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BIOFUEL FOR SUSTAINABLE (AND ECO-FRIENDLY) ENERGY DEVELOPMENT

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Abstract:
Biofuel is as old as the existence of man, made of three categories; solid, liquid and gas. Dried manure, charcoal and wood are well known solid biofuels .The liquid biofuels include; biodiesel, bioethanol, biobuthanol and biopropanol. The last three are called bioalcohols of which, biopropanol is the least commonly use in this group and biothenol the most. Biogases are methane and Syngas. Biodiesel can be produced by homogenous and heterogeneous catalysis with heterogeneous catalysis now found to be better process. The liquid biofuels burn better than fossil fuels and therefore give engines longer lives. Bioethanol has higher octane rating than gasoline. Both biodiesel and bioethanol mix completely with conventional diesel and gasoline respectively. This review highlights the benefits of biofuels and their production.

Key words: biofuels, energy, sustainable, environmental benign, degradability

Introduction

Ever since their discovery, the fossil fuels have benefited mankind and have made man prosper and develop. These fuels that are extracted from the decomposed fossils, millions of years old, buried in the depths of the earth, are the reason why we are living today. These fossil fuels are coal, gas and petroleum crude. It's impossible now to live without these resources. But the sad part is that these fuels are non renewable resources and we will run out of them one day, in fact, we already are. Bioenergy is considered as a potential source of energy due to its numerous and overwhelming environmental, socioeconomic benefits including rural development and land reclamation (Ibrahim et al, 2011)

With the increase in population, which has taken place drastically over the centuries, the demand for these fuels has also increased. This increase in demand has lead to much more use of these fuels, that has made the earth's fuel bank half empty, and with the rapid increase of their demand, it will soon be completely emptied. In addition to their depletion, they are also environmentally destructive due the emission of greenhouse gases and their being non biodegradable. All these factors have increased the global interest in the search for the use of renewable, environmental benign and biodegradable biofuels.

Biofuels also known as bioagrofuels are fuels derived from biomass. Biomass here represents a renewable energy source as it is derived from living organisms and byproducts of living organisms. According to Reith and Sherow (pdf), the traditional use of biomass is combustion in stoves or boilers for heat. It is a significant source of energy for U.S. industries and homes. Yet biomass can also be converted to liquid and gaseous biofuels such as ethanol, methanol, biogas, biodiesel fuel and methane. Biofuels are not only considered as potential sources of energy but also as environmental, socioeconomic benefits including rural development, land and soil reclamation (Adam et al, 2011).

Biofuels can be used for many applications, but their greatest use is in the transportation sector. Most vehicles require liquid fuels which provide high power to the engines and clean combustion in their engines. Biofuels satisfy these conditions much more than the conventional fossil fuels. Biofuels are produced mainly from starch, sugar, vegetable oils and animal fats. The biofuels mostly in use are biodiesel, bio-alcohols (e.g. bioethanol) and biogas. The liquid fuels are easily pumped into vehicle tanks. Their vapour-air mixture forms a homogenous mixture that is most suitable for internal combustion engines (IEA, 2007).

2. Types of Biofuel

Biofuel has been in use since man discovered fire. Wood was the first form of biofuel in solid form in use for cooking and warming. Dried manure and charcoal are other examples of Solid biofuels (Internet (a)). Biofuel can be classified basically into three categories; solid, liquid and gas. This paper will review mainly the liquid biofuels.

2.1 Biodiesel

The biodiesel is the best *alternative of the usual diesel* used in vehicles. The chemical process by which biodiesel is prepared is known as the transesterification reaction, which involves a Triaglyceride, TAG reaction with a short-chain monohydric alcohol normally in the presence of a catalyst at elevated temperature to form fatty acid alkyl esters (FAAE) and glycerol (Moser, 2009). This fuel is very similar to the mineral diesel and is chemically known as fatty acid methyl ester (FAME), if alcohol used is methanol or fatty acid ethyl ester if ethanol is used. This oil is produced after mixing the biomass (plant oil or animal fats) with methanol and sodium hydroxide (base homogenous transesterification). The most significant difference between biodiesel and diesel fuel composition is their oxygen content, which is between 10 and 13% (Barabás and Todoruţ, 2011).

