Mahua Oil as Renewable Resources for Biodiesel Production: Indian Perspective

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Abstract: ***Biodiesel, a methyl or ethyl ester of fatty acid is an attractive alternative of fossil fuels and can be obtained from various edible or non - edible oil feed stocks. Mahua oil is an excellent raw material in terms of cost and especially this oil does not have any issue with food security. Biodiesel is produced from Mahua oil through different transesterification processes but mostly two step transesterification method is used widely. The cost and efficiency of biodiesel production mainly depends on presence of free fatty acid (FFA) in the feed stock. This paper reviews, discusses and analyses the production of biodiesel from Mahua oil, its hybrid with other non - edible oil and its effect on the efficiency of four stroke diesel engine compared to other esters on the basis of performance and emissions briefly***

Keywords: Mahua oil, Transesterification, Biodiesel, Free fatty Acid

1. Introduction

In recent years the interest in renewable fuels has increased many folds due to high demands of energy and limitation of fossil fuels creating opportunities to develop domestic resources in cost effective manners. It has been a major environmental and political challenge now - a - days for the search of biofuels world wide. India has great concern of ever rising consumption of fossil fuels. Biodiesel has received more attention among other renewable energy sources during last few fens, since it is renewable, biodegradable, nontoxic and has low emission profile such as lower emission of carbon mono - oxide, particulate matters and unburnt hydrocarbons [1].

Two major spices of Mahua found in India are Madhuca India (Longifolia) and Mahuca India (Latifolia) and belongs to spatacac family. It is found in different region of India, Srilanka, Maynamar and Nepal etc. Large quantities of Mahua trees are found in different states of India such as Utter Pradesh, Madhya Pradesh, Orrisa, Jharkhand, Bihar, Chattisgarh, Andhra Pradesh, Maharashtra, West Bengal, Karnataka, Gujarat and Rajasthan. Mahua fruits which is abundantly available across northern and central India during summer season, Mahua is more values for its seeds which contains a high quantity of lipids 50 - 61% [2]. The seed potential of this tree is 50, 000 tons and oil potential is 180, 000 tons in India. Mahua tree grows up to 20 meters in height and producing 20 to 200 kg seeds annually per tree. This tree matures within 8 to 15 years and fruits up to 60 years. The most important chemical process for biodiesel production is two step transesterification of Mahua oil which gives high conversion yield with only one bi product Glycerin.

The objective of this paper is to have critical study on different methods and technology adopted by various researchers for the production of biodiesel from mahua oil and its hybrid and also to discuss the future possibility for upgradation of process with economical point of view.

2. Mahua Oil Extraction

Sun dried mahua seeds has the average yield of 1kg oil per 1.6 kg Mahua kernels contains 20 – 61 percent of oil depending on the process of expeller. The residual oil is extracted with proper solvent from pressed cake. The colour of fresh oil is yellow which turns greenish yellow due to biodegradation. Fresh Mahua oil has FFA around (1 – 2) % as compared to poorly stored Kernals (up to 30%) [3].

The production of non - edible oils from different feed stock is outlined in Table 1. It shows the significant amount of Mahua oil being 180, 000 ton per annum in India

Table 1: Production of non - edible oil from different feed stock in India [4]

Non - edible oil sources	Production ton per annum
Mahua	180, 000
Sal	180, 000
Neem	100, 000
Karanja	55, 000
Kusum	25, 000
Ratanjot	15, 000

The characteristics of different non - edible raw vegetable oil is given in table 2. The properties of mahua raw vegetable oil nearly match with the pure diesel (B 0) except the value of viscosity and flash point. Flash point of Mahua oil is 236^{0}C as compared to 65^{0}C for diesel (B 0), viscosity of mahua oil is much higher 31.1 cST as related to 2.6 for (B 0). This indicates that direct use of mahua oil in diesel engine is not possible since it causes operational problem such as carbon deposits, oil ring sticking, thickening and gelling of lubricating oil.

