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A NOVEL REVIEW ON BIODIESEL PRODUCTION FROM WASTE COOKING OIL

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ABSTRACT:

Biodiesel is proved to be the best replacement for diesel because of its unique properties like significant reduction in green house gas emissions, non-sulfur emissions, non-particulate matter pollutants, low toxicity and biodegradability. This paper reviews the pretreatment step, the physical and chemical properties of waste cooking oil, etherification, transesterification and production of biodiesel from waste cooking oil by various methods. and catalysts reported so far. The factors affecting the process parameters reported are studied and the point of interest focuses on their alcohol to oil ratio, reaction temperature, catalyst both qualitative and quantitative scope. The optimum condition is investigated and the exhaust emissions of biodiesel and petroleum diesel are compared.

I. INTRODUCTION:

The world is confronted with the twin crises of fossil fuel depletion and environmental degradation. The arbitrary extraction and consumption of fossil fuels have led to a reduction in petroleum reserves. These finite reserves are highly concentrated in certain region of the world. Therefore, those countries not having these resources are facing a foreign exchange crisis, mainly due to the import of crude petroleum oil. At present, India is producing only 30% of the total petroleum fuels required. The remaining 70% is being imported, which costs about Rs. 80,000 crore every year. Hence it is considered to be the important trigger for many initiatives to search for the alternative fuels, like bio-fuels [1, 2, and 3].

One hundred years ago, Rudolf Diesel tested peanut oil as fuel for his engine for the first time on August 10, 1893 [1]. In the 1930s and 1940s vegetable oils were used as diesel fuels from time to time usually only in emergency **[2].** Biodiesel has become more attractive recently because of its environmental benefits and fact that it is made from renewable resources. Biodiesel has better properties than that of petroleum diesel such as renewable, biodegradable, non-toxic, and essentially free of sulfur and aromatics. Biodiesel fuel has the potential to reduce the level of pollutants. Use of bio-diesel in a conventional diesel engine results in substantial reduction in unburned hydrocarbon (UBHC), carbon monoxide (CO), particulate matters (PM) emission and oxide of nitrogen. The brief review of biodiesel discusses about energy scenario, vegetable oils and its blends, properties, suitability, engine characteristics, standards and chemistry of transesterification. Also, mentioned biodiesel merits, demerits, government polices etc. Methyl ester of bio-diesel (B100) can be directly used in diesel engines. Brake thermal efficiency for bio-diesel was slightly increased in B20. Brake-specific energy consumption for B20 was reduced slightly. The CO, CO2, HC PAH emissions were reduced. NOx emissions were slightly increased. The B20 is best alternative fuel for diesel [2, 3, and 4].

- **SOURCE:**

The source of Biodiesel usually depends on the crops amenable to the regional climate. In the United States, soybean oil is the most commonly Biodiesel feedstock, whereas the rapeseed (canola) oil and palm oil are the most common source for Biodiesel, in Europe, and in tropical countries respectively [**2**]. A suitable source to produce Biodiesel should not competent with other applications that rise prices, for example pharmaceutical raw materials. But the demand for pharmaceutical raw material is lower than for fuel sources. As much as possible the Biodiesel source should fulfill two requirements: low production costs and large production scale. Refined oils have high production costs, but low production scale; on the other side, waste cooking oil (WCO), non-edible seeds, algae and sewerage have low production costs and are more available than refined or recycled oils.

- **CHEMICAL COMPOSITION:**

From a chemical point of view, oils from different sources have different fatty acid compositions. The fatty acids vary in their carbon chain length and in the number of unsaturated bonds they contain. Fats and oils are primarily water-insoluble, hydrophobic substances in the plant and animal kingdom that are made up of one mole of glycerol and three moles of fatty acids and are commonly referred as triglycerides **[**2**]** Fig. 1 Chemically the oil/fats consist of 90–98% triglycerides and small amount of mono and diglycerides. Triglycerides are esters of three fatty acids and one glycerol. These contain substantial amount of oxygen in their structures. When three fatty acids are identical, the product is simple triglycerides, when they are dissimilar the product is mixed triglycerides fatty acids which are fully saturated with hydrogen have no double bonds. The main objective in the purification of crude biodiesel is to remove the fatty acid alkyl esters from the mixture and maintain lower cost of production and also ensure a highly purified biodiesel product. Glycerol, considered as a major secondary product of the transesterification reaction in its purest form can be sold to various commercial manufacturing industries such as cosmetic, food, tobacco and pharmaceutical industries, etc. **[3,4].**

