Production and characterization of biodiesel from Mackerel fish oil

Pavan Pujar, B. K. Venkanna

Abstract— Mackerel Fish oil was used as the raw material to produce the biodiesel in this study. The raw oil (RO) was collected from discarded fish products. This oil was filtered and heated to 110^0C and made it moisture free. The filtered and moisture free RO was transesterified to produce biodiesel. The experimental results showed that oleic acid and lauric acid were the two major components of the fish oil biodiesel (FOB). Palmitic acid and linoleic acid were found approximately same in the quantity. The fuel properties kinematic viscosity, flash point, fire point, specific gravity, calorific value, cetane number, density, acid value, saponification value, iodine value, cloud point, pour point, ash content, copper strip corrosion, carbon residue, American Petroleum Institute (API) gravity were determined for FOB. A comparative study of the properties was carried out with RO and Neat diesel (ND). It was found that cetane number was 59 for FOB which was more than RO, which showed 57. Blends (B20, B40, B60, B80: example: B20: 20% FOB + 80% ND) of FOB and ND were prepared on volume basis and comparative study was carried out with ND and FOB.

Index Terms— Blends, cetane number, fish oil biodiesel, Mackerel fish oil, neat diesel, properties, raw oil.

1 INTRODUCTION

BIODIESEL is an alternative fuel derived from a verity of fatty acid methyl ester producing processed vegetable oils, animal fats or waste cooking oil [1], [2], [3], [4], [5]. It is described as an alternative fuel which improves environmental conditions and contributes to gaining energy sustainability [6]. The use of blends with 2 – 30% ND fuel does not require any modifications of the engine. In some cases minor modifications are required for the use of 100% pure biodiesel. The combustion properties of the biodisesel are also very close to those of additive [8]. Cultivated land is generally too limited to grow enough seed-oil plants, such as rapeseed, soyabean, sunflower, and peanut, among others, for biodiesel production, particularly in countries with high population density like India. In addition, used cooking oil collected from restaurants and homes is neither a stable nor continuous source of raw material for biodiesel fuel. Algae grown in aquatic systems have also been considered as renewable sources for biodiesel production, but the discussion in the literature is limited in comparison to that of land-based oleaginous plants [9].

Bastianoni et al. [10] argued that macro algae could be considered a good source for biodiesel production if oil extraction methods could be improved. They found that oil extraction from macroalge is not profitable with using existing methods of oil yield extraction. This means that the production cost of the biodiesel from algae is generally higher from other land-based biomass such as rapeseed or sunflower oil, although the former source can bear higher oil yields.

Mrad et al. [11] produced biodiesel from fish oil industrial residue and ran this biodiesel and its blend in a single cylinder, air cooled, direct injection diesel engine. The biodiesel from fish oil industrial residue was produced by catalytic cracking. Their results showed that the brake thermal efficiency of the fish oil biodiesel was slightly higher than that of diesel. The biodiesel and blend emitted less HC, CO and particulate matter but slightly more NOx than diesel. Investigator [11] concluded that the fish oil industrial residue biodiesel produced by catalytic cracking is viable substitute for diesel fuel.

Cherng –Yuan Lin et al. [12] reported as the biodiesel from marine fish oil had much lower peroxide value and grater in the rate of peroxidation with the increase in the time that it was stored than had the biodiesel from waste cooking oil. The investigator [12] also reported as the biodiesel from the soapstock of marine fish found to have larger cetane index and carbon residue and a lower flash point and distillation temperature than those of biodiesel from waste cooking ol.

Although there is great potential for the use of FOB as transportation fuel or as a power source, research into the fuel properties of FOB is rather limited [12]. This present study is focused on the production of biodiesel from Mackerel fish oil followed by the fatty acid composition determination and determination of properties of pure FOB and blends.

2 MATERIALS AND METHODS

2.1 Pretreatment of RO

Total eleven litres of RO was collected, filtered to remove solid impurities followed by heating to 110^0C and made it moisture free.

2.2 Determination of free fatty acids

Investigator [15] reported that direct preparation of biodiesel without careful considerateon of free fatty acid (FFA) will hamper the process. Pure, moisture free RO was subjected to the determination of FFA. 10 ml of RO was mixed with 50 ml of isopropyl-alcohol and five drops of 0.1 normal sodium hydroxide solutions and titrated against 0.1 normal sodium hydroxide solution using phenolphthalein indicator.

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2.3 Biodiesel production

Eleven litres of RO was used for the production of biodiesel. A chemical reaction process was adopted for the production of biodiesel from pretreated RO. Transesterification is the processs of reacting a triglyceride with an excess of alcohol in the presence of sodium hydroxide as a catalyst to produce fatty acid esters and glycerol. Triglycerides are first reduced to diglycerides then diglycerides are reduced to monoglycerides and finally monoglycerides produce fatty acid esters. By this reaction the viscosity gets reduced considerably. For transesterification initially methoxide was prepared from the reaction between three litres of methanol and fifty-nine grams of sodium hydroxide, simultaneously RO was heated at 60^0C in transesterification chamber and methoxide was made to react with this. Reaction was carried out for two hours and samples were taken to ensure the settlemet of the reaction by-product glycerol. The products of the reaction were kept for nineteen hours for the complete settlement of the glycerol. Methyl ester was then separated from the glycerol and circulated to a different chamber for washing. Warm water at 50^0C was used for washing and washed water was fed to determination of pH. Washing was continued till pH of the washed water becomes equal to the pure warm water. This process was followed by heating the biodiesel to 110^0C and made FOB moisture free.

