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Review

Biofuel Development Current Status: A Review

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Sustainable biofuel development and utilization have been established as a strong way to mitigate the perilous climate change we experience today. It has been long now; there have been progressive efforts in developing biofuels in different parts of the world which have resulted into varieties of biofuels in existence today. Some of them include bioethanol fuel, mixed ethanol, bio ethers, biodiesel, green diesel, Fisher-Tropsch gasoline, biomass briquettes, biogas, etc. Based on their feedstock used in their production, they are classified as first generation, second generation, third generation and fourth generation biofuel. First generation biofuel is derived from edible food crops, the second generation is made from lignocellulosic materials, while the third generation biofuel is derived from algae which have been reported to be a perfect biofuel feedstock because of their high oil content and their phenomenal growth rate. Fourth generation biofuel was based on genetically modified carbon negative crops. This paper reviewed the current development in biofuel.

Keywords: Biofuel, sustainability, development, prospect, challenge

INTRODUCTION

Biofuel is a type of energy derived from renewable plant and animal materials. It is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion rather than a fuel produced by geological processes such as those involved in the formation of fossil fuel such as coal and petroleum, from prehistoric biological matter.

Biofuels have been around as long as cars have. At the start of the 20th century, Henry Ford planned to fuel his Model Ts with ethanol, and early diesel engines were shown to run on peanut oil. Countries around the world are using various kinds of biofuels. For decades, Brazil has turned sugarcane into ethanol, and some cars there can run on pure ethanol rather than as additive to fossil fuels (Aransiola *et al.*, 2014).

A biodiesel is a diesel-like fuel commonly made from palm oil is generally available in Europe (Chena *et al.*, 2015). But discoveries of huge petroleum deposits kept gasoline and diesel cheap for decades, and biofuels were largely forgotten. However, with the recent rise in oil prices, along with growing concern about global warming caused by carbon dioxide emissions, biofuels have been regaining popularity (Aransiola *et al.*, 2014). Carbon dioxide and other gases making up greenhouse gas, allow solar energy to enter the earth's atmosphere, but reduce the amount that re-radiates back into the space. When there is excess concentration of such gases in the atmosphere, more heat energy from the sun is trapped on earth thereby causing global warming. The global temperature has increased by about 0.7°C since the advent of industrialization and the rate of the increase is going high every year (UNDP, 2008).

Consequently, the world energy policy is targeted at promoting the use of bio fuels. Biofuels are renewable energy sources meaning that, the sources can be replaced by natural process such that they are never used up. They generally produce considerably lower emissions on combustion compared to fossil fuels and are carbon neutral, that is, they only release the same amount of carbon dioxide as the plants which are the main source take up while growing.

The biofuels produced from the renewable resources could help to minimize the fossil fuel burning and CO_2 production. Biofuels produced from biomass such as plants or organic waste could help to reduce both the world's dependence on oil and CO_2 production. These biofuels have the potential to cut CO_2 emission because the plants they are made from use CO_2 as they grow (Osamu and Carl, 1989; Williams, 2006). Biofuels and bio-products produced from plant biomass would mitigate global warming. This may be due to the CO_2 released in burning equals the CO_2 tied up by the plant during photosynthesis and thus does not increase the net CO_2 in the atmosphere. Additionally, biofuel production along with bio-products can provide new income and employment opportunities in rural areas (Naik *et al*., 2010). Biofuel has been certified to, have the potential to reduce global warming and being renewable, it will generate energy security (Ogbu *et al.,* 2011). Cars are a major source of atmospheric carbon dioxide, the main greenhouse gas that causes global warming. But since plants absorb carbon dioxide as they grow, crops grown for biofuels should suck up about as much carbon dioxide as comes out of the tailpipes of cars that burn these fuels. And unlike underground oil reserves, biofuels are a renewable resource since we can always grow more crops to turn into fuel. There are different varieties of biofuels (Ogbu *et al.,* 2011) which include:

(i) Solid biofuels: e.g. fuel wood and biomass briquettes, etc.
(ii) Liquid biofuels: such as bioethanol, bioethers, biodiesel, green dieses (Fisher Tropsch diesel and hydro refined vegetable oil), Mixed alcohol, Fischer-Tropsch gasoline and Fischer-Tropsch liquids etc. The two most common forms of biofuels are biodiesel and ethanol. Biodiesel is made by combining alcohol with vegetable oils or animal fats and recycled cooking oils and remains the fuel of choice in Europe, while ethanol is widely used in the US (Williams, 2011).
(iii) Gaseous biofuels: e.g. biogas (Onuegbu, 2010).

