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Biodiesel Production from Plant Seed Oil - A Review

Nwosu-Obieogu K*, Chiemenem L. I., Adekunle K. F.

Chemical Engineering Department, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

ABSTRACT

Recent environmental and economic concerns have prompted resurgence in the use of biofuels throughout the world, there is increase in CO_2 emissions as well as several other air pollutants., considering sustainability, biodiesel has proven to be a good candidate to meet increasing energy requirements for internal combustion engines since they are renewable, have similar properties to petrodiesel and seems to be an ideal solution for global energy demands. Edible and non-edible seed oil crops have proven to be recognized sources of vegetable oils for biodiesel production, although the production process has been developed for edible seed oil , this work advocates for its use in non-edible plant seed oil and agricultural wastes so that the feedstock will not compete with food supply in the long term leading to high production cost. Hence this review highlights the production of biodiesel from plant seed oil , some of the factors that influences its production, the criteria the pure biodiesel must meet, the conversion techniques and the various methods of production acknowledging transesterification as the preferred choice.

Keywords: Biodiesel, Plant Seed Oil, Transesterification, Catalyst, Petrodiesel

I. INTRODUCTION

Fossil fuels are currently the main resources of energy meeting the world requirements. The major part of all energy consumed worldwide comes from fossil based resources (petroleum, coal and natural gas). Recently, due to increase in crude oil prices, limited resources of fossil oil and environmental concerns, there has been a renewed focus on searching for alternatives that are renewable and sustainable. [1-3].

A potential diesel oil substitute is biodiesel, hence, Biomass derived fuels such as methane, ethanol, and methanol are well-accepted alternatives to diesel fuels as they are economically feasible, renewable, environmental friendly and can be produced easily in rural areas where there is an acute need for modern forms of energy.

Biodiesel is attracting an increasing deal of attention worldwide for it is currently the only renewable energy carrier which could directly replace diesel fuel in compression ignition engines [2-4]

Biodiesel is an ecofriendly, alternative diesel fuel prepared from domestic renewable resources, It is a renewable source of energy which seems to be an ideal solution for global energy demands. It has attracted considerable attention during the past decade as a renewable, biodegradable and non-toxic fuel which has served as an alternative to fossil fuels [5-7].

The American Society for Testing and Materials (ASTM) defines biodiesel fuel as monoalkyl esters of long chain fatty acids derived from a renewable lipid feedstock, such as vegetable oil or animal fat. 'Bio' represents its renewable and biological source in contrast to traditional petroleum-based diesel fuel; 'diesel' refers to its use in diesel engines. As an alternative fuel, biodiesel can be used in neat form or mixed with petroleum-based diesel [8, 9].

Biodiesel represents a largely closed carbon dioxide cycle (approximately 78%), as it is derived from renewable biomass sources [10]. Compared to petroleum diesel, biodiesel has lower emission of pollutants, it is biodegradable and enhances the engine lubricity [10] and contributes to sustainability [11, 12]. A major obstacle in the commercialization of biodiesel production from edible vegetable oils is their high production cost, which is due to the demand for human consumption “the food versus fuel dispute” [13]. Reducing the cost of the feedstock is necessary for biodiesel’s long- term commercial viability. The cost of feedstock accounted for 88% of total estimated production cost [13-15]. One way to reduce the cost of this fuel is to use a less expensive feedstock including waste cooking oils and vegetable oils that are non-edible and/or require low harvesting costs [2]. In all cases, more than 80% of the production cost is associated with the feedstock, such as recycled cooking oils. Reusing of these waste greases not only reduce the burden of the government in disposing the waste, maintaining public sewers, and treating the oily wastewater, but also lower the production cost of biodiesel significantly [13]. Waste vegetable oil (WVO), which is much less expensive than edible vegetable oil, is a promising alternative to edible vegetable oil [14, 16- 18].

