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EMPIRICAL REVIEW OF BIODIESEL AS AN ALTERNATIVE SOURCE OF FUEL FOR INTERNAL COMBUSTION ENGINE PERFORMANCE AND EMISSIONS FUELLED WITH BIODIESEL-DIESEL-ETHANOL BLENDS

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ABSTRACT

Biodiesel is an attractive alternative fuel for diesel engines.The feedstock for biodiesel production is usually vegetable oil, pure oil or waste cooking oil, or animal fats The most common way today to produce biodiesel is by transesterification of the oils with an alcohol in the presence of an alkaline catalyst. It is a low temperature and low- pressure reaction. It yields high conversion (96%-98%) with minimal side reactions and short reaction time. It is a direct conversion to biodiesel with no intermediate compounds. This work provides an overview concerning biodiesel production. Likewise, this work focuses on the commercial production of biodiesel. The Valdescorriel Biodiesel plant, located in Zamora (Spain), is taken like model of reference to study the profitability and economics of a biodiesel plant. The energy used for the biodiesel production is 30% less than the obtained energy from the produced biodiesel. Replacing petro diesel by the biodiesel produced in the plant, a significant CO2 reduction can be reached (about 48%). It means that the CO2 emission can be reduced by 55 000 tons CO2 per year. The production of biodiesel from sunflower oil and ethanol using sodium hydroxide as catalyst was performed in the laboratory and the results are discussed. The results are analyzed using the statistic method of Total Quality. The effect of the ethanol/oil ratio and the amount of used catalyst on the yield of biodiesel as well as on the properties of the produced biodiesel is studied. In the experimental part the density, viscosity and refractive index of the produced biodiesel are measured. The ethanol/oil ratio influences the biodiesel production. The yield of biodiesel increases with the ethanol/oil ratio. Regarding the influence of the amount of catalyst on biodiesel production in the studied conditions, an increase of the biodiesel yield with the amount of catalyst can be appreciated. The study of the evolution of the transesterification during time shows that a reaction time of one hour is sufficient enough in order to reach the highest yield of biodiesel.

Keywords: Global energy consumption, emission, diesel engine, ethanol, biodiesel

I. INTRODUCTION

Ever increasing drift of energy consumption due to growth of population, transportation and luxurious lifestyle has motivated researchers to carry out research on biofuel as a sustainable alternative fuel for diesel engine. Biofuel such as biodiesel and ethanol, produced from renewable feedstocks, are the most appropriate alternative of petroleum fuels. However, direct using of ethanol in diesel fuel face some technical problem especially in cold weather, due to low cetane number, lower flash point and poor solubility. Biodiesel can be blended with both ethanol and diesel fuel and biodiesel–alcohol–diesel blends can be used in diesel engines. The aim of this review paper is to discuss the effect of mixed blends of biodiesel alcohol and diesel on engine performance and emission parameters of a diesel engine. Most of the researchers reported that adding ethanol into biodiesel-diesel blend in diesel engines significantly reduce HC, PM, NOx and smoke emissions but slightly increase fuel consumption. The study concluded that biodiesel-diesel-ethanol blend can be used as a substitute of petro-diesel fuel to reduce dependency on fossil fuel as well as the exhaust emissions of the engine.

