Production of Jatropha Biodiesel in Laboratory Scale

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Abstract

The paper presents how to convert jatropha curcas oil into biodiesel in Sudan. It Concerns about the depletion of fossil fuel reserves and increasing prices of oil. The negative effects of fossil fuels on the environment and on human health have necessitated the creation of sustainable biofuels that will reduce our reliance on fossil fuels. Biodiesel which is made from animal fats and non-edible plant oil sources is classified as a sustainable, renewable and ecofriendly source for biofuel. The method used consisted of two-steps process, first the esterification then followed by transesterification process. There were some important factors that affected biodiesel production like molar ratio, temperature, and catalyst amount. The molar ratio of oil to methanol (1:6) with 5% (weight) of NaOH concentration was examined at reaction temperature of about 60oC. The produced biodiesel's specifications were analyzed and addressed. Kinematics viscosity was found to be about 5.251 mm2/s at 40oC, flashpoint value was 200oC, density obtained was 0.8852 g/cm3 at 15oC and the cloud point was found to be +9. The produced biodiesel was characterized and compared to standards biodiesel physical and fuel properties (D6751ASTM Standards).The work presented here introduces jatropha oil as a sustainable feedstock for biodiesel and may fill the gap of diesel production in the future.

Keywords: Trans-esterification; Jatropha oil; Biodiesel; renewable energy ; biofuel .

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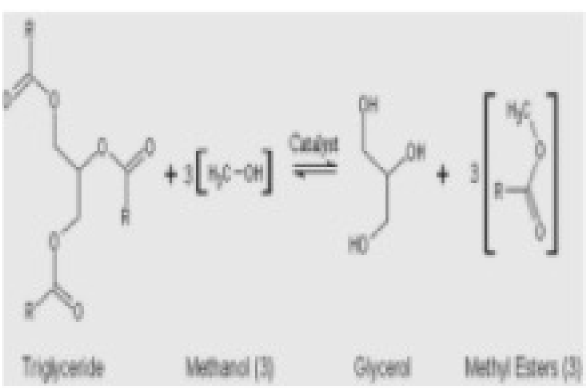
1. Introduction

Energy is one of the major issues in the area of economic development. As it is well known the energy is required in every sector of the country. In Sudan, the implementation of the economic development plans needed a huge amount of energy so the utilization of different energy types increased all over the country. Energy consumption has also led the country to become heavily dependent on other fuels, such as gas and oil. Increasing fossil fuels prices and possible shortages led to thinking about how to let the energy required for Sudanese economic development to be sustainable. From another side of view, the use of fossil fuels often causes environmental problems [1]. In Sudan, the increased demand for high-speed diesel (HSD) with a lack of fossil oil production caused a major problem in the transportation sector, in addition to increasing the consumption of fossil oil by other industrial sectors. [2]. Responsibility for the depletion of fossil fuel sources and environmental degradation has led to increase researches in this area, so that to identify and select alternative fuel sources to be widely applied, bearing in mind that alternative and unconventional energy sources used in the transportation sector will play a major role in the generation and consumption of energy in the future. [3]. Biofuels, especially biodiesel and ethanol have become more used in some countries. Biofuels have the advantage of durability due to its production from renewable sources and thus provide energy security for a long time to the country. It also provides more job opportunities in agricultural management and processing fields. It also saves foreign currency spent on buying fossil fuels. The use of biofuels is not yet applicable in most countries. This needs to promote institutions involving the cultivation of energy crops, biofuel production, marketing and consumption which will take some time. The blending of different ratio of biofuel in fossil fuel is developed by many countries to match market demand and supply. To help vehicle manufacturers in modifying engines to offer stability during biofuel usage, the practice of plant and animal oil or fats as diesel's substitutes are called biodiesel which has given attention all over the world. The increase in the prices for petroleum fuel products cause the biodiesel's demand increase respectively [4]. Some studies have confirmed a reduction in CO2 emissions of about 78% when compared to petrodiesel fuel [5]. Vegetables and animal fats are similar in that they contain long-chain hydrocarbons and both of them are friendly to the environment but some evaluations need to be done separately to ascertain the potential of each [6]. Many researchers [7] have advocated for the use of non-edible feedstock from plants, especially alike Jatropha curcas because it is considered one of the most suitable types for the production of biodiesel as it meets European Union standards. Others investigate non-edible crops, such as R.communit and M.azedarach which considered as high concentration oil sources [8]. In the aspect of the private investors, there is a new energy crop available which is evaluated to produce biodiesel and be cheaper than others like soybeans and rapeseed. Also Microalgae conducted as alternative feedstock for biodiesel and met a high attention, because of it's a high quality production [9]. This argument is based on the availability of low-cost labor and land in Africa. Anyhow, the jatropha production to use as feedstock to produce biodiesel has been developed by private sections, non-governmental organizations and overseas development assistance agencies working in Africa such as Kenya. It is within the context of this background that we looked at the possibility for jatropha in Sudan as a share of the Sudan