II. METHODS AND MATERIAL

2. Biodiesel production

2.1 Methods

In biodiesel preparation from vegetable oils and alcohol in the presence of a catalyst. The mixture is blended into the vegetable oil causing a chemical reaction, called transesterification, which separates the vegetable oil into two components. One component is a heavier liquid called glycerol (also called glycerin). The by-product, glycerol, has an economical value. Glycerol has many food and industrial uses such as cosmetics, toothpaste, pharmaceuticals, foodstuffs, plastics, explosives and cellulose processing, hand cream and soap However, the material obtained from biodiesel production requires purification before it could be used for these purposes. The second component is called an ester of the oil or biodiesel. The ester is lighter than the glycerol and so rises to the top after the reaction is complete. The ester after carefully processing to remove all remaining catalyst, alcohol and glycerol can be used as a fuel in diesel engines. The esters are good solvents, cleaning agents, and can be used in cosmetics. They have been used to prevent asphalt from sticking to metal such as truck beds, and are used as surfactants in agricultural chemicals. They are lubricants and have other similar uses. [19, 20]

2.1.1 Direct use and Blending.

In this process, pure or used vegetable oil is used directly to power a diesel engine or as a blend with petro-diesel. Problems appear only after the engine has been operating on vegetable oils for longer period of time, especially with direct-injection engines. The problems include (1) coking and trumpet formation on the injectors to such an extent that fuel atomization does not occur properly or is even prevented as a result of plugged orifices, (2) carbon deposits, (3) oil ring sticking and (4) thickening and gelling of the lubricating oil as a result of contamination by the vegetable oils. Direct use of vegetable oils and/or the use of blends of the oils have generally been considered to be not satisfactory and impractical for both direct and indirect diesel engines. The high viscosity, acid composition, free fatty acid content, as well as gum formation due to oxidation and polymerization during storage and combustion, carbon deposits and lubricating oil thickening are obvious problems [21].

2.1.2 Thermal cracking (pyrolysis)

Pyrolysis, strictly defined, is the conversion of one substance into another by means of heat or by heat with the aid of a catalyst . It involves heating in the absence of air or oxygen and cleavage of chemical bonds to yield small molecules Pyrolytic chemistry is difficult to characterize because of the variety of reaction paths and the variety of reaction products that may be obtained from the reactions that occur. The pyrolyzed material can be vegetable oils, animal fats, natural fatty acids and methyl esters of fatty acids. The pyrolysis of fats has been investigated for more than 100 years, especially in those areas of the world that lack deposits of petroleum [40]. The first pyrolysis of vegetable oil was conducted in an attempt to synthesize petroleum from vegetable oil. Since World War I, many investigators have studied the pyrolysis of vegetable oils to obtain products suitable for fuel. In 1947, a large scale of thermal cracking of tung oil calcium soaps was reported [22- 24].

2.1.3 Microemulsion

A microemulsion is defined as a colloidal equilibrium dispersion of optically isotropic fluid microstructures with dimensions generally in the 1±150 nm range formed spontaneously from two normally immiscible liquids and one or more ionic or non-ionic amphiphiles .

Solvents such as methanol, ethanol and 1-butanol have been studied. They can improve spray characteristics by explosive vaporization of the low boiling constituents in the micelles . All microemulsions with butanol, hexanol and octanol met the maximum viscosity requirement for No. 2 diesel. The 2-octanol was an effective amphiphile in the micellar solubilization of methanol in triolein and soybean oil. Methanol was often used due to its economic advantage over ethanol [21, 24, 25]