The demand for energy, specifically the demand for petroleum fuels around the world is increasing every day [1]. From 2012 to 2015, 41% increase in global energy consumption is forecasted, 30% and 52% increase over last ten and last twenty years respectively. Non-OECD economies will account for 95% of this growth, half of which is expected to come from China and India. Compared to 2012, 69% higher energy will be used in 2035 in the non-OECD economics. Due to having benefits such as adaptability, high combustion efficiency, availability, reliability as well as the handling facilities, fossil fuels results in most energy consumption. Shares of the major fossil fuels are converging, with natural gas, oil and coal each contributing 27% of the total mix by 2035 and the remaining share supplied by nuclear and renewable energy. Table 1 shows the primary energy consumption by fuel type between 2012 and 2035 [2]. Burning of fossil fuels produces emissions t h a t have serious effect on both the environment as well as human health. Fuel, coal and gas each contributes 38% of the increase in emissions and 24% increase is coming from oil. It is predicted that by 2035 global CO2 emissions from energy use will increase 29%. Compared to 1990, global emissions will be nearly double in 2035. Price hiking of the petroleum products, world-wide environmental concerns as well as the rapid depletion of fossil diesel fuel have encouraged researcher to search for alternative fuel sources which will provide cleaner combustion of diesel engines. Therefore, it has become a global agenda to develop clean alternative fuels which are domestically available, environmentally acceptable and technically feasible. According to the Energy Policy Act of 1992 (EPACT, US), natural gas, biofuel, electricity and methanol are the most suitable substitute to fossil fuels that can reduce global warming, fossil fuels consumption and exhaust emissions [3]. As an alternative fuel, biofuel such as ethanol, biodiesel are the best choices due to having properties such as environment friendly behaviour and similar functional properties with diesel fuel. In both developing and developed countries biofuel are at the top of their agendas and thus it is predicted that world biofuel production will be quadruple by 2020 [4]. The biofuels are produced from biomass. The biofuels may be in solid (vegetables wastes, and a fraction of the urban and industrial wastes) liquid (bioalcohols and biodiesel) or gaseous (biogas and hydrogen) form. The first generation biofuels are produced from cereal crops (e.g. wheat, maize), oil crops (e.g. rape, palm oil) and sugar crops. Biodiesel is a first generation biofuel. Other first generation biofuels are bioethanol, biogas and straight vegetable oils. Second generation biofuels are produced from lignocellulosic materials. The syngas produced by gasification of biomass is used as precursor of second generation biofuels like Biomass to liquid (BTL), Bio Dimethylether / Methanol, Bio_Synthetic Natural Gas and biohydrogen. Biooil, produced by pyrolysis of biomass, and cellulosic ethanol are also second generation biofuels.

II. BIODIESEL

The biodiesel refers to methyl or ethyl esters obtained by transesterification of animal fats or vegetable oils. Biodiesel can be blended with petrodiesel. In the case of mixtures, the respective proportion of biodiesel in petrodiesel should be indicated. B20 means a mixture 20% biodiesel and 80% petroleum diesel. B100 is pure biodiesel. Two main groups of raw materials for production of biodiesel can be distinguished: vegetable oil and waste cooking oil. The used cooking oil is an important waste and it can be used for biodiesel production. However, the actual tendency is the utilization of pure vegetable oils cultivated for energetic use. The main raw materials to elaborate biodiesel are: · Conventional vegetable oils of sunflower, rapseed, soybean, coconut and palm.Alternative vegetable oil of Brassica carinata (Ethiopian mustard), Cynara curdunculus (Cardoon), Camelina sativa usually known as camelina, Pogianus, Jathopha curcas, Crambe abyssinica. · Seed oil genetically modified. Animal fats (buffalo and beef tallow). · Waste cooking oil. · Oil from other sources (microbial production and microalgae).

III. BIODIESEL PRODUCTION

The commercial method used for the biodiesel production is the transesterification (also called alcoholysis). The transesterification consists on the reaction of oils or fats (triglycerides between 15 and 23 atoms, being the most common with 18) with an alcohol of low molecular weight (usually ethanol or methanol) with the presence of an alkaline catalyst (usually NaOH or KOH) to produce esters and glycerin. Normally, the reaction takes place at atmospheric pressure and 65ºC of temperature. The process uses constant agitation, during an interval of time between one or twelve hours. The transesterification consists of three consecutive and reversible reactions (Figure 1). The stoichiometric ratio for the transesterification reaction is three moles of alcohol and one mole of triglyceride (Figure 2). An extra amount of alcohol is added in order to move the reaction to the methyl esters formation. Glycerin is also formed in the reaction.
Biofuel such as biodiesel and ethanol are produced from renewable feedstocks. Especially, compared to fossil fuels, biodiesels, made from various crops and animal fat, are non-toxic, bio-degradable, eco-friendly and renewable. Biodiesel can be used in its pure form (B100) or may be blended with petroleum diesel in modern diesel engines. Using only alcoholic fermentation process, ethanol can be produced from agricultural products. Significant particulate matter (PM) emission reduction can be achieved by using ethanol in diesel fuel [5]. However, due to having properties such as low cetane number, lower flash point and poor solubility the direct use of ethanol in diesel engine faces some technical barriers. Biodiesel can be mixed with both alcohols and diesel; using biodiesel as an emulsifier with alcohols and diesel can be used as biodiesel–alcohol– diesel blends in diesel engines [6, 7]. Thus this review aims to investigate different fuel properties of diesel– biodiesel-ethanol/bioethanol blends and the performance of an internal combustion engine fuelled with these blends, investigated by many researchers.