Biofuels Roadmap-Aeronautical Research Centre (ARC –Sudan, July 2013). The Jatropha plant height is about 5 m and the yield of its seed is about 7.5 to 12 tons for every hectare annually. Oil contents of whole Jatropha seeds are 30-35 % by weight [10]. The methods for producing biodiesel include pyrolysis, micro emulsification and transesterification. Transesterification is done by reacting the vegetable oil or animal fat with alcohol. Different catalysts can be used such as enzymes, bases and acids or determined out under special conditions in the presence of a catalyst. [11,12,13] The use of ethanol, which is less cost has great consideration [14] and can be obtained from biomass. For all that, higher conversions to biodiesel was obtained using methanol which is low sensitive to water when using the process of alkali catalyst compared with ethanol. Commercial biodiesel generated from plant oil was created mostly by alkali catalyzed- transesterification shown in Fig 1.

Fig. 1 Transesterification Reaction for Biodiesel Production



The reaction between plant oil and alcohol gives alkyl esters (biodiesel) as a basic product and glycerol as a by-product. The glycerol purity is around 50% with excess alcohol and catalyst [15]. Glycerin must be refined in other manufacturing processes before using in order to purify it from impurities [16]. On the other hand, some researchers worked on the model of multi steps in a cold flow effect in gas distribution from biomass which was affected by the flow rate of the gas and the used materials [17].In addition to, many simulation reactors were investigated using gasification reactor. The cold flow of the mixture of gas and solid were studied using software programming such as (ANSYS Fluent) [18].

The work objective is to establish a jatropha biofuel production, compares it with diesel petrol and calls for more studies to involve jatropha oil as a sustainable raw material in the biodiesel industry.

2.Material and Methods

2.1. Materials

The Jatropha oil which was used in this process was obtained from the local market (planted & extracted in local area). Oil was used with alcohol. Methanol is alcoholic solvent of 99.8% purity with density of 0.79 g/ml. Sodium hydroxide is a base which was adopted as a catalyst. Sulphuric acid of 98% purity was used to neutralize the feedstock oil from high fatty acid. Other reagents were used for analytical steps.

2.2. Apparatus

A lab-scale apparatus was developed for the technique. It consists of a reactor flask placed on a hot plate which is attached to a water bath with r.p.m. controller to control the speed and a condenser. A thermometer for measuring the temperature and another volumetric flask were used.

