iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** III **Month of publication:** March 2018

DOI: http://doi.org/10.22214/ijraset.2018.3210

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue III, March 2018- Available at www.ijraset.com

A Comprehensive Review on Waste Fish Oil as Feed-Stock of Biodiesel

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Abstract: The rapidly declining fossil fuel reserves across globe, upsurge in usage of petro-diesel fuel and very hazardous effect on environment fascinated the researchers towards economically feasible, eco-friendly plant based vegetable oil and animal fat based biodiesel as alternative renewable fuel to replace partially or completely the fossil fuel. Recently biodiesel produced from feedstock such as vegetable oil or animal fat using by the transesterification process has more attention. But some researchers revealed that edible vegetable oil based biodiesel may cause rise in food-product price and eventually trigger for food-crisis for future generations. On the other side, even though non-edible oil plants are cultivated in barren and uncultivated waste lands, the production cost of non-edible oil also increased due to heavy use of fertilizers and intense usage of pesticides. The best alternative to cut the price of biodiesel feed stock was identified animal fat and fish waste as feed stock. This is because in livestock and aqua industry that globally, over a million tons of animal fat and fish parts such as fins, viscera, tails, eyes etc., have been unused/underutilized and most of the time discarded as a waste. In this review paper, a comprehensive review has been conducted to study the different research accomplishments on fish and aqua waste as feed-stock of biodiesel in the production alternative bio-fuel for a diesel engine.
Keywords: Biodiesel, Methyl Ester, Animal fat, Fish oil, Performance and emission characteristics, Transesterification.

I. INTRODUCTION

The national economic and energy security are threatened by the global energy crisis, which is due to disruption of fossil fuel supplies, interruption of crude oil production from fossil fuel rich countries such as OPEC nations and increase in production cost which rapidly raise the fuel prices. These also have a considerable impact on importing nations' economy and meeting the energy needs due rapid consumption of fossil fuels especially in automotives. The most probable way to meet this increasing demand is by the renewable biodiesel as alternative fuel [1-3]. The chemical properties of biodiesel are almost similar to petro-diesel fuel and it became a most fascinating set in bio-fuels, because it can be used directly in any unmodified diesel engine [4]. Besides the biodiesels are clean burning, most environmental friendly and non-toxic fuel than petroleum based fossil fuels.

In the recent decades, many researches were conducted experimental investigations with vegetable based edible oils such as soybean, peanut, sunflower, etc., and with non-edible sources such as Jatropha oil, Simarouba oil, Mahua oil, Neem oil, Karanja oil etc., to replace the petro-diesel with a suitable alternative biodiesel [5-7] . The vegetable oils as feed-stock of biodiesel have many predilections such as oil can be cultivated in a short period of time, many plants related non-edible oils can grow in uncultivated waste lands with minimum water source [7-9].

Vegetable oils and animal fats can be used as is in a diesel engine without any modification, yet not ideal because of their higher viscosities and lower volatilities which make it incomplete and inefficient for combustion engines. Be that as it may, the possibility of using vegetable oils as fuel has been perceived, just when therefore modified by using transesterification process to get fatty alkyl esters of the vegetable oil and animal fats which can be considered as fuel that has comparative properties as diesel fuel [10-11]. The reviewed literature revealed that the transesterification process is a most suitable and distinctive method for preparation of biodiesel from animal fat, aqua waste and waste cooking oil. From the experimental studies, it has been unveiled that the biodiesels typically causes the reduction in engine torque and power, but the lower smoke emissions, carbon dioxide, carbon monoxide, pollution and with the biodiesel as compared to neat diesel with a minor increased in NOx exhaust emissions.

The biodiesels are prepared from edible oils have raised a concern about cost of the food products, especially in thickly populated developing countries. For this reason, the research and production of biodiesel then focused towards using non- edible oils such as Jatropha curcas oil, Cotton seeds oil, Karanja oil, Linseed oil, Mustard oil, Neem oil etc., as biodiesel feed-stock. Though the non-edible vegetable oil seeds can be grown-up in uncultivated, unfertile baron lands with very less water in uneven intervals, the usage pesticides and fertilizers are increasing the cost of production of feedstock and became as costly as edible oil feedstock [12]. Although adequate and significant work has been carried out to evaluate the characteristics of diesel engine using biodiesels produced from both edible and non-edible vegetable oils, from the literature it was observed that inadequate amount of work has been done to analyze the characteristics of DI diesel engine fuelled with animal-fat based biodiesels especially waste fish oil. Hence this paper is concerned to review of previous work related to fish oil methyl ester (FOME) and its diesel blends used in diesel engine.

