FEASIBILITY OF BIODIESEL PRODUCTION FROM *JATROPHA CURCAS* OIL

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Abstract
Production of biodiesel from renewable sources has come to stay. The usefulness of biodiesel over the fossil diesel in combating the environmental degradation caused by fossil diesel combustion is a major reason for the continuous production of biodiesel. The usefulness of biodiesel over fossil diesel includes its biodegradability, higher flash points hence safer to transport and the production of far lesser carbon iv oxide gas during combustion. However, the high cost of biodiesel production is a challenge that should be considered. In this study, the cost analysis of the production of a liter of biodiesel produced from Jatropha curcas seed oil is presented in this study. The best economic way for biodiesel usage to mitigate the environmental challenges caused by fossil diesel are also highlighted.
Keywords: *Biodiesel, Jatropha curcas, fossil fuel, cost analysis*

Introduction

The use of fossil fuels in combustion processes, transportation and energy generation have resulted to the negative effects of global warming, environmental pollution and degradation as well as fast depleting reserves (Johnson et al, 2018). Based on these considerations, biodiesel has been extensively researched as a suitable alternative to the conventional fossil diesel due to its physical and chemical similarity to diesel properties. These properties include: flash point (Azad 2015), high cetane number (Rashid et al, 2008), and viscosity (Sajjadi et al, 2015). Particularly, the suitability of several vegetable oils and animal fat feedstocks have been extensively researched (Lin et al, 2009; Kuss et al, 2015; Encinar et al, 2018; Zhang et al, 2013; Onuh et al, 2019). However, production limitations, biodiesel price competitiveness, and cost of feedstocks are major challenges confronting the enhancement of biodiesel production (Avinash and Murugesan, 2017; Knothe et al, 2009).

Nevertheless, the cost of biodiesel feedstock is a major limitation in production, other forms of costing such as fixed and variable cost also affect general biodiesel production processes. The fixed cost of production includes cost of operating labor, supervision, direct salary overhead, maintenance, property taxes, insurance, rent of land, marketing and sales. The variable cost includes cost of raw materials consumed by the process, fuel burned in process, catalyst used, effluent disposal, packaging and shipping costs. Costs of biodiesel production have previously been found to depend on geographic area, price of crude oil, variability in crop production from season to season and feedstock cost (Demirbas, 2005). Other recent research have also presented cost of feedstock as a challenge in biodiesel production (Rao and Ramakrishna, 2015; Avinash and Murugesan, 2017). From their research, Rao and Ramakrishna (2015) identified cost of feedstock as the major drawback in biodiesel production. Similarly, Avinash and Murugesan (2017) confirmed cost of feedstock as one of the most significant variables affecting the economic viability of biodiesel manufacture.

Unfortunately, most research on cost and economic analysis of biodiesel production process has focused only on vegetable and animal fat (You et al, 2008; Rao and Ramakrishna 2015; Kapsuta et al, 2016). Though a recent study investigated the economic analysis of the production process from waste cooking oil which is non-edible (Avinash and Murugesan, 2017), more research is needed on the use of other non-edible feedstocks such as *Jatropha curcas* seed oil. To this end, this study is aimed at performing a simple cost analysis of the biodiesel production process of *Jatropha curcas* seed oil. The feedstock cost as well as that of the procedures are presented and comparisons with other feedstock and current diesel prices are also shown. For purpose of simplicity, the cost estimate of the biodiesel production from *Jatropha curcas* seed oil was based on the cost of raw materials, including fixed costs, effluent disposal cost, cost of fuel or electricity and cost of biodiesel washing which was included in labor cost.

Materials and Methods

Materials used in this work include *Jatropha curcas* seed oil which was extracted from fresh *Jatropha* seeds using a hydraulic press, methanol of high grade (HPLC grade), sodium hydroxide purchased from Sigma Aldrich Company Germany, hot plate with a magnetic stirrer and temperature regulation system. An improvised reactor (500ml beaker), mercury in glass thermometer, cotton wool and gas chromatography with a mass spectrophotometer.

