PRODUCTION OF BIODIESEL USING THE ONE STEP ALKALI-CATALYZED METHOD

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ABSTRACT

The study was based on production of biodiesel using the one step alkali-catalyzed method. The researchers used research questions and laboratory experimental pattern to production of biodiesel using the one step Alkali-Catalyzed methods. The transesterification was carried out using NaOH as a catalyst. The objective for silica gel addition was to remove trace amounts of water formed during the transesterification reaction. From the study, it would be concluded that the transesterification with methanol at degrees Celsius gave higher yields than 65 degrees Celsius. This is because the higher reactivity of methanol at higher temperature favored the forward reaction. The cost of the ester purification process may be reduced if an heterogeneous catalyst is used instead of an homogeneous catalyst, mostly because of the easy separation of ester and glycerol from the catalyst. Synthesis, characterization, and regeneration of the heterogeneous catalyst used in transesterification of vegetable oil are recommended.

KEYWORDS: ***Biodiesel, One Step Alkali-Catalyzed Methods***

INTRODUCTION

Increasing concern regarding environmental impacts, the soaring price of petroleum products together with the depletion of fossil fuels have prompted considerable research to identify alternate fuel sources. Biofuel has recently attracted huge attention in different countries all over the world because of its renewability, better gas emissions and its biodegradability. It is estimated that biodiesel/bio-ethanol could replace approximately 10% of diesel consumption within Europe and 5% of Southeast Asia's total fuel demand.

Biodiesel production is based on transesterification of vegetable oil and fats through the addition of methanol. Presently, biodiesel is produced mainly from variety of oils like corn oil, canola oil, macadamia nut, sunflower, hemp oil, soybean, rapeseed and so on. In Europe, biodiesel is produced from rapeseed, sunflower and so on. In United States, soybean is also processed for the production of biofuel.

Biodiesel is a non-toxic and biodegradable fuel that is made from vegetable oils, animal fats or tail oil (a by-product from pulp and paper processing). Biodiesel is produced from these feed stocks through a process called transesterification, by reacting the oil with alcohol (usually methanol, although ethanol can also be used) and a catalyst (such as sodium hydroxide). The resulting chemical reaction produces glycerin and an ester called biodiesel. The majority of biodiesel is produced by this method compared with conventional diesel. Biodiesel combusts better with a higher cetane rating and produce fewer life cycle greenhouse gas emissions (GHG), which contributes to climate change. Biodiesel blends mixture of petroleum diesel and can be used in any diesel engine.

As biodiesel can blend with diesel in any concentration, the blend level depends on economics, availability, the desired emission level, material compatibility and combustion characteristics. An increasing number of original equipment manufacturers are endorsing the use of lower biodiesel blends, e.g. 5% in their engines. Some manufacturers now extend warranty coverage for new diesel powered vehicles to use lower blends of biodiesel, provided the fuel meets applicable standards.

Some manufacturers also provide vehicles pre-filled with biodiesel blends. In colder climates, biodiesel tends to lose viscosity, particularly at higher blend levels. To counter this effect, changes to feedstock source or additives may be needed to address the cold flow properties of this fuel. Research and testing is underway to reduce biodiesel production cost and address cold weather problems. Biodiesel is commonly added to the petro-diesel sold at pumps today to increase the lubricity of pure ultra-low sulfur diesel (ULSD), which is advantageous since biodiesel has almost no sulfur content. Its primary advantages are that it is one of the most available and it is also nontoxic and biodegradable. It can also be used directly in most diesel engines without requiring extensive engine modifications. Biodiesel is commonly produced in batch reactors using heat and mechanical mixing as energy input.

Biodiesel production is based on transesterification of vegetable oil and fats through the addition of methanol. In Europe, they produce biodiesel from rapeseed, sunflower and so

on. In the United States, they used soybean for the production of biodiesel, also in Malaysia they used palm oil for biodiesel production and Jatropha oil in production of biodiesel.

