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Feasibility analysis of using waste fish oil as an alternate fuel

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ABSTRACT

The production of fossil fuels seems to be in falling trend as the most commonly used fuel is getting depleted day by day on the other hand consumption is increasing, thereby leading us to an inevitable position in near future. The environmental pollution is also the key concern and fossil fuels are the major pollutants. Pollution from burning diesel causes health problems and environmental hazards. In order to meet these requirements and overcome the problems we have to look towards alternatives to petroleum based fuels like petrol and diesel. Vegetable and animal fat oils are considered as good alternatives to diesel as their properties are close to diesel since they offer the advantages of being used readily in existing diesel engines without alterations. Initially, a base line data was generated with diesel, jatropha and fish oil. Subsequently, the fish oil was converted into biodiesel by degumming and neutralization in the chemistry laboratory. This project aims at finding an alternate to the conventional diesel fuel by investigating the feasibility of biodiesel from fish oil as fuel in diesel engine for various blends. Hence various tests were carried out in the diesel engine of kirloskar make and the various characteristics like flash point, fire point and viscosity were studied and the results are tabulated. The results obtained after conducting the experiments shown that using biodiesel (prepared from fish oil) can be an effective and eco-friendly fuel in the present day engine without any modifications.

Keywords: *Alternate fuel; Waste fish oil; Bio-diesel; Thermal properties.*

1. INTRODUCTION

Demand for petroleum is gaining momentum due to rapid depletion of fossil fuels and degradation of the environment, which thereby caused a resurgence of interest in finding alternate fuels [1]. The use of bio-fuel in diesel engine has been significantly increased since the oil crisis occurred on 1973. In view of this, vegetable and animal fat oils are becoming as a promising alternative since it is renewable, eco-friendly and can be produced easily in rural areas, where there is an acute usage for modern forms of energy. As the availability of crude petroleum products is scarce, India is importing crude petroleum from Gulf countries. The price distribution of diesel is as follows- 45% for the crude oil, 38% as taxes, 11% for distribution and marketing, 6% for refining [2]. From the above statistical data, it is clear that one is paying 38 % of the total price as taxes, regarding import and others. In order to overcome these expenses, an alternate source of energy has to be developed. Moreover, the depletion of fossil fuel has given us a warning to search for new fuels.

These problems can be overcome by using bio-diesel, otherwise called as ethyl or methyl ester of vegetable oil and animal fat oil. In India, the use of vegetable oil as biodiesel has be in practice but the use of animal fat has not been used. We have a vast costal region and among the harvested fish only 50% of the fish is been consumed but still the remaining 50% which is wasted can be used as a good source of oil resource [3]. This can be used as biodiesel. Bio-diesel stands a best option as a substitute for the conventional diesel in the coming years of fuel scarcity (near future). India will also benefit from the increased demand for employment in infrastructure, logistics and

transportation, once the bio-diesel concept is implemented successfully nationwide.

A detailed literature survey was conducted on the harvesting, preparation, transesterification, production, testing and potential of using fish oils as fuel in diesel engines. The literatures pertaining to the usage of bio-diesel and the content of fish oil blending with diesel in the engines was also studied. Fish from the very primitive age has been used as food and till today fish is used as the main diet in major part of the world as it is considered to be a rich source of protein, minerals and vitamins [4]. Fish has been used only for consumption for a very long time, whereas the fish liver contains large amount of oil and nowadays it is harvested mainly for oil extraction. Apart from oil fish has been used for medicinal purposes especially in Chinese medicine.

Out of the total fish harvested only 50% is consumed but the fact is no part of the fish is wasted. The fish meat is used for consumption the head, fins, tail and intestine is used for the production of oil. The solid left after removing oil is used for aquatic food and poultry food. Fish oil is mainly used for veterinary purpose as the Omega 3 removed from it is used for cardiac medicine. It is also a prime medicine for pregnant women, nursing women, premature children, new born, youth and athletes [5]. Fish oil can be used in health care, pharmaceuticals, farm feeds, wooden canoes, leather tannery, veterinary and manufactures of insecticides. In 2000, the scientists said fisheries around the world burned about 13 billion gallons of fuel to catch 80 million tons of fish. And although the fish-per-gallon ratio varies widely from species to species, they said, it is getting worse over all because boats must venture farther and farther out to sea in search of dwindling stocks. "This is the only major industry in the world that is getting more and more energy-inefficient," said Daniel Pauly, director of the Fisheries Center of the University of British Columbia and one of the report's authors [6].

