell was approximately 35.5% by wt.Recovery of high-quality glycerol from biodiesel is an option to be considered to lower the cost of biodiesel was also studied.

Keywords- Cashew Nut Shell Liquid (CNSL) Oil, Biodiesel, Transesterification.

1 INTRODUCTION

Rapidly growing population of the world and the increasing standard of living of the people has put strain on the petroleum reserves and caused faster depletion of these reserves. As these petroleum reserves are non-renewable so there is a need to find alternative sources of fuel and petrochemical stock so as to maintain the standard of living of peoples and continuity of industrial sector.[1]

Biodiesel industry needs a cheaper and economical viable raw material that can replace the currently used vegetable oil. Obtaining cheaper raw materials are one of the continuous targets of many biodiesel producing facilities since 70 to 95 % of the production costs are attributed to raw materials. One of the main options is to use waste material from animal and plant sources.[2]

Sarina Sulaiman, Abdul Aziz Abdul Ramanl and Mohammed KheireddineAroual carried out study on coconut waste to produce biodiesel using methanol and KOH. The oil content in coconut waste varies from 10-11 wt.%. The highestyield, 64 % is achieved with 5 wt.% of KOH within 3 hr bymixing raw material and methanol. Coconut waste is a promising raw material that is cheapand abundant. There is 10-10.5 wt.% of oil in coconut wasteafter the coconut milk extraction. The highest yield, 64 % isachieved at 3hr with 5 wt.% of catalyst. However, usinghexane as a co-solvent increases the yield of biodiesel. Their finding shows that in situ production eliminates the need toextract the oil and helps in cost reduction in production ofbiodiesel.[2]

Producing biodiesel from algae is widely regarded as one ofthe most efficient ways of generating biofuels and alsoappears to represent the only current renewable source of oilthat could meet the global demand for transport fuels [3].

The diesel engine runs with waste plastic oil as fuel. The authors concluded that, the smoke was reduced by 40% than diesel.[4]

Biodiesel was prepared from non-edible palm oil by transesterification and used as a fuel in C.I engine. The authors reported that blend B5 exhibits lower engine emissions of unburnt hydrocarbon, carbon monoxide, oxides of nitrogen and carbon dioxide at full load.[5]

Cashew nut shell oil for biodiesel production-

Cashew (*Anacardium occidentale*) is an important plantation crop of India and is one of the well-known species of the Anacardiceaefamily [6]. Cashew, a native of Brazil, was introduced in India during the latter half of the Sixteenth Century for the purpose of afforestation and soil conservation. It is mainly cultivated in eastern and western coast of India mainly in Andrapradesh, goa, Karnataka, Kerala, Maharashtra, Orissa, Tamil nadu, and West Bengal. In addition, Cashew is also grown in small areas of Assam, Chhattisgarh, Gujarat, Meghalaya, Nagaland and Tripura. India has the largest area under cashew (9.23 lakh ha) and stands as the second largest producer of cashew (7.00 lakh MT) in the world [6]. India has a comparative advantage in the production and processing of cashew nuts on account of its skilled labour force. Today, India is the largest processor and exporter of cashew in the world [7]. Maharashtra ranks first in the production (28.78 % of the country) and productivity of cashew nut in India. Production of Cashew nut shell in Konkan region is 20,000 metric tons as waste product obtained during deshelling of cashew kernels The fruit of the tree consist of an outer shell (epicarp), a tight fitting inner shell (endocarp), testa and kernel. Cashew kernels have the highestprotein content among tree nuts (19.5%). This protein content matches soybean and is higher than peanut. The cashew nut shell contains 25-30% dark reddish brown viscous phenolic liquid known as Cashew Nut Shell Liquid (CNSL)and is a by-product of the cashew