2.1.4 Transesterification (Alcoholysis)

Transesterification (also called alcoholysis) is the reaction of a fat or oil with an alcohol to form esters and glycerol. There are three basic routes to ester production from oils and fats. They are the base catalysed transesterification, the acid catalysed esterification and enzymatic catalysis. The use of base or acid catalyst in transesterification reaction is known as chemical transesterification. A catalyst is usually used to improve the reaction rate and yield. Because the reaction is reversible, excess alcohol is used to shift the equilibrium to the products side After transesterification of triglycerides, the products are a mixture of esters, glycerol, alcohol, catalyst and tri-, di- and monoglycerides In chemical transesterification, the base or acid catalyst may dissolve completely during the reaction, in which case the reaction is homogeneous. Also the base or acid catalyst may not dissolve, but remain in the solid form throughout the reaction time in which case the reaction is heterogeneous [26-28]

2.1.5 Enzymatic Transesterification

Several authors have reported on the enzymatic transesterification for biodiesel production as it produces high purity product (esters) and enables easy separation from the by-product, glycerol. Lipase can be obtained from microorganisms like *Mucor miehei*, *Rhizopus oryzae*, *Candida antarctica*, *Pseudomonas fluorescens* and *Pseudomonas cepacia* was found to be capable of catalyzing transesterification. Enzymatic biodiesel production is possible using both intracellular and extracellular lipases. For the industrial transesterification of fats and oils, *Pseudomonas* species immobilised with sodium alginate gel can be used directly as a whole cell bio-catalyst [29 - 32].

Devanesan *et al.* [33] reported maximum yield (72%) of biodiesel from transesterification of *Jatropha* oil and short chain alcohol (methanol on hexane) using immobilized *P. fluorescens* at the optimum conditions of 40°C, pH 7.0, molar ratio of 1:4, 3 grammes amount of beads and reaction time of 48 hours.

The enzymes or whole cells are immobilized and used for catalysis. The advantage of immobilisation is that the enzyme can be reused without separation. Also the operating temperature of the process is low (50°C) compared to other methods which operate at harsh conditions. However, the cost of enzymes remains a barrier for its industrial implementation [34, 35]. In order to increase the cost effectiveness of the enzymatic process, the enzyme (both intracellular and extracellular) is reused by immobilizing in a suitable biomass support particle and that has resulted in considerable increase in efficiency [36, 37]. Jackson and King [38] reportedly used immobilised lipases as biocatalysts for transesterification of corn oil in flowing supercritical carbon dioxide and reported an ester conversion of more than 98%. But the activity of immobilized enzyme is inhibited by methanol and glycerol present in the mixture.

2.2 Process Production of Biodiesels Based on Catalyst

Two preferred methods for the industrial production of biodiesel from non-edible oils are base catalyzed and acid catalyzed transesterification.

2.2.1 Base-Catalyzed Transesterification

This is the traditional technology commonly employed for the commercial production of biodiesel from the refined vegetable oils/fats that are low in free fatty acids (FFAs < 0.1 wt %). It involves the transesterification of triglycerides present in oil/fat with a lower alcohol (mostly methanol) in the presence of a catalytic amount of a base (alcoholic solution of KOH/NaOH or sodium methoxide) at the atmospheric pressure under the reflux condition for alcohol (60-70 °C) [39] .

2.2.2 Acid-Catalyzed Transesterification

This process is especially suitable for the feedstocks such as unrefined or waste cooking oils that are high in free fatty acids. It uses an acid (commonly sulfuric acid) as the catalyst. This process does not require the pretreatment of oil with an alkali for reducing its FFA content. However, it has the following drawbacks. It is very slow and needs a very high methanol-to-oil molar ratio. The water produced by the reaction of FFA with the alcohol inhibits the transesterification of triglycerides in this process. The acid, if added in large amounts, would burn some oil, thus reducing the overall yield of biodiesel [39].