In the report, the scientists said fisheries accounted for about 1.2 percent of global oil consumption, and they use about 12.5 times as much energy to catch fish as the fish provide to those who eat them. The JS McMillan Fish Reduction Plant in Prince Rupert BC converts fish offal, by-catch, and other fishery wastes generated from the fish processing facilities in northern British Columbia into fish meal and other fish by-products. The operation primarily produces salmon oil as a byproduct. Estimated volume is approximately 40 tonnes per year (approx. 45,000 litres) [7]. Oil production is extremely seasonal, with virtually all output being generated in July and August. The oil is currently sold under contract to Purdue Chicken, which uses both the fish meal and oil as feed in its Abbotsford BC operation. The raw oil is sold FOB McMillan's plant in Prince Rupert for approximately $500 per tonne (equivalent to approximately CAD $0.45 per litre). Table 1 represents the people actively involved, dependent in fishing and Table 2 shows the economic importance of fisheries in some countries including India.

Table 1 Number of people actively involved and dependent in fishing

Country	Coastline	Numbers dependent on fishing	Numbers actively involved in fishing
India	8000 Km	9,000,000	5,000,000
Bangladesh	480 Km	12,000,000	1,200,000
Sri Lanka	1,800Km	200,000	110,000

Table 2 Economic Indicator of the importance of fisheries

Country	Total production (metric tonnes)	Exports of marine Products (metric tonnes)	Value of marine Products (in local currency)	Contribution to Gross Domestic Product
India	4,700,000	208,600	IND Rs 17,674 million	2.4%
Bangladesh	1,268,000	41,500	BOD Tk 14,570 million	3.6%
Sri Lanka	275,997	*7,591*	SRL Rs 855 million	2.0%

Figure 1 explains the annual harvesting of marine fish in India. Our fisheries are geared for human consumption. Processing thus removes much of the nutrient value, leaving relatively low-nutrient waste. Therefore, achieving similar nutrient levels to those found in meal from whole fish reduction fisheries (sardines, anchovies, menhaden, herring, etc.) is difficult in Alaska waste-based fishmeal production. Fish waste may be converted to fish fuel comparable to diesel. Alaska Energy Authority on a pilot project to test the efficiency of using fish oil with diesel fuel for electrical generation [8-10]. The results so far have been positive and await the results of long-term testing on the engines. A number of factory trawlers have been adding a fraction of fish oil to their fuel for years. Alaska fisheries produce large amounts of fish by-products. Due to environmental concerns damage from disposing of fish waste products, some of this waste is now processed into fish oil and dried fish meal.