II. MATERIALS AND METHODS

In general, the biodiesel will be prepared using transesterification, micro-emulsion, pyrolysis, technique or by direct blending with diesel fuel. Transesterification chemical process is one of the best processes to reduce the viscosity of the vegetable or animal fat oil and to increase the cetane number of biodiesel . The chemical reaction of transesterification process was given in figure 1.

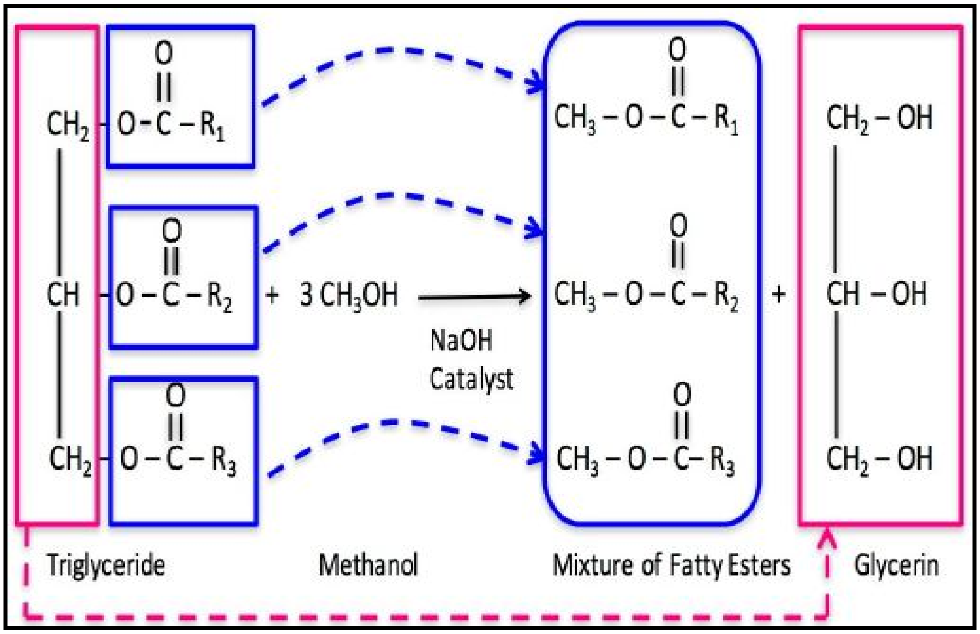

Fig. 1 Transesterification Process.

These transesterified plant based vegetable oils after chemical reactions with ethyl or methyl alcohol will produce diesel engine friendly fuel. Generally, biodiesels are produced through the reaction of vegetable oils with methanol in the presence of catalyst to yield glycerine and methyl esters. Methanol in the presence of NaOH as a catalyst was used for transesterification of vegetable oil. The parameter involved in the above processing includes the amount of catalyst, reaction temperature, molar ratio of alcohol to vegetable oil, and reaction time. The fuel properties of diesel and fish oil biodiesel (FOME) are shown in table I.

TABLE I
PROPERTIES OF DIESEL AND MIOME BIODIESEL

Fuel Property	Unit	ASTM Standards	Diesel	FOME
Kinematic Viscosity @ 40^0C	CST	D445	3.52	5.85
Flash Point	^{0}C	D93	49	167
Density @ 30^0C	kg/m^3	D1298	840	875
Calorific Value	kJ/kg	D4868	42850	38000
Cetane Number	--	D613	50	53
Carbon Residue	% w/w	D4530	0.1	0.48
Total Sulphur	% by mass	D5453	0.01	0.05
Ash	% by mass	D1119	0.01	0.03

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A. Experimental Setup

The experimental work can be conducted using the following experimental setup as shown in figure 2 and 3. The experimental setup is demonstrated as schematic diagram below at figure 2 and photographic view in figure 3.. The setup consists of diesel engine, eddy current dynamometer, smoke meter, and exhaust gas analyser. The eddy current dynamometer was coupled with a test engine to operate the engine at various loads such as 25, 50, 75 and 100% load conditions.