II. BIODIESEL PRODUCTION METHODS:

The exhaustive efforts have put forth to develop vegetable oil derivatives that approximate properties and performance of hydrocarbons-based diesel fuels. The problem with substituting triglycerides for diesel fuel is mostly associated with high viscosity, low volatility and polyunsaturated characters. Sing S. P., et al., (2010) [2] have put forth thorough review of biodiesel as an alternative to diesel. It was systematically mentioned about ASTM D6751 specification of 100% biodiesel, physical properties, comparative specifications between diesel and biodiesel. Further, transesterification method was suggested as crucial for biodiesel preparation. Further, problems and possible remedies were also suggested for use of biodiesel in CI engine. These can be changed in at least four ways: pyrolysis, dilution, micro emulsion and transesterification [4].

- **PYROLYSIS:**

Pyrolysis is a method of conversion of one substance into another by mean of heat or by heat with the aid of the catalyst in the absence of air or oxygen. The process is simple, wasteless, pollution free and effective compared with other cracking processes [4].

- **DILUTION:**

The vegetable oil is diluted with petroleum diesel to run the engine. Caterpillar Brazil, in 1980, used pre-combustion chamber engines with the mixture of 10% vegetable oil to maintain total power without any alteration or adjustment to the engine. At that point it was not practical to substitute 100% vegetable oil for diesel fuel, but a blend of 20% vegetable oil and 80% diesel fuel was successful. Some short-term experiments used up to a 50/50 ratio [4].

- **MICROEMULSION:**

A micro emulsion define as a colloidal equilibrium dispersion of optically isotropic fluid microstructure with dimensions generally into 1–150 range formed spontaneously from two normally immiscible liquids and one and more ionic or more ionic amphiphiles. They can improve spray characteristics by explosive vaporization of the low boiling constituents in micelles. The engine performances were the same for a microemultion of 53% sunflower oil and the 25% blend of sunflower oil in diesel. A microemultion prepared by blending soyabean oil, methanol, and 2-octanol and cetane improver in ratio of 52.7:13.3:33.3:1.0 also passed the 200 h EMA test [4].

- **TRANSETERIFICATION:**

Biodiesel is a clean burning alternative fuel, produced from domestic, renewable resources. It can be used in CI Engines with little or no modifications. Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics. Fangrui Maa, et al., (1999) [16] Transesterification is basically a sequential reaction. Triglycerides are first reduced to diglycerides. The diglycerides are subsequently reduced to monoglycerides. The monoglycerides are finally reduced to fatty acid esters. The order of the reaction changes with the reaction conditions. The main factors affecting transesterification are molar ratio of glycerides to alcohol, catalysts, reaction temperature and time and the contents of free fatty acids and water in oils and fats. The commonly accepted molar ratio of alcohol to glycerides is 6:1. Base catalysts are more effective than acid catalysts and enzymes. The recommended amount of base used to use is between 0.1 and 1% w/w of oils and fats. Higher reaction temperatures speed up the reaction and shorten the reaction time. Biodiesel is made through a chemical process called “transesterification Hereby the glycerin is separated from the fat or vegetable oil as shown in Fig.1 below[5, 6]

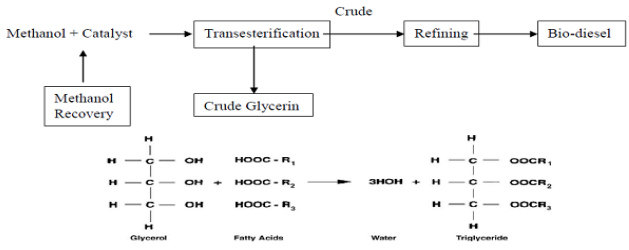

Fig. 1. Basic Transesterification Process and reaction [5, 6]

The most common way to produce biodiesel is by transesterification, which refers to a catalyzed chemical reaction involving vegetable oil and an alcohol to yield fatty acid alkyl esters (i.e., biodiesel) and glycerol (Fig. 1). Triacylglycerols (triglycerides), as the main component of vegetable oil, consist of three long chain fatty acids esterified to a glycerol backbone. When triacylglycerols react with an alcohol (e.g., methanol), the three fatty acid chains are released from the glycerol skeleton and combine with the alcohol to yield fatty acid alkyl esters (e.g., fatty acid methyl esters or FAME). Glycerol is produced as a by-product. Methanol is the most commonly used alcohol because of its low cost. Transesterification reaction can be alkali catalyst, acid or enzyme catalyzed.