2.3 Biodiesel production from non-edible plant seed oil; its potentials and prospects.

The use of edible vegetable oils and animal fats for biodiesel production has recently been of great concern because they compete with food materials. This prompted the use of non-edible plant oils as sources of biodiesel production. The non-edible vegetable oils such as *Madhuca indica, Jatropha curcas* and *Pongamia pinnata* are found to be suitable for biodiesel production under experimental conditions. Oil content in the castor bean, hemp and pongame seed is around 50, 35 and 30-40 % respectively. Neem seed contains 30% oil content. Biodiesel is the pure or 100%, biodiesel fuel. It is referred to as B100 or ‘‘neat’’ fuel. Non-edible oils are not fit for human consumption because they contain toxic compounds. [40]

By converting edible oils into biodiesel, food resources are actually being converted into automotive fuels. In other words, biodiesel is competing with limited land availability for plantation of oil crops. The expansion of oil crop plantations for biodiesel production on a large scale may increase deforestation in countries like Malaysia, Indonesia and Brazil. Arable land that would otherwise have been used to grow food would instead be used to grow fuel. [40- 42]

Non-edible oils from the plant seeds are the most promising alternative fuel for diesel engines as they are inexpensive and economically viable alternative feed stocks for biodiesel production . Examples of such plants are:

2.3.1 Jatropha (*Jatropha curcas L.*)

Jatropha curcas L. is a succulent shrub belonging to Euphorbiaceae family originated from East Africa that produces a significant amount of oil from its seeds. This is a non-edible oil-bearing plant widespread in arid, semi-arid and tropical regions of the world. Jatropha is a drought resistant perennial tree that grows in marginal lands and can live over 50 years [43]. It is reported that Jatropha seeds contain about 30 to 40% of oil [44]. The presence of some anti-nutritional factors such as toxic phorbol esters and a high content of stearic acid (*ca* 17%) render Jatropha oil unfit for edible purposes [45, 46].

2.3.2 Chinese wild tallow tree (*Sapium sebiferum*)

This tree is native to China and Japan where the waxy outer covering of the seed it is used for machine oil, soap making and fuel oil [47]. Seeds are toxic to animals and humans. It has been reported that Chinese tallow trees can produce up to 7700 kg oil/ha annually and can be harvested for several decades. As a woody perennial oilseed crop, the tallow tree can grow on marginal land and has a high energy profit ratio (energy out/energy input). The major fatty acids in tallow seed oil constitute palmitic, oleic, steric and linoleic acids. Major fatty acids in oil constitute lauric acid (0-2.5%), myristic acid (0-.5-3.7%), palmitic acid (58-72%), stearic acid (1.2-7.6%), oleic acid (20-35%) and linoleic acid (0-1.6%) [48].

2.3.3 Rocket oil seed plant (*Eruca sativa*)

Eruca sativa commonly known as rocket seed oil belong to family “Brassicacaceae” is an annual herb native to Mediterranean region and now commonly cultivated in arid parts of the world, Pakistan, India, Middle East [49]. Seed contains 32-40% oil with pungent smell and odor [50]. The oil is not recommended for edible purposes due to its bitter taste.

2.3.4 Paw paw (*Carica papaya*) Seed oil

Carica papaya fruit is majorly produced in Mexico, Florida, Hawaii, Nigeria, South Africa, Sri- Lanka, India, Malaysia and Australia with Nigeria being the leading producer (748,000 Mt per annum). It is an underutilized seed oil used for biodiesel fuel. The fruit pulp is used as food for human and the foliage is used in fishery livestock feeding [51].

2.4 Characteristics of Plant Seed Oils Affecting Their Suitability for Use as Biodiesel

Biodiesel is better than diesel fuel in terms of sulfur content, flash point, aromatic content, and biodegradability [52]. Biodiesel esters are characterized by their physical and fuel properties including density, viscosity, iodine value, acid value, cloud point, pure point, gross heat of combustion and volatility.

2.4.1 Calorific Value, Heat of Combustion

This is the amount of heat energy released by the combustion of a unit value of fuel. One of the most important determinants of heating value is moisture content. Air-dried biomass typically has about 15-20% moisture, whereas the moisture content for oven-dried biomass is negligible. Moisture content in coals varies in the range 2-30%. However, the bulk density of most biomass feed stocks is generally low, even after densification – between 10 and 40% of the bulk density of most fossil fuels. Liquid biofuels however have bulk densities comparable to those for fossil fuels.