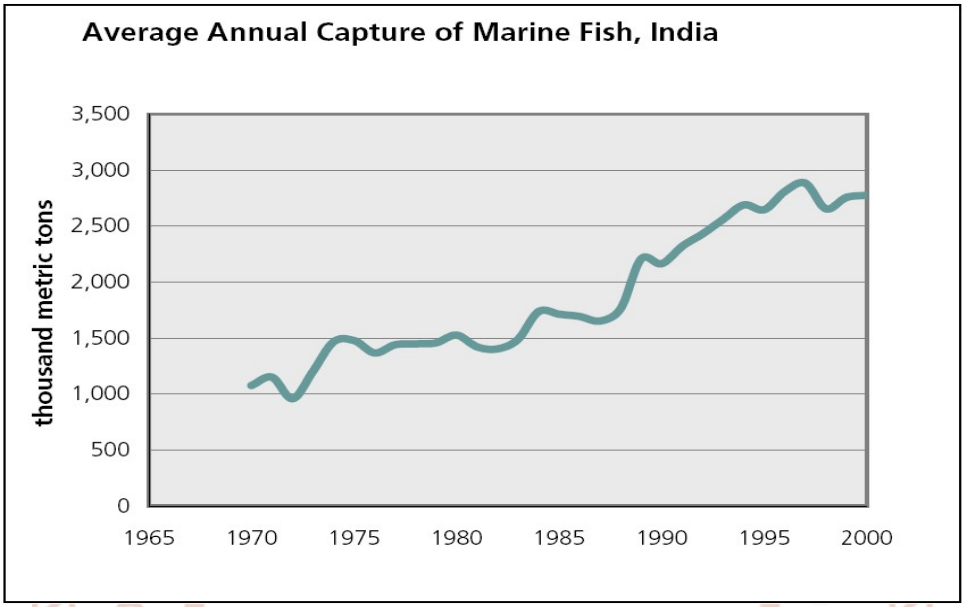


Figure 1 Annual harvesting of marine fish

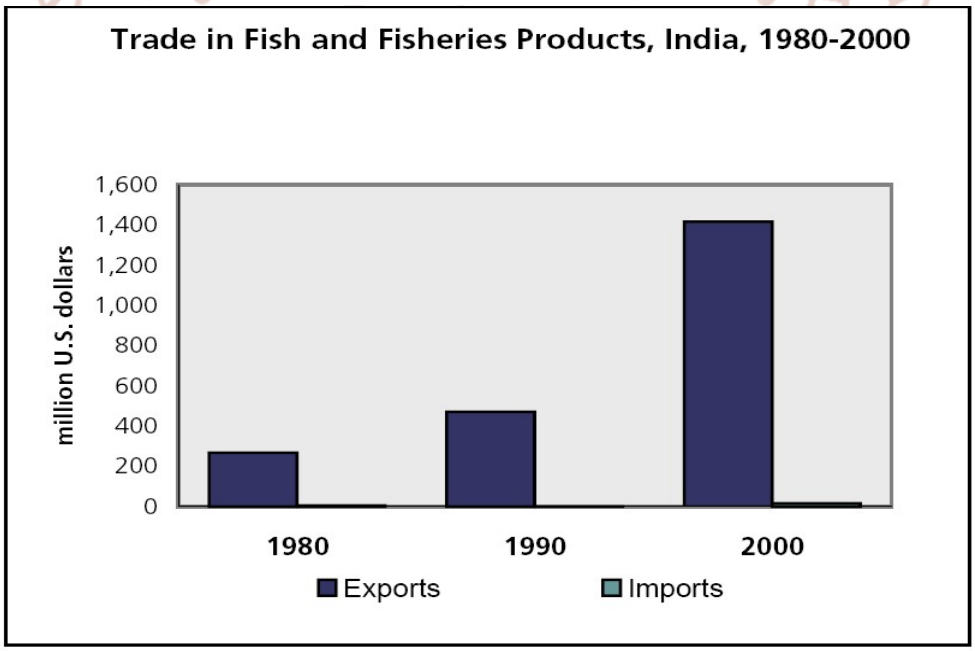


Figure 2 Trade in fish and fisheries product in India

The fisheries and seafood processing industries in British Columbia (British Columbia) are both diverse and volatile. Especially, in India trade in fish and fishery products are more and it is depicted in figure 2. The primary potential source of biodiesel feedstock from this sector is fish oil. Fish oil is currently being used as feedstock for biodiesel blends in Alaska and in Nova Scotia. Fish oil produced in the province is derived from

processing fish wastes and by-products from several fisheries and value-added seafood operations. So in the present work, extraction of the oil from the waste fish and processed it into bio-diesel using the various standard test procedures. Then the various properties like flash point, pour point viscosity and fire point were determined. Later, it is blended with conventional diesel and made run in a diesel engine for testing the feasibility of the extracted bio-diesel in commercial purposes.

2. MATERIALS AND METHODS

Trash fishes were collected from the nearest local fisheries harbour and aseptically transported to the laboratory. Then the lipid content of the trash fishes was extracted using direct steaming method and purification of the separated oil was carried out. Bio-diesel was prepared by trans-esterification process, after refining the selected oil and then the investigations on the prepared bio-diesel was performed. The whole process is displayed in figure 3 as below.