Biodiesel was known to be produced with homogenous catalysts such as strong alkalines and acid, but nowadays a lot of solid catalysts have been found to have good potential for producing biodiesel. The chemical reaction thereof produces biodiesel. Biodiesel is very commonly used for the various diesel engines after mixing up with mineral diesel. Now in many countries the manufacturers of the diesel engine ensure that the engine works well even with the biodiesel (Internet (b)). It is observed that people who use biodiesels in their diesel engines do not face any difficulty and their engine runs as smooth as before and in some cases even better (Internet (a)).

2.1.1 Homogenous Catalytic Transesterification

In this process usually, the catalysts use are sodium hydroxide and potassium hydroxide sometimes strong acids such as sulphuric acid, hydrochloric acid and phosphoric acid are used too, but their reaction rate is about 4000 times slower than alkaline catalysts (Au and Dai). The feed oil is first titrated against potassium hydroxide solution to determine the percent of free fatty acid (FFA) in the oil. If the percentage FFA is high it has to be brought down to less than 1% since high FFA will lead to the formation of salt which inhibits production of the desire product, biodiesel (Garpen, et al, 2004). The quantity of the catalyst can be 0.5 to about 1.5% of the mass of oil used. It is dissolved in the methanol and the mixture is poured into the oil that is preheated to about 60^{0}C. The reacting mixture is stirred continuously and heated to a temperature of 60 to 65^{0}C for about an hour. The product is separated with separating funnel or centrifuge into glycerol and biodiesel. However, the biodiesel obtained contains some quantity of the catalyst used. The catalyst is removed by washing the biodiesel with warm water and then dries by heating the washed biodiesel until it stops bubbling.

2.1.2 Heterogeneous Catalytic Transesterification

In this process, the solid catalyst of about 1.5% of the mass of oil is poured into the methanol and stirred well to mix. The mixture is poured into preheated oil and heated to temperature of 60 to 65^{0}C for about 60 to 90 minutes. The reacting mixture is stirred during the heating to ensure good contact. The product is filtered to remove the catalyst before separation of biodiesel and glycerol. Recently it has been found that 98 to 100% biodiesel yield can be obtained using solid catalysts. According to Arafaat (2011) solid catalysts such as calcium oxide, zinc oxide, sulphated zirconia, sulphated tin oxide and sulphated titanium oxide are good enough to replace the conventional homogenous catalysts.

2.1.3 Advantages of Heterogeneous Catalysis over Homogenous Catalysis

Homogenous catalysis have good yield of biodiesel but it has a lot of drawbacks (Wayne, 2008 and Edger et al, Retrieved 2011) which solid catalysts are found suitable for replacement. Below are the advantages of solid catalysts over homogenous catalysts;

1. Solid catalysts are cheaper.
2. Can be recovered and recycled over many times.
3. Solid catalysts are harmless and environmentally friendly.
4. Less quantity of process water is used.
5. Little process equipment is required.

2.1.4 Benefits of Biodiesel

According to Biodiesel Technocrats (Internet (b)), the following benefits are derived from biodiesel.

1. Biodiesel is a substitute or extender for conventional petroleum diesel and you don't need special pumps or high pressure equipment for fueling. In addition, it can be used in conventional diesel engines, so you don't need to buy special vehicles or engines to run biodiesel.

2. Scientists believe carbon dioxide is one of the main greenhouse gases contributing to global warming. Pure biodiesel (100 percent biodiesel) reduces carbon dioxide emissions by more than 75 percent over petroleum diesel. Using a blend of 20 percent biodiesel reduces carbon dioxide emissions by 15 percent.

3. Biodiesel also produces fewer particulate, carbon monoxide, and sulfur dioxide emissions, all targeted as public health risks by the Environmental Protection Agency. Biodiesel contains only trace amounts of sulfur, typically less than the new EPA standards.

4. Since biodiesel can be used in conventional diesel engines, the renewable fuel can directly replace

petroleum products; reducing the country's dependence on imported oil.

