Biodiesel Production from Palm Methyl Ester (PME) –Review

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Abstract - In the era of the increase in globalization, this led to increase in industrialization and motorization. It's obvious that with the increase in motorization the consumptions of auto fuels had been increased since long. This may lead to a reduction of fuels (diesel & petrol). Also, environmental issues have arisen from the emissions of toxic pollutants and greenhouse gases. Hence, it is necessary to look for an alternate energy source to respond this problem. To overcome this problem the replacer of fuel in CI engines had been introduced, i.e. "biodiesel". Biodiesel is composed of fatty acid and some vegetable oils. This review paper briefly describes different biodiesel production methods, especially the production of biodiesel using palm methyl ester (PME) oil, by transesterification process. In addition, it also compares the yield of biodiesel produced from mill effluents and palm oil by-products using flask and batch reactor.

Keywords - Biodiesel, transesterification, PME, Reactor, mill effluent.

1. INTRODUCTION

Energy is the main element for the economic development of the nation. Due to rapidly increasing demands of energy supply of fossil fuel sources such as coal, petroleum and natural gas leads to boost the cost, environmental degradation and minimize security [1]. Currently, India imported approx. 2/3rd of its petroleum requirements every year, which occurred a cost nearly Rs. 81,000 crores in foreign exchange. Although, even five percent replacement of diesel and petrol based fuel by biodiesel can help India to save Rs.4000 crores every year in foreign exchange. Hence biodiesel is an alternate renewable source for long period energy security. Biodiesel has many advantages like non toxic, inexhaustible, high cetane no., biodegradable, clean burning, eco-friendly, reduce harmful emissions (HC, CO, NO_x) and have low sulphur content [2-5]. There are ample of sources from where biodiesel can be produced i.e. from soybean oil, coconut oil, palm oil, sunflower oil, cotton seed oil, etc. However, due to low volatility, large molecular mass, and more kinematic viscosity of vegetable and animal oils it cannot directly use in the engine. [6]. Hence, to solve these issues, different methods have been used for the production of biodiesel namely blending with petro-diesel, pyrolysis, micro emulsification and transesterification.

1.1 Blending (mixing)

Fuel can be prepared for functioning of the engine by the process of blending or mixing, in which the diesel fuel is directly mixed with preheated vegetable oil or animal oil. When a blend of 95% of filtered used cooking oil and 5% of diesel was prepared, the process was experimentally carried out which gave a positive result while used in diesel engine [7]. Some of major problem faced during blending was regarding the high fuel viscosity, low volatility, poor atomization and incomplete fuel combustion [8]. Hence some other methods were introduced to overcome these problems.

1.2 Micro-emulsification

It is an ideal method for biodiesel production that overcome the problem of the high viscosity of fuel in which the vegetable or animal oils were solubilised in a solvent (alcohol) and surfactant until the desired viscosity was achieved. Some commonly used solvent during this process are methanol (CH₃OH), ethanol (C₂H₅OH) and butanol (C₄H₉O) [9].

1.3. Pyrolysis (thermal cracking)

The process in which the vegetable or animal oils is preheated and decomposed at high temperature ($>350^{\circ}\text{C}$) is known as pyrolysis. This method is effective, eco friendly and not requiring washing, drying or filtering. But it has some limitations such as it produce low purity of biodiesel, costly equipment and need high temperature. Pyrolysis of vegetable oil became a major course for investigators to be studied for the production of fuel product [10].

1.4 Transesterification

Transesterification is a process where triglycerides changed to diglycerides then diglycerides are transformed to monoglycerides, subsequently monoglycerides changed to esters and glycerol as represented in Figure 1. This process has high conversion with relatively low cost. The commonly used catalyst to boost the rate of chemical reactions during transesterification process includes sodium hydroxide (NaOH), potassium hydroxide (KOH), and sodium methoxide (CH_3NaO) [11].

Figure 1: Transesterification reactions

II. BIODIESEL PRODUCTION FROM PALM OIL BY TRANSESTERIFICATION METHOD.

The steps involved during biodiesel production from palm oil by transesterification reaction are shown in Figure 2.

Figure 2. Steps involved during biodiesel production from palm oil [12].