industry. It is a naturally occurring substituted phenol which can take part in a variety of reactions. It is a cheap and renewable substance and can be employed for the manufacture of a multitude of useful products. It can replace phenol in many applications with equivalent or better results [8].As of now cashew nut processing industries are looking for quick disposal of cashew nut shells at reasonable prices. Presently it is burnt in a semi open pit for thermal energy generation for roasting of the nuts and is also picked up by hotels, bakeries at a cheaper rate and fired for cooking applications. In all these applications the efficiency is very low [9]. CNSL is extraction from cashew nut shell (CNS) by using of different methods. The heating process (roasting) can be achieved by open recipients or drums. The cashews can also be heated by CNSL in a process denominated as thermo – mechanic (hot oil process). In the cold, the CNSL can be obtained by extrusion, in solvents or by pressing [10]. Biodiesel is a clean burning alternate fuel, produced from renewable resources like virgin or used vegetable oils, both edible and non-edible. It can be used in compression-ignition (diesel) engines with little or no modifications. The use of edible oil to produce bio diesel in India is not feasible in view of big gap in demand and supply of such oil. Indian plants like Jatropha (Jatropha curcas), Mahua (Madhuca Indica), Karanja (Pongamiapinnata) and Neem (Melliaazadirachta) contain 30% or more oil in their seed, fruit or nut. In India, as edible oils are in short supply, non-edible tree borne oilseeds (TBOs) of karanja, Jatropha, Mahua and Neem are being considered as the source of straight vegetable oil (SVO) and biodiesel. Plant species, which have 30% or more fixed oil in their seeds or kernel, have been Paper ID: 0201562 2028 [11]. The mesocarp of cashew nut consists of honey comb network of cells containing a viscous liquid called cashew nut shell liquid (CNSL). It obtained from the shell of a cashew nut. About 30-35% CNSL is present in the shell, which amounts to approximately 6% of the nut [12]. Hence, Cashew nut oil can also be used to produce fuel to run CI (Diesel) engines.

1.1 CASHEW NUT SHELL OIL(CNSL)-

Cashew nut shell liquid (CNSL) is the by-product of the cashew industry. Conventionally, CNSL is extracted by various methods such as open pan roasting; drum roasting, hot oil roasting, cold extrusion, etc. [12]. The main product of cashew plant is cashew nuts, while the secondary products are false fruits and cashew nut shell liquid (CNSL). Currently, both the false fruit and CNSL have not been exploited optimally, mostly just as wastes. The main components of CNSL are anacardic acid, cardanol, and cardol [13].

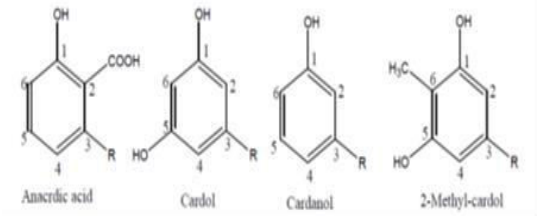

Figure 1 Components of CNSL Oil [25]

1.2 PRODUCTION OF CNSL OIL-

CNSL is classified into Technical CNSL and natural CNSL depending upon the type of Extraction. Technical CNSL is rich in Cardanol (also known as Decarboxylated CNSL) whereas Natural CNSL is rich in Anacardic acid. There are three main methods generally used in extracting cashew nut shell liquid from cashew nuts namely thermal, mechanical and solvent extraction.[14]

1.2.1 Thermal extraction

In this there three methods are there, like Roasting method, hot oil bath method or by Using Solar cooker. The roasting process not only removes the corrosive CNSL, but also makes the shell brittle, thereby aiding the cracking process. In order to extract the retained CNSL, the nuts are roasted in baths at a temperature of 180–185ºC. Vents in the equipment dispel the unpleasant fumes. This method recovers 85–90% of the liquid. In hot oil bath method cashew nut shells were collected in the cylinder, where steam heating was applied at temperatures around 200-250°C for 2-3 minutes. CNSL was then released from the shells and the process was repeated. This method yields CNSL of around 7-12% by weight. Where as in Solar cooker method Cashew nut shell oil was extracted using concentrating solar cooker of 1.4 kW capacity and a diameter of 1.4m. The focal point diameter of the cooker was 30m and was used to collect the reflected heat from reflector and achieved a temperature of 225-300°C [14].

1.2.2 Mechanical extraction:

The raw cashew nut shells are put in the hydraulic press on screw pressing and then exert high pressure in order to release CNSL from shells. By using screw speed of 7-13 rpm and feeding rate of 54-95 kg/h, the percentage of CNSL extracted was 20.65-21.04 percent, the percentage of CNSL purity was 85.53-87.8 wt % and the rate of extraction was 11.93-14.90 kg/h 40 [14].

1.2.3 Solvent extraction

Cashew nut is a high value edible nut. It yields two “Oils” one of these found, between the seed coat (or pericarp) and the nuts, is called the Cashew Nut Shell Liquid (CNSL) [15]. Extraction of oil from cashew nut shell is explained by many investigators. Tejas Gandhi et al. [10] explain that, The Cashew nut has a shell of about 1/8-inch thickness, with a soft honeycomb structure inside, containing a dark brown viscous liquid. It is called cashew nut shell liquid (CNSL), which is pericarp fluid of the cashew nut. CNSL is extractionfrom cashew nut shell by using different methods. Solvent extracted Solvent-extracted CNSL contains anacardic acid (60–65%), cardol (15–20%), cardanol (10%) and traces of methyl cardol. Technical CNSL is obtained by roasting shells and contains mainly cardanol (60–65%), cardol (15–20%), polymeric material (10%), and traces of methyl cardol.[10]