LITERATURE REVIEW

Current Status of Biodiesel Production

The current hike in prices of crude has given room for emergence of biodiesel production and has become the fastest growing industries worldwide. Several countries especially United States and members of European Union are actively supporting the production of biodiesel from agriculture sector. In the year 2006, nearly 6.5 billion liters of biodiesel was produced globally (TBW, 2008). It is interesting to note that 75% of the total biodiesel production comes from European countries. This is mainly due to substantial support from European government such as consumption incentives (fuel tax reduction) and production incentive (tax incentives and loan guarantee) which will further catalyze the growth of biodiesel market in the next ten years. Besides that, the United States spent around US$5.5 billion to 7.3 billion a year (TBW, 2008) to accelerate bio-fuel production. As a result, around 450 million gallons of biodiesel was produced in the United States in the year 2007 compared to only 25 million gallons in year 2004 (Thurmond, 2008). This 1700% increment was indeed a shocking increase in the entire history of biodiesel production. However, by the year 2020, it is predicted that biodiesel production from Brazil, China, India and some South East Asia countries such as Malaysia and Indonesia could contribute as much as 20% (Thurmond, 2008). The driving forces for development of biodiesel in these countries are economic, energy and environmental security, improving trade balances and expansion of agriculture sector (Zhou and Thomson, 2009). In addition, in Brazil, China and India each have set targets to replace 5% to 20% of total diesel with biodiesel by the year 2010 with emphasis on second generation non-edible feedback (Thurmond, 2008). If governments from these countries continue to aggressively promote biodiesel generation and continue to invest in research and development for non-edible feedstock such as jatropha, castor, algae and grease, the prospects to achieve biodiesel targets will be realized faster than anticipated depicts a more recent world biodiesel production and capacity in the recent years (Thurmond, 2008).

Oscillatory Flow Reactor (OFR) for Transesterification Reaction

Oscillatory flow reactor (OFR) was first introduced by Harvey et al. (2003) to produce biodiesel through some improvement in mixing intensity between reactants. OFR is a novel type of continuous flow reactor, consisting of tubes containing equally spaced orifice plate baffles. Therefore, an oscillatory motion is superimposed upon the net flow of the process fluid, creating flow patterns conducive for efficient heat and mass transfer, whilst maintaining plug flow regime (Harvey et al., 2003). In addition, each baffle essentially behaves as a stirred tank that lead to excellent mixing and suspension by creating vortices between orifice baffles and oscillating fluid (Zheng et al., 2007). This is an essential element in designing a biodiesel reactor especially when heterogeneous catalysts are used due to the

presence of three immiscible phases (oil-alcohol-catalyst) at the initial stage of reaction. Thus, improvement in mixing and suspension of catalysts tend to produce higher yield of biodiesel in a shorter reaction time compared to conventional-type stirred tank reactor. Apart from that, OFR allows longer residence time as the mixing is independent of the net flow and hence the reactor length-to-diameter ratio can be reduced. This is an important plus point if the process is scaled up for commercial application in order to reduce the overall capital and pumping cost.

PURPOSE OF THE STUDY

The study looked at production of biodiesel using the one step Alkali-Catalyzed methods. The study specifically intends to:

1. Find out the effect of catalyst loading on ester concentration with 6:1 methanol to oil molar ratio at 95^0C.
2. Find out the effect of catalyst loading on ester concentration with 6:1 methanol to oil molar ratio at 65^0C.

RESEARCH QUESTIONS

The following research questions were adopted and used for the study:

1. What is the effect of catalyst loading on ester concentration with 6:1 methanol to oil molar ratio at 95^0C?
2. What is the effect of catalyst loading on ester concentration with 6:1 methanol to oil molar ratio at 65^0C?

SCOPE OF THE STUDY

The study is limited to the use of one step Alkali-Catalyzed methods in the production of biodiesel. The study was conducted in the chemical laboratory of University of Benin, Edo State.

METHODS

The researcher used laboratory experimental pattern to production of biodiesel using the one step Alkali-Catalyzed methods. Waste cooking oil was used for the experimental analysis using one-step Alkali-Catalyzed methods.

Sample Calculation

For methanol: MeOH required = 1 mol of WCO required. Theoretically, 3 moles of MeOH 677.09g will require 3×32g. Therefore, 100g of WCO will require (100×96) = 14.1783g.