2.4 Analysis of fuel properties

The weight properties of the composition of the saturated and unsaturated fatty acids were analyzed for the biodiesel by a gas chromatography (GC). The physical and chemical properties such as kinematic viscosity (IS: 1448 [P: 26]), flash point and fire points (IS: 1448 [P: 21]), density (IS: 1448 [P: 32]), specific gravity at 15^0C (IS: 1448 [P: 25]), calorific value (IS: 1448 [P: 6]), pour point (IS: 1448 [P: 10]), cloud point (IS: 1448 [P: 10]), ash content (IS: 1448 [P: 4]), copper strip corrosion (IS: 1448 [P: 8]), carbon residue (IS: 1448 [P: 8]), cetane number for both RO and FOB were determined from their respective iodine and saponification values.

3 RESULTS AND DISCUSSION

3.1 Production process of biodiesel

The total moisture content in the RO was found to be 0.3427% which was well below 3% as prescribed by the quality specifications [15]. FFA was found 1.8894%. Single step process was carried out for the production of biodiesel and yield was 75%.

3.2 Relative compositions of fatty acid contents

The relative weights of the compositions of FOB and standard sample of fatty acids were analyzed and composed in table 1. It was found that fatty acids of FOB composed of 0.55 wt. % of mysteric acid (C14:0), 4.08 wt. % of palmatic acid (C16:0), 1.73 wt. % of stearic acid (C18:0), 12.08 wt. % of oleic acid (C18:1), 4.25 wt. % of linoleic acid (C18:2), 1.39 wt. % of linolenic acid (C18:3). It is compared to the fatty acid compositions of commercial biodiesel from waste cooking oil and biodiesel from salmon oil. Commercial biodiesel composed of 47.51 wt. % of oleic acid (C18:1), 24.83 wt. % of linoleic acid (C18:2), 4.97 wt. % of linolenic acid (C18:3) and 3.77 wt. % stearic acid (C18:0) as shown in table 1. The commercial biodiesel was produced

TABLE 1
RELATIVE COMPOSITIONS OF FOB IN COMPARISON WITH THE COMMERCIAL WASTE COOKING OIL AND BIODIESEL FROM SALMON OIL

Fatty acids	Fatty acid composition			
	CS	FOB	WCO	SOB [13]
Myristic acid	C14:0	0.55	0.54	5.08
Palmitic acid	C16:0	4.08	14.18	15.39
Stearic acid	C18:0	1.72	3.77	4.00
Oleic acid	C18:1	12.08	47.51	20.76
Linoleic acid	C18:2	4.25	24.83	3.78
Linolenic acid	C18:3	1.39	4.97	0.99

CS: chemical structure, WCO: waste cooking oil, SOB: salmon oil biodiesel

from waste cooking oil by transesterification reaction [12]. In comparison with the fatty acid composition of the commercial biodiesel, fatty acid composition of the FOB is simpler, both commercial biodiesel and FOB were having higher percentage of oleic acid (C18:1). In comparison with biodiesel from salmon oil which is composed of 5.08 wt. % of myristic acid (C14:0), 15.39 wt. % of palmatic acid (C16:0), 4.00 wt. % of stearic acid (C18:0), 3.08 wt. % of linoleic acid (C18:2) as shown in table 1. The fatty acid composition of FOB was more comparible with the fatty acid composition of the biodiesel from salmon oil than commercial biodiesel from waste cooking oil.

3.3 Properties of FOB and blends

Table 2 gives physical, chemical and fuel related properties of FOB and blends of FOB and ND. The kinematic viscosity at 40^0C, of FOB (B100) was found high compared to ND as shown in figure 1. The kimatic viscosity of the blends decreases with increase in the quantity of the diesel in the blend. B20 is comparable with the ND.

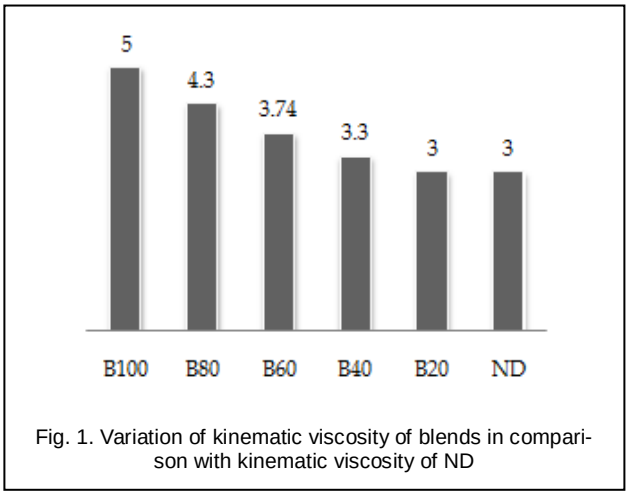

Fig. 1. Variation of kinematic viscosity of blends in comparison with kinematic viscosity of ND