1.3 Properties of CNSL Oil

Table 1Properties of Cashew Nut Shell Oil [1]

Parameter	CNSL (pyrolysis)	CNSL (hexane extracted)	CNSL (decarboxylated)
Colour	Dark brown	Dark brown	Dark brown
Moisture content	4.1	6.4	3.2
Refractive index	1.693	1.688	1.698
Specific gravity	0.943	0.926	0.928
viscosity (centipoise)	57	40	38
Ash (%)	1.22	1.53	1.50
Saponification value (mg of KOH/g)	58.5	47.2	56.3
Iodine value (mg/100g)	212	236	227
Acid value (mg of KOH/g)	12.4	15.6	12.9
Free fatty acid (mg of KOH/g)	6.5	7.9	8.2
pH	4.8	4.5	5.2
Calorific value (kJ/g)	47.62		

1.4 Methods of producing Biodiesel

From CNSL Studies have revealed that the usage of non-edible oil in neat form is possible but not preferable. The high viscosity of non-edible oils and low volatility affects the atomization and spry patterns of fuel, leading to incomplete combustion and severe carbon deposits, injector choking and piston ring sticking.

The methods used to reduce the viscosity are.

- Emulsification.
- Pyrolysis.
- Dilution.
- Transesterification.

Among these, the transesterification is commonly used commercial process to produce clean and environment friendly fuel [16].

i. Emulsification or micro Emulsification

To solve the problem of high viscosity of vegetable oil, micro emulsions with solvents such as methanol, ethanol and butanol have been used. A micro emulsion is defined as the colloidal equilibrium dispersion of optically isotropic fluid microstructures with dimensions generally in the range of 1– 150 nm formed spontaneously from two normally immiscible liquids and one or more ionic or non-ionic amphiphiles. These can improve spray characteristics by explosive vaporization of the low boiling constituents in the micelles. All micro emulsions with butanol, hexanol and octanol will meet the maximum viscosity limitation for diesel engines [17]. The formation of micro emulsions (cosolvency) is one of the potential solutions for solving the problem of vegetable oil viscosity. A micro-emulsion can be made of vegetable oils with an ester and dispersant (cosolvent), or of vegetable oils, an alcohol and a surfactant and a cetane improver, with or without diesel fuels [18].

ii. Pyrolysis

Pyrolysis strictly defined; is the conversion of one substance into another by means of heat or by heat with the aid of a catalyst. It involves heating in absence of air or oxygen and cleavage of chemical bonds to yield small molecules [19]. The decarboxylated cardanol is termed as CNSL biodiesel. The biodiesel obtained from CNSL not required for further processing like transesterification [20]. It can be obtained by pyrolysis. Risfaheri et al. [14] explain the pyrolysis procedure of CNSL, Heating CNSL decomposed the anacardic acid into cardanol and CO2. Decarboxylation of CNSL to convert anacardic acid into cardanol could be done by heating, with an optimum heating temperature of 140°C for 1 hour. Cardanol was isolated from the CNSL by vacuum distillation (4-8 mmHg) at high temperature, with an optimum temperature of 280°C, and the rendement 74.22%.

iii. Dilution

The vegetable oil is diluted with petroleum diesel to run the engine. Caterpillar Brazil, in 1980, used pre-combustion chamber engines with the mixture of 10% vegetable oil to maintain total power without any alteration or adjustment to the engine. At that point it was not practical to substitute 100% vegetable oil for diesel fuel, but a blend of 20% vegetable oil and 80% diesel fuel was successful. Some short-term experiments used up to a 50/50 ratio [21].

iv. Transesterification

Pure oils are not suitable for diesel engines because they can cause the carbon deposits and pour point problems and they can also cause the problems like engine deposits, injector plugging, or lube oil gelling. So, to use the oils in the diesel engines, they are chemically treated and that chemical process is known as transesterification. The transesterification which is also known as alcoholises is the reaction of fat or vegetable oil with an alcohol to form esters and glycerol. Mostly a catalyst is also used to improve the rate and yield of the reaction. Since the reaction is reversible in nature, excess alcohol is used to shift the equilibrium towards the product. Hence, for this purpose primary and secondary monohydric aliphatic alcohols having 1-8 carbon atoms are used. The chemical reaction of transesterification processes is shown below in figure.4 [22]. Okoro et al. [23] explains production of Biodiesel from CNSL as, 50ml (36.0g) of cashew nut oil was measured and poured into a conical flask. The oil was preheated to 70°C. Sodium hydroxide (0.225g) was weighed and added to 20ml of methanol in a conical flask. The sodium hydroxide and methanol were properly mixed by stirring till the entire pellet dissolves to form sodium methoxide solution. The sodium methoxide solution was poured into the preheated cashew nut oil. The solution was mixed and stirred properly until homogeneity was achieved. This same procedure was followed while using potassium hydroxide as catalyst. The reaction mixture was maintained at a temperature of 70^0C for 1.5hr. The product was poured into a separating funnel and left overnight for proper settling of the glycerine