Then for the methanol: WCO mole ratio of 6:1, the amount of methanol required will be twice the theoretical value that is 14.1783×32g = 28.3566g.

To convert the weight of methanol to volume using density formula:

We use density = mass/ volume

Volume in ml = mass/density

Density of methanol from the label = 0.793g/ml

Weight of methanol as computed above = 28.3566g

Hence the volume of methanol = 25.60ml approximately.

RESULTS AND TABLES

Research question 1

What is the effect of catalyst loading on ester concentration with 6:1 methanol to oil molar ratio at 95^0C

Table 1:*Effect of catalyst loading on ester concentration with 6:1 methanol to oil molar ratio at 95^0C*

Time	0.5wt.%NaOH	1.0wt.%NaOH	1.5wt.%NaOH
0	2.432	2.320	2.569
0.5	6.123	16.360	21.897
1	10.423	19.830	22.586
1.5	13.121	20.133	22.650
2	14.362	21.065	23.015
3	16.243	21.230	23.955
4	17.274	21.325	24.120
5	17.823	21.415	24.553
6	18.134	21.506	24.654
7	18.353	21.597	24.893
8	18.462	21.689	25.018
9	18.554	21.781	25.250
10	18.981	21.873	25.250

Results obtained from table 1 show that catalyst loading on ester concentration with 6:1 methanol to oil molar ratio at 95%C reveals time variation from 0s to 10s indicates an increase in 0.5wt%NaOH at different interval. The result also reveals that at 0s and 10s of 1.0wt%NaOH value yielded a difference of 19.553. Further, at 1.5wt%NaOH value at different time interval increased and had a minimum value of 2.569 and a maximum value of 25.250. The result in general reveals a steady increase of NaOH across the table.

Research question 2

What is the effect of catalyst loading on ester concentration with 6:1 methanol to oil molar ratio at 65^0C

Table 2:*Effect of catalyst loading on ester concentration with 6:1 methanol to oil molar ratio at 65^0C*

Time	0.5wt.%NaOH	1.0wt.%NaOH	1.5wt.%NaOH
0	2.322	2.443	2.452
0.5	5.637	14.214	16.596
1	8.719	19.193	20.681
1.5	11.368	19.726	21.463
2	12.874	20.842	22.104
3	14.788	21.186	22.337
4	15.993	21.297	22.482
5	16.692	21.378	22.619
6	17.108	21.456	22.758
7	17.365	21.534	22.897
8	17.534	21.612	23.037
9	17.653	21.690	23.179
10	17.651	21.769	23.230

Results obtained from table 1 show that catalyst loading on ester concentration with 6:1 methanol to oil molar ratio at 65%C shows that the time variation from 0s to 10s indicates an increase in 0.5wt%NaOH at different interval. The result also reveals that at 0s and 10s of 1.0wt%NaOH value yielded a difference of 19.326. Further, at 1.5wt%NaOH value at different time interval increased and had a minimum value of 2.452 and a maximum value of 23.230. The result in general reveals a steady increase of NaOH across the table.

DISCUSSION

Free fatty acid (FFA) and water are problematic factors for transesterification using alkaline-type catalyst. Unlike water, which can easily be removed using silica gel, FFA in WCO is difficult to eliminate. In this experiment, the FFA was not neutralized. The transesterification was carried out using NaOH as a catalyst. The objective for silica gel addition was to remove trace amounts of water formed during the transesterification reaction. If less water is present in WCO, during alkali-catalyzed transesterification, a higher yield of biodiesel should be achieved.

CONCLUSION

From the study, it would be concluded that the transesterification with methanol at degrees Celsius gave higher yields than 65 degrees Celsius. This is because the higher reactivity of methanol at higher temperature favored the forward reaction.

RECOMMENDATION

The cost of the ester purification process may be reduced if an heterogeneous catalyst is used instead of an homogeneous catalyst, mostly because of the easy separation of ester and glycerol from the catalyst. Synthesis, characterization, and regeneration of the heterogeneous catalyst used in transesterification of vegetable oil are recommended.

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