IV. CELLULOSIC ETHANOL

Cellulosic ethanol, also called cellanol, is ethanol fuel produced from cellulose. Cellulose is a naturally occurring complex carbohydrate polymer commonly found in plant cell walls. Cellulosic ethanol is chemically identical to ethanol from other sources such as corn or sugar but is available in a great diversity of biomass including waste from urban, agricultural, and forestry sources. Processing cellulosic ethanol differs from ethanol because it requires an extra step called cellulolysis, or the breaking down of cellulose into sugars. It is more difficult to break down cellulose to convert it into usable sugars for ethanol production. However, making ethanol from cellulose dramatically expands the types and amount of available material for ethanol production. Although the refining process for cellulosic ethanol is more complex than that of corn-based ethanol, cellulosic ethanol yields a greater net energy benefit and results in much lower greenhouse-gas emissions. Cellulosic ethanol can be produced from a wide variety of cellulosic biomass feedstocks including but not limited to agricultural residues (rice, corn stover, and wheat straw), agricultural wastes (sugar cane, bagasse waste, rice husks, and citrus pulp), forestry and wood wastes (including willow and poplar), municipal solid waste (including paper pulp and saw dust), and energy crops (switchgrass).

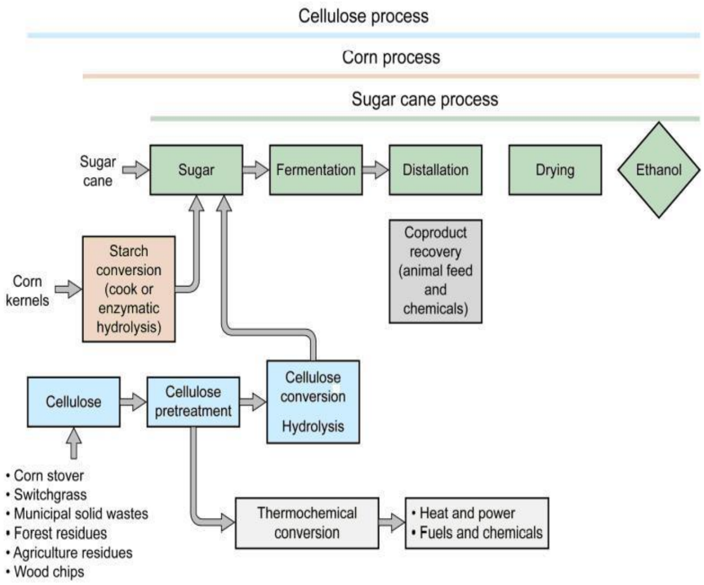

Figure 1.—Ethanol production flowchart

According to Hill et al. [5], biodiesel production is highly efficient, generating 93 percent more energy than is required to make it. They also found that biodiesel reduces greenhouse-gas emissions by 41 percent compared with fossil fuels. Biodiesel is almost always mixed with conventional diesel by fuel distributors because of its higher cost, engine compatibility issues, and cold weather operation concerns. The most common blends are B2, B5, and B20 (2, 5, and 20 percent biodiesel, respectively). Pure 100 percent biodiesel (B100) can also be used unblended as a fuel in some diesel engines. The environmental benefits of using biodiesel scales with the percent of biodiesel contained in the blend. B20 can be more broadly applied to existing engines with little or no modification. Biodiesel feedstock plants utilize photosynthesis to convert solar energy into chemical energy. The stored chemical energy is released when it is burned, therefore plants can offer a sustainable oil source for biodiesel production. Using biodiesel in a conventional diesel engine substantially reduces emissions of unburned hydrocarbons, carbon monoxide, sulfates, polycyclic aromatic hydrocarbons, nitrated polycyclic aromatic hydrocarbons, and particulate matter. Most of the carbon dioxide emitted when burning biodiesel is simply recycling what was absorbed during plant growth, so the net production of greenhouse gases is small. Biodiesel typically produces about 60 percent less net CO2 emissions than petroleum-based diesel fuel since it is produced from atmospheric carbon dioxide via photosynthesis in plants. There are a variety of oils that can be used to produce biodiesel such as rapeseed and soybean oil, which account for approximately 90 percent of all fuel stocks. Other crops include mustard, flax, sunflower, canola, palm oil, hemp, jatropha, and