Among the varieties liquid biofuels have gained an increasing interest in the world today because of their unique ability to replace most of common existing fossil fuels (Table 1). The expansion in production and utilization of the liquid biofuels has been rapid today in the developed countries such as the united State of America, Germany, France and Italy as while as in the developing countries like; Argentina, Brazil, Indonesia and Malaysia. (World watch Institute, 2006).The aim of this paper is to review the current development in biofuel.

Classification of Liquid Biofuels

On the bases of the feedstock materials used in the production, liquid biofuels are generally classified into (Benemann, 2008; WHO, 2008 and Ogbu *et al.,* 2011):

(a) First- generation biofuel
(b) Second-generation biofuel
(c) Third- generation biofuel
(d) Fourth- generation biofuel.

First generation Biofuels

First generation biofuels are derived from edible crops such as vegetable oil, corn, cassava, sugar cane, yam and maize. Hence it competes with food over feedstock (Williams, 2007). Since only small parts of the plants e.g seed and tuber are utilized, large area of land is required to grow enough feedstock for fuel production (Williams, 2010). Some of the available first generation biofuels are:

(a) Biogas
(b) Biodiesel from trans-esterification of plant oil or animal fats.
(c) Ethanol from fermentation of starchy food e.g. wheat, corn, potato, sugar cane, sugar beet, etc.

They are first generation biofuel of which worldwide large quantities have been produced so far and for which the production process is considered ‘established technology.

Advantages of the first generation

(i) Environmentally friendly.
(ii) Economic and social security.
(iii) It has a simple and well known method of production.
(iv) It is compatible with existing petroleum derived product.
(v) The feedstock is common.
(vi) It is produced in different part of the world.

Disadvantages of the first generation

(i) Limited feedstock because it competes with food over feedstock.
(ii) It is partly compatible with the conventional fuel.
(iii) The cost of production of feedstock is high making it expensive.
(iv) Large area of land is required to grow enough feedstock for fuel production, since only small parts of the plants e.g seed and tuber are utilized while other parts such as stalks and leaves are discarded.
(v) It has least net greenhouse gas reduction compare to other classes of biofuel.
(vi) The by-products of first generation biofuel still need market.
(vii) It has limited potential for a complete replacement of fossil fuel in terms of feedstock availability and cost.

Second generation Biofuels

The second generation biofuel are produced from non-food, cheap and abundant plants waste biomass (Agricultural and forest residue, grass, aquatic biomass, water hyacinth, switchgrass etc) (Bouton, 2007). The second generation biofuel is sustainable in terms of feedstock availability, affordability and their impact on greenhouse gas emission reduction, land use efficiency, food security and biodiversity (Williams, 2009). It is further

Table 1. Fossil fuels and their biofuel substitutes

Fossil fuel	Biofuel
Gasoline (petrol)	Bioethanol, fischer-tropsch gasoline and mixed alcohol.
Diesel	Biodiesel, fischer-tropsch diesel, hydrorefind renewable oil and dimethyl ether (DME)
Kerosene	Fischer-tropsch liquid
Paraffin	Fischer-tropsch liquid
Liquefied petroleum gas (LPG)	Dimethyl ether (DME)
Natural gas	Biogas
Crude oil	Biocrude

classified into two based on the techniques used in their conversion. They are (The royal society, 2008; Ogbu *et al*., 2011).

Biochemical Biofuels: These are made from biological (enzymatic) transformation of cellulosic materials. Examples of such fuels are:

(a) Butanol from enzymatic hydrolysis of lignocellulosic material.
(b) Ethanol from enzymatic hydrolysis of lignocellulosic material (cellulosic ethanol).

Biochemical processes for production of second generation biofuel are summarized as follows (Ogbu *et al.,* 2011):

(i) Biomass handling: At this stage the biomass goes through a size-reduction to make it easier to handle.
(ii) Biomass pre-treatment: At this stage, the hemicellulose fraction of the biomass is selectively broken down in to sugar
(iii) Cellulose Hydrolysis: This stage means sugar forming.
(iv) Glucose Fermentation: The glucose is fermented to ethanol.
(v) Pentose Fermentation: At this stage pentose is fermented by genetic modified organism
(vi) Ethanol Recovery: At this stage the ethanol is separated from the other components of the broth by mainly distillation method.

