Energy Analysis of Biodiesel Production From Waste Groundnut Oil

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Abstract: The objective of the study was to carry out energy analysis of biodiesel production from Waste groundnut oil (WGO). 13 experimental runs were designed by *Minitab software 16* to carried out the trans-esterification of WGO which involved the variation of catalyst concentration and methanol/oil mole ratio. Total Input energy and output energy of the process were determined to obtain the energy efficiency of the process. The results of the research gavehighest biodiesel yield of 92 % at the methanol/oil mole ratio of 7 and catalyst concentration of 0.7 wt/wt % Oil. The calculated input energy and output energy of 124.51MJ/Land 98.47 MJ/L respectively were obtained. The energy efficiency obtained from the biodiesel production was 0.72. The net energy of -35.04 MJ while the energy productivity of 0.08 kg.MJwas arrived at. Further research work on how to reduce input energy during biodiesel production needs to be carried out.
Keywords:Biodiesel, Input Energy, Net Energy, Output Energy, Trans-esterification.

1. Introduction

In the world at large,there is ever-increasing urge to develop fuel substitutes that are renewable and sustainable, due to finite amounts of fossil fuels and the associated high rate of environmental pollution (Ayoola, 2015; Canakci, 2007). The release of fossil fuels gases(such as CO_2, CH_4,and N_2O)pose great risks to man and its environment. Biodieselis now considered as an alternative to the conventional fossil fuel.

Biodiesel are methyl esters of the fatty acids contained in the tallow or vegetable oil triglycerides (Kurki *et. a.l*, 2007). Some of the characteristic that present biodiesel as alternative fuel include; its high cetane number, good lubricity properties, energy content and molecular weight of the methyl esters comparable to conventional mineral diesel fuels (Canakci,2007).

Edible vegetable oils such as soyabeanoil, palm oil and groundnut oil have been used for biodiesel production and are proven diesel substitutes (Lang*et al.,* 2002).Biodiesel can be introduced directly into diesel engine without engine modification and it also prolongs the life of diesel engine which in turnreduces the need for frequent maintenance (Nada, 2011; Wang *et al.,*2010).

For the sustainable development of biodiesel, feedstock availability is one important issues and the cost of production of biodiesel from edible vegetable oil is another issue of concern. To overcome these challenges, the use of waste cooking oil has been adopted for it is less expensive and readily available (Ogunwole, 2012)

Energy is an essential aspect of our human society. It plays active role in economic activities of any nation and the maintenance of quality human life (Mohammadshirazi*et.al.*, 2014). It can be derived from both renewable and non-renewable sources.In recent years, energy consumption has been on the increase due to the significant growth in the population and change in life style of the society (Khan *et al.,* 2007).

For biodiesel to be considered as a sustainable source of energy, the input of energy into the extraction or production of biodiesel must not exceed the output of the energy that can be extracted from the biodiesel (Mohammadshirazi*et. al.,* 2014).Sustainable energy can be achieved through extensive research on energy involved in biodiesel production. That is, improvement on energy efficiency of biodiesel production will reduce biodiesel production cost and make life more bearable to man. This study focus on the energy analyses of biodiesel production from wastegroundnut oil**.**

2. Materials and Methods

The experimental runs were carried out in Chemical Engineering, Covenant University, Ota, Nigeria. Oil used was referred to as waste groundnut oil because the fresh oil obtained in a local market was used for frying on several occasion before being used. High grade reagents were used in the course of this research work.

2.1 Pretreatment of Waste Groundnut Oil: Impurities (in the form of suspended particles, sand, food items) present in the waste oil were first removed through filtration by using industrial sieve of pore diameter of 65 µm. The free fatty acid (FFA) present was also removed as stated below. Water present in the oil was removed by heating the oil in an oven for 30 minutes at 110^0C.

2.2 Removal of Free Fatty Acid (FFA): For every 10g of the treated waste groundnut oil, 95% alcohol was taken and neutralized with dilute NaOH solution. 50ml of this neutral alcohol and 50ml benzene were added to the oil in the flask. The content of the flask was shaken well to dissolve the FFA. This was then titrated using 0.1 M KOH solution and phenolphthalein as indicator.

2.3 Biodiesel Production: The groundnut oil was first carefully filtered to remove any form of impurities (suspended and deposited particles) in the oil. The oil was then heated to a temperature of 110^0C for 30 minutes to evaporate water molecules that may be present in the oil sample. The heated oil was allowed to cool off to 60^0C. The required quantity of KOH catalyst was weighted and added to the measured methanol, and agitated to ensure the catalyst dissolved completely in it to form a methoxide solution. The methoxide solution was gently added to the 100g heated oil sample inside a conical flask which was air tight with a thermometer used to monitor the temperature of the reaction; the experimental setup was placed on a magnetic stirrer where the content was continuously stirred for 60 minutes and maintain at the reaction temperature of 60^0C.