2.4.2 Melt Point or Pour Point

Melt or pour point refers to the temperature at which the oil in solid form starts to melt or pour. The pour point is the lowest temperature at which the oil specimen will flow. In cases where the temperatures fall below the melt point, the entire fuel system including all fuel lines and fuel tank will need to be heated.

2.4.3 Cloud Point

The cloud point is the temperature at which is the fuel starts to form crystals, with further decrease in temperature these crystals increase in size and quantity until the fuel gels and does not move again. The temperature at which an oil starts to solidify is known as the cloud point. While operating an engine at temperatures below oil's cloud point, heating will be necessary in order to avoid waxing of the fuel [53].

2.4.4 Flash Point

The flash point temperature of a fuel is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source. Flash point varies inversely with the fuel's volatility. Minimum flash point temperatures are required for proper safety and handling of diesel fuel. The flash point of biodiesel is higher than the petro diesel, which is safe for transport purpose. High values of flash point decreases the risk of fire [53, 54].

2.4.5 Iodine Value (IV)

This is the amount of iodine, measured in grams, absorbed by 100 grams of a given oil. Its value only depends on the origin of the vegetable oil, the biodiesel obtained from the same oil should have similar iodine values [55].

2.4.6 Viscosity

Viscosity refers to the thickness of the oil, and is determined by measuring the amount of time taken for a given measure of oil to pass through an orifice of a specified size. Viscosity affects injector lubrication and fuel atomization. A less viscous fuel will flow easily in the engine. Fuels with low viscosity may not provide sufficient lubrication for the precision fit of fuel injection pumps, resulting in leakage or increased wear. Fuel atomization is also affected by fuel viscosity. Diesel fuels with high viscosity tend to form larger droplets on injection which can cause poor combustion, increased exhaust smoke and emissions.

2.4.7 Cetane Number (CN)

The cetane number of a fuel is a measure of the ignition quality of the fuel, the higher the cetane number the better the ignition quality, which is conceptually similar to the octane number used for gasoline. In general, diesel engines will operate better on fuels with cetane number above 50. On the basis of ignition quality, biodiesel can be said to be better than the petroleum diesel because they have cetane numbers higher than that of the petroleum diesel, this high cetane number is due to higher oxygen content. This means that they will burn smoothly and with less noise in a diesel engine than petroleum diesel. However, this increase of cetane number implies decrease in iodine value which means there will be increase in saturated fatty acid composition.

2.4.8 Density

This is the weight per unit volume. Oils that are denser contain more energy. For example, petrol and diesel fuels give comparable energy by weight, but diesel is denser and hence gives more energy per liter.

2.4.9 Ash Percentage

Ash is a measure of the amount of metals contained in the fuel. High concentrations of these materials can cause injector tip plugging, combustion deposits and injection system wear. The ash content is important for the heating value, as heating value decreases with increasing ash content.

2.4.10 Sulfur Percentage

This is the percentage by weight of sulfur in the fuel. Sulfur content is limited by law to very small percentages for diesel fuel used on-road applications

2.5 Factors affecting biodiesel production from plant seed oil

Several factors affect the production of biodiesel from waste vegetable oil. These factors are discussed below and they are;