5. Biodiesel offers safety benefits over petroleum diesel because it is much less combustible, with a flash point greater than 150°C, compared to 77°C for petroleum diesel. It is safe to handle, transport, and store, and has a higher flash point than petroleum diesel. It can also be stored in diesel tanks and pumped with regular equipment except in colder weather, where tank heaters or agitators may be required.

6. Biodiesel mixes readily with petroleum diesel at any blend level, making it a very flexible fuel additive.

7. Biodiesel is an oxygenated fuel, so it contributes to a more complete fuel burn and a greatly improved emissions profile. The more biodiesel used in a blend, the higher the emission reductions. One of the unique benefits of biodiesel is that it significantly reduces air toxic that is associated with petroleum diesel exhaust and is suspected of causing cancer and other human health problems. NOx emissions are an exception to the rule, since biodiesel tends to increase NOx emissions. Recent research has shown a number of ways to mitigate this problem.

Engine performance with B20 is virtually the same as with petroleum diesel. At a blend of 25% -35% Biodiesel, Diesel cars give a minimum of 10% Extra mileage. Even very low amounts of biodiesel (1% to 2%) can provide substantial lubricity benefits to premium diesel fuels.

Every litre of biodiesel replaces 0.95 litre of petroleum-based diesel over its life cycle. It is also very energy efficient. For every unit of fossil energy used to produce biodiesel, 3.37 units of biodiesel energy are created.

Additionally, biodiesel reduces the amount of carbon dioxide (CO_2) being released into the atmosphere. It releases less fossil CO_2 than does conventional diesel, and the crops used to produce biodiesel absorb large amounts of CO_2 as they grow. And because biodiesel is nontoxic and biodegradable, it is an excellent fuel for use in fragile environments such as estuaries, lakes, rivers and national parks.

Due to its less polluting combustion, biodiesel provides a 90% reduction in cancer risks & neonatal defects.

- Biodiesel is biodegradable & renewable by nature.
- Biodiesel can be used alone or mixed in any ratio with conventional diesel.
- The preferred ratio of mixture-ranges between 5 & 20%.
- Biodiesel enhances the life of diesel engines.
- Biodiesel could be cheaper than conventional petrodiesel.
- Biodiesel has good potential for rural employment generation.

The production of biodiesel is increasing steadily over the years. This could be attributed to the growing awareness of the foreseeable global warming, declining fossil fuel reserves and unstable prices of petroleum products. Non-edible oilseeds are considered for the production of biodiesel as against the edible oil food to avoid food crisis. In fact the Energy Commission of Nigeria has made it mandatory for all biodiesel in the Country to use non-edible oilseeds. A lot of non-edible oilseeds have been identified; these include Sapindus mukorossi, Pongamia pinnata and Jatropha curcas. Jatropha curcas is considered to be potential for biodiesel production as it has high oil yield and also its oil has high biodiesel yield and yet its plantation does not require much attention as compare to other crops.

2.2 Bioalcohols

Bioalcohols are another type of biofuels that are produced by the action of certain aerobic and anaerobic bacteria. The most commonly produced bioalcohols are ethanol, butanol and propanol. Amongst these ethanol is the most commonly used bioalcohol, butanol is used comparatively less and propanol is used rarely (Internet (a)).

2.2.1 Bioethanol

Due to increasing petroleum shortage, fermentation production of ethanol from renewable resources has received considerable attention (Neelakandan and Usharani, 2009). Ethanol fuel is the most commonly used biofuel in the world and particularly in Brazil. Ethanol can be put to use in petrol engines as a substitute for gasoline. Also, it can be mixed with gasoline in any ratio. The contemporary automobile petrol engines can work on mixtures of gasoline and ethanol that have 15% bioethanol. This mixture of gasoline and ethanol has more quantity of octane. This indicates that the engine would burn hotter and more efficiently. By blending ethanol with gasoline oxygenates the fuel mixture so it burns more completely and reduces pollution emission. In high altitude spots, the mixture of gasoline and ethanol is used as a winter oxidizer and thereby atmospheric pollution is decreased (Internet (a)). Ethanol is a high octane fuel and has replaced lead as an octane enhancer in petrol (Oyeleke et al, 2012).