Thermochemical biofuels

Thermochemical processing defines the conversion of biomass into a range of products, by thermal decay and chemical reformation, and essentially involves heating biomass in the presence of different concentrations of oxygen. The clear advantage of thermochemical processing is that it can essentially convert all the organic components of the biomass compared with biochemical processing which focuses mostly on the polysaccharides (Naik *et al*., 2010; Aljerf, 2015). These types of biofuels are produced by thermal transformation of lignocellulosic materials. Some of them include the following:

(a) Pure ethanol
(b) Mixed alcohols
(c) Fischer-Tropsch diesel
(d) Fischer-Trospsch gasoline
(e) Dimethyl ether

Advantages of Second generation Biofuel

The advantages of second generation biofuel are (Benemann, 2008):
(i) Environmentally friendly
(ii) Not competing with food
(iii) The feedstock is cheap; they can sometimes collected free of charge.
(iv) The biofuel is more sustainable than the first generation biofuel.
(v) The feedstock is more available
(vi) Most of the above-ground parts can be converted to biofuel. Hence the feedstock yield per square meter of land is higher compared to first-generation feedstock production.
(vii) The feedstock can be cultivated purposely for fuel.

Disadvantages of Second generation Biofuel

The main disadvantage of the second generation biofuel is that, the available production process requires more sophisticated equipment and techniques. Also the process is economical only in large –scale production (Benemann, 2008). In addition the emerging bio economy is likely to result in the single largest reconfiguration of the agricultural landscape since the advent of industrial agriculture. The scale and pace of this revolution pose significant challenges for sustainable bio economic development (Raghu *et al*., 2011).

Biomass

Biomass are derived from trees, agro-forest residues, grasses, plants, aquatic plants and crops. The approaches to integral utilization of biomass for sustainable development are more reasonable, where all parts of the plant such as leaves, bark, fruits, and seeds can be utilized to useful products (Naik *et al*. 2010).

Biomass as multiple feed stocks for bio refinery

Biomass is versatile and important renewable feedstock for chemical industry. Through photosynthesis process, plants convert carbon dioxide and water in to primary and secondary metabolite biochemical. Both of these are industrially important chemicals. Primary metabolites are carbohydrate (simple sugar, cellulose, hemicellulose, starch, etc.) and lignin called lignocellulose present in high volume in biomass. The lignocellulosic biomass can be converted into biofuels. The secondary metabolite are high value biochemical such as gums, resins, rubber, waxes terpenes, tepenoids, steroids, triglyceride, tannin, plant acids, alkaloids, etc. are present in low volume in the plants (Clark *et al.,* 2006). The secondary metabolites can be utilized for production of high value chemicals such as food flavours, feeds, pharmaceuticals, cosmoceuticals, and nutraceutical, etc. using integrated processing technique.

Bio refinery

The term 'Bio refinery' was initially established in 1990, for the utilization of biomass for production of fuels and other bio products. This term refers to a facility (or group of facilities) which combines the production of materials, chemicals, or fuel products with energy production (Fernando *et al*., 2006). The bio refinery system includes biomass production, biomass Transformation/processing, and end use. A bio refinery is a facility that integrates biomass conversion processes and equipment to produce fuels, chemicals and power from biomass. The goal of a bio refinery is to transform biomass into useful products using technology and processes (Naik *et al*., 2010; Hubenova, 2014).

Bio refinery system/concept

The bio refinery system is based on biomass as processing input (feedstock) for production of multiple bio-based products. The basic concept of the bio refinery system is to produce biofuel and platform of chemicals from biomass.

Classes of bio refinery

(i) The first one has fixed processing capabilities and uses dry grain as feedstock to produced ethanol, dried distillers grain (DDG)/feed products and carbon dioxide.
(ii) The second type bio refineries used same feedstock and have more processing flexibilities than first one. It can produce starch, high fructose syrup, ethanol, carbon dioxide, DDG and corn oil.
(iii) Third type of bio refinery is most advanced and can use a mix of biomass feed stocks and produced different products by employing combination of technologies. It is based on both the High Value Low Volume (HVLV) and Low Value High Volume (LVHV) output principle. The third type of bio refinery are again classified in three categories like, Whole Crop, Green and Lignocellulose feedstock bio refineries, which are in research and development stage (Fernando, 2006).