2.5.1 Alcohol to Oil ratio

One of the most important parameters affecting the yield of biodiesel is the molar ratio of alcohol to triglyceride. Stoichiometrically 3 moles of alcohol and 1 mole of triglyceride are required for transesterification to yield 3 moles of fatty acid methyl/ethyl esters and 1 mole of glycerol [56]. Biodiesel yield could be elevated by introducing an excess amount of methanol to shift the equilibrium to the right hand side [57]. Methanol, ethanol, propanol, butanol and amyl alcohol can be used in the transesterification reaction, amongst these alcohols methanol is applied more frequently as its cost is low and it is physically and chemically advantageous (polar and shortest chain alcohol) over the other alcohols [56]. In contrast, ethanol is also preferred alcohol for using in the transesterification process compared to methanol since it is derived from agricultural products and is renewable and biologically less offensive in the environment [56]. The effect of volumetric ratio of methanol and ethanol to oil was studied. Results exhibit that highest biodiesel yield is nearly 99.5% at 1:6 oil/methanol [56]. In comparison, biodiesel yield using methanol continuously increases with the rise of methanol molar ratio [57]. Ehiri [58] produced biodiesel via base-catalyzed transesterification reaction of waste cooking oil (WCO) with methanol so as to determine optimal alcohol: oil volume ratio for maximum biodiesel production. The catalyst used was 2.0% sodium hydroxide. The methanol: oil volume ratio fed into the batch-process reactor were taken at 1:1, 2:1, 3:1, … 10:1 in order to produce biodiesel while keeping other variable factors constant. Results show that the optimal methyl ester yield of 95.0% occurred at methanol: oil volume ratio of 8:1.

2.5.2 Catalyst

Biodiesel formation is also affected by the concentration of catalyst. There are three basic routes to ester production from oils and fats. They are the base catalysed transesterification, the acid catalysed esterification and enzymatic catalysis [59]. The chemical transesterification, the base or acid catalyst may dissolve completely during the reaction, in which case the reaction is homogeneous. Also the base or acid catalyst may not dissolve, but remain in the solid form throughout the reaction time in which case the reaction is heterogeneous [60,61]. However for the base catalysed reaction care must be taken to avoid water in the system, the reactants must be pure and anhydrous. Dehydrated oil must be used to prevent saponification reaction taking place.

Saponification not only consumes the alkali catalyst, but also results in the formation of emulsions [62]. Most commonly used catalyst for biodiesel production is sodium hydroxide (NaOH) or Potassium hydroxide (KOH) [63]. The type and amount of catalyst required in the transesterification process usually depend on the quality of the feedstock and method applied for the transesterification process. For a purified feedstock, any type of catalyst could be used for the transesterification process [56]. However, for feedstock with high moisture and free fatty acids contents such as waste vegetable oil, homogenous transesterification process is unsuitable due to high possibility of saponification process instead of transesterification process to occur.

The yield of fatty acid alkyl esters generally increases with increasing amount of catalyst. This is due to availability of more active sites by additions of larger amount of catalyst in the transesterification process.

However, on economic perspective, larger amount of catalyst may not be profitable due to cost of the catalyst itself. Therefore, similar to the ratio of oil to alcohol, optimization process is necessary to determine the optimum amount of catalyst required in the transesterification process [64,65]. The use of a solid catalyst for biodiesel production has been undertaken by researchers and scientists. The use of solid catalyst which may be solid base catalyst such as CaO, ZnO or solid acid catalyst such as zeolites (SiO_2/Al_2O_2) have major advantage over the liquid catalyst [66]. Solid catalyst can be separated easily from the biodiesel fuel and thus can be removed quickly. The process of production is therefore less expensive when using a solid catalyst. The process is also more environmentally friendly, since there is no sodium methoxide formation.

Enzymes do their catalytic job well in mild pH and temperature conditions [67]. Enzymes are nonliving substances produced by living cells such as microorganisms like bacteria, fungi and yeast. Enzymes are biochemically protein in nature, hence their processes are safer and more environment friendly than the chemical methods [68]. Lipase a group of water soluble enzymes which can be produced by popular yeast known as *candida antartica* have been found to be a very effective catalyst in fats/oils transesterification to biodiesel. The amount of enzymes used should be as low as necessary, e.g. 0.1g to obtain the desired product [66].