2.1. Blending (Alcohol+Catalyst)

During this process the sodium hydroxide (0.8% of vegetable oil) is used as a catalyst and mixed with CH₃OH (25% of vegetable oil) properly.

2.2. Reaction

After blending the mixture is poured into a conical vessel and then heated palm oil (45°C) is added and keeps the system in an air tight environment. Subsequently, on the water heater, the reaction take place at an isothermal temperature (50°C-60°C) and reaction duration changes from one to eight hours.

2.3. Separation

During this step, glycerin (which is denser than biodiesel) is separated from biodiesel using gravity separation. Subsequently, vaporization is used to remove the remaining CH₃OH which was still present in the biodiesel.

2. 4. Washing of methyl ester

During this step washing is done 3 to 4 times to remove CH₃OH, residual free glycerine, catalyst and soap from obtaining biodiesel. Finally, pure biodiesel is obtained after heating of washed biodiesel at 100°C for a time period of 10 minutes to remove the water exist in the washed biodiesel. The Table 1 is illustrated below which indicates the name and chemical structures of common fatty acid found in palm oil.

Table 1: Composition of fatty acid observed in palm oil by wt. % [11]

S.NO.	Common Name	Chemical Name	Shorthand	Molecular Formula	%age (By wt.)
1	Lauric	Dodecanoic	12:0	C ₁₂ H ₂₄ O ₂	0.1
2	Myristic	Tetradecanoic	14:0	C ₁₄ H ₂₈ O ₂	0.7
3	Palmitic	Hexadecanoic	16:0	C ₁₆ H ₃₂ O ₂	36.7
4	Stearic	Octadecanoic	18:0	C ₁₈ H ₃₆ O ₂	6.6
5	Oleic	Cis-9-octadecenoic	18:1	C ₁₈ H ₃₄ O ₂	46.1
6	Linoleic	Cis-9,Cis-12-octadecadienoic	18:2	C ₁₈ H ₃₂ O ₂	8.6
7	Linolenic	Cis-9,Cis-12,Cis-15-octadecatrienoic	18:3	C ₁₈ H ₃₀ O ₂	0.3

Palm oil is an effective and useful feedstock material for biodiesel production [13]. Currently, palm oil has become the 2nd highest consumed feedstock material throughout the world with a less price in comparison with edible oils [14]. It is grown economically in South America, Africa, South Pacific, Southeast Asia and in other tropical areas [15].

III. RESULT AND DISCUSSION

3.1 Production of biodiesel from palm oil by-products and mill effluent using Flask reactor.

Various researchers produced biodiesel from from palm oil by-products and mill effluent using flask and batch reactor and give a different yield. Chongkhong, S. et al. [16] used palm fatty acid distillate as a raw material to produce (fatty acid methyl esters) FAME using a flask method in the presence of methanol and H₂SO₄ as catalyst. The reaction was carried out at a temperature b/w 343 to 353°F for 1.5 hours and gives 93.9% yield.