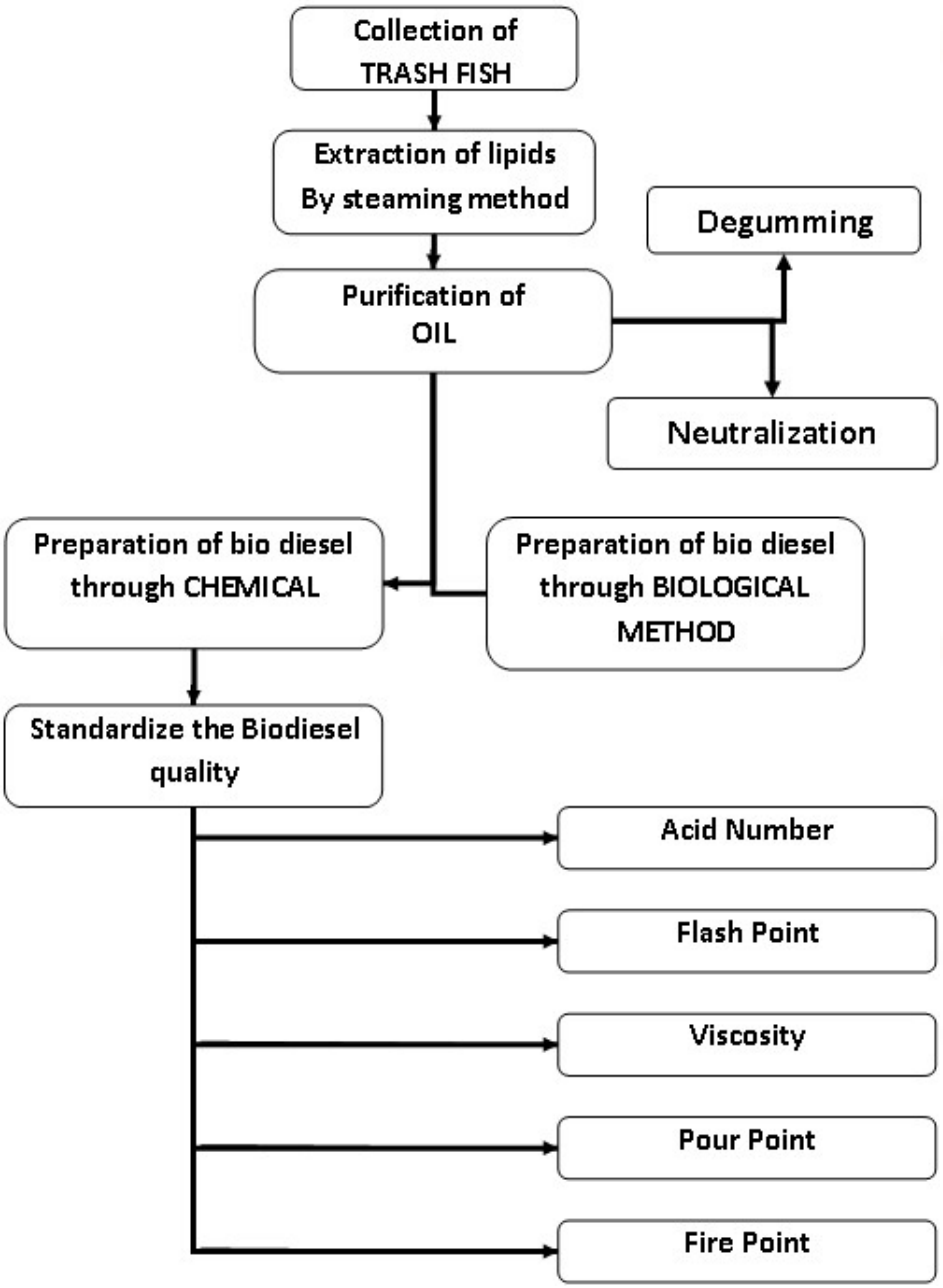


Figure 3 Process chart from trash fish to testing of bio-diesel

2.1. Preparation of bio-diesel from crude fish oil

The flow diagram of preparation of biodiesel from fish oil is displayed in figure 4 as below.