2.5.3 Temperature effect

Reaction temperature is the important factor that will affect the yield of biodiesel. For example, higher reaction temperature increases the reaction rate and shortened the reaction time due to the reduction in viscosity of oils. However, the increase in reaction temperature beyond the optimal level leads to decrease of biodiesel yield, because higher reaction temperature accelerates the saponification of triglycerides [63] and causes methanol to vaporize resulting in decreased yield [67]. Usually the transesterification reaction temperature should be below the boiling point of alcohol in order to prevent the alcohol evaporation. The range of optimal reaction temperature may vary from 50°C to 60°C depends upon the oils or fats used [63]. Therefore, the reaction temperature near the boiling point of the alcohol is recommended for faster conversion by various literatures. At room temperature, there is up to 78% conversion after 60 minutes, and this indicated that the methyl esterification of the FFAs could be carried out appreciably at room temperature but might require a longer reaction time. In butyl esterification, however, temperature had stronger influence. Temperature increases the energy of the reacting molecules and also improves the miscibility of the alcoholic polar media into a non-polar oily phase, resulting in much faster reactions [68].

2.5.4 Reaction time

This is the increase in fatty acid esters conversion observed when there is an increase in reaction time. The reaction is slow at the beginning due to mixing and dispersion of alcohol and oil. After that the reaction proceeds very fast. However the maximum ester conversion was achieved within < 90 min. Further increase in reaction time does not increase the yield product i.e. biodiesel/mono alkyl ester. Besides, longer reaction time leads to the reduction of end product (biodiesel) due to the reversible reaction of transesterification resulting in loss of esters as well as soap formation [63, 64].

2.5.5 Mixing speed

Oils and alcohols are not totally miscible, thus reaction can only occur in the interfacial region between the liquids and transesterification reaction is a moderately slow process. So, Mixing is very important in the transesterification process, adequate mixing between these two types of feedstock is necessary to promote contact between these two feed stocks, therefore enhance the transesterification reactions to occur [56]. Mechanical mixing is commonly used in the transesterification process. The intensity of the mixing could be varied depending on its necessity in the transesterification process. In general, the mixing intensity must be increased to ensure good and uniform mixing of the feedstock. When vegetable oils with high kinematic viscosity are used as the feedstock, intensive mechanical mixing is required to overcome the negative effect of viscosity to the mass transfer between oil, alcohol and catalyst [69, 64] Agitation speed plays an important role in the formation of end product (mono alkyl ester or biodiesel), because agitation of oil and catalyst mixture enhances the reaction. For example, Alemayehu and Abile [56] chose 200 rpm, 400 rpm, 600 rpm and 800 rpm for 60 min while other parameters were kept constant. At 400 rpm higher conversion of end product were obtained. Lower stirring speed shows lower product formation. On the other hand higher stirring speed favors formation of soap. This is due to the reverse behavior of transesterification reaction [63].

2.5.6 Free Fatty Acid and Moisture Content

The free fatty acid and moisture content are the key parameters for determining the viability of vegetable oils to be used in transesterification process. Presence of moisture content in the oil increases the amount of free fatty acids. To carry out this reaction to completion, less than 3% free fatty acid content in oils is needed. Base-catalyzed transesterification reaction requires water free and low acid value (< 1) raw materials for biodiesel production [56]. If the oil samples have high FFA content (more than 1%) then the reaction requires more alkali catalyst to neutralize the FFA. Presence of water gives greater negative effect than that of FFAs because water can cause soap formation and frothing which can cause increase in viscosity. In addition formation of gels and foams hinders the separation of glycerol from biodiesel. Free fatty acid and water always produce negative result during transesterification and causes soap formation and consumes the catalyst which leads to reduction of catalyst effect. They also lead to the reduction of methyl ester [56]. To overcome this problem, supercritical methanol method was proposed. It may be noted that water has less influence in supercritical methanol method [63]. As Jagadale and Jugulkar [64] stated the moisture levels of the collected waste chicken fats vary widely, being as high as 18%. Therefore, it is not possible to convert these oils to biodiesel by using a single process. One drawback of biodiesel is that there is an inverse relationship between biodiesel's oxidative stability and its cold flow properties. Saturated compounds are less prone to oxidation than unsaturated compounds but they raise the cloud point of the fuel. The reaction of FFAs with alcohol produces ester, but also water that inhibits the of the transesterification glycerides. This is due to the effect of the water produced when the FFAs react with the alcohol to form esters. The coincidence of the lines indicates that water formation is the primary mechanism limiting the completion of the acid catalyzed esterification reaction with FFAs [56].