2.2.1.1 Production of Bioethanol

Bioethanol is made by fermenting the sugar and starch components of plant by-products - mainly sugarcane and crops like grain, using yeast. It is also made from cassava, corn, potatoes, milk, rice, beetroot and recently grapes, banana and dates depending on the countries agricultural strength (Internet (d)). If starch is the starting material, it is hydrolyzed to sugar by action of enzyme *invertase* and then fermented to ethanol and carbon dioxide by enzyme zymase from yeast. To achieve the most effective productivity, the appropriate parameters, which can maximize the enzymatic activities and minimize the cost, are required. In an ethanol industry, the most closely controlled parameters are temperature and pH. Basically, the higher temperature gives the higher productivity. However, above a certain temperature, the enzyme starts losing its activity (Shinnosuke, Pdf). This is because the protein form of the enzyme is broken by the heat. Also, an enzyme has an optimal pH range. In the range, the enzyme shows the high production. However, if the pH changes drastically from the range, the enzyme loses its activity again. This phenomenon is same as one with high temperature, that is to say, the extreme pH can break enzyme formation and it cannot be recovered. However, this crude ethanol contains a lot of water. For use as ethanol fuel grade it has to be distilled to 99.6% pure ethanol.

Lignocellulose has been described as the most promising raw material, cellulose is the most common biopolymer present in wood, organic industrial wastes and is a polysaccharide that can be converted into sugars and fermented (Ibrahim et al, 2011). Thus, bioethanol from lignocellulosic materials has the potential to be a valuable source of raw material for the production of bioethanol. New more processes for the production of bioethanol from lignocellulosic biomass are being developed; this includes enzymatic hydrolysis and fermentation process and gasification (Ibrahim et al, 2011) of agricultural residues. The use of agricultural residues for production of bioethanol is considered the better process because it does not cause any food crisis but rather turn waste into wealth.

2.2.1.2 The benefits of using Ethanol

The following are benefits derived from using bioethanol in vehicle engine as claimed by (Internet (c)):

1. Ethanol has high octane rating that prevents premature detonation under load.
2. Ethanol burns more cleanly because it contains oxygen, less carbon monoxide emission.
3. Ethanol burns slightly cooler, thus extends engine life.
4. Ethanol has higher volumetric efficiency, thus contributes to engine power.
5. Most gasoline vehicles can operate on pure ethanol with a few basic modifications. 10% ethanol blend with gasoline does not require engine modification yet making contribution to reduction emissions.

2.2.3 Biopropanol

Biopropanol is a secondary alcohol that is commonly used as a solvent. Its applications can be found in most paints and wood stains as well as cleaners, cosmetics, and adhesives. The alcohol also finds use in industrial processes as a dehydrating agent. Its most commonly known domestic use is in rubbing alcohol at generally a mixture of 70% isopropanol and 30% water. Isopropanol, or isopropyl alohol, is a clear, flammable liquid which smells of acetone (Internet (e)).

2.2.3.1 Production of Biopropanol

Biopropanol can be produced from E. coli bacteria via fermentation of carbohydrate stuffs. There has been an increasing demand for isopropanol production without the use of petroleum products. Due to recent advances in metabolic engineering, production of bioisopropanol has become possible. Researchers at Kyushu University have developed a fermentation process which converts sugars present in biomass to isopropanol (Internet (e)). Utilizing the TA76 strain of Escherichia coli under controlled conditions, glucose is converted to isopropanol. Under this process, the sugars are converted to propanol which must then be removed using a gas stripping recovery method. This is due to the impact which isopropanol has on the bacteria. After the alcohol accumulates in the culture, production drastically decreases. Removal of the product allows for the continuation of the conversion process. Further development of this process may result in the reduction of petroleum dependence for isopropanol production.

2.2.3.3 Uses of Biopropanol

1. As solvent

2. As preservative, hence it can be substitute for toxic formaldehyde.

3. For production of propylene in plastic industries.

4. It is used in paints, adhesives, strainers and cosmetics.

5. As dehydrating agent

2.2.4 Biobutanol

Biobutanol can be used directly in a gasoline engine and hence is considered a direct replacement for gasoline (Biofuels, 2007). Biobutanol is in the same family as other commonly known alcohols, namely single-carbon methanol and the more-well known two-carbon alcohol ethanol. According to Christine and Gabbles (2011) the importance of the number of carbon atoms in any given molecule of alcohol is directly related to the energy content of that particular molecule. The more carbon atoms present, especially in a long carbon-to-carbon bond chains, the denser in energy the alcohol is.