Table 2: Properties of non - edible raw vegetable oil [5]

Parameter	Diesel (B 0)	Mahua Oil	Jatropha oil	Karanji oil	Rape seed oil	Cotton seed oil	Rubber seed oil	Tobacco seed oil
Density (Kg/m^3)	820	926	921	927	918	874	926	920
Calorie Value (MJ/Kg	45.60	36.4	39.78	35.80	36.89	39.65	38.96	39.40
Cetane Number	46	43.5	45	40	39	45	40	38
Viscosity[at]40^{0}c (cST)	2.6	31.1	49.9	56	55	21.4	55.6	27.7
Flash point (^{o}C)	65	236	240	250	275	260	242	220
Carbon Residue (%)	0.1	0.45	0.44	0.66	0.31	0.55	0.46	0.57

3. Transesterification

Transesterification process consists of base catalysed esterification process. Prior to this, acid catalyst based esterification process is carried out to reduce the free fatty acid from around 16% to 1%. This step is necessary to avoid the formation of soap with high amount of FFA present in the mahua oil. The process flow chart of bio diesel production from mahua oil is depicted in fig 1. The steps, process and method generally used to produce is mentioned order wise starting from Mahua oil to pure biodiesel in the given figure mainly three process like acid catalyse esterification, base catalysed transesterification

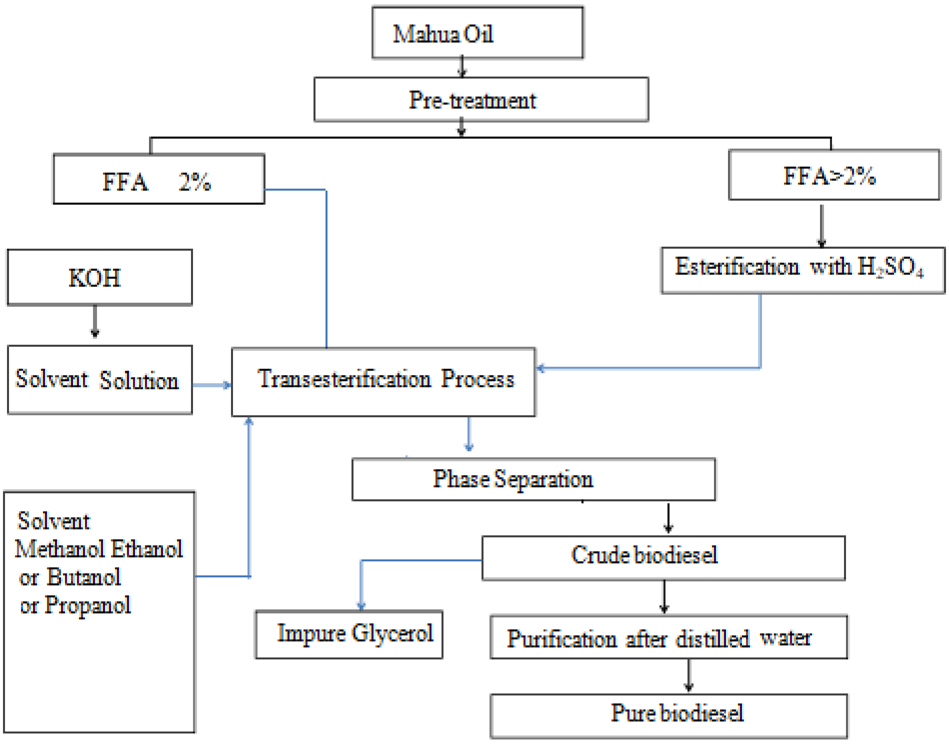

Figure 1: Process flow chart of biodiesel production from mahua oil [6]

Transesterification is a reversible reaction between triglycerides and alcohol. The reaction is shown in fig - 2. When triglyceride reacts with 3 mole of alcohol in the presence of catalyst, alkyl esters (Biodiesel) with one molecule of glycerol is formed. Triglycerides have molecular weight between 800 – 900 and are nearly four times longer than pure diesel molecule which makes straight vegetable oil non suitable as fuel for diesel engines.