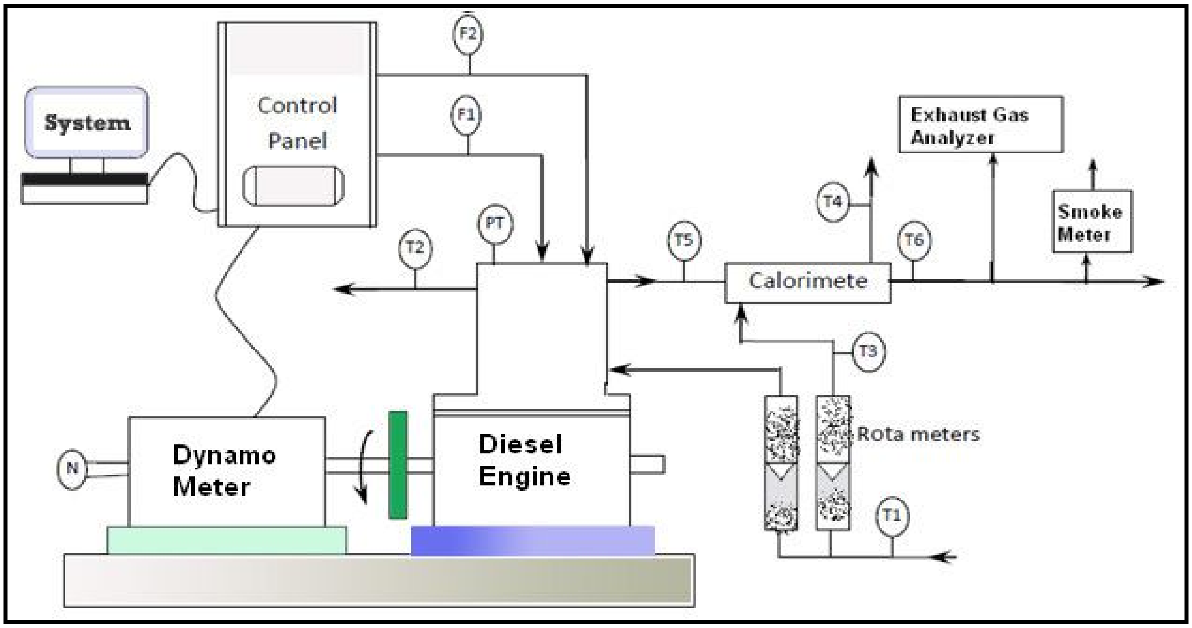

Fig. 2. Schematic Diagram of Experimental Setup

T1	Inlet water temparature	PT	Pressure transducer
T2	Outlet engine jacket water temp	F1	Air intake differential pressure unit
T3	Inlet water temparatue	F2	FuelFlow differential pressure unit
T4	Outletcal.water temparature	T6	Exhaust gas temparatue after Cal
T5	Exhaust gas temparatue before Cal		