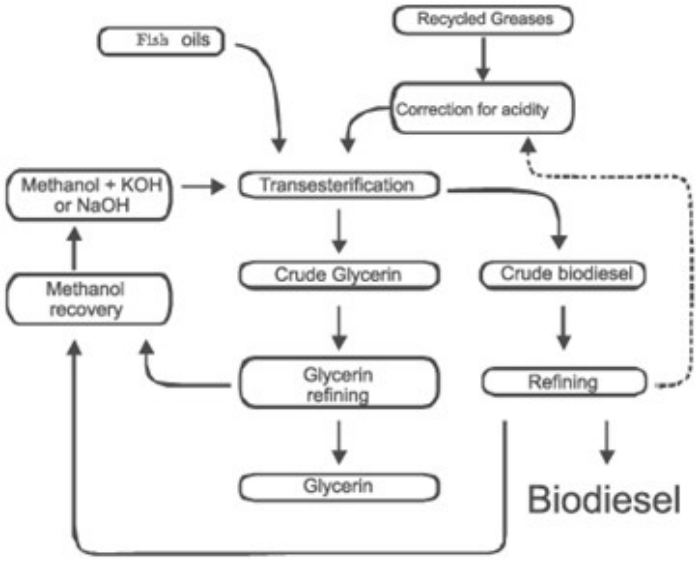


Figure 4 Bio-diesel preparation

2.1.1. Raw materials and equipment needed

- Fish oil and Red Devil Lye (NaOH)
- Methanol, Dropper and Measuring cups (with metric measures)
- Glass or stainless stirrers and Spoons
- Rubber gloves, safety glasses and Plastic apron
- Heat bath, Physical balance and Thermometer
- HDPE container, Iodine flask and Conical flask
- Scrubber, Aluminium pan, Beaker, Funnel and Filter
- Watch glass, Redwood viscometer and Cleveland cup apparatus

2.1.2. Trash fish collection and lipid extraction

The dead and trash fishes (figure 5) were collected from the local fisheries harbor and aseptically transported to the laboratory. The lipid content of this trash fishes were extracted using direct steaming method. 10 kg of the collected fishes were washed thoroughly to remove sand and other unwanted materials. The scales were removed by scrubbing and the fishes were cut open to fetch the liver and visceral parts, whereas other parts such as head, tail and fins were disposed. The collected parts were taken in a muslin bag and put on a metal screen over an aluminum pan. Later it was cooked with steam in a retort at 70-80°C for 30 minutes for hand pressing [11-12]. Oil and water released in the form of press liquor was collected in a container and the water dehydrated during the steaming process released from the liver and visceral parts were mixed together. The oil was separated from the water by centrifuging at 2000 rpm for 15 minutes in a preparative clinical centrifuge, further dried with anhydrous sodium sulphate and separated from the dried material by filtering using a Butchner funnel. Then the filtered oil was kept in an air tight bottle at room temperature.

Figure 5 Collected trash fish

2.2. Purification of fish oil

The purification of the separated oil was carried out by the methodology as follows.

2.2.1. Degumming

50 gm phosphoric acid was added in 100 ml distilled water and stored in a reagent bottle. From that solution 0.25 ml was transferred to 100ml distilled water. 100 ml fish oil was heated thoroughly in an oil bath and 20 ml of 0.25% phosphoric acid was added and heated for 5 minutes in an oil bath (figure 6). Distilled water was added with the oil for washing and then transferred to a separating funnel for removal of water. Again the oil was heated and washed well with distilled water [13].