The resulting product of two layers was placed in a separating funnel for 10 hours, to allow clear separation of the two products formed into layers: the top layer was biodiesel while the bottom layer is glycerol which was first drained off

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2.4 Biodiesel Washing: Warm distilled water was continuously added to the impure biodiesel to *wash away* the impurities in the biodiesel. This process was repeated for several time until the water leaving the biodiesel was as clean as the one introduced. The wet but pure biodiesel obtained was heated to 110^{0}C for 10 minutes to remove moisture content in it.

3. Results and Discussion

3.1 Effect of Methanol/Oil moleRatio and Catalyst Concentration on Yield

From the surface response and interaction plots above (Figures 1 and 2), the conditions at which highest biodiesel yield was obtained were methanol/oil mole ratio of 7 and catalyst concentration of 0.7 wt/wt % Oil. The result justified the report of Leung and Guo (2006) which says that trans-esterification of waste oil produced highest biodiesel yield at methanol/oil mole ratio and catalyst concentration of 7 and 0.7 wt/wt % Oil. Being a forward-backward reaction process, increasing the values of the two factors above their values that gave highest yield resulted in backward reaction leading to consumption of products (biodiesel and glycerol). And soap formation due to the use of excess catalyst that reacted with triglycerides.

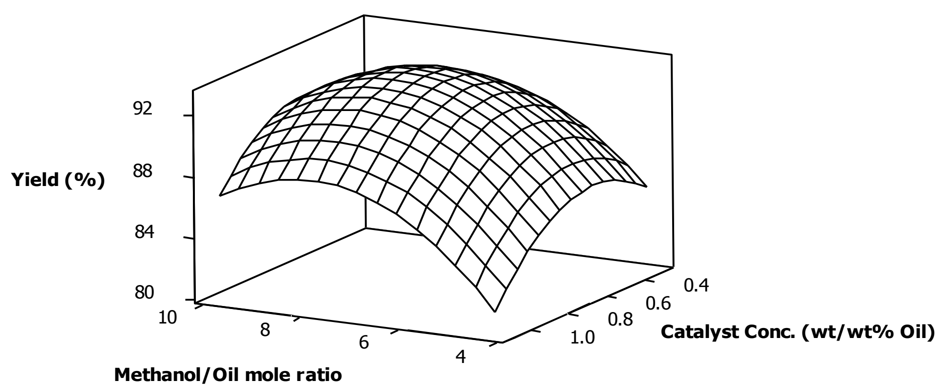

Figure 1: Surface Plot of Yield against Methanol/Oil mole ratio and Catalyst concentration