algae. Waste vegetable oil, animal fats (tallow, lard, yellow grease, chicken fat, and fish oil), and sewage are also used for biodiesel production. Thermal depolymerization, a new process that reduces almost any hydrocarbon-based feedstock, including non-oilbased feedstocks into light crude oil can be used to produce biodiesel. Worldwide production of vegetable oil and animal fat is not yet sufficient to replace liquid fossil fuel use. According to the U.S. Environmental Protection Agency, restaurants in the United States produce about 300 million U.S. gal (0.001 km^3) of waste cooking oil annually. The estimated transportation fuel and home heating oil used in the United States is about 230 billion U.S. gal (0.87 km^3) (Ref. 16). Waste vegetable oil and animal fats would not be enough to meet this demand. In the United States, estimated production of vegetable oil for all uses is about 24 billion lb (11 million tons) or 3 billion U.S. gal (0.011 km^3). The estimated production of animal fat is 12 billion lb (5.3 million tons). The use of biodiesel decreases the solid carbon fraction of particulate matter (since the oxygen in biodiesel enables more complete combustion to carbon dioxide) and reduces the sulfate fraction (biodiesel contains less than 15 ppm sulfur), while the soluble, or hydrocarbon, fraction stays the same or increases. Therefore, biodiesel works well with emission control technologies such as diesel oxidation catalysts (which reduce the soluble fraction of diesel particulate but not the solid carbon fraction). Emissions of nitrogen oxides increase with the concentration of biodiesel in the fuel and the increase is roughly 2 percent for B20. Some biodiesel produces more nitrogen oxides than others, and some additives have shown promise in reducing the increases. One disadvantage of using biodiesel for the aviation industry is its freezing point. Biodiesel from corn feedstock, vegetable oil, and animal fats F, which is well above typical fuel temperatures used in jet airplanes. Other disadvantages°freezes at –20 to using biodiesel are its cloud point, gel point, and thermal stability. Fuel storage is also a major concern since biodiesel degrades sufficiently over time in storage.

TABLE I —PHYSICAL PROPERTIES OF BIODIESEL

Specific gravity	0.87 to 0.89
Kinematic viscosity at 40 °C	3.7 to 5.8
Cetane number	46 to 70
Higher heating value, Btu/lb	16 928 to 17 996
Sulfur, wt%	0 to 0.0024
Cloud point, °C	–11 to 16
Pour point, °C	–15 to 13
Iodine number	60 to 135
Lower heating value, Btu/lb	15 700 to 16 735

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V. BIODIESEL FROM ALGAE

While a number of biofeedstocks are currently being used for ethanol and biodiesel production, algae has emerged as one of the most promising sources—especially for biodiesel. The yields of oil from algae are orders of magnitude higher than those for traditional oilseeds. As a comparison, a single acre of algae ponds can produce 15 000 gal of biodiesel, an acre of soybeans produces up to 50 gal of biodiesel per acre, an acre of jatropha produces up to 200 gal per acre, coconuts produce just under 300 gal per acre, and palm oil produces up to 650 gal of biodiesel per acre (Ref. 16). Table III lists the gallons of oil per acre per year for corn, soybeans, safflower, sunflower, rapeseed, palm oil, and microalgae.