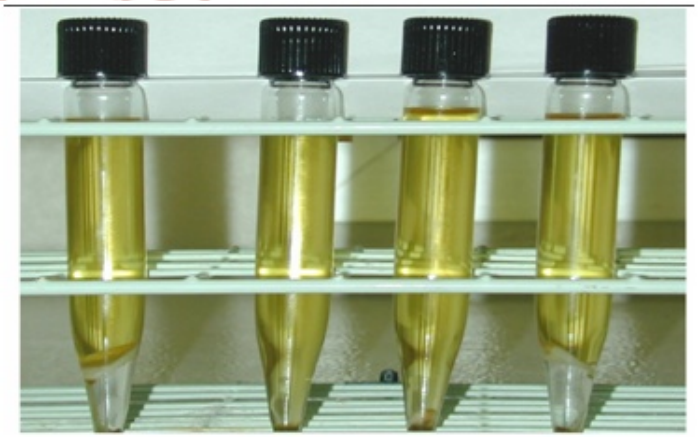


Figure 6 Degumming process

2.2.2. Neutralization

16gm of NaOH was added to 100ml distilled water. The oil obtained after degumming was heated thoroughly in an oil bath. 25ml of 4 N. NaOH was added so that soap was removed (figure 7). Then the oil was washed with distilled water. The oil and water were separated using a separating funnel. Again the oil was heated and 25ml of 0.4 N. NaOH was added again heated well and washed with hot distilled water [14].

Figure 7 Neutralization process

2.2.3. Drying

The neutralized oil was heated to 95°C, 6N sodium carbonate (4% vol / wt on oil) and 30% sodium silicate solution (4% vol / wt on oil) were added slowly to the oil with fast stirring. The temperature was then raised to 100°C by sparging with live steam and sparging continuously for 20-30 minutes. The oil was cooled to 95°C and allowed to settle for 30 minutes [15]. The still oil was washed with water and allowed to settle. The aqueous layer was run off. The stirred oil was then washed until neutral and dried under vacuum.

2.2.4. Deodorization

After drying process the oil was deodorized for 5 hours at 180-185°C and 3-5 mbar. During heating and cooling 50 mg / kg citric acid was added to the oil as 50% solution. Steam sparging was discontinued at nearly 110°C and replaced with N_2 sparging, while cooling the oil to < 40°C under high vaccum. The oil was left via a polishing filter, the deodorizer and was collected in a polypropylene container [16].

2.3. Preparation of standard biodiesel

The concept behind the production of Biodiesel through the chemical method is to reduce the complex lipids in to simple free fatty acids and further to combustible transesters. For this purpose, first fish oil was heated to warm the temperature and further reduced by alkyl methoxides or alkyl ethoxides which is a derivate of the reaction between alkali and alcohol.

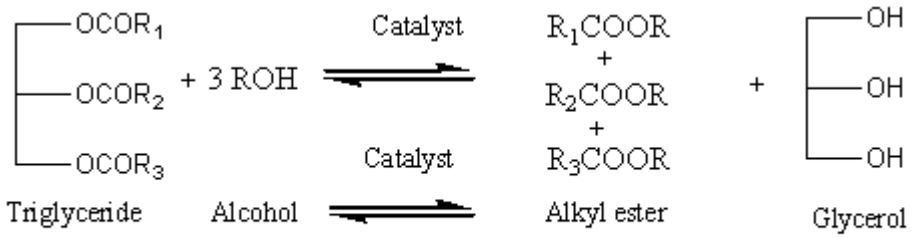
2.3.1. Steps to prepare the Biodiesel from fish oil

1. Measured 10ml of methanol (100% purity) and pour it in to a half liter of high density polyethylene (HDPE) container.
2. Lyre was added to the HDPE container and cap was tightly closed. KOH was used as lye (0.35g of 96% pure NaOH was used)
3. The container was shaken for few minutes by swirling it round rather than shaking it up and down, since, mixing the mixture gets hot until it should completely dissolved in methanol to form potassium methoxide.
4. 100 ml of hot (55°C) fish oil was poured in to the blends. Slowly poured the prepared methoxide from HDPE container in the warmth fish oil.

Trans-esterification also called **alcoholysis**, is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis. This process has been widely used to reduce the viscosity of triglycerides. The transesterification reaction is represented by the general equation, which is the key reaction for bio-diesel production [17].