III. WASTE COOKING OIL BIODIESEL:

The feedstock coming from waste vegetable oils is commonly known as waste cooking oils. It is one of the alternative sources among other higher grade or refines oils. Waste cooking oil is easy to collect from other industries such as domestic usage and restaurant and also cheaper than other oils (refine oils). Hence, by using these oils as the raw material, we can reduce the cost in biodiesel production.

The advantages of using waste cooking oils to produce biodiesel are the low cost and prevention of environment pollution. These oils need to be treating before dispose to the environment to prevent pollution. Due to the high cost of disposal, many individuals dispose waste cooking oils directly to the environment especially in rural area. So that, the use of waste cooking oils is an effective way to reduce the cost of biodiesel production.

Used cooking oil has sufficient potential to fuel the compression ignition engines. The kinematic viscosity of used cooking oil (UCO) is about 10 times greater, and its density is about 10% higher than that of mineral diesel. These properties play vital role in the combustion; therefore these must be modified prior to the use of UCO in the engine. Many techniques have been developed to reduce the kinematic viscosity and specific gravity of vegetable oils, which include pyrolysis, emulsification, leaning and transesterification. Among these techniques, transesterification is the hot favorite. This is because of the fact that this method is relatively easy, carried out at normal conditions, and gives the best conversion efficiency and quality of the converted fuel.

Various researchers [5-18] have made a review of the alternative technological methods that could be used to produce this fuel. Different studies have been carried out using different oils as raw material, different alcohol (methanol, ethanol, buthanol) as well as different catalysts, homogeneous ones such as sodium hydroxide, potassium hydroxide, sulfuric acid and supercritical fluids, and heterogeneous ones such as lipases. Xiangmei Menga,et al., (2008) [9] studied and reported that, waste cooking oils (WCO) contains large amounts of free fatty acids. Biodiesel production from WCO was studied through experimental investigation of reaction conditions such as methanol/oil molar ratio, amount of alkaline catalyst, reaction time and reaction temperature which were deemed to have main impact on reaction conversion efficiency. Experiments have been performed to determine the optimum conditions for this transesterification process by orthogonal analysis of parameters in a four-factor and three-level test. The optimum experimental conditions, which were obtained from the orthogonal test, were methanol/oil molar ratio 9:1, with 1.0 wt.% sodium hydroxide, temperature of 50 °C and 90 min.

Mofijur M., et al., (2013) [19] have presented in details on biodiesel feedstock's, process for production and engine test. The feedstocks discussed were a) Edible vegetable oil: rapeseed, soybean, sunflower, palm and coconut oil. b) Non-edible vegetable oil: Jatropha curcas, pongamia pinnata, sea mango and algae. c) Waste or recycled oil, d) Animal fats-tallow, yellow grease and chicken fat. The transesterification process was discussed in details and remarked as most assuring and conventional process. Various physic-chemical properties of different feedstocks were discussed. The effect of different feedstock's on engine characteristics was discussed. Nor Hazwani Abdullah et al., (2013) [20] have prepared biodiesel from waste cooking oil sample collected from a local factory in Malaysia. The biodiesel was characterized for its physical and fuel properties using ASTM standard methods for biodiesel fuel quality assurance The composition of final biodiesel was determined by physical properties such as density, viscosity, flash point, water content and acid value. From the tests, the flash point was found to be 97^0C, water and sediment was 0.02%, total acid number was 0.29 mgKOH/g, viscosity at 40^0C was 4.2 mm2/sec and density 0.82g/cm. Out of 5 properties tested, all of them met the ASTM criteria for fuel standard.

IV. CATALYST IN TRANSESTERIFICATION:

Many researcher [5-25] suggested that, transesterification reaction can be alkali-catalyzed, acid-catalyzed or enzyme-catalyzed. The first two types have received significant attention due lesser reaction time as for enzyme-catalyzed system.