TABLE II —ANNUAL YIELDS OF OIL PER ACRE OF VARIOUS BIOFUEL FEEDSTOCKS

Feedstock	Yield, gal
Corn	18
Soybeans	48 to 50
Safflower	83
Sunflower	102
Rapeseed	127
Jatropha	200
Coconut	300
Palm	635
Microalgae	5000 to 15 000

Algae can be grown in sewage and next to power-plant smokestacks, where they digest pollutants. Although research into algal oil as a source for biodiesel is not new, the current oil crisis and fast depleting fossil oil reserves have made it more imperative for organizations and countries to invest more time and efforts into research on suitable renewable feedstock such as algae. Berzin has developed a method of capturing carbon dioxide from smokestack emissions using algae and turning the result into biodiesel, ethanol, and even a coal substitute. His process, based on technology he developed for NASA in the late 1990s, captures more than 40 percent of emitted CO2 on sunny days, up to 80 percent) along with over 80 percent of NOx emissions. In turn, it produces biodiesel at rates per acre that could make a full conversion to biofuel for transportation readily achievable. Berzin calculates that just one 1000-MW power plant using his system could produce more than 40 million gal of biodiesel and 50 million gal of ethanol per year. According to the U.S. Department of Energy, most current research into efficient algal-oil production is being done in the private sector. The per unit area yield of oil from algae is estimated to be from 5000 to 20 000 gallons per acre, per year; which is 7 to 31 times greater than the next best crop, palm oil (635 gal). Algal oil can be processed into biodiesel as easily as oil derived from land-based crops. The difficulties in efficient biodiesel production from algae lie not in the extraction of the oil, but in finding an algae strain with a significant lipid content and fast growth rate that is not too difficult to harvest. Openpond systems have not been considered feasible for the cultivation of algae with high oil content. This is due to the algae not being able to withstand wide variations in temperature and pH as well as competition from invasive algae and bacteria. Algae species with lower oil content, not having to divert their energies away from growth, have an easier time in the harsher conditions of an open system. Research into algae for the mass production of oil is mainly focused on microalgae capable of photosynthesis that are less than

2 mm in diameter as opposed to macroalgae (seaweed). This preference towards microalgae is due largely to its less complex structure, fast growth rate, and high oil content (for some species). Some commercial interests into large-scale algae-cultivation systems are looking to tie into existing infrastructures, such as coal power plants or sewage treatment facilities. This approach not only provides the raw materials for the system, such as carbon dioxide and nutrients, but it changes those wastes into resources.

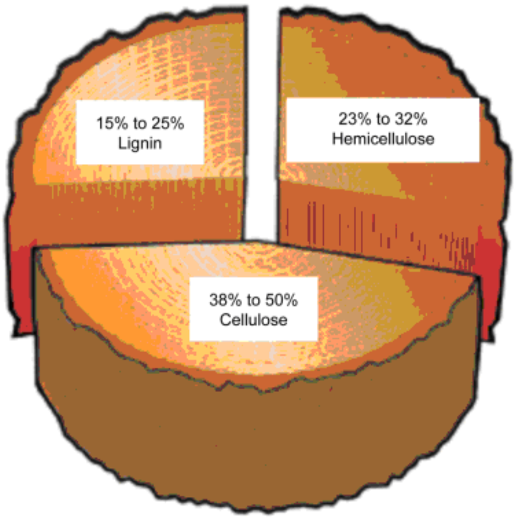

Figure 2.—Three main components of the great bulk of biomass resources

The production of biomass is a growing industry with advances being made every year as pressure for sustainable nonfossil fuels increases. Biomass has surpassed hydroelectric power as the largest domestic source of renewable energy. Biomass currently supplies over 3 percent of the U.S. total energy consumption primarily through industrial heat and steam production by the pulp and paper industry and electrical generation with forest industry residues and municipal solid waste (Ref. 30). A new industry is emerging around the production of bioenergy and bio-based products. Facilities that integrate biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass are called biorefineries and are very similar in concept to petroleum refineries. These refineries concentrate specifically on refining biomass feedstock (agricultural and forestry crops and residues and municipal and process wastes) into chemicals, fuels, pressboards, biocomposites, and other valuable products.