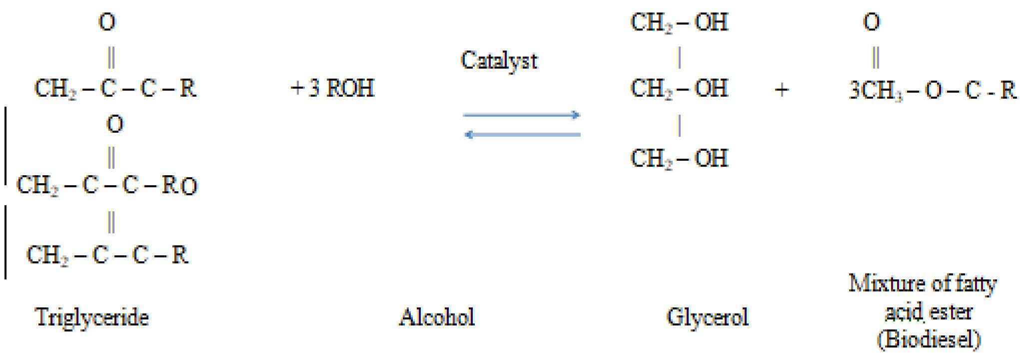

Figure 2: Chemical reaction involved in biodiesel production

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4. Biodiesel Standards

Various countries like Germany, Italy, France and USA has developed their own standards for biodiesel quality. India has also developed its own standard under the name IS: 15607. All standards of different countries has been mentioned in table 3, which shows the limiting values of viscosity, flash point and acid value being slightly higher than DIN standard. Carbon residue has almost equal limiting values in all standards. Viscosity is the key parameter which controls the diesel engine injection property. The viscosity of fatty acid methyl ester can be go to very high level. Therefore, it is important to control the value of viscosity to acceptable level to avoid the negative impact of performance of diesel engine injection system.

Table 3: Biodiesel of various standards [7]

Sr. No.	Parameters	India BIS	Austria ON	France	Germany DIN	Italy UNI	USA ASTM
1	Density at 15^{0}C (g/cm^3)	0.87 - 0.89	0.85 - 0.89	0.87 - 0.89	0.87 - 0.89	0.86 - 0.90	0.88
2	Viscosity at 40^{0}C (mm^2/s)	1.9 – 6.0	3.5 - 5.0	3.5 - 5.0	3.5 - 5.0	3.5 - 5.0	1.96
3	Flash Point (^{0}C)	130	100	100	110	100	130
4	Pour Point (^{0}C)	-	-	10	-	1 - 5	15 - 18
5	Cetane Number	40	49	49	49	-	47
6	Neutralisation Number (mg KOH/g)	0.5	0.8	0.5	0.5	0.5	0.87
7	Carbon Residue (%)	0.05	0.05	-	0.05	-	0.05

5. Biodiesel from Different Feedstock

The density of mahua biodiesel is 872 (kg/m3) of 150C which is well under ASTM limit. The limiting value of kinematic viscosity 3.9 mm^2/s which is less than Rubber seed and Jatropha biodiesel and nearly match with pure diesel as well as in accordance with ASTM value. The flash point of Mahua oil biodiesel slightly higher than other biodiesel which suggest that this biodiesel can be used in a blend with pure diesel. Carbon residue of mahua biodiesel 0.2% which is nearly same as in case of pure diesel, Jatropha biodiesel and Rubber seed oil biodiesel. The value of caloric value and cetane number of Mahua oil is well matched with pure diesel and biodiesel obtained from different feed stock. A comparison of physical and chemical properties of pure diesel, biodiesel from different feed stock along with ASTM standard is presented in table 4.

Table 4: Comparison of physico chemical properties of mahua oil methyl ester with other biodiesel [8]

Properties	ASTM D6751	Straight Diesel	Mahua Biodiesel	Jatropha Biodiesel	Rubber seeds oil biodiesel
Density at 15^{0}C (kg/m^3)	860 – 900	839	872	880	874
Kinematic viscosity of 40^{0}C (mm2/s)	1.9 – 6.0	3.18	3.9	4.328	5.81
Calorific Value (MJ/kg)	-	44.8	39	40	36.5
Flash point (^{0}C)	Min 130	68	205	140	130
Carbon residue (%)	-	0.1	0.2	0.25	0.24
Fire point (^{0}C)	Min.145	103	218	155	145
Ash content (%)	< 0.02	0.01	0.02	0.02	0.02
Acid value (mgKOH)	< 0.8	0.35	0.5	0.32	0.118
Cetane Number	-	51	52	57	54

6. Parameters Affecting Transesterification

The main parameters which effect the transesterification reaction are alcohol – triglyceride ratio, reaction time, nature of catalyst presence of moisture and free fatty acid content. Table 4. describes the effect of several parameters associated with transesterification during production of production. Alcohol triglyceride molar ratio is the key parameter for yield of biodiesel. Different parameters with their effect on production process has been outlined in table 5.