3.Experimental procedure

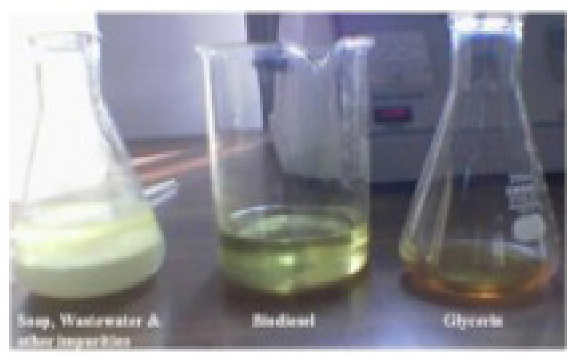
3.1. Neutralization

The oil of jatropha contains approximately (14-19.5%) of natural free fatty acids [19]. Before being taken into the actual process of conversion, it must be carefully purified. The result of 15.9 % of free fatty acid makes Jatropha oil unacceptable for the development of industrial biodiesel. Stirring up the dehydrated oil with a 2% H2SO4 solution for an hour and then 20% methanol amount was added. This approach brings the content value of free fatty acid below 2 % which is a great achievement to the biodiesel industry. The oil was filtered to isolate the waste from it. The reaction rate is then preheated at 35oC to remove the water content which can negatively affect the process. To find the range of NaOH catalyst concentration, the oil was titrated.

3.2. Trans-Esterification process of Jatropha oil.

To commodity a methyl ester (biodiesel), the Jatropha curcas oil trans-esterification method was used [20]. The process was taken place in a reactor (glass equipment) fitted with a reflux condenser and a thermometer. Also, a mechanical stirrer and sample port were used. The reactor was constructed to undergo a 60oC temperature at atmospheric pressure with a molar ratio of 1:6 (oil to methanol) with 5% weight concentration NaOH catalyst. Firstly the oil was put into the reactor. The catalyst and methanol were put in a volumetric flask and a magnetic stirrer was used for 15 minutes. The stirred mixture was put in the reactor and mixed up for about 60 minutes to enable the trans-esterification reaction to take place. When the process ended and the feedback completed, the solution was spread in a flask and settled about 12 to 24 hr to isolate methyl ester and glycerol . Then the methyl ester was washed and stirred for 15 minutes using distilled water. Using a rotary vacuum evaporator [21], the excess solvent was removed. The product was analyzed using gas chromatography (GC) in order to determine the kinematic viscosity, density and flash point. Referring to the American Society for Testing and Materials (ASTM), the methyl ester results were compared. Fig. 2 shows the product sample.

Fig. 2. Sample of the product



3.3. Analysis of Biodiesel by Gas-Mass Chromatograph Equipment

The GC is used to separate the components of the solution. The distinction is based on the holding of the measurement between two phases (the mobile gas phase and the stationary liquid phase). The interface of GC Column points into the mass spectrometer which consists of three components:

1. Mass filter
2. Ion source
3. Quadruple and Detector (continuous dynode electron multiplier.

The system components are controlled via MS-DOS Chem. Station. The software data contains programs to calibrate MSD acquire data, data processing, file management and Editing.

Instrument information:

Name: GC.MS Detector, mass spectrometer

Model: GC.MS-QP2010 Ultra.

Company: Shimadzu from Japan.

Column Rtx-5MS, length (30m), Diameter (0.25mm), thickness (0.25µI) and Carrier gas is Helium.

Peak report Tic obtained from GC show that the main ester produced is 9, 12-Octadecadienoic acid (z,z)-methyl ester with an area of about 36.77 % and retention time is 17.553 min. The analysis was done at UMST University of medical science & Technology, Khartoum- Sudan.

4.Results

The results of jatropha oil properties were obtained in IRCC laboratory, Sudan and measured by titrimetric method. Below are the chemical analysis results of jatropha oil.

Table 1. Chemical analyses results of Jatropha oil

Item	Value
Viscosity cP	± 91
Moisture %	± 0.1242
Acid value%	± 31.8
FFA%	± 15.9
Density (g/cm^3)	± 0.959

Table 2. Yield results of Jatropha biodiesel produced under selected method conditions

Item	Yield Result%
Biodiesel produced	80
Glycerol	28

N.B: The product percentage is calculated as:
Product % = output/input ^{x} 100

Table 3: Jatropha Biodiesel Analysis results compared with standard specifications

Test name	Test method	unit	Jatropha biodiesel Result	ASTM D6751
Density at 15 ^{o} C	ASTM D4052	g/cm^3	0.8852	-
S.G	ASTM D4052	-	0.8861	0.95 max
Kinematics viscosity at 40^o C	ASTM D445	Cst	5.251	1.9-6.0 (mm^2/s)
Flash Point	ASTM D93	C	< 200	130 min
MCR	ASTM D4530	Wt%	0.00	-
Cloud point	ASTM D2500	C	+9	40 max
Water content by a distillation	ASTM D95	V%	0.00	0.5 max

*Samples analysis was done in Sudanese Petroleum Corporation (SPC), Petroleum laboratories, Research and studies in Khartoum-Sudan.

