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Biodiesel Production: Feedstocks, Usage, and Global Status- A Review

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ABSTRACT

Development of biodiesel is not only to mitigate the climate change but also to provide sustainable energy, develop rural communities, provide jobs and reduce health and safety risks. The quest for mitigating environmental degradation is taken seriously by the European Union, U.S., South America and Asia countries. Their production and consumption of biodiesel is on the increase. Currently U.S., Brazil, Germany, and France are world's leading producing nations and Argentina, Brazil, Indonesia, Philippine and Malaysia are the major net exporters of biodiesel. Only three Africa countries: Ghana, Niger and Togo, have started commercial biodiesel production.

Keywords: Biodiesel, consumption, feedstocks, Nigeria biodiesel status, production

INTRODUCTION

Due to environmental degradation being caused by fossil fuels, interest has shifted to the use of biodegradable fuels (biofuels) to replace or blend with fossil fuels. Among the reasons for the people shifting their interest to biofuels are the rising prices of fossil fuels, emission of the greenhouse gases (GHG) and rural development. Use of biofuels is among the best way of reducing emission of the greenhouse gases and can also be looked up on as a way of energy security as alternative to fossil fuels. According to ICCT [1], biofuels are one of the options considered to increase renewable energy and decrease the pollution of the transportation sector. Bioethanol and biodiesel are the most common types of biofuels being used as transport fuels. They are very attractive due to reduction of combustion emissions, accessibility from renewable resources, and biodegradability [2]. As demand for clean energy increases, biofuels are becoming increasingly attractive [3]. In 2015, according to the Renewable Energy policy for the 21st Century—REN21, global biofuels production was composed of 74% ethanol, 22%

biodiesel, and 4% hydrogenated vegetable oil (HVO) [4]. Zhou and Thomson [5] reported that International Energy Agency (IEA) scenarios presented in the 2008 World Energy Outlook reports, that biofuels contributed 1% of the world's road fuel consumption in 2006, and could rise to 4% by 2030. The report of International Energy Agency in 2013 claimed that, the transportation sector was responsible for 23% of energy-related CO_2 emissions globally [3].

Biofuels were humanity's first liquid fuels which included vegetable oils, animal fats, ethanol from crops, and methanol and turpentine from wood. They predate the general use of petroleum for illumination, cooking, heating and transportation [6]. It is a clean, renewable, domestically available fuel and has long been recognized as energy of the future. The first internal combustion engine in the U.S. built by Samuel Morey that powered a small boat up the Connecticut River in 1826 was fueled with a mixture of turpentine and alcohol [7]. Rudolf Diesel, whose invention in 1900 now bears his name, had envisioned vegetable oil as a fuel source for his engine [6]. Siegel [7] reported that Alexander Graham Bell made an observation that alcohol a beautiful, clean and efficient fuel manufactured from corn can replace fossil fuel. Vegetable oils were used in the early 1700s fueling lamps up the major streets in European and American cities. They were also used for diesel fuel during the 1930s and 1940s [6]. A German inventor Nicolas Otto invented four-stroke internal combustion engine in 1876 powered by alcohol [7] and Ford Model Tractor invented by Henry Ford in 1908 was designed to run on ethanol [7]. Siegel [7] reported that concerns about dependence on foreign oil, as well as awareness of climate change have worked their way onto public and government agendas, resulting in a number of actions that have opened the doors for a resurgence of biofuels. Many studies on sustainability debates around biofuels, including the pros and cons of various measurement tools to assess the effects that biofuels might have on changing land use, GHG emissions, and agricultural production, among others have been carried out [8]. Biofuels are seen as a potential energy contributor, hence, many countries are advocating policies that encourage their production and consumption [9].

Biodiesel is a fuel that consists of long straight chain aliphatic fatty acid esters produced from plant and animal oils and fats by transesterification. Biodiesel is a renewable, biodegradable fuel that can be manufactured domestically from vegetable oils, animal fats, or recycled restaurant grease [10]. Development of modern biodiesel is reported by EUBIA [11] to have started in Austria in 1982, to provide a secure supply of liquid transport fuels, create an environment-friendly fuel for diesel engines, and reduce health and safety risks and provide customers with a reliable fuel at a reasonable ratio of costs to benefits. The fuel is popular because it is domestically produced, supports industry, and represents a good balance of cost, emissions, cold-weather performance and materials compatibility. According to EBB [12], in the transport sector, it may be effectively used both when blended with fossil diesel fuel and in pure form. Biodiesel can be blended with diesel and used in many different concentrations. The most common are B100, B20, B5 and B2 [10].Tests undertaken by motor manufacturers in the European Union on blends with diesel fuel up to 5-10%, or at 25-30% and 100% pure have resulted in guarantees for each type of use [12]. Alleman et al [10], reported that every Original Equipment Manufacturer (OEM) of diesel vehicles approves the use of biodiesel blends up to B5 and almost 80% of OEMs approve blends up to B20 in some or all of their diesel vehicles. It has been found to have significant environmental benefits in terms of reduction of emissions, reduction in global warming, increase in life spam of vehicle engines due to its high lubricity and jobs creation. Biodiesel virtually eliminates the notorious black soot emissions associated with diesel engines [13]. The average biodiesel emissions in comparison with fossil diesel are presented in Table 1.