produced. The products of the transesterification reaction Fatty Acid Methyl Esters (FAME) contain some impurities like unreacted methanol, potassium methoxide and the by-product of biodiesel (glycerol) therefore it needs some forms of purification before it can be used in diesel engines. Hence, the following procedure was used in washing the biodiesel: 30ml of water was measured using a measuring cylinder and poured gently on the product sample. The mixture was gently stirred to avoid foam formation. Shaking rigorously is not advised. The mixture of water and biodiesel was left for 5 hrs to settle into two phases which are; water-impurities phase and biodiesel phase. The two-phase mixture was then separated using a separating funnel, drying is recommended.

1.5 PROPERTIES OF BIODIESEL

Table 2Comparison of CNSL Biodiesel with Conventional Biodiesel [24]

PROPERTIES	CONVENTIONAL DIESEL	BIODIESEL
Water content (%)	0.001	0.11
Density at 18°c(kg/m^3)	0.8210	0.8833
Kinematic viscosity(mm^2/s)	2.5	4.30
Calorific value(kJ/kg)	42,950	38,108
Cetane no	46	52
Flash point	50	140

2 MATERIALS AND METHODOLOGY

Materials required-

i. CH_3OH - 300ml.
ii. NAOH - 5g
iii. H_2SO_4 - 2ml.
iv. CNSL OIL - 1 litre

Firstly, the oil from cashew nut shell was extracted using the cold press method.

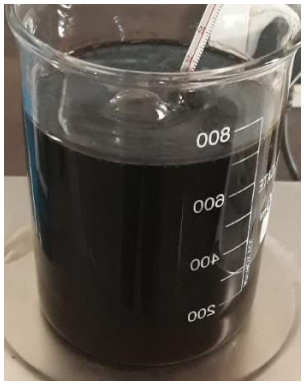

Figure 2 Extraction of oil by cold press method

Then 1 litre of CNSL oil was mix with 200ml ofCH_3OH and 2ml of H_2SO_4 heated with 60°c for 3 hours and then mixed with 100ml ofCH_3OH and 5g of NAOH and then heated for further 3 hours and then kept it in a settling separator over a night. Then removed theglycerol and the bio diesel was obtained. Then washing with the warm water was done. Finally, pure bio diesel free from methanolwas obtained.

3 OBJECTIVES

1. To conform the feasibility of cashew nut shell as a source of biodiesel.
2. To conform the feasibility of cashew nut shell as a source of solid fuel briquettes.
3. To extract oil from cashew nut shell which is an industrial waste.
4. To Compare the emission characteristics and performance of Petroleum diesel with the produced biodiesel from CNSL oil.
5. Find suitable method to produce biodiesel from CNSL which is cost effective and reliable.
6. To encourage the agriculture sector.

4 SCOPE OF STUDY

At present, Scarcity of Fossil Fuels is increasing, as they are available in restricted amount. So it is important to find alternative fuel source. Here the biodiesel is produced from CNSL which is produced from waste cashew nut shell and the by-product obtained from extracting oil is converted into Bio manure. Emission and Performance analysis is also carried to check its feasibility.

5 CONCLUSION

1. The study from the results reveals that biodiesel from cashew nut shell oil has a number of advantages over petroleum diesel, namely: low fuel consumption, higher combustion pressure and longer combustion period.
2. The study reveals that Solid fuel briquettes from cashew nut shell oil residue have higher calorific value than any other biomass briquettes.

3. In the view of majority positive results obtained from the experiments, it is rational to say that biodiesel from Cashew nut shell oil can be used as a substitute for petroleum diesel in diesel engines. Hence, biodiesel from Cashew nut shell oil contributes to be an alternative source of green renewable energy to meet the energy demands of the future.

6 FUTURE WORK

1. Preparing Cashew Nut Shell oil by cold press method and to produce biodiesel from this oil in laboratory.
2. Comparing different characteristics of the petroleum diesel with the produced biodiesel from Cashew Nut Shell Oil.
3. Making small scale model for biodiesel production using low cost equipment and checking its feasibility for large scale plants.

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