2.6 Current trend on biodiesel production

Recently, various researchers are focusing on non-edible seed oils, waste edible seed oil and oils from agricultural waste for biodiesel production. It is believed that large-scale production of biodiesel from edible oils may bring global imbalance to the food supply and demand market [70, 71].

Studies have shown that there exists an immense potential for the production of plant based oil to produce biodiesel. Azam *et al*. [72] studied the prospects of fatty acid methyl esters (FAME) of some 26 non-traditional plant seed oils including Jatropha to use as potential biodiesel in India. Among them, *Azadirachta indica*, *Calophyllum inophyllum*, *J. curcas* and *Pongamia pinnata* were found most suitable for use as biodiesel and they meet the major specification of biodiesel for use in diesel engine. Several studies have showed that biodiesel is a better fuel than fossil-based diesel in terms of engine performance, emissions reduction, lubricity, and environmental benefits [73,74].

Hossain A. and Boyce A. [75] compared the optimum conditions of alkaline catalysed transesterification process for biodiesel production using pure sunflower cooking oil (PSCO) and waste sunflower cooking oil (WSCO) The research demonstrated that biodiesel obtained under optimum conditions from PSCO and WSCO was of good quality and could be used as a diesel fuel which considered as renewable energy and environmental recycling process from waste oil after frying Manop C. and Juthgate T. [76] investigated the optimum conditions in biodiesel production from waste frying oil using two-step catalysed process, sulfuric acid and potassium hydroxide were used as catalyst. The optimum conditions for biodiesel production were obtained when using methanol to oil molar ratio of 6.1:1, 0.68 wt.% of sulfuric acid, at 51 °C with a reaction time of 60 min in the first step, followed by using molar ratio of methanol to product from the first step of 9.1:1, 1 wt.% KOH, at 55 °C with a reaction time of 60 min in the second step. The percentage of methyl ester in the obtained product was 90.56±0.28%. In addition, the fuel properties of the produced biodiesel were in the acceptable ranges according to Thai standard for community biodiesel.

Anya Uzo Anya [77] carried out a research on the reduction of free fatty acid content on a non-edible plant seed oil (neem seed oil), investigating the effect of various methanol quantities on acid concentration of the reduced free fatty acid, after pretreatment, transesterification reaction was carried out and from the physicochemical analysis carried out, the biodiesel produced conformed to ASTM specification.

Hence, more research are ongoing, using rice husk and other agricultural waste regarded as non ecomically viable but abundantly available within our environment for the production of biodiesel.

III. CONCLUSION

The world's accessible oil reservoirs are gradually depleting, it is important to develop suitable long-term strategies based on utilization of renewable fuel that would gradually substitute the declining fossil fuel production. In addition, the production and consumption of fossil fuels have caused environmental damage by increasing the CO2 concentration in the atmosphere. Biodiesel derived from vegetable oil or animal fat by transesterification with alcohol such as methanol or ethanol, is recommended for use as a substitute for petroleum based diesel because biodiesel is oxygenated, (the gasses released during combustion are essentially the gasses absorbed from the atmosphere whilst the plant was growing.) Efforts should be made to; establish sustainable bio energy crops mainly non-edible within existing and future cropping systems and agro climates and to develop new, value-added technologies to make in-state production of biodiesel more economical "from seed to pump.

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