Suwanno, S. et al. [17] produced biodiesel from palm oil mill effluent (POME) and palm fruit and catalyst gives yield ($92.07 \pm 1.04\%$) at 35°C using flask method. From the experimental result, it was noticed that 8% of oil was regained from palm oil mill effluent and produced biodiesel possess a high cetane number and cloud temperature ($59\text{--}60$) and ($10\text{--}13^\circ\text{C}$) respectively. Hindryawati, N. et al. [18] used ultrasound method to convert residual oil from palm decanter cake (PDC) into biodiesel. It was found that about 11.3 wt.% of oil regained after 60 min. extraction. Aladetuyi, A. et al. [19] regained Palm kernel oil from spent bleaching earth and subsequently fresh oil was obtained from palm kernel gives a yield of 16% and 40.23% respectively using n-hexane. After that trans-esterified process was used and the reaction takes place with methanol (oil/methanol: 5:1) at 373K for 120 min. The percentage yield obtained with cocoa pod ash catalyst was higher (94%) than potassium hydroxide (90%). Akinfalabi, S. et al. [20] used Palm fatty acid distillate to synthesis the biodiesel in the presence of a SPSC-SO₃H catalyst. The result indicates that at 333.15 K biodiesel yield 97.8% during 120 minute reaction. Also, no treatment of catalyst needed up to eight esterification cycles and reused successfully. Surasit, C. et al. [21] applied tungstophosphoric acid to synthesis biodiesel from PFAD at 338.15K for 28800sec. About 90% yield of fatty acid methyl ester was obtained and properties of the biodiesel were as per the ASTM EN 14214 and D6751 standard. Astar, I. et al. [22] obtained the optimum conversion of methyl ester from sludge oil and crude palm oil in the presence of EFB ash & alum catalyst and 86.17% yield was achieved. Manurung, R. et al. [23] prepared biodiesel using sludge palm oil by esterification and transesterification reactions gives a yield of 83.19%. Ricca, R.N. et al. [24] produced biodiesel using Sludge palm oil in the presence of enzymatic catalysis and gives a yield of 62.3%. The result indicates that different alcohol, reaction temperature, alcohol to oil molar ratio, speed of mixing, enzyme loading and duration of the reaction, are the main parameters that influence the enzymatic biodiesel produced from sludge palm oil. Ngaini, Z. et al. [25] used palm oil mill sludge as a feedstock material and produced biodiesel in the presence of silica-based heterogeneous catalysts derived from *Imperata cylindrica* sp. The biodiesel was prepared using flask reactor, at 65°C , for 1hour gives yields of 80%. The results of biodiesel production from Palm Oil by using Products with the help of Flask reactor are summarized in Table 2 and summarized graphically in Figure 3.

Table 2. Summary of biodiesel production from Palm Oil by using Products with the help of Flask Method.

1. Biodiesel Production Using Flask Method/Reactor.								
S No .	Year	Author	Raw Material	Catalyst	Alcohol	Time (s)	Temp (K)	Yield %
1	2007	Chongkhong, S. et al. [16]	PFAD	H ₂ SO ₄	CH ₃ OH	5400	343.15-353.15	93.9
2	2017	Suwanno, S. et al. [17]	POME	Crude lipase	CH ₃ OH	129600	308.15	92.07 $\pm$ 1.04
3	2017	Hindryawati, N. et al. [18]	PDC	Sulfonating rice husk ash	CH ₃ OH	18000	393.15	70.2
4	2014	Aladetuyi, A. et al. [19]	SBE	CPA	CH ₃ OH	7200	373.15	86.0
			SBE	KOH	CH ₃ OH	7200	373.15	81.2
5	2017	Akinfalabi, S. et al. [20]	PFAD	SPSC-SO ₃ H	CH ₃ OH	7200	333.15	97.8
6	2017	Surasit, C. et al. [21]	PFAD	TPA/Cs1.0/Nb2O ₅	CH ₃ OH	28800	338.15	90
7	2017	Astar, I. et al. [22]	SO	EFB ash & Alum	CH ₃ OH	10800	338.15	86.17
8	2017	Manurung, R. et al. [23]	SO	NaOH & Deep eutectic solvent	NIL	3600	353.15	83.19
9	2013	Ricca, R.N. et al. [24]	SO	C. cylindracea lipase	C ₂ H ₅ OH	86400	313.15	62.3
10	2016	Ngaini, Z. et al. [25]	SO	Imperata cylindrica sp.	CH ₃ OH	3600	338.15	80

Abbreviations: (PFAD- Palm Fatty Acid Distillate), (SO- Sludge Oil), (PDC- Residual oil from palm ecanter cake), (SBE- Residual oil of spent bleaching earth), (POME- Residual from Palm oil mill effluent), (CPA-

Cocoa pod ash), (KOH- potassium hydroxide), (SPSC-SO₃H -sulfonated soaked palm seed cake), (TPA/Cs1.0/Nb₂O₅- tungstophosphoric acid), (CH₃OH –Methanol), (H₂SO₄. Sulphuric acid)

Figure 3. Biodiesel yield % age vs. raw material/catalyst/alcohol/time (s) /temperature (K) by using Flask reactor.