The fresh *Jatropha* seeds were obtained from a farm in Ogoni-Olomu, a small town in Ughelli South Local Government Area of Delta State, Nigeria. A locally fabricated hydraulic press was used to extract the oil from the ground seeds. *Jatropha* seed oil and methanol of the equivalent of a molar ratio of methanol to oil 8:1 were weighed and placed each in two beakers, A and B. Beaker A containing the oil was heated to a temperature of 100^{o}C for about 5 to 10 minutes to drive off any moisture that may be present in the oil. The free fatty acid of the oil was tested and found to be 0.8%, hence the oil was suitable for a one-step trans-esterification to occur. One per cent sodium hydroxide by weight of oil was added to beaker B containing the methanol. The heated oil was allowed to cool to 60^{o}C. The oil was trans-esterified with sodium hydroxide in methanol by adding the mixture of sodium hydroxide in methanol to the oil while stirring at 450 rpm. The temperature of the reaction was kept at about 60^{o}C. The reaction was allowed to continue for an hour. After an hour the mixture was allowed to cool and settle. The separated biodiesel was analyzed on gas chromatography with a mass spectrophotometer to determine percentage methyl ester formed. The fuel properties of the biodiesel produced were also determined.

Results and Discussion

The weight of the liquid extract obtained from this experiment containing majorly methyl esters was 62.78g while the solid extract containing majorly glycerol was 50.90g. The analysis of the liquid extract for percentage methyl esters with gas chromatography gave a percentage yield of methyl ester of approximately 95 %. This result shows a reasonable conversion and reveals that most the monoglycerides and diglycerides have been converted to methyl ester. It also shows that the quality of the biodiesel produced or its blend will be suitable for internal combustion engine.

Comparison of *Jatropha curcas* biodiesel properties with standards

Comparison of some of the properties of the biodiesel produced with standards of biodiesel in Asia, Europe and America are shown in Table 1.

Table 1: Comparison of the fuel properties of *Jatropha curcas* biodiesel produced and standards of biodiesel in Asia, Europe, and America.

	Produced *Jatropha curcas* oil	CHINA GB/T 20828-2007	EUROPE, EN 14214	USA ASTMD6751-02
Viscosity at 40^0C (mm^2/S)	4.91	-	3.5-5.0	1.9-6.0
Flash point, ^{O}C	191	≥130	≥120	>130
Cetane number	49.17	≥49	51	47

The close similarity of the properties of obtained *Jatropha curcas* to the standards makes the biodiesel generally acceptable for use. Although rapeseed and moringa tend to have better properties due to their higher oleic and linoleic acid contents, the flash point of *Jatropha curcas* which is highest shows that the biodiesel produced from *Jatropha curcas* oil is safer and can be better stored at room temperature (Azad, 2015).

Fatty acid profile of *Jatropha curcas* oil compared with other feedstocks.

Table 2: Comparison of Fatty Acid contents of *Jatropha curcas* seed oil with other feedstock

Fatty acids / % Composition	Obtained *Jatropha curcas* seed oil (Akhihiero 2014)	*Jatropha curcas* seed oil (Adebowale and Adedire, 2006)	Soybean oil (Agarwal et al, 2010)	Moringa oil (Kivevele and Huan 2015)	Rapeseed oil (Ramadhas et al, 2005)	Sunflower oil (Demibras , 2008)	Rice bran oil (El-Boulifi, 2013)
Myristic acid	0.260	-	-	-	-	-	0.5
Palmitic acid	14.398	11.3	12.13	6.5	3.36	6.6	19.1
Palmitoleic acid	0.704	-	0.3	2	-	0.1	-
Stearic acid	6.65	17	3.49	6	1.12	3.08	2.55
Oleic acid	43.39	12.8	23.41	72.2	63.33	17.31	40.4
Linoleic acid	32.984	47.3	54.18	1	-	73.31	36.1
Linolenic acid	0.351	-	6.5	-	8.11	-	2
Arachidic acid	0.218	4.7	-	4	-	-	-

Oleic acid has been shown to have good potential for biodiesel (Azad, 2015). The composition of oleic acid in the *Jatropha curcas* oil analyzed in this study was 43.39%. Possible reasons for the wide difference between the oleic acid values reported for this study and that of Adebowale and Adidire 2006 are; 1. the type of soil where the plant was grown, the location, or exposure of the plant to sunlight and varied climatic conditions (Akhihiero et al, 2013). Also, this production process is cost effective in comparison to other methods. Although oils with very high unsaturated fatty acid content such as moringa and rapeseed oils show better biodiesel performance than *Jatropha curcas* oil (Cayli and Kusefoglu, 2008; Kara et al, 2017), the biodiesel from feedstock with high FFA content are often produced through the use of acid and enzyme catalysts which increase reaction time and costs of catalyst separation (Lam et al, 2010; Sander et al, 2018).