Fig. 3. Photographic View of Experimental Setup

III. WASTE FISH OIL AS BIODIESEL FEED-STOCK

In the past few decades, the biodiesel from vegetable oils has increased momentum, but the availability of feedstock for biodiesel has become a critical and crucial challenge faced. It was observed that over a million tons of fish wastes worldwide have been unused or underutilized. Generally, in the making process of fish food products, the fins, viscera, tails, eyes are substantially discarded. The discarded parts of the fish are generally converted into fishmeal for livestock and have very modest economic value. However, the crude fish oil extracted from these discarded parts may provide profuse, inexpensive, and stable source of raw oil to allow the countries like India which have vast coastal area to produce biodiesel and thus help to reduce dangerous emissions. Kerihuel et al. (2005) studied the performance and emissions of diesel engine by conducting series of experiments using micro emulsions of animal fat with water and methanol. An increased volumetric efficiency and reduced exhaust gas temperatures than conventional diesel fuel was observed. They also noticed reduced NOx, CO and un-burnt hydrocarbon emissions when biodiesel used as fuel [13]. Metin et al. (2010) evaluated the exhaust emissions and engine performance of a single cylinder, CI direct injection engine when 10% blend of chicken fat methyl ester and diesel fuel with synthetic Mg additive used as fuel with several engine speeds from 1800 rpm to 3000 rpm. Their experimental results identified no change in engine torque, but observed increase in specific fuel consumption (SFC) and this is due to lower heating value of biodiesel. They also noticed decrease in CO and smoke emission, but identified an increased NOx emission by 5% [14]. Preto et al. (2008) evaluated the engine combustion and emission properties of a horizontally mounted, front firing, tunnel furnace using blend of fish oil and No.2 fuel oil. They observed good combustion characteristics with less exhaust emissions except NO emission [15]. Sharanappa Godiganur et al. (2009) investigated the influence of methyl ester of fish oil (biodiesel) and its diesel blends on the engine characteristics in terms of performance and emissions of a kirloskar H394 DI-CI engine. The study results identified insignificant change in performance and combustion characteristics except reduction in exhaust emissions other than NOx emission. The optimum result with higher thermal efficiency was observed for 20% blend of biodiesel with diesel fuel [16]. Cengiz Oner et al. (2009) used inedible animal tallow biodiesel and its blends as fuel and conducted series of experiments to evaluate the performance and emissions. They noticed reduction in thermal efficiency, increased specific fuel consumption, but overall performance is comparable to diesel fuel. This is because of low heating value of animal tallow biodiesel fuel. It was also observed that low carbon monoxide, NOx emissions and high EGT with B20 blend and low NOx, CO, smoke density and SO2 emissions with B100 blend [17]. Cherng-Yuan et al. (2009) conducted experiments using trans-esterified fish oil as biodiesel and compared with waste cooking oil methyl ester. From the experimental test results revealed lower fuel consumption and less BSFC with waste cooking oil methyl ester when compared with fish oil methyl ester. However higher NOx emission, EGT and black smoke opacity was observed with waste cooking oil biodiesel due to it higher heating value, elemental carbon, cetane index, and content of hydrogen than that of fish oil biodiesel [18]. Lin & Li. (2009) investigated the performance and emissions of four stroke, 4-cylinder, naturally aspirated, DI diesel engine using marine fish oil biodiesel, waste cooking oil biodiesel and compared with petro-diesel fuel. The higher fuel consumption rate, more brake fuel conversion efficiency and NOx emissions while the lower EGT, carbon monoxide (CO) emission, and black smoke density at speeds lower than 1400 rpm was observed for two biodiesels when compared with 2D diesel fuel. The reduced brake fuel conversion efficiency was noticed with both biodiesels at speeds more than 1400 rpm. Furthermore, the biodiesels have low carbon content and high elemental oxygen content when compared with ASTM No. 2D type diesel fuel [19]. Sakthivel et al. (2011) evaluated the characteristics of a single cylinder DI-CI engine by conducting series of experiments using fish oil ethyl ester (biodiesel) and its diesel blends. They noticed insignificant change in performance and reduced emission characteristics such as NOx, smoke density, hydro-carbon, carbon monoxide (CO) except trivial raise in CO2. This is because the properties of biodiesel such as density, kinematic viscosity; flash point and calorific value are almost similar to that of petro-diesel fuel [20]. Rasim Behçet (2011) investigated the effect of blends of anchovy fish oil biodiesel and its diesel blends on emission and engine performance of single cylinder, CIDI engine at variable load conditions. Their test results shown reduction in engine torque, in engine power, and increased specific fuel consumption with fish oil biodiesel and its blends when compared with diesel fuel was noticed. However reduced emission such as CO, CO2, HC and increased NOx emission was observed with biodiesel and its blends than that of diesel fuel. Finally the results has substantiated that biodiesel can be used as an alternative renewable fuel in place of diesel [21]. Swaminathan et al. (2012) investigate the properties of a single cylinder, 4-storke, water-cooled, DI diesel engine using mixture of fish oil biodiesel and its blends with diesel with diethyl ether with 1-3% with 1% increment as additive as fuel. Their experimental results shown no significant change in BTE, but observed reduced CO2, CO, and NOx when engine operated with EGR at full load condition. They recommended 2% additive is the best blend to use in unmodified diesel engine as biodiesel [22]. Sharma et al. (2014) conducted comparative analysis on the engine performance and emission characteristics of a medium capacity diesel engine using blends of mahua oil methyl ester and fish oil biodiesel and their blends along with the utilization of Urea-SCR as an exhaust treatment technology. Their test results showed the reduction in NOx emission and higher BTE with fish oil biodiesel blends when compared with mahua oil biodiesel blends. [23].