Triglycerides are readily trans-esterified in the presence of alkaline catalyst (Lye) at atmospheric pressure and temperature of approximately 60-70°C with an excess of methanol. The mixture at the end of reaction is allowed to settle. The excess methanol is recovered by distillation and sent to a rectifying column for purification and recycled. The lower glycerol layer is drawn off while the upper methyl ester layer is washed with water to remove entrained glycerol. Methyl esters of fatty acids are termed as bio-diesel. The general trans esterification process is shown in equation (1) as below [18-19]:

RCOOR' + R"OH ⟷ RCOOR" + R'OH (1)
(Triglyceride) (Alcohol) (Mix of alkyl esters) (Glycerol)



Transeterification of triglyceride with alcohol

5. Blended for 20 minutes at lower speed using a hand held blender at 55°C.
6. Pour the blend mixture in to a 250ml conical flask and allow the material to settle down over night.
7. Next day separate the transparent top layer of the settled matter without disturbing the darker bottom layer of glycerin.
8. Store the bio diesel in air tight container to avoid oxidation.

Figure 8 depicts the laboratory process done for preparation of bio-diesel from the crude fish oil as below.

Figure 8 Laboratory process for preparation of bio-diesel

2.4. Standardization of biodiesel

2.4.1. Calculation of acid number

95% neutral ethyl alcohol, standardized 1N NaOH and phenolphthalein. A known quantity of sample was taken into a sample bottle. To this 500-100ml hot neutral alcohol and dimethyl ether were added in the ratio of 1:1 and titrated against 1N NaOH. Depending on fatty acid content and phenolphthalein was used as

indicator. The acid value was calculated using the equation (2) as shown below [20].

$$\textbf{Acid value} = \frac{M \times N \times 40}{sample\ \ weight} \qquad (2)$$

Where

Acid value = mg KOH or NaOH required to neutralize acid in 1gm of fat oil emulsifier.

M = ml of NaOH required

N = Normality of NaOH solution

40 Molecular weight of NaOH.

2.4.2. Determination of Flash point and Fire point

1. Fill the cleaned open cup with the given oil sample upto the standard filling mark.
2. The thermometer was inserted in the holder on the top edge of the cup and made sure that the bulb of the thermometer was immersed in the oil and should not touch the metallic part.
3. The oil sample was heated by means of an electric heater so that the sample of oil gives out vapour at the rate of 108°C per minute.
4. When the oil has given out vapour, introduced the glowing splinter and watched for any flash with flickering sound.
5. The burned vapour was blown out or expelled out before introducing the next glowing splinter. This ensured that always fresh vapours alone were left over the surface of the oil and the test was carried out accurately.
6. Continued the process of heating and playing the glowing splinter every 10 degrees of the rise in temperature from the first flash, till you heat the peak flickering sound and note the corresponding temperature as the flash point.
7. Continued the heating further after retaining the flash point and watch the point that was noted when the body of the oil vapour ignites and continued to burn at least for five seconds. The corresponding temperature is noted as fire point.
8. Repeated the test twice or thrice with fresh sample of the same oil until the results were concurrent.
9. Finally the observations were tabulated.

2.4.3. Determination of viscosity

1. The cup was cleaned and made sure the jet was free from dirt.
2. Closed the cup with a help of ball valve and filled the cup with given oil up to the tip of the hook gauge.
3. Inserted the thermometer in the holders and read the room temperature of oil.
4. Placed the cleaned standard receiver flask of 50cc capacity just below the opening of the jet and adjusted the flask such that the stream of oil coming out of the jet strikes the flared mouth since the direct flow of oil causing foaming.
5. Started heating the oil by switching on and stir the water continuously.
6. Stirred the water continuously up to the temperature of water and oil are same.
7. Cut off the heating process when the temperature of the bath reaches the required temperature of the oil.
8. Lifted the ball valve and started the stop watch simultaneously.
9. Stopped the stop watch when the oil just came up to 50cc mark in the flask and noted the time taken. This was called Red wood's seconds. Viscosity was calculated using the equation (3) as below [18-21]:

$$\textbf{Kinematic Viscosity} = (At - B/t) \qquad (3)$$

Where, A = 0.26

B = 171.5

t = Red wood's seconds

2.5. Determination of the quantity of Water and Sediment

100ml of well shaken Biodiesel sample was taken in a centrifuge tube. Centrifuged it at 10,000 rpm for 20 minutes. The volume of water and sediment get settled at the bottom was recorded; from this the percentage of water and sediment was noted [6].