Table 5: Parameters with their effect on transesterification process

Parameter	Effect	Reference
Temperature	Depending on the catalyst temperature effects the reaction ratio. The optimised temperature is around 600C.	[9, 10]
Alcohol triglyceride molar ratio	The best stoichiometric ratio optimised is 6: 1 alcohol to oil molar ratio to produce three moles of alkyl ester and one mole of glycerol. However, residual alcohol interferes the glycerol separation from biodiesel since it is highly soluble in alcohol.	
Time	Longer time increases the conversion of fatty acid to fatty acid methyl ester.	
Catalyst	Alkaline catalyst increases the reaction rate in comparison with an acid catalyst. However the vegetable oil containing high FFA and high water content an acid based transesterification is recommended to avoid the soap formation.	
FFA content	In the alkaline catalyst, FFA content should be as low as <1.0% to inhibit soap formation.	

7. Result & Discussion

Kandasamy Sabriswan et. al. (2014) made an attempt to produce biodiesel using Indian Mahua oil and methanol. The maximum conversion efficiency of biodiesel was reported to 90% under optimised condition of 0.5 wt% of acid catalyst during esterification and 0.4% of NaOH with 6: 1 molar ratio mahua oil to methanol of reaction temperature

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60+_1^{0}cand 60 minutes of reaction time [11]. The researcher has used methanol for transesterification process which makes the process economically feasible for industrial use.

Prakash Chandra Jene, et. al. (2010) produced biodiesel from a mixture of Indian mahua oil and simarouba oil having high free fatty acid. The mixture was preheated to reduce FFA to approx.1% which was then transesterified with methanol and KOH an 600C. The researcher reported the biodiesel conversion above 90% [12]. This effort to produce biodiesel from the mixture of two oil finds a scope for further study so that two or more non - edible oil sources could be utilized for biodiesel production in a single attempt.

Yogesh C Sharma et. al. (2010) have synthesized biodiesel from karanja, mahua and hybrid (Karange and mahua) (50: 50 v/v) feed stock. A high yield of 95 – 97% biodiesel with all three feed stock was reported. Conversion yield of 98.6%, 95.71% and 94% was observed for karanja, mahua and hybrid feed stock. The optimised value for esterification reaction was found to be 6: 1 (methanol to oil) molar ratio, H_2SO_4 (1.5% v/v) at 55+_ 0.5^{0}C for one hour reaction time. For alkali transesterification a molar ration (8: 1) methanol to oil, 0.8% (wt%) KOH at 55+_ 0.50c for one hour reaction was found the optimum condition [13]. This work uses the opportunities oil and its hybrid with other oil with similar optimised value of important involved in the esterification and transesterification reaction.

A researcher S. Guharaja et. al. made an effort to synthesize biodiesel from Indian Mahua, which is renewable and agriculture based non - edible oil. Mahua oil was extracted from its seeds using expeller method which was then subjected totransesterification in two steps. The primary esterification was employed to reduce FFA to less than 2% with concentrated H_2SO_4 and methanol. In the second stage transesterification was carried out using base catalyst (NaOH) for conversion of biodiesel. The instrumentation methods such as GC/MS and FT - IR was used to analyse the formation of biodiesel which confirm the product [14].

In an another investigation Sukumar Puhan et. at. prepared methyl, ethyl and butyl ester and studied on four stroke, direct injection diesel engine for their performance and emission properties. The result showed that in the case of methyl ester thermal efficiency of the engine is maximum as compared to other esters. The emission of gases like CO, oxides of nitrogen (NOx) and hydrocarbon is low for all alkyl ester as compared to fossil diesel. When comparing nox emission over other alkyl esters it was found that methyl ester has lowest emission of NOx [15]. The result obtained from this study clearly shown that biodiesel obtained from methanol has maximum efficiency towards thermal efficiency of engine as well as emission of NOx gases is least in the case of methyl ester. This is added advantage of methyl ester since it is low cost and widely available.