Table 1: Average Biodiesel Emissions Compared to Conventional Diesel [14]

Emission Component	**B100**	**B20**
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
NOx	+10%	+2%
Sulfates	-100%	-20%
PAH	-80%	-13%

The reasons for biodiesel worldwide surge are that: it reduces the emission of gases responsible for global warming, promote rural development, contribute toward the goal of energy security, it is renewable, and reduces pollution [15]. However, its' mass production is facing some challenges due to higher prices for oilseeds and lower diesel prices [16]. According to EBB [17], various studies have estimated that the use of 1 kg of biodiesel leads to reduction of some 3 kg of CO_2. Hence, the use of biodiesel results in a significant reduction in CO_2 emission (65%-90% less than conventional diesel), particulate emissions and other harmful emissions.

This paper discusses the usefulness of biofuels, the history of biofuels usage, impact of biodiesel in particular, the feedstocks for biodiesel production globally, global biodiesel status and the status of biofuel in Nigeria.

Biodiesel Feedstocks

Biodiesel feedstocks are classified into first, second and third generations according the stages they were discovered for use in biodiesel production. The first generations are edible oils which has generated a lot of heated debates of energy over food security [18]. Among the first generation biodiesel feedstocks are corn, soybeans, sunflower seeds, cottonseeds, canola, crambe, rapeseeds, safflowers, flaxseeds, rice bran, mustard seeds, and camelina, and animal fats [19]. Those vegetable oils that are virgin and can be used for cooking are classified as first generation feedstocks. These include rapeseed oil, soybean oil, ground nuts oil, palm oil and cotton seed oil. The above mentioned oils after used for frying and are no longer suitable for consumption are classified as second generation oils. Also in this category is vegetable oil from non-edible plants such as *Jatropha curcas*, castor, neem etc. The third generation biodiesel feedstocks are the microalgae. Algae produce oil that can easily be refined into diesel or even certain components of gasoline. It can be genetically manipulated to produce everything from ethanol and butanol to even gasoline and diesel fuel directly [20].

In Europe, Rapeseed oil is still the dominant biodiesel feedstock accounting for 45 % of totalbiodiesel feedstocks followed by used cooking oil (UCO) with 21 % of total feedstock production in 2017 [20]. European Union use rapeseed oil, palm oil, soybean, sunflower, used cooking oil, animal product, *Jatropha*, brown grease, soap stock acid oil, and refining residue with rapeseed amount to 55% of total feedstock [21]. In the United States, soybean oil is the largest feedstock for biodiesel production [10]. Brazilian biodiesel production is mainly from vegetable oil and animal fats with soybean oil account over 70% of the total feedstocks [4]. Indonesia’s biofuel policy focuses primarily on the use of palm oil to make biodiesel, and secondarily on Jatropha-derived oil and Malaysia uses only palm feedstock [5]. In Thailand, biodiesel is produced from palm oil derived feedstock such as crude palm oil, refined bleached deodorized palm oil, palm stearin, and free fatty acids of palm oil [22].

Global Biodiesel Status

Biodiesel Production in US

Biodiesel production in U.S. increased from 343 million gallons (1.298 billion litres) in 2010 to 1.278 billion gallons (4.838 billion litres) in 2014, an increase of 272% for the five year period [23]. According to Alleman et al., [10], the data released by U.S. Environmental Protection Agency (EPA) in January 2015, shows U.S. biodiesel consumption during 2014 fell to 1.75 billion gallons, down from 1.8 billion gallons in 2013. In 2017, US produced 1,596 million gallons equivalent of 6.04 billion litres of biodiesel and in 2018 she produced 7.05 billion litres [14]. In February, 2019 U.S. production of biodiesel was 131 million gallons (495.18 million L) 13 million gallons (49.14 L) lower than production in January 2019 [24]. This indicates that US is in continuous production of biodiesel. EIA [23] also claimed that, there were a total of 985 million pounds (44.325 million kg) of feedstocks used to produce biodiesel in February 2019 of which Soybean oil accounted for 560 million pounds (25.2 million kg) consumed. This indicates that soybean oil remains the largest biodiesel feedstock in US with 56.85% of the total feedstocks used in U.S. US has 101 biodiesel plants scattered all over the country with a total annual production capacity of 9.641 billions litres [24]. In 2016, biodiesel imports from Argentina reached 449 million gallons and accounted for nearly 20% of U.S. biodiesel consumption [25].