The third generaion biofuels

Biodiesel is derived from either plant or animal oils by chemical trans-esterification (Scott *et al*., 2010). There are many biomasses that have been proposed as biofuel feedstocks such as palm oil, jatropha and microalgae. Among these biomasses, microalgae have received notable attention because of their high photosynthetic rate, which can be more than 6.9 × 104 cells/ml/h. This shows that microalgae have a photosynthetic rate that is approximately 50 times higher compared to terrestrial plants. Microalgae have been reported to accumulate more than 70% lipid on a dry weight basis (Lackner, 2003). The lipid content of microalgae, specifically the triglyceride content, is important for biodiesel. Biomass, however, can be converted into biofuel oil through a thermochemical conversion process. Third-generaton biofuels are biofuel derived from algae and other microbes. Algae are group of (aquatic) plants belonging to thallophytes in the plant kingdom. They are generally classified into 2:1) Microalgae: multicellular species exclusively found in marine environments which are usually referred to as seaweed and 2) micro-algae-unicellular species found in fresh water. They tend to occur in dense cocentrations historically, algae has long been recognised as a potential source of fuel, and much research occurred in Japan and in US in the seventies and eigthies toward developing commercial algae for fuel production (Clark *et al*., 2006). For decades, commercial algae cultivation has been on in many countries of the world for as raw materials for production of food, food-additives and health-food, feed for fish shrimp and shell-fish, colorants and omega-3- fatty acids, etc. Algae were considered perfect biofuel feedstock because of their very high oil or starch content, their phenomenal growth rate, the fact that they can be grown on non-agricultural land, and that they only need sunlight, wastewater and carbon dioxide to flourish (Beneman, 2008 and Ogbu *et al*., 2011). Biodiesel from Algae: Oil is one of the main components of micro-algae. Depending on the species and growth conditions, it may consist of 2-60 percent of total cell dry matter (Ogbu *et al.,* 2011). Algae oil is mainly unsaturated (Global Bioenergy Partenership, 2009). In order to efficiently produce biodiesel from algae, strains have to be selected with a high growth rate and oil content. After extraction, algae oil can be converted to biodiesel by the conventional process. Biodiesel is the most attractive biofuel from algae (Htet *et al*., 2013). Micro algae biodiesel production system involves the following steps: cultivation, harvesting, dewatering, extraction, and transesterification (Harun *et al*., 2010). Bioethanol from algae; algae that happens to produce starch or sugar can serve as feedstocks for conventional ethanol production via fermentation. Besides, there were attempts to develop strains of algae that will synthesize ethanol directly by normal metabolic processs (Global Bioenergy Partenership, 2009). Further more, the entire algae biomass can also be converted in to alcohol via gasificaton process followed by fermentaton of the resulted sungas or through biochemical conversion of the biomass by micro-organism.

Benefits of algae

Unlike plants, unicellular microalgae do not partition large amounts of biomass into supportive structures such as stems and roots that are energetically expensive to produce and often difficult to harvest and process for biofuel production. Microalgae have a number of advantages in CO_2 capture and bio-oil generation.These include high photosynthetic conversion efficiencies, rapid biomass production rates, year round harvest (Demirbas *et al.,* 2011), the capacity to produce a wide variety of biofuel feedstock, ability to thrive in diverse ecosystems, distinguished environmental bioremediation such as CO_2 fixation from the atmosphere or flue gas, and water purification (Chisti, 2007; Wang *et al*., 2008) non-competitiveness for land with crops and non-competitiveness with the food market. Moreover, microalgae have carbon concentrating mechanisms that suppress photorespiration(Jansson *et al*., 2010).

Challenges of third geration biofuel

Finding the right place to grow large amounts of algae and improving the economics of the procesing (e.g extracting the oil from the algae) remains the main challenge of the third generation biofuel development (Lackner, 2003).

Fourth-generation biofuel

One definition of a fourth generation biofuel is crops that are generally engineered to consume more CO_2 from the atmosphere than they will produce during combustion later as a fuel. In order words, fourth-generation biofuel technology combines generally optimized feedstock, which are design to capture large amount of carbon, with synthesized microbes that will convert the biofuels produced into even more efficient fuels. The process relies on CO_2 capture and sequestration, a process that makes the biofuel carbon negative (Ogbu *et al*. 2011). The comparison between petroleum fuel and different generations of biofuel in terms of feedstock, products, benefits and problems are summarized in (Table 2).