VI. CONCLUSION

Finding a viable source of renewable energy is a global task. We presented several biofuel alternatives to using fossil fuels. The use of corn for ethanol production shows promise for local farmers as well as the automotive industry, but the technology is quite mature and growth is not expected for traditional ethanol. However, cellulosic ethanol is gaining interest for its ability to utilize more biomass from plants than ethanol. Biodiesel has shown promise but demand far exceeds current capacity. Biodiesel from algae has the potential to generate orders of magnitude more fuel than any other method, and it should be researched so that an ideal algae species or strain can be identified and utilized for efficient biofuel production. Biodiesel from halophytes also show great promise because of their ability to serve not only as a fuel source, but a food source as well. Synthetic oil and hydrogen also show promise for the future as we look for efficient, safe, and affordable biofuels as a

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replacement for fossil fuels. We plan to investigate the feasibility of using halophytes as well as marine algae for use as biofuels for the aviation industry with the hope that we will provide some insight and guidance into the large-scale research and development of renewable energy sources in the future.

Lower operating temperatures are also achieved, with engines tending to run 50^0 C cooler than with current fuel. Because AGE–85 fuel causes considerably less buildup of to 100 combustion byproducts in the engine, the time between engine overhauls is greater, and maintenance costs are lower. Daggett et al. (Ref. 36) provide an excellent overview of alternative fuels and their feasibility for use in the aviations industry. They considered bioderived fuels, methanol, ethanol, liquid natural gas, liquid hydrogen, and synthetic fuels for their potential to replace or supplement conventional jet fuels. They point out that synthetic fuel made from coal, natural gas, or other hydrocarbon feedstock shows significant promise as a fuel that could be easily integrated into present and future aircraft with little or no modification to current aircraft designs. Alternatives, such as biofuel, and in the longer term hydrogen, have good potential but presently appear to be better suited for use in ground transportation. CFM International (Ref. 37) has successfully performed an initial test of a CFM56–7B engine using an ester-type biofuel. The CFM56–7B is the exclusive engine for the Boeing next-generation single-aisle airliner: 737–600/–700/–800/–900. The thrust ranges from 18 500 to 27 300 lb. The biofuel used for this test was a 30 percent vegetable oil methyl ester blended with 70 percent conventional Jet-A1 fuel. This test was designed to check the operation of a jet engine using a fuel made from biomass, without making any technical changes to the engine. With this type of biofuel, the target is a net reduction of 20 percent in CO2 emissions compared with current fuels. The U.S. Defense Department has been directed to explore a wide range of energy alternatives and fuel efficiency efforts in a bid to reduce the military's reliance on oil to power its aircraft, ground vehicles, and nonnuclear ships. The Defense Advanced Research Projects Agency (DARPA) is interested in proposals for research and development efforts to develop a process that efficiently produces a surrogate for petroleum-based military jet fuel (JP–8) from oil-rich crops produced by either agriculture or aquaculture (including but not limited to plants, algae, fungi, and bacteria) and which ultimately can be an affordable alternative to petroleum-derived JP–8. Current commercial processes for producing biodiesel yield a fuel that is unsuitable for military applications, which require higher energy density and a wide operating temperature range. There are several research institutions and companies collaborating on this effort. Summary and Conclusion Finding a viable source of renewable energy is a global task. We presented several biofuel alternatives to using fossil fuels. The use of corn for ethanol production shows promise for local farmers as well as the automotive industry, but the technology is quite mature and growth is not expected for traditional ethanol. However, cellulosic ethanol is gaining interest for its ability to utilize more biomass from plants than ethanol. Biodiesel has shown promise but demand far exceeds current capacity. Biodiesel from algae has the potential to generate orders of magnitude more fuel than any other method, and it should be researched so that an ideal algae species or strain can be identified and utilized for efficient biofuel production. Biodiesel from halophytes also show great promise because of their ability to serve not only as a fuel source, but a food source as well. Synthetic oil and hydrogen also show promise for the future as we look for efficient, safe, and affordable biofuels as a replacement for fossil fuels. We plan to investigate the feasibility of using halophytes as well as marine algae for use as biofuels for the aviation industry with the hope that we will provide some insight and guidance into the large-scale research and development of renewable energy sources in the future.

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