A. ALKALI-CATALYZED SYSTEM:

Y. zang (2003) reported a reaction temperature near boiling point of alcohol (eg. 60 0C for methonol)

and a 6:1 molar ratio of alcohol to soybean oil. It was observed that, 90-98% oil conversion to methyl ester was observed within 90 min. To speed up reaction addition of tetrahydrofuran (THF) as co-solvent was suggested. It was concluded tha, use of hot water washing at 50 0C was best way to obtain high purity (99%) and yield (86%) of biodiesel. The limitation to alkali catalyzed system was very sensitive to both water and free fatty acids. The presence of water causes ester saponification while FFA reacts with alkali catalyst to produce soaps and water. Also, resulting soap can cause formation of emulsions. Analysis showed that the alkali-catalyzed process using virgin vegetable oil as the raw material required the fewest and smallest process equipment units but at a higher raw material cost than the other processes. The optimum experimental conditions, which were obtained from the orthogonal test, were methanol/oil molar ratio 9:1, with 1.0 wt.% sodium hydroxide, temperature of 50 °C and 90 min. Verified experiments showed methanol/oil molar ratio 6:1 was more suitable in the process, and under that condition WCO conversion efficiency led to 89.8%. For high free fatty acid (FFA) content, the FFA was esterified with methanol by sulfuric acid. When the FFA content was lower than 1.0%, the sulfuric acid was drained and the sodium hydroxide was introduced into the system to complete the transesterification. The methanol was insufficient to perform a complete reaction. With the methanol/oil molar ratio increasing, WCO conversion efficiency will be correspondingly increased. The maximum conversion efficiency (88.9%) was achieved at 7:1 methanol/oil molar ratio. Further increase in molar ratio the conversion efficiency more or less remained the same. The WCO conversion efficiency is 88.4%. From the ranges 0.5–1.0 wt.%, the WCO conversion efficiency increased proportionally with increasing sodium hydroxide amount. The maximum WCO conversion efficiency (85.0%) was observed at 1.0 wt.% sodium hydroxide. Addition of excess amount catalyst, gave rise to the formation emulsion.

B. ACID-CATALYZED SYSTEM:

Zhang Y., et al., (2003) [5] reported that, use of waste cooking oil to produce biodiesel reduced the raw material cost. Despite its insensitivity to FFA in feedstocks, acid catalyzed transesterification has been largely ignored mainly because of its relatively slower reaction rate. The transesterification was investigated of Soybean oil with methanol using 1 % wt concentrated sulfuric acid. It was noted that, at 65 0C and a molar ratio of 30: 1 methanol to oil it took 69 hr to obtain 90% oil converted into methyl ester. The increased ester conversion could be obtained at increased molar ratios of alcohol to oil, increased reaction temperatures, increased concentration of sulfuric acid and longer reaction times. However, possible interaction of these variables was not investigated and optimal conditions for acid catalyzed were not recommended. The acid-catalyzed process using waste cooking oil proved to be technically feasible with less complexity than the alkali-catalyzed process using waste cooking oil, thereby making it a competitive alternative to commercial biodiesel production by the alkali-catalyzed process. Mangesh G. Kulkarni et al., (2006) [12] explained that, depending on the water and FFA content of the waste cooking oil, a transesterification method should be selected. If the FFA and water contents are <1 wt % and <0.5 wt %, respectively, then an alkaline catalyst is more suitable for the ester production. If the FFA content of oil is high (>1 wt %), then an acid catalyst is a good choice. The catalyst-free supercritical methanol method has great potential for biodiesel production from waste cooking oil; however, the requirements of high temperature (350 °C), high pressure (45 MPa), and high molar ratio of oil to alcohol (1:42) makes the use of this process difficult on an industrial scale. Y. Zhang et al., (2003) [13] The economic feasibilities of four continuous processes to produce biodiesel, including both alkali- and acid-catalyzed processes, using waste cooking were assessed. Although the alkali catalyzed process using virgin vegetable oil had the lowest fixed capital cost, the acid-catalyzed process using waste cooking oil was more economically feasible overall, providing a lower total manufacturing cost, a more attractive after-tax rate of return and a lower biodiesel break-even price.

Carlos A. Guerrero F.,et al., (2011) [21] have concluded that, using acetic acid or water as a washing agent does not affect the reaction productivity, similar to the reaction temperature has no effect on the variable response within the levels used in the research. The unique variables that affect the biodiesel production are the catalyst concentration and the molar ratio alcohol/oil. The Molar ratio alcohol/aceite: 9:1, Catalyst concentration of: 0.7% w/w, Reaction temperature: 50 °C and Washing agent: water at 40 °C. Ebenaza Godson.T et al., (2015) [22] have studied acid esterification reaction for four different molar ratios. The sulfuric acid catalyst amount was varied in the range of 0.3% to 2%. These percentages are based on volume of the oil used for the acid esterification reaction. The acid-catalyst process attained maximum yield for waste cooking oil at 0.5% catalyst concentration. It was observed that the yield started to decline when the catalyst concentration was increased to above 0.5%.Methanol to oil molar ratio was varied for waste cooking oil within the range of 3:1 to 9:1. The maximum biodiesel yield for waste cooking