Price and yield variation for feedstock

A comparison of feedstock oil and biodiesel yields with prices is as given in Table 3.

Table 3: Comparison of feedstock oil and biodiesel yields with prices

	Biodiesel Yield (%) (Zahan and Kano 2018; Encinar et al, 2018; Qiu et al, 2011; Azad et al, 2015; Kafuku et al, 2010)	**Oil Content (**Kg oil/ha) (Kuss et al, 2015**;** Sumathi et al, 2008)	**Price (USD/ton)** at July 2019 (https://www.indexmundi.com)
Palm Oil	~93	5000	543.88
Soybean	~94	375	748.17
Rapeseed	95	1000	845.21
Coconut	-	2670-3310	657.31
Peanut	-	890	1,437.71
Sunflower	-	800	753.83
Moringa oleifera	84	38-40	-

Cost Estimation

62.78g of biodiesel was produced from 100g (110mls) of *Jatropha* seed oil. The methanol used for a molar ratio of 8:1 was 37.2mls (29.54g) and the sodium hydroxide catalyst was 1% the weight of oil (1gram). From this it was deduced that 1000mls (1 litre) of biodiesel would be produced from 1571mls (1405g) of *Jatropha* seed oil.

With the aid of the fabricated hydraulic press, 260ml (232.6g) *Jatropha* oil was extracted from 674g of seeds. Therefore 1571mls (1405g) of the oil could be extracted from four kilograms of seeds. One kilogram of *Jatropha* seeds cost two hundred naira (N200.00). So four kilograms would cost eight hundred naira (N800.00). About 531mls (421.5g) of methanol was required for the process. Considering the present market price, the methanol required for the process would cost N1,593.00. Catalyst cost was assumed to N10.00 per gram.

Table 4: A summary of the total cost of raw materials for production of 1 litre of biodiesel from *Jatropha curcas* seed oil.

Material	**Quantity**	**Rate**	**Total Cost**
Jatropha seed oil	from 4kg of seeds	N200 per kg	N800.00
Methanol	531ml	N3 per ml	N1,593.00
Catalyst	14.05g	N10.00 per g	N140.50
Hot plate	1	Per hour	N200.00
Oil press	1	Per hour	N200.00
Reactor	1	Per hour	N300.00
Heating cost	1 electric unit per hour	Per hour	N7.00 for a single phase.
Labour	1 worker	Per hour	N500.00
Grand Total			N3,740.50

From the cost breakdown for materials for 1 liter of biodiesel in Table 4, the estimated cost of production of one liter of biodiesel from *jatropha* oil is N3,740.50. This implies that 250 milliliters of *jatropha* biodiesel would cost N935.13 per kg of seeds. This is rather high compared to the current average price of petroleum diesel which is N224.43 per litre in Nigeria. The cost of production being very high could be due to the batch production process used. Also this cost is an experimental cost and it is not optimized. With the use of a continuous process and cost optimization, the production cost can be drastically reduced to compete with the price of fossil diesel.

Although biodiesel produced from vegetable oils in this manner may be more expensive than fossil diesel, their production and discovery is a welcome development due to the environmental friendly nature of the fuel. The advantages of this renewable fuel over the fossil diesel far outweigh the challenges of the high production cost. However, the fuel could be used as a blend with fossil diesel to minimize cost. This is confirmed by the findings of Akhihiero et al (2019) that a blend of biodiesel to fossil fuel of 20:80 gave promising fuel properties that could mitigate environmental pollution.

Conclusion

This study has shown the simple cost analysis of biodiesel production from *Jatropha curcas* oil. Though several studies have considered other feedstocks ~~more~~ suitable for biodiesel production, this study has shown why *Jatropha curcas* oil should remain the preferred feedstock. It was demonstrated that though biodiesel produced from *Jatropha curcas* oil may be more expensive than fossil diesel, its' safeness and moderate fatty acid content still makes it an attractive option for biodiesel production. This was illustrated through the comparison of its fatty acid and fuel properties with other feedstock and standards respectively.

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