European Union

The European Union started producing biodiesel on an industrial scale in 1992, largely in response to positive signals from the EU institutions [26]. In 2003, EU has started a promotion campaign for biodiesel by setting clear targets for biodiesel consumption in the transport sector and by enabling member states to give various fiscal and regulatory supports to attract the interest of individual investors [16]. To address the emission of greenhouse gas, the EU came up with Renewable Energy Directive (RED) which was adopted in 2009 covering the period of 2010-2020 [8]. According to Stattman et al [8], the Directive prescribes minimum greenhouse gas (GHG) emission reductions for biofuels, relative to the fossil fuel that biofuels are intended to replace. It also prohibits biofuel feedstock production on land with recognized high biodiversity and carbon stocks and on peat land. EU is out to reduce fossil fuel for transportation by 10% and replace it with biofuels. To ensure quality fuel, the EU has published strict guidelines in compliance with CEN Standardisation (EN14214) in quality and performance EIA [26].

EBB [17] reported that, in 2016 European Union produced a total of 11, 576 tonnes and 21, 119 tonnes of biodiesel in 2016 and 2017 respectively with Germany topping the group with 3,017 tonnes and 4, 005 tonnes. From the records, 24 countries of the union participated in production in 2016 but the number increased to 27 countries in 2017, indicating that, people of this region are showing more interest in this fuel for mitigating environmental degradation. The record also showed that each of the participating countries increased their production output. The base feedstock for biodiesel production in Germany and other producing countries of the region is rapeseed oil.

According to Flach et al [21], EU is world largest biodiesel producer with up to 60% of the world production [20]. Individually, in 2015 United States were the main producer, which produced 4.8 billion litres (15.9% of biodiesel global production), followed by Brazil (3.9 billion litres—12.9%), Germany (2.8 billion litres—9.3%), France (2.4 billion litres—7.9%), and others (16.2 billion litres—53.8%) [4]. Biodiesel is also the most important biofuel in the EU and, on an energy basis, represents about 75 percent of the total transport biofuels market [21]. Besides the quantity of biodiesel produced in EU, she still imported 852, 000tonnes of the fuel between August 2018 and January, 2019 from Argentina [8]. In 2018 EU imported 3.32 mt of biodiesel with Argentina supplied 50% of the imported fuel. Record shows that the import came from Argentina, Indonesia, Malaysia, China and Norway in the decreasing order of quantity supplied [22].Garofalo [22], reported that sustainable biodiesel delivers significant GHG emissions saving, mitigates the need for EU to import additional animal feeds, and avoid the need to import even more fossil fuels from third countries. According to EBB [17], there are approximately 120 plants in the EU producing up to 6,100,000 tonnes of biodiesel annually. These plants are mainly located in Germany, Italy, Austria, France and Sweden.

South America

In 2016 and 2017, Argentina produced 3,020 million litres and 3, 260 million litres of biodiesel. Biodiesel production for 2018 was forecast to decline to 2.76 billion liters, lower than the previous two years due to trade policy actions taken by the EU and United States, but the fifth largest volume since the industry started eleven years ago [17].In 2015, Brazilian biodiesel production was about 3.9 billion litres increased by 15% related to 2014, mainly due to the stimulus given to the sector through the increase of the biodiesel blending mandate, from 5% (B5) to 7% (B7) [4]. Brazil produced 4.3 billion litres of biodiesel in 2017 and increment of 13 % compared to 2016 and 5.4 billion in 2018 an increase of 26 % [28]. Barros [29], reported that, the increment in 2017 was due to the slight increase in diesel consumption and the increase of the biodiesel blend to eight percent (B8) in March 2017 and that of 2018 was based on the increase of the biodiesel blend to 10 percent (B10) in March 2018. Biodiesel production in Brazil is increasing steadily.

Biodiesel Status in Asia

The biofuels producing nations in Asia are Indonesia, Malaysia, Thailand, the Philippines, (the) PRC and India [5]. The projection of Thailand biodiesel plants was 14 with a total production capacity of 2, 290 million litres per annul and consumption of 1, 470 million litres per annul [3].The Government of Indonesia has issued several policies concerning the development of alternative energy. Biofuels are to account for 2%, 3% and 5% of Indonesia's total energy mix, respectively, in 2010, 2015 and 2025 and by 2025, it is envisaged that biodiesel will replace 20% of the diesel consumed [5].