oil was found at the methanol to oil molar ratio of 6:1 in acid esterification. In alkali transesterification, the maximum yield for waste cooking oil was obtained at the methanol to oil molar ratio of 9:1. Fuel properties analysis was carried out according to ASTM Biodiesel Standards. Fuel characteristics of biodiesel and high speed diesel (HSD) which were tested include dynamic viscosity at 40°C 5.311 eta., kinematic viscosity at 40°C 4.720 any, density at 40°C 0.860 Rho, color comparison, flash point 183°C, cloud point 4°C, pour point -5°C, specific gravity at 60°F 0.890 kg/1, sulphur contents 0.003 %, cetane index 50.40.

C. SOLID ACID CATALYZED:

Kathlene Jacobson, et al., (2008) [7] various solid acid catalysts were evaluated for the production of biodiesel from low quality oil such as waste cooking oil (WCO) containing 15 wt.% free fatty acids. The zinc stearate immobilized on silica gel (ZS/Si) was the most effective catalyst in simultaneously catalyzing the transesterification of triglycerides and esterification of free fatty acid (FFA) present in WCO to methyl esters. The catalysts were recycled and reused many times without any loss in activity. Ajay Kumar Dalai reported catalyst preparation and characterization was discussed. Specific surface area and pore size measurement of the catalysts were performed using micrometrics absorption equipment (model ASAP 2000) at 78 K using nitrogen. Different types of solid acid catalyst were studied like Ammonium heptamolybdate, Ammonium metatungstate, zironyl chloride octahydrate, Aluminium nitrate and zinc stearate etc. Zinc stearate immobilized on silica gel was found to be the most active and stable heterogeous catalyst. The catalyst was reused many times without any loss in activity and at optimized condition of reaction temperature of 200 0C, stirring speed of 600 rpm, 1:18 molar ratio of oil to alcohol, and 3% w/w catalyst loading, a maximu ester content of 98 wt% was obtained.

Guoqing Guan et al., (2009) [23] have put forth Transesterification of waste cooking oil with methanol, using tri-potassium phosphate as a solid catalyst, was investigated. Tri-potassium phosphate shows high catalytic properties for the transesterification reaction, compared to CaO and tri-sodium phosphate. Transesterification of waste cooking oil required approximately two times more solid catalyst than transesterification of sunflower oil. The fatty acid methyl ester (FAME) yield reached 97.3% when the transesterification was performed with a catalyst concentration of 4 wt. % at 60 °C for 120 min. After regeneration of the used catalyst with aqueous KOH solution, the FAME yield recovered to 88%. Addition of a co-solvent changed the reaction state from three-phase to two-phase, but reduced the FAME yield, contrary to the results with homogeneous catalysts. The catalyst particles were easily agglomerated by the glycerol drops derived from the homogeneous liquid in the presence of solvents, reducing the catalytic activity.

D. TWO STEP CATALYST:

Yong Wang, et al., (2006) [6] compared traditional acid and the new two-step catalyzed processes for synthesis of biodiesel, (fatty acid methyl ester, FAME) were comparatively studied to achieve an economic and practical method for utilization of waste cooking oil (WCO). The conversion of free fatty acids of WCO into FAME in the two-step method was 97.22% at the reaction time of 4 h, mole ratio of methanol to TG of 10:1, compared in the acid method with 90%, 10 h, and 20:1, respectively. This new two-step process showed advantages of no acidic waste water, high efficiency, low equipment cost, and easy recovery of catalyst compared with the limitations of acidic effluent, no reusable catalyst and high cost of equipment in the traditional acid process. Gokhan ayl,et al., (2008) [10] discussed short chain alcohol esters of fatty acids can be used as diesel fuel. One step and two step base catalyzed room temperature transesterification reaction of used cooking oil was compared.