The saponification values of FOB and RO are shown in table 2. These values directly affect the cetane number [14]. Cetane number of FOB is higher than the minimum limit set by bio-

diesel standards. The cetane number or cetane index is frequently used to indicate the quality of the compression ignition of diesel fuel. It is generally accepted that a larger cetane number for diesel fuel results in shorter ignition delay and duration of the combustion period, less occurrence of knocking and lower formation of nitrogen oxides [8]. The acid number of a biodiesel can be used to indicate the content of free fatty acids of the fuel. The marine fish oil biodiesel was found to have larger acid number than the commercial biodiesel produced from waste cooking oil [16]. According to 1S: 1448 [P: 32], range of density of diesel fuel is 820 to 880. Figure 2 shows the variation of the density. B20, B40, B60, B80 fall within the range but B100 is having bit higher value. That is increase in the percentage of biodiesel in the blend increases the density of the blend.

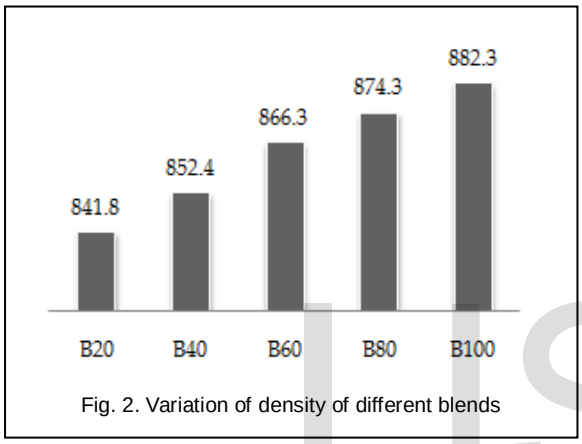

Fig. 2. Variation of density of different blends

After transesterification the specific gravity of FOB decreases because of separation of glycerol [12]. The variation of specific gravity of different blends is shown in figure 3.

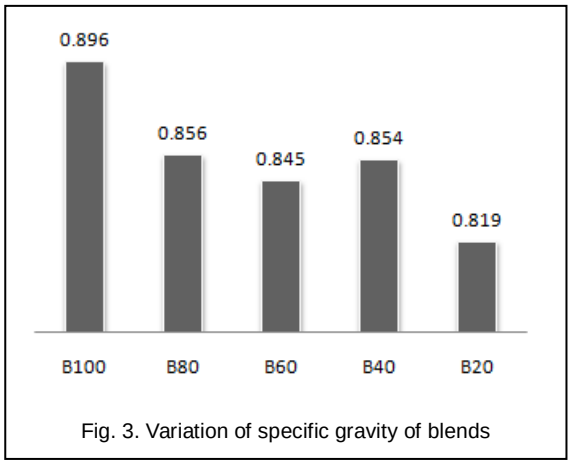

Fig. 3. Variation of specific gravity of blends

The quantity of carbon residue, released after the burning of biodiesel, which is found to be 0.37 (wt. %). It is reported [12], [17] that the higher level of oxygen content in the fuel results in a grater extent of complete combustion and thus less carbon residue produced after burning.

4 CONCLUSIONS

This study is summerized as follows

TABLE 2

PHYSICAL, CHEMICAL AND FUEL RELATED PROPERTIES OF BLENDS AND RO

Properties	B20	B40	B60	B80	B100	RO
Flash point (^{0}C)	66	74	78	82	162	290
Fire point (^{0}C)	68	78	80	86	164	294
Kinematic viscosity at 40^{0}C (cst)	3.0	3.3	3.74	4.3	5.0	--
Specific gravity at 15^{0}C	0.819	0.854	0.845	0.856	0.896	--
Calorific value (cal/g)	11206	10363	9709	9709	8997	--
Density (kg/m^3)	841.8	852.4	866.3	874.3	882.3	--
Cetane Number	--	--	--	--	59	57
Pour point (^{0}C)	--	--	--	--	1.5	--
Cloud point (^{0}C)	--	--	--	--	5.0	--
Ash content (%)	--	--	---	--	0.02	--
Copper strip corrosion	--	--	--	--	Not worse than 1	--
Iodine value	--	--	--	--	41.55	47.84
Saponification value (milligrams)	--	--	--	--	245.59	250.14
API Gravity (deg)	41.27	34.19	35.95	33.80	26.42	--
Acid Value	--	--	--	--	0.8	8.0
Carbon residue	--	--	--	--	0.37	--

The fatty acid composition of FOB contains more amount of oleic acid (12.08 wt. %), this improves the combustion quality of FOB and leads to less emissions.Cetane number of FOB is higher; this ensures the complete combustion of FOB. Kinematic viscosity of B20 is considerable when it is compared with ND and preheating of B100 can reduce the kinematic viscosity. Calorfic value of B100 is less and increases with increase in the amount of diesel fuel in the blend. Flash and fire points increase with increase in the amount of biodiesel in the blend.

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