According to David and Shang (2004) demonstration of gallon for gallon replacement of gasoline with butanol an unmodified '92 Buick has been driven 10,000 miles across the United States from Columbus, Ohio to California via Phoenix and back via Denver Colorado to Washington DC (July–August 2005). The butanol powered Buick gets 20-26 miles per gallon. And in 10 states E-Test facility – Butanol's average reduction of Hydrocarbons was 95%, Carbon monoxide to 97%, Oxides of Nitrogen by 27% and had a background of only 14.7% Carbon Dioxide. With this development, butanol's application as a replacement for gasoline will outpace ethanol. Biobutanol shows great promise as a motor fuel due to its favorable energy density, and it returns better fuel economy and is considered a superior motor fuel.

2.2.4.1 Production of Biobutanol

Biobutanol is derived mainly from the fermentation of the sugars in organic feedstocks (biomass). Historically, up until about the mid-50s, biobutanol was fermented from simple sugars in a process that produced acetone and ethanol, in addition to the butanol component (Christine and Gable 2011). Actually, this method was discovered by a Russian chemist C. Weizman (Abraham, 2010) who later became the Israeli President at the Manchester University, 1912.The process is known as ABE (Acetone Butanol Ethanol) and has used unsophisticated (and not particularly hearty) microbes such as *Clostridium acetobutylicum.* He isolated a bacterium later known as *Clostridium acetobutylicum* which was used to ferment starch into acetone, butanol and ethanol. Then acetone was in high demand for the production of cordite, cartridge and propellant during the World War. Thereafter, the method was almost abandoned but due to rapid expanding automobile industry, the demand for butanol and its ester butyl acetate (Abraham, 2010) that make lacquer dry quickly on car bodies, revive it again. Also in the early 20th inadequate level of supply of natural rubber resulted in high demand for buthanol (Władysław et al, 2011). At that time, butanol was used as one of raw material for the production of butadiene. The problem with this type of microbe is that it is poisoned by the very butanol it produces once the alcohol concentration rises above approximately 2 percent. This processing problem caused by the inherent weakness of generic-grade microbes, plus inexpensive and abundant (at the time) petroleum gave way to the simpler and cheaper distillation-from-petroleum method of refining butanol.

The abundant inexpensive renewable resources as feedstock for fermentation, and recent advances in the fields of biotechnology and bioprocessing have resulted in a renewed interest in the fermentation production of biobutanol (David and Shang, 2004). In recent years, with petroleum prices skyrocketing steadily upwards, and worldwide supplies getting tighter and tighter, scientists have revisited the fermentation of sugars for the manufacturing of biobutanol. Great strides have been made by researchers in creating “designer microbes” that can tolerate higher concentrations of butanol without being killed off (Christine and Gable, 2011).

The ability to withstand harsh high concentration alcohol environments, plus the superior metabolism of these genetically enhanced bacteria has fortified them with the endurance necessary to degrade the tough cellulosic fibers of biomass feedstocks such as pulpy woods and switch grass. With this development door has been kicked open and the reality of cost competitive, if not cheaper, renewable alcohol motor fuel is upon us (David and Shang, 2004). According to David and Shang (2004), inactivation of pta gene reduced phosphotransacetylase (PTA) and acetate kinase (AK) activities and significantly reduced acetate production; while inactivation of buk gene reduced butyrate kinase (BK) activity and significantly reduced butyrate production and increased butanol production. The final butyrate levels were 52-77% lower, butanol levels up to 50% higher, and acetone levels 20-50% lower than wild type. However, butyrate was not completely abolished and butanol yield from glucose was only marginally improved, possibly due to the existence of other isozymes which catalyze butyrate production. New approach using antisense RNA (as RNA) as a metabolic engineering tool to down-regulate genes involved in butyrate formation has also been studied and shown to result in 50% and 35% higher final titers of acetone and butanol, respectively. The breakthrough in biobutanol processing methods, vis-à-vis the discovery and development of genetically modified microorganisms has set the stage for biobutanol to surpass ethanol as a renewable fuel.