IV. CONCLUSIONS

The biodiesel which is produced from fish and aqua waste fish oil as feed-stock will be potential alternative bio-fuel source and will therefore play an increasingly remarkable role in solving the energy crisis and providing energy security along with curbing environmental pollution problem. The domestically prepared biodiesel properties must stick with the international biodiesel standard specifications such as the American Standards for Testing Materials (ASTM 6751-3) or the European Union (EN14214) for biodiesel fuel. The physicochemical properties of fish oil biodiesel are within the specified range of ASTM standards. Hence the fish oil biodiesel is compatible and can be used with diluting with diesel fuel as a fuel in any compression ignition engine.

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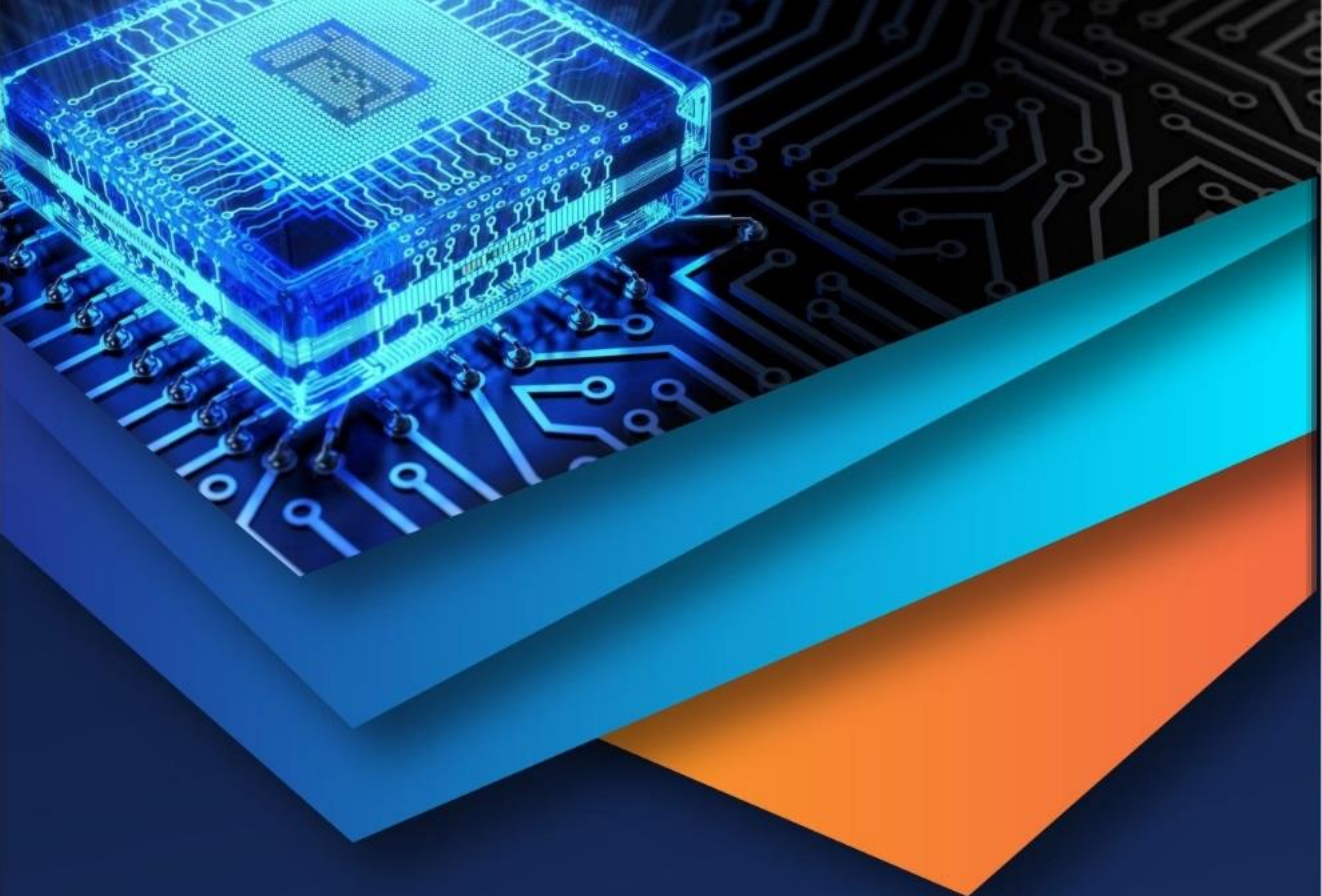

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