4.1. Discussionof Results

The results obtained from the experimental procedure were currently involving jatropha oil as a sustainable feedstock for biodiesel production . Analysis results of jatropha oil samples showed in table (1) show that the results of different physical and chemical properties of the produced jatropha oil are in the range of its standard specifications and mentioned as (±) due to standard deviations values . As obtained, the moisture content is ± 0.1242 % which considered as a critical property .If the oil sample has high moisture content, the soap formation quantity will be more and there will be a problem in the separation of the by-product (glycerol). Acid value is also a significant property with a rate of ± 31.8

% and the free fatty acid is about ± 15.9 %. Both parameters are within the range of the standard values. The jatropha oil Viscosity is found to be ± 91 cP which is greater than the standard specification and it must be improved before taken into the actual transformation process. The percentage yield 80% of biodiesel in table (2) is acceptable and near to result reached by previous study, which about 79.5%[20]. The chemical reaction that yielded the biodiesel was carried according to the standard conditions. The biodiesel tests were analyzed at the (SPC) laboratory in Khartoum, Sudan. The results were presented in table (3) compare with the corresponding limit set in the last Column in table (3) for (ASTM D6751) methods . The obtained biodiesel flash point which is about 200oC is considered as high value when compared to diesel. This causes it to be safer for users and stores. Biodiesel viscosity is 5.251cst, which is higher than diesel but still within the range of ASTM standard. The high viscosity has a large tendency to cause problems but diesel blends solve this problem. The produced biodiesel cloud point test result is +9 which is not higher than petrodiesel. This makes the biodiesel performance acceptable in the cold season in addition to the nil water which help to avoid the contamination and other problems that may happened in the operating system. The temperature, agitation, actual quantity, catalyst value and Methanol ratio are the pass- key parameters for the best biodiesel production quality.

Conclusions

All the above results confirmed that Jatropha oil is a good and sustainable raw material to produce biodiesel. Jatropha can be planted in any area for a long life period .It yields about 30% oil which is economical so it is a sustainable feedstock for biodiesel besides it is non-edible oil. The experimental result showed about 80% biodiesel yield. The promising research field of alkaline–catalyzed transesterification classified it as a suitable process to produce biodiesel on a large scale. Used oil from the restaurants' kitchens can be reused but in small scale biodiesel production. The glycerin which is a 20% by-product, can be sold to cover a part of the high cost of biodiesel production. Materials used in the production process are available and no addition for special equipment is required. Jatropha biodiesel which is obtained from green material make it eco-friendly to the environment. Finally the chemical and physical properties of Jatropha biodiesel make it competitive in bio-energy fields.

References

[1] A. Yadav and V. Krishna, 2012.Sustainable energy production from Jatropha bio-diesel: Lap Lambert Academicpubl, vol. 1, ISSN 2278-7763 .

[2] B. Abdalla and F. Oshaik, 2013." Base-transesterification process for biodiesel fuel production from spent frying oils," Agricultural Sciences, vol. 4, pp. 85-88.

[3] A. Okullo and T. Noah, 2017. "Process simulation of biodiesel production from

jatropha curcas seed oil," American Journal of Chemical Engineering, vol. 5, pp. 56-63.

[4] G. Knothe, 2005. "Dependence of biodiesel fuel properties on the structure of fatty acid alkyl esters," Fuel processing technology, vol. 86, pp. 1059-1070.

[5] K. Tyson, 2004. "Biodiesel Handling and Use Guidelines. 2001," National Renewable Energy Laboratory: Golden, CO, pp. 1-17.