In the two step base catalyzed process, for 1000 g of used cooking oil 4.2 g NaOH and 140 ml MeOH was used in the first step and 1.8 g NaOH and 60 ml MeOH was used in the second step. All reactions were done at 25 °C; the effects of water content and suspended particles on the yield were studied. The yields were easily determined by Thermo Gravimetric Analysis (TGA) instead of the usual Gas chromatography (GC). It was found that two step processes gives a better yield (96%) than the one step process (86%). Amin Talebian Kiakalaieh et al., (2013) [11] explained utilization of waste cooking oil is a key component in reducing biodiesel production costs up to 60–90%. However, the cooking process has negative influences on oil properties and can create different types of impurities in the oil and can also increase the FFA and water content of oil. The transesterification reaction is the best method for production and modification of biodiesel. Acid, alkali, or enzymatic catalyzed, and non-catalyst transesterification are different approaches that have been tried for biodiesel production.

Magin Lapuerta et al., (2008) [15] two different alcohol-derived biodiesel fuels: methyl ester and ethyl ester, both obtained from waste cooking oil. These biodiesel fuels were tested pure and blended (30% and 70% biodiesel content, volume basis) with a diesel

reference fuel, which was tested with diesel engine. The NO emissions still remains higher while HC CO were lower. The type of alcohol used in the production process was found to have a significant effect on the total hydrocarbon emissions and on the particulate matter composition. As the alcohol used was more volatile, both the hydrocarbon emissions and volatile organic fraction of the particulate matter were observed to increase.

V. NOVEL APPROACH:

Man Kee Lam et al., (2010) [14] Presented an overview on the current status of biodiesel production and the potential of waste cooking oil as an alternative feedstock. It was found that using heterogeneous acid catalyst and enzyme are the best option to produce biodiesel from oil with high FFA as compared to the current commercial homogeneous base-catalyzed process. However, these heterogeneous acid and enzyme catalyze system still suffers from serious mass transfer limitation problems and therefore are not favorable for industrial application.

Alemayehu Gashaw et al., (2014) [17] Explained that, biodiesel is an alternative and renewable fuel for diesel engines and has become more attractive in recent times. The catalysts used in the production of biodiesel are acids, bases and enzymes. Transesterification is a commonly employed method to reduce the viscosity during the production of biodiesel. The purpose of this method is to reduce the viscosity of oil or fat using acid or base catalyst in the presence of methanol or ethanol. However, the biodiesel production by transesterification is strongly affected by molar ratio of alcohol, reaction temperature, reaction time and catalyst concentration. The main advantage in biodiesel usage is attributed to lesser exhaust emissions in terms of carbon monoxide, hydrocarbons and particulate matter.Van Kasteren J.M.N., et al., (2007) [18]

A supercritical transesterification process for biodiesel continuous production from waste cooking oil has been studied for three plant capacities (125,000; 80,000 and 8000 tonnes biodiesel/year. The supercritical transesterification can be scaled up resulting high purity of methyl esters (99.8%) and almost pure glycerol (96.4%) attained as by-product. The economic assessment of the biodiesel plant shows that biodiesel can be sold at US$ 0.17/l (125,000 tonnes/year), US$ 0.24/l (80,000 tonnes/year) and US$ 0.52/l for the smallest capacity (8000 tonnes/year). The sensitive key factors for the economic feasibility of the plant are: raw material price, plant capacity, glycerol price and capital cost. Overall conclusion is that the process can compete with the existing alkali and acid catalyzed processes.

VI. CONCLUSIONS:

Biodiesel is an effective alternative fuel for conventional diesel and can be directly used as fuel in a diesel engine without any modifications to the engine. It has many positives like high biodegradability, reduction in green house gas emissions, non-sulfur emissions, non-particulate matter pollutants, low toxicity and excellent lubricity and is obtained from renewable source like vegetable oils, animal fat etc. Transesterification is the most common method for biodiesel production. Waste cooking oil is a cost effective and promising feedstock. WCO with higher FFA content results is decrease in the overall yield. In this case, esterification is to be done before Transesterification.

Homogeneous catalysts like NaOH and KOH are known for having less reaction time and moderate reaction conditions but oils with high FFA may result in soap formation which reduces the overall yield and the recovery if catalyst is difficult.

Heterogeneous catalysts have better separation and better quality of product but they have extreme reaction conditions. For carrying Transesterification, batch reactors are preferred over continuous because of easy assemblage, maintenance, inexpensive and easy to design.

Obtaining higher yield of product depends upon the quality of oil used. The parameters affecting the reaction were identified to be methanol to oil molar ratio, the catalyst used and its amount and the reaction temperature. The produced biodiesel mixed with proportions of petroleum diesel (B20: 20% biodiesel and 80% petroleum diesel) showed significant reduction in CO, HC and smoke emissions.

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