3.2 Production of Biodiesel from palm oil by products and mill effluent using batch reactor.

Aranda, D.A.G. et al. [26] investigated the esterification of palm fatty acid to prepare biodiesel in the presence of different catalysts. The author studied the influence of alcohol used, presence of H₂O, concentration of catalyst, and type of catalysts on biodiesel yield. The author reported that H₂SO₄ and CH₄O₃S were the best catalysts. The presence of H₂O in the reaction medium represented a adverse consequences in the reaction velocity whereas, reaction with CH₃OH gives more yields. Baroutian, S. et al. [27] carried out transesterification of refined, deodorized and bleached palm olein with CH₃OH, C₂H₅OH and their blends at different CH₃OH/C₂H₅OH ratio and molar ratio of 1/6 in the existance of KOH. The author attained 98.10% biodiesel yield when using CH₃OH/C₂H₅OH ratio of 4:2 and molar ratio of alcohol to oil was 6:1, a reaction duration of 60 minutes, at 50°C. Sakdasri, W. et al. [28] produced biodiesel at low CH₃OH /oil molar ratio (12:1) from used and refined palm olein oil. The author concluded that the used palm olein oil with more FFA (4.56 wt. %) can be used as a feedstock material for biodiesel production that gives a higher ester content of eighty percent. Also, the side reaction between C₃H₈O₃ and CH₃OH at 673.15K and 15×10⁶ N/m² represented a positive influence in increasing fuel yield by 2% to 7%. Suryani, A. et al. [29] produced biodiesel from residual oil of spent bleaching earth in a 100 liter batch reactor at the different transesterification time (60, 90 and 120 minutes), and stirring speeds (650 rpm and 730 rpm). The result showed that at 730 rpm and 90 minutes transesterification time gives best result with the yield of 85%. Klabsong, M. et al. [30] evaluated the parameters of residual oil and observed 3.767 % wt FAME, 22.03 % wt of FFA, acid value of 49.29 mg KOH/g, a H₂O content of 1.01 % mg/Kg, total glycerines as triglyceride, diglycerides and monoglycerides at 87.54 % m/m, 11.88 % m/m and 1.15 % m/m respectively. The results of biodiesel production using Palm Oil by using Products with the help of Batch reactor are summarized in Table 3 and summarized graphically in Fig. 4.

Table 3. Summary of biodiesel production from Palm Oil by using Products with the help of Batch Method or Reactor.

2. Biodiesel Production Using Batch Reactor								
S No.	Year	Author	Raw Material	Catalyst	Alcohol	Time (s)	Temp (K)	Yield %
1	2008	Aranda, D.A.G. et al. [26]	FAR	H ₂ SO ₄	C ₂ H ₅ OH	3600	403.15	>90.0
2	2009	Baroutian, S. et al. [27]	UPO	KOH	CH ₃ OH/ C ₂ H ₅ OH (4:2)	3600	323.15	98.1
3	2015	Sakdasri, W. et al. [28]	PO	KOH	CH ₃ OH/C ₂ H ₅ OH	3600	323.15	98.1
4	2017	Suryani, A. et al. [29]	SBE	H ₂ SO ₄ & NaOH	CH ₃ OH	5400	338.15	85
5	2017	Klabsong, M. et al. [30]	POME	Non- Catalytic	CH ₃ OH	18000	503.15	77.64

Abbreviations: (FAR-Fatty acid residue), (FAC- Fatty Acid Residue), (UPO- Used Palm Olein/Glycerol), (PO- Palm Olein), (SBE-Residual oil of spent bleaching earth), (POME- Residual from Palm oil mill effluent), (C₂H₅OH-Ethanol).

Figure 4. Biodiesel yield %age vs. raw material/catalyst/alcohol/time (s) /temperature (K) by using Batch reactor.

IV. CONCLUSIONS

Due to increasing the number of vehicles, energy demand is also increasing which result in depletion of fossil resources. Hence effort must be applied to search inexhaustable and eco friendly energy sources (vegetable oils/animal fats). Palm oil by-products and mill effluent is one of the best low cost alternative and renewable feedstock material for biodiesel production because of its attractive properties such as easily available, environment-friendly, techno-economically competitive as well as less impact on food security. Further, it has been concluded that Palm fatty acid distillate and refined bleached and deodorized palm olein offered a very high yield, i.e. 97.8% and 98.1% using flask and batch reactor respectively. Hence a comprehensive study is still needed.

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