2.5.1. Determination of Pour point

The pour point is the lowest temperature at which a fuel sample flows. The Pour point also has the implications for the handling of fuels during cold temperatures.

Procedure

1. The Biodiesel sample was cooled at a specified rate.
2. Then it was examined at 3°C intervals for flow.
3. The lowest temperature at which movement observed was noted.

Figure 9 and Table 3 shows the kirloskar diesel engine used for testing of oil and its specifications respectively.

FIG 5.10: Tested Engine

Table 3 Engine specifications

ENGINE TYPE	KIRLOSKAR
Number of strokes	4 strokes
Number of cylinders	Single cylinder
Type of cooling	Water cooled
Bore	80mm
Stroke	110mm
Displacement	552.9cc
Compression ratio	16:1
Rated power	3.7kw
Rated speed	1500rpm

3. RESULTS AND DISCUSSION

Nowadays, fishing is one of our most important industries which always try hard to increase the production of fisheries. In fact, many recent studies have been interested in the valorization of fish-waste. The one that has received the greatest attention is the synthesis of a biofuel that meets the security of supply criteria: response to local development needs ensuring the reduction of the production of CO_2, the main greenhouse gas emissions. Biofuel is an alternative fuel for diesel engines. It can be used in pure form (B100) or may be blended with petroleum diesel at any concentration in most injection pump diesel engines. Research in this field is managed in order to improve the process of converting vegetable oil or animal fat into biodiesel. That is usually produced by different processes. The fuel properties of the prepared bio-diesel from the waste fish and comparison of the properties with the already existing bio-fuels are reported below in the Table 4 and Table 5 respectively.

Table 4 Fuel properties of biodiesel from fish oil

Fuel Properties	Unit	Analysis results
1. Acid Number	mg KOH/gram	0.33
2. Flash Point	$^{\circ}$C	120°C
3. Fire Point	$^{\circ}$C	140°C
4. Viscosity	@40^{0}C CST	4.6
5. Water and Sediment	Vol %	0
6. Pour Point	$^{\circ}$C	3°C

After the transesterification process, viscosity and density gets reduced and hence, the various properties of the bio-diesel achieved after the transesterification process is as mentioned below.

Table 5 Bio-diesel properties (prepared from various oils) and diesel properties

PROPERTIES	FISH OIL	REFINED SUN-FLOWER OIL	JATROPHA OIL	RUBBER SEED OIL	SOYABEEN OIL	DIESEL
Density gm/ cc @ 30 ºC	0.9301	0.8943	0.8800	0.8740	0.8850	0.8359
Net Calorific value (kJ/kg)	40150	41465	38450	36500	39760	42500
Kinematic viscosity@40ºC (CST)	4.6	6.98	5.65	5.81	4.08	3.9
Color	Golden Yellow	Light Yellow	Brown	Light Brown	Pale Brown	Light Brown
Flash Point ºC	240	140	170	170	69	56
Sulphur content %	0.14	0.02	0.15	0.07	0.048	NIL

4. CONCLUSIONS

The concept of waste recycling and energy recovery plays a vital role for the development of any economy. The conclusion of the project work is that the bio-diesel obtained from the fish oil when blended with diesel gives a satisfactory performance and it can be used in present day without any modifications in the engine. Moreover, there was a reduction in engine noise which was due to uniform and complete combustion. All these factors will result in the reduction of the dependence on petroleum fuels in the coming years of its scarcity and unavailability. Making our country self-dependent on fuel and have an economical up liftment. Ultimately, bio-diesel prepared from fish oil is neither a god nor a king. It is just an excellent tool for real sustainable development and a good alternate fuel for the conventional diesel in the predicted times of its scarcity and unavailability.

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