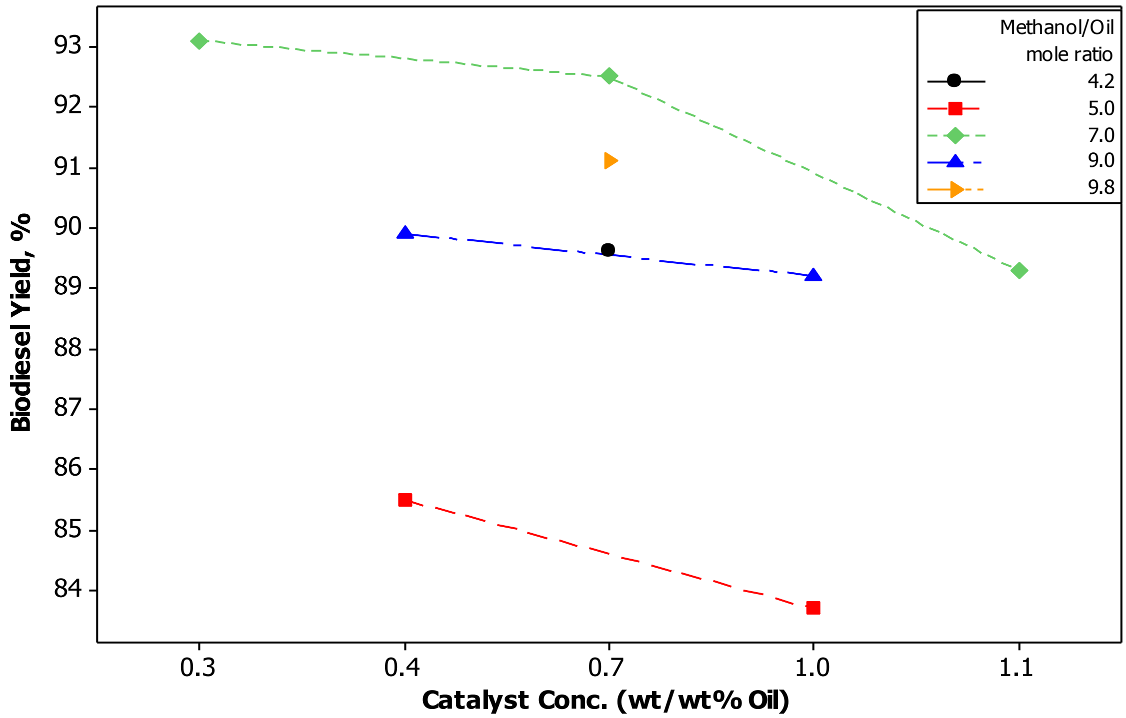

Figure 2: Interaction of Methanol/Oil mole ratio and Catalyst concentration for Yield

3.2 Analysis of Energy Involved in Biodiesel Production: The total energy involved in the biodiesel production was obtained by multiplying the input or output equivalent energy by the quantity per unit volume of biodiesel (Table 1). The energy equivalents used in the computation of energy input and energy output were obtained from literatures; sources of these were included in the table.

The results of the WGO trans-esterification process showed that 2.25h of human labour, 1.25 L of oil, 0.36 L of methanol, 0.0078 kg of catalyst, 4.39 KWh of electricity and 3.02hrs of machinery were used in the production of 1 Liter of biodiesel. The total energy input and output were obtained as 124.51 MJ per liter of biodiesel and 89 MJ per liter of biodiesel respectively.Electricity has the highest value of the energy input (52.37 MJ). This high value of Electricity (in form of electrical energy) was due to the fact that almost all stages involved in the biodiesel production require electricity. The energy input from the use of KOH was the least (0.15 MJ) and this energy was in the form of chemical energy.The energy from the biodiesel produced has the highest value of 37.25MJ out of the total energy output.The distribution of the total input energy and total output energy are shown in Figure 3 and 4 respectively.

Table 1: Energy Input and Output duringBiodiesel Production

Parameter	Quantity /Unit Vol. of Biodiesel	Energy Equivalent (Source) MJ/unit	Energy MJ	Percentage %
INPUTS				
Human Labour	2.25 hr	1.98 (Ghobadian, 2010)	4.46	3.6
Waste Cooking Oil	1.25 L	25.0 (Ghobadian, 2010)	31.25	25.1
Alcohol (methanol)	0.36 L	33.67 (Singh and Mittal, 1992)	12.12	9.7
Catalyst (KOH)	0.0078 kg	19.87 (Nguyen *et al*, 2007)	0.15	0.1
Electricity	4.39 KWh	11.93 (Singh and Mittal, 1992)	52.37	42.1
Machinery	3.02 hr	8 (Hou*et.al.*, 2009)	24.16	19.4
Total Input Energy			***124.51***	***100***
OUTPUTS				
Biodiesel	1L	37.25 (Kitani, 1998)	37.25	41.6
Glycerol	0.25L	25.30 (Krohn and Fripp,2012)	6.33	7.1
Alcohol (Methanol)	0.36L	33.67 (Singh and Mittal, 1992)	12.12	13.5
Water	8.08L	4.18 (Murphy, 2007)	33.77	37.7
Total Output Energy			***89.47***	***100***