Biodiesel

Biodiesel is produce by trans-esterification reaction between lipids and alcohol usually methanol in the presence of catalyst. Biodiesel is among the commonest liquid biofuels used in the world today. However, biodiesel fatty acid methyl ester (FAME) has some compatibility issues with existing diesel engines and distribution facilities due to oxygen content of the fuel (Ogbu *et al.* 2011). As at today, pure biodiesel cannot be used in the conventional diesel engine .This necessitated researches towards transforming renewable oil into biofuel analogue fossil diesel which can be used purely in conventional diesel engines without any modification. The researches focus on conversion of vegetable oil or animal fats into hydrocarbon similar to the ones in fossil diesel without jeopardizing the derivable characteristic of biofuel through hydro refining of the oil. The diesel obtained by this process is referred to as green diesel' just like fischer-tropsch diesel because they are similar to fossil diesel in their chemical composition. Nevertheless, biodiesel still remains one of the most viable biofuels in the world, largely, its economical production process compared to other liquid biofuels.

Green diesel by hydro refining of renewable oil

Hydro refining of vegetable oil or animal fats converts the oil to hydrocarbon similar to the ones in petroleum diesel. This process utilizes catalytic saturation. Hydrodioxigenation, decarboxylation and hydroisomerization reactions to produce an isoparaffin – rich diesel fuel from vegetable oil or animal fats (Immer *et al*., 2009).The resulted biofuel product has a high cetane value, a lower gravity, good cold flow properties and excellent storage stability. In contrast (Table 3) to biodiesel, where fuel properties depend on feedstock origin and process configuration; the green diesel is independent of feed origin and cold flow properties can be controlled by adjusting hydroisomerization reactor severity, making the process more flexible than biodiesel production with respect to feedstock selection.

Challenges of green diesel production by hydro refining renewable oil

The challenges of hydro treating vegetable oil include; a high hydrogen consumption and large exotherms across

Table 2. Comparison between petroleum fuels and the different generations of biofuel.

	Petroleum fuel	First generation biofuel	Second generation biofuel	Third generation biofuel	Fourth generation biofuel
Feedstock	Crude petroleum	Vegetable oil, cassava, maize etc	None food cheap and abundant plant waste biomass	Algae and other microbes	Carbon negative crops
Product	Diesel, kerosene, petrol, Jet fuel etc	Biodiesel, biogas, ethanol, butanol etc	Bio oil, FT oil, butanol, mixed alcohol etc	Bio diesel, bio ethanol, alcohol etc	Bio fuel
Benefits	It can be used in all petrol engines	Environmentally friendly. It has simple and a well-known method of production etc	Environmentally friendly, not competing with food etc	Rapid bio mass production rate, year round harvest etc	Environmentally friendly, consume more carbon dioxide etc
Problem	Environmental pollution, economic and ecological problems	Limited feedstock (food vs fuel), feedstock is expensive	The process is economical only in large scale production etc	Finding the right place to grow large amount of Algae, improving the economic process.	It takes time to optimize feedstock which is design to capture large amount of carbon.

Table 3. Comparison of properties of various diesels.

Properties	Petrol diesel	Biodiesel	Green diesel	FT diesel
Oxygen content (%)	0	11	0	0
Specific gravity	0.84	0.88	0.78	0.77
Sulphur content (fppm)	<10	<1	< 1	<1
Heating value (MJ/kg)	43	38	44	44
Cloud point (°C)	-5	-5 to+15	-20 to +20	Not available
Cetane	40	50-65	70-90	>75
Stability	Good	Marginal	Good	Good

the catalyst beds, which must be faced to avoid catalyst deactivation and fouling. Petrol diesel, Biodiesel: fatty acid methyl ester (FAME), Green diesel: hydro refined vegetable oil, Fischer-Tropsch (FT) diesel (Ogbu *et al.,* 2011).

Prospect of biofuel

The expansion in production and utilization of the liquid biofuels is increasing rapid in the developed countries. Being a renewable energy sources meaning that, the sources can be replaced by natural process such that they are never used up. The world energy policy is targeted at promoting the use of bio fuels as a replacement of fossil fuels. The international energy agency (IEA) affirmed that by the mid of this century, bio-fuels will provide over one quarter of all transport fuel including Jet fuel.

Conclusion

Biofuels have been around as long as cars have. In the recent years, there has been a rapid expansion in the development and utilization of biofuel around the globe. However, recent researches are focused much on positioning non- edible crops and wastes as the main feedstock for biofuels (to guarantee their sustainability) and addressing some compatibility issues associated with some biofuels. For the future, many think a better way of making biofuels will be from grasses and saplings, which contain more cellulose. Cellulose is the tough material that makes up plants' cell walls, and most of the weight of a plant is cellulose. If cellulose can be turned into biofuel, it could be more efficient than current biofuels, and emit less carbon dioxide.

AUTHOR DECLARATION

I declare that this review was carried out by me and I agree to publish it in the journal.

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