2.2.4.2 Biobutanol Advantages

Christine and Gabbles (2011) enumerate the following advantages of biobuthanol over ethanol.

1. **Biobutanol has higher energy content** than ethanol, so there is a much lower loss of fuel economy. With an energy content of about 105,000 BTUs/gallon (versus ethanol’s approximate 84,000 BTUs/gallon), biobutanol is much closer to the energy content of gasoline (114,000 BTUs/gallon).
2. **Biobutanol can be easily blended** with conventional gasoline at higher concentrations than ethanol for use in unmodified engines. Experiments have shown that biobutanol can run in an unmodified conventional engine at 100 percent, but to date, no manufacturers will warrant use of blends higher than 15 percent.

3. **Because it is less susceptible to separation** in the presence of water (than ethanol), it can be distributed via conventional infrastructure (pipelines, blending facilities and storage tanks). There's no need for a separate distribution network.
4. **It is less corrosive than ethanol.** Not only is biobutanol a higher-grade more energy dense fuel, it is also less explosive than ethanol.
5. **EPA test results show that biobutanol reduces emissions,** namely hydrocarbons, carbon monoxide (CO) and oxides of nitrogen (NOx). Exact values depend upon the engine state of tune.

Biobutanol as a motor fuel with its long chain structure and preponderance of hydrogen atoms could be used as a stepping-stone in bringing hydrogen fuel cell vehicles to the main stream. One of the biggest challenges facing hydrogen fuel cell vehicle development is the storage of on-board hydrogen for sustainable range and the lack of hydrogen infrastructure for fueling. The high hydrogen content of butanol would make it an ideal fuel for on-board reforming. Instead of burning the butanol, a reformer would extract the hydrogen to power the fuel cell. Disposable canisters made of PLA that carry butanol to be reformed and used to generate electricity for computers, night vision and stealth equipment can be easily disposed of without causing much harm to the environment (David and Shang, 2004).

2.2.5 Biogases

Anaerobic digestion is a biological process that uses bacteria in the absence of oxygen to convert biomass to a mixture of methane and carbon dioxide called "biogas" (Reith and Sherow, pdf). This anaerobic digestion takes place at different conditions of temperatures. There are psychrophilic (temperature diapason 10-25^{0}C), mesophilic (25-40^{0}C) and thermophilic (50-55^{0}C) regimes of bioconversion. Biogas production in a thermophilic regime is much higher than for the mesophilic and psychrophilic regimes (Ibrahim et al, 2001).

Liquid and solid wastes are particularly amendable to this process, which is already providing energy in many locations around the world. Like syngas, biogas can be used directly or converted to other fuels. During production, there is a solid byproduct called digestate which can be used as a biofuel or fertilizer (Internet (a)). Biogas consists of methane. The gas that is now most commonly produced as a biogas is methane.

The Syngas is a special type of biogas which is produced as result of combined processes of gasification, combustion and pyrolysis of biomass. The Syngas can be used in internal combustion engines and are also used to create hydrogen and methanol.

3. Conclusion

The production of these biofuels is a great step towards making the earth again a better place for its inhabitants. The use of these biofuels will not only compensate the loss of naturally occurring fossil fuels but will also reduce the pollution in environment and will slow down the rapidly increasing green house effect in the environment. Another positive effect of these biofuels is the reduction in political and economic crises arising from pollution due to oil spillage and the ownership of the locations where the fossil fuel is found as we have in Niger Delta, Nigeria. It is encouraging going into the business of biofuels production to empower rural dwellers thereby alleviating poverty and reducing environmental destruction and enjoining sustainable energy usage. The numerous benefits of biofuels include sustainability, mitigation of green house gases emissions, regional developments, employments, energy security, conflict resolutions, agriculture and socioeconomic benefits will make a lot of changes for the benefit of man when their production and usage are fully practical zed globally.

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