[6] A. K. Agarwal, 2007. "Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines," Progress in energy and combustion science, vol. 33, pp. 233-271.

[7] D. Bajpai and V. Tyagi, 2006. "Biodiesel: source, production, composition, properties, and its benefits," Journal of OLEo science, vol. 55, pp. 487-502.

[8] M. Awais, S. e. A. Musmar, F. Kabir, I. Batool, M. A. Rasheed, F. Jamil, et al , 2020. "Biodiesel Production from Melia azedarach and Ricinus communis Oil by Transesterification Process," Catalysts, vol. 10, pp. 390 - 427.

[9] F. Kabir, M. Gulfraz, G. K. Raja, M. Inam-ul-Haq, M. Awais, M. S. Mustafa, et al., 2020. "Screening of native hyper-lipid producing microalgae strains for biomass and lipid production," Renewable Energy, vol. 160, pp. 1295-1307.

[10] A. Lang and H. F. A. Elhaj, 2013. "Jatropha Oil Production for Biodiesel and Other Products."ARC_sudan, SD-ARC-WBA-G09-002.

[11] P. Ejikeme, I. Anyaogu, C. Ejikeme, N. Nwafor, C. Egbuonu, K. Ukogu, et al., 2010. "Catalysis in biodiesel production by transesterification processes-An insight," E-Journal of Chemistry, vol. 7, pp 1120-1132.

[12] T. T. B. Lan and P. N. Hoa, 2015. "Lipase catalysis for transesterification produces biodiesel using coconut oil as the main raw material source," Biological and Chemical Research, vol.2015, pp. 258-267.

[13] M. Tuter, C. Akdere, C. Yerlikaya, and A. Sirkecioğlu, 2011. "The Evaluation of Fusel Oil Fraction for Lipase Catalyzed Alcoholysis of Hazelnut Oil," Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, vol. 33, pp. 521-528.

[14] A. Demirbas, 2009. "Production of biodiesel fuels from linseed oil using methanol and ethanol in non-catalytic SCF conditions," Biomass and bioenergy, vol. 33, pp. 113-118.

[15] I.Contreras-Andrade, E. Avella-Moreno, J. F. Sierra-Cantor, C. A. Guerrero-Fajardo, and J. R. Sodre, 2015." Purification of glycerol from biodiesel production by sequential extraction monitored by 1H NMR," Fuel Processing Technology, vol. 132, pp. 99-104.

[16] M. Nanda, Z. Yuan, W. Qin, M. Poirier, and X. Chunbao, 2014. "Purification of crude glycerol using acidification: effects of acid types and product characterization," Austin Journal of Chemical Engineering, vol. 1, pp. 1-7.

[17] M. Dhrioua, W. Hassen, L. Kolsi, V. Anbumalar, A. S. Alsagri, and M. N. Borjini, 2019. "Gas distributor and bed mate-

rial effects in a cold flow model of a novel multi-stage biomass gasifier," Biomass and Bioenergy, vol. 126, pp. 14-25.

[18] W. Hassen, M. Dhrioua, L. Kolsi, V. Anbumalar, A. A. Al-Rashed, and M. N. Borjini, 2018. "CFD modeling of gas-particles flow in a circulating fluidized G-Volution gasification reactor," International Journal of Mechanical Sciences, vol. 144, pp. 438-451.

[19] M. Mathiyazhagan, A. Ganapathi, B. Jaganath, N. Renganayaki, and N. Sasireka, 2011. "Production of biodiesel from non-edible plant oils having high FFA content," International Journal of Chemical and Environmental Engineering, vol. 2.

[20] C. A. Z. Jamil and A. Muslim, , 2012."Performance of KOH as a catalyst for Trans-esterification of Jatropha Curcas Oil," International Journal of Engineering Research and Applications, vol. 2, pp. 635-639.

[21] M. Y. Koh and T. I. M. Ghazi, 2011. "A review of biodiesel production from Jatropha curcas L. oil," Renewable and sustainable energy reviews, vol. 15, pp. 2240-2251.