8. Conclusion

On the basis of study made by different researcher it can be asserted that biodiesel can be produced successfully using Indian crude Mahua oil. The hybrid of Mahua oil with simarauba oil and mahua oil with karange oil looks promising feed stock for biodiesel production in India. Biodiesel yield of (90 – 94) % was reported using two step transesterification process. The optimised molar ratio of mahua oil to methanol was reported as 6: 1 for base catalysed transesterification process. Methyl ester biodiesel among other alkyl biodiesel such as ethyl and butyl esters was found better properties in terms of thermal efficiency of four stroke direct injection diesel engine and less emission of oxides of carbon, nitrogen aid hydrocarbons. This is added advantage of methyl ester since methanol is low cost chemical and widely available in India. Therefore, the biodiesel obtained from Indian mahua oil seems to be very effective since it meets the Indian requirement of high speed diesel oil and is renewable, biodegradable non - toxic and free from sulphur and aromatic compound emission.

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References

[1] Azam MM, Waris A, Neahar NM (2005). Prospects and potential of fatty acid methyl esters of some traditional seed oils for use as biodiesel in India. Biomass and Bioenergy (29): 293 - 302.

[2] Saluja MS, SangameshwaramB, Huva IS and Sharma A (2011). In vitro cyclotexic activities of leaves of MadhucaLongfollia against EAC cell lives. Int. J. Drug Dev. Res. (1): 55 - 57.

[3] Mahto D, Kumar A (2017). Manufacturing of Biodiesel from Mahua (Madhuca Indica) oil. Biofuels and Bioenergy. (16): 261 - 269 Government of India, Trified. nic. in.

[4] Sudarapandian S, Devarasljane G. (2007). Performance and emission analysis of bio - diesel openated C. I. Engine. Journal of Engineering, Computing and Architecture 1 (2), 1 – 22.

[5] Kapilan N, Reddy RP (2008). Evaluationof Methyl ester of mahua oil (Madhuca Indica) as diesel fuel. J. Am. Oil Chem. Soc. (85): 185 – 188.

[6] Mittle back M, (1996). Diesel fuel derived from vegetable oil, Bioresource Technology, (27): 35 – 437.

[7] Sikdar DC, Jain R, Dorjee N, Sanchi J (2018). Studies on Transesterification of Mahua (Madhuca Indica) seed oil. International journal of Technical Research and application 3 (6): 1 - 4.

[8] Sikdar DC, Jain R, Dorjee N, Sanchi J (2018). Studies on Transesterification of mahu (Madhuca India) seed oil international journal of technical research and application 3 (6): 1 - 4

[9] Ghadge SV. Rehman H, (2005) Biodiesel production from mahua (Madhuca Indica oil) having high free fatty acid, Biomass and Bioenergy, (28): 601 - 605.

[10] Mishra PC, Nayak KS, Ghose DP, Manoj UK, Sahu SK (2013), Performance characteristics of diesel engine fuelled with biodiesel produced from Mahua oil using additive IORS Journal of Mechanical and Civil

engineering 8 (2): 26 - 34.

[11] Kandaswami S, Sunderaj S, Alagupandian K (2014) Chemical science Review and letter, 3 (9): 52 – 57.

[12] Jane PC, Rehman H, Prasana K, MachavaramR (2010). Biodiesel production from mixture of mahua and simarouba oil with high free fatty acid. Biomass and bioenergy, 34 (8): 1108 – 1116.

[13] Sharma YC, Singh B, (2010). A hybrid feed stock for very efficient preparation of biodiesel, fuel processing technology, 91 (10): 1267 - 1273.

[14] Guharaja S, Dhakshinamoortthy S, Hassan I, Arun B (2015). Biodiesel production from mahua (Madhuca India).

[15] Sukumar P, Vedaram N, Rambrahan BV and Nagraja G (2005). Mahua (Madhuca Indica) seed oil: A resource of renewable energy in India. Journal of Scientific & Industrial research. (64): 890 - 896.