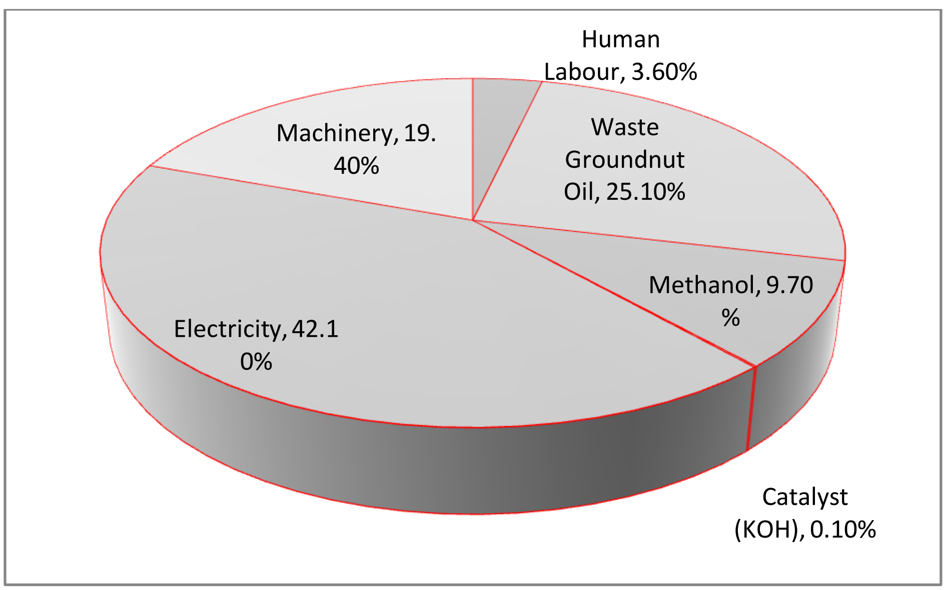

Figure 3: The distribution of Total Input Energy

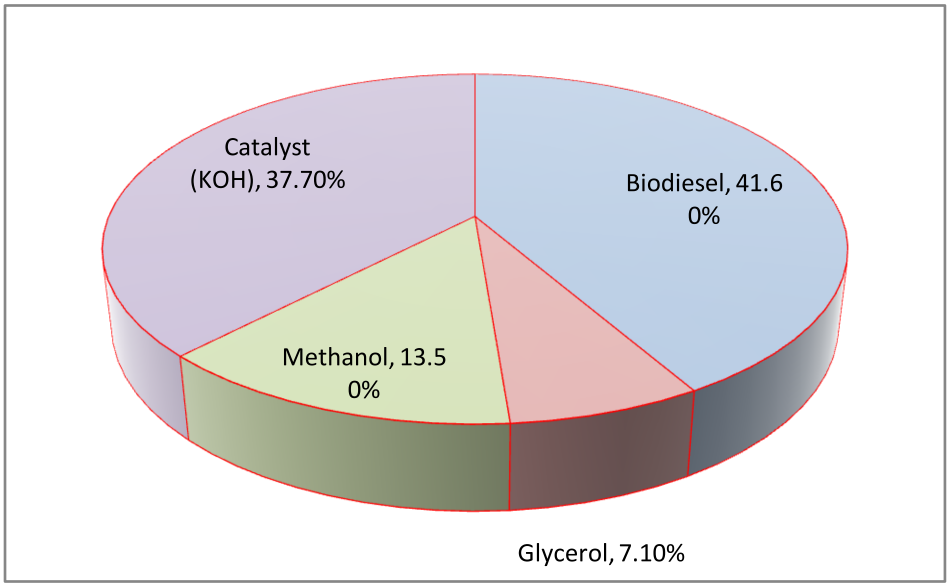

Figure 4: The distribution of Total Output Energy

Energy input-output relationships were represented in Table 2. Energy output–input ratio has been described as one of the important indicators used to maintain efficiency in production of biodiesel.The energy output–input ratio of the biodiesel production was calculated as 0.72 (i.e72% energy use efficiency)using Equation 1; this significantly implies that for every 1MJ of energy consumed to produce biodiesel, 0.72 MJ of energy was obtained.Trans-esterification process is prefer to the process that involves the use of algae for biodiesel production, simply because Passell *et. al.*(2011) reported 64 % energy use efficiencywhen algae were used for biodiesel production. Also, the use of virgin oil (instead of the waste oil) will reduce the total input during trans-esterification; since energy involved in the pretreatment of waste oil would be avoided.

$$\text{Energy Use Efficiency} = \frac{\text{Energy Output}}{\text{Energy Input}} X\ 100 \qquad (1)$$

$$\text{Net Energy} = \text{Energy Output} - \text{Energy Input} \qquad (2)$$

$$\text{Energy Productivity} = \frac{\text{Yield}}{\text{Energy Input}} \qquad (3)$$

The Net Energy value of -35.04 MJ obtained (using Equation 2) suggested that further research work needs to be done in order to minimise energy input and increase the energy output, thereby ensure a positive net energy value.According to Mohammadshirazi*et.al.* (2014), energy productivity was calculated using Equation 3. Energy productivity of 0.08kg/MJ implies that 0.08 unit of biodiesel was produced from 1MJ of energy consumed.

Table 2: Energy Input – Output Relationship

Parameter	Unit	Value
Energy Use Efficiency	-	0.72
Net Energy	MJ	-35.04
Energy Productivity	kg/MJ	0.08

Conclusion

Though the work justifies the fact that biodiesel is a renewable source of energy but energy input-output ratio of 0.72 obtained shows that further research work, particularly in the area of ways of minimizing energy ultilisation during biodiesel production should be intensify in order to attain sustainable energy.

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