Zhou and Thomson [5] reported that the specific goals set up by Indonesia National Biofuel Policy to 2010 are:

1. Job creation for 3.5 million.
2. Increasing income for on- and off-farm workers up to the regional minimum payment.
3. Development of biofuel plantations on 5.25 million ha of unused land.
4. 1000 Energy self-sufficient villages and 12 special biofuel zones.
5. Reducing fossil fuel use for transport by up to 10%.
6. Reducing fuel subsidies.

China's production of biodiesel developed later than ethanol production with the USDA reporting 1.13 billion liters in 2014 and 1.14 billion litres in 2015 using almost 100% used cooking oil also called gutter oil [29]. A report by Dyka et al [29] claimed that unlike ethanol, China has no official national mandate for biodiesel use in the transportation sector, although a small trial program using 2% and 5% biodiesel blends was carried out in Hainan province. Lack of feedstock and national policy support limit biodiesel expansion in China. Hence, China's small-scale, private owned biodiesel producers have primarily relied on used cooking oil and oil rendered from animal fats as their main feedstock. Corpuz [30] reported that, the 11 biodiesel plants in Philippine, produced 226 million litres amounted to an estimated 2.8 % blend level with carryover stocks.

With no policy support to introduce large volumes of biodiesel, the demand for biodiesel in Japan is very limited, and thus biodiesel plays virtually no role in meeting renewable energy goals [31].

Nigeria Biodiesel Status

A rapid expansion in biodiesel production capacity is being observed not only in developed countries such as Germany, Italy, France, and the United States but also in developing countries such as Brazil, Argentina, Indonesia, and Malaysia [15]. In the whole of Africa, it is only three countries: Ghana, Niger and Togo, which have started biodiesel production, with Ghana at the top of the group with average production capacity of 50 million litres per annual while Niger and Togo produced10 million litres each [9]. The US and European nations have being in a surge of interest in the use of biodiesel to displace petroleum-sourced diesel fuel for transport and home heating oil., According to the data released by U.S. Environmental Protection Agency 2016 Biodiesel Conference and Expo, U.S. consumed nearly 2.1 billion gallons (7.949 billion litres) of biodiesel in 2015, reducing America's carbon emissions by at least 18.2 million metric tons [32].

It is very necessary for Nigeria to join the Paris Climate Agreement and COP23, setting out targets to reduce greenhouse gas emissions in the future. In 2018, the European Union (EU) set its climate and energy objectives for 2030. They included a greenhouse gas reduction of at least 40% and a minimum of a 32% share of renewable energy consumption across all sectors [1]. The Nigerian Biofuels Policy and Incentives drafted in 2007 by the national oil company (NNPC) [33] is not being implemented. In December 2015, Brazil joined the 21st Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) in Paris, where governments from 190 countries discussed potential agreement on preventing global climate change [28]. In this conference, each country submitted their plan to reduce domestic emissions of greenhouse gases (GHG), called an "Intended Nationally Determined Contribution (INDC)," with the intention of limiting the rise of global temperatures to a maximum of 2ºC by 2100. The Government of Nigeria should as a matter of urgency set up a special focus on renewable energy. With a population of about 190 million, Nigeria should be among the League of Nations mitigating environmental degradation.

Federal and state governments should enact laws to regulations, and provide incentives for the production and use of biodiesel to ensure fuel quality, which is important given biodiesel's unique properties and diverse feedstocks. These measures should also apply to qualified producers, distributors, and users. These may come by providing grants and loans to biodiesel producers, tax credit, export duty and any incentives that will help the growth of the business in Nigeria. Good incentives and laws from Federal and State government and regulations will sustain production and use of biodiesel across the country. It is such laws and regulations at the federal, state, and local levels that are important drivers of the growth of biofuels production and use in the United States [34]. The state should have her renewable energy standards to guide the producers and distributors as it is the case in advanced countries. According to Situmbeko [2], a well-developed biofuels industry will contribute to solving the transportation problem. In addition a number of spin-of benefits to be gained from biofuels industry will include:

I. ensuring availability of affordable fuel to rural communities for household electrification, powering farming machinery, and transportation;
II. reducing the quantity of oil importing;
III. creating opportunities for exports of biofuel feedstocks to industrialized countries by Nigerian farmers;
IV. providing many employment opportunities to Nigerian people and boost the country's economy; and
V. assisting industrialized Africa countries, like Egypt and South Africa that are among the leading carbon emitters in the continent in mitigating carbon emissions.

CONCLUSION

EU, U.S., Brazil, Argentina, Indonesia, Philippines and Malaysia are into large scale production and consumption of biodiesel. In Africa, only Ghana, Niger and Togo have started biodiesel production. The Nigerian Biofuels Policy and Incentives drafted in 2007 by the national oil company (NNPC) should be put to use. The policy should provide regulations and incentives for production and consumption of biodiesel [35], develop our rural communities and reduce health and safety risks. Implementation of enabling policy for biodiesel will ginger these potential entrepreneurs.

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