Bahera (T. Bellirica) Biodiesel Production in Bangladesh, Characterization of Bahera Biodiesel and its Performance on a Diesel Engine

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Abstract

This paper represents the difference between conventional process and modified process in pyrolysis technology. In this experiment it was tried to lessen the fuel cost and energy consumption using a parabolic solar collector, some side glasses and some magnifying glasses to concentrate sun beams and magnify the solar intensity for heating up the opaque reactor. The energy consumption in the conventional process was obtained as 9900000 J. The energy consumption obtained in case of modified pyrolysis process using solar energy was 7290000 J. Hence, the energy consumption was lessened by modified process by 26

Index terms — pyrolysis; biomass oil; diesel; preheating.

1 Introduction

he world is presently confronted with the twin crises of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground-based carbon resources. The search for alternative fuels, which promise a harmonious correlation with sustainable development, energy conservation, efficiency and environmental preservation, has become highly pronounced in the present context. The technology of biodiesel production from vegetable oil feed stockis clearly defined, although the process economics may be improved by selection of lower cost feedstock, which does not have the pitfalls like limited supply potential and high oil costs (Azam et al., 2005). Rashid et al. **??**2008) has reported the use of Moringa oleifera oil as a possible source of biodiesel. The potential of Sesamum indicum seed oil was also studied for biodiesel manufacturing (Saydut et al., 2008). In continuation of our work on exploring new bioresources (Sarin et al., 2009), the study on potential of Terminalia bellirica (T. bellirica) as biodiesel resource is reported here.Biomass T. bellerica is a potential source of biodiesel which is transesterified to obtain biodiesel getting acceptance under the concern mentioned above.

T. Bellerica is commonly called as bahera under the family of Combretaceae. Deciduous forests are the main land of it. It is found in indian subcontinent in large proportion particularly in Bangladesh.

It is a large tropical deciduous tree, whose height is upto 30-40 m and 1.8-3.0 m in girth. Bark is colour of blue and ash grey containing numerous longitudinal cracks. It can be cultivated in almost all over Bangladesh though preferable in tropical and subtropical areas. It takes 6 to 8 years to mature and produce 500 kg fruits annually. The fruits are globular containing a hard thick shelled. Fruits are collected during winter which ripens at the end of rainy season. Chemically T. bellerica contains phenolics, sugars, gallics acid, belleric acid and ?-sitosterol. It has medicinal values for the treatment of liver and digestion disorders (Anand et al., 1997). The dry fruits of T. bellerica also possess potential broad spectrum antimicrobial activity (Elizabeth, 2005).It is also used as medicine to treat several illnesses, such as fever, cough, diarrhea, skin diseases and oral thrush. There is no statistics of the utilization of T. bellerica kernel as a resource for biodiesel inducement.

Many researchers have shown that (Pullagura et al., 2012) using raw vegetable oils for diesel engines can cause numerous problems. Vegetable oils have increased viscosity, low volality, cold flow properties and high cetane number causing injector cocking, piston ring sticking, and fuel pumping problem with deposits on engine. For this reason the vegetable oil cannot be used direct in engine instead of conventional diesel. However the above limitation can be greatly minimized by converting the vegetable oil into ester through esterification which is named as bio-diesel. Mature and raw fruits of T. bellirica were collected from local trees. The seeds were dried in the sun for about five weeks. The sun-dried all seeds. Then they are stored in a room at normal temperature. After drying, the weight of the seeds was about 11.2 kg. The kernels were separated from the fruits by scraping the fruit pulp (pericarp) manually and stored in an airtight container for experimental purpose. After drying, seed kernels were ground into powder by a ball mill. The weight of the dried powder was 1.44 kg that is the 12.8% of dried T. bellirica seeds. Then the oil was extracted from the dried and powdered meal with hexane using a soxhlet or solvent apparatus.

2 b) Oil Extraction

Thimble of soxhlet apparatus was filled with crushed kernel powder of T. bellirica seeds. Then, the upper part of the thimble was covered with thick paper and attached to the mouth of a round bottomed flask containing n-hexene as an extractive solvent. Some boiling chips were added into the flask to avoid bumping during heating. For completing the extraction through desired number of cycles, the refluxing was continued for 6 hrs. Then the solvent was removed by a rotary evaporator from mixing of oil and solvent. The separated oil was stored in a bottle. The amount of extracted oil is 29.86% by mass of the crushed kernel. c) Refining Process Crude extracted T. belerica oil contains impurities like free fatty acid (1.68%), moisture content (0.15%) and contaminants such as P (220 ppm), Ca (68 ppm), Mg (30 ppm), Mn (2 ppm) and Zn (16 ppm). The oil was refined by total degumming process (Zufarov et al., 2008), involving treatment with phosphoric acid and sodium hydroxide. The processed oil was dissolved in n-hexane and washed with distilled water. The pure oil was obtained by evaporation of hexane. Collected oil was found to have P (<10 ppm), Ca (5 ppm), Mg (2 ppm), Mn (<1 ppm) and Zn (2 ppm), free fatty acids (0.05%) and moisture (400 ppm).

3 d) T. Bellirica Methyl Esterization

Reactions were carried out in a 500 ml beaker, equipped with a thermometer and a mechanical stirrer. Methanol was poured to the beaker, followed by slow addition of sodium hydroxide catalyst (0.35% wt. of oil) with stirring. The stirring was continued till the complete dissolution of the catalyst (15 min). Desired quantity of T. bellirica oil was added and the reaction mixture was heated at 650C temperature. Progress of the reaction was monitored by TLC (Thin Layer Chromatography) at regular intervals. After completion of the reaction, the material was transferred to separator and both the phases were separated. Upper phase was biodiesel and lower phase was glycerine. Methanol from both the phases was distilled off under reduced pressure. Biodiesel layer was washed with hot water to remove the traces of glycerine, unreacted catalyst and soap formed during the transesterification and subsequently dried under reduced pressure. The product obtained (>98%) was sufficiently pure for testing. Statistical analysis of biodiesel synthesized from T. bellirica was done on the basis of experimental results in terms of ester conversion and yield calculated. Average yield and ester conversion were 98% and 98.5%, respectively, with standard deviation of 0.44% and 0.31%.

4 III.

Result and Discussion a) Quantity of Biodiesel production in Bangladesh In Bangladesh biodiesel from Bahera oil can be produced and the quantity of biodiesel can be calculated as follows: ( )A Year 013 2 b) Oil Characterization

The physico-chemical properties of T. bellirica oil vis-a-vis jatropha, sunflower, soybean and rapeseed oils is given in Table 1 which is the earlier reported data (Agarwal et al., 2007;Ramadhas et al., 2005) for comparison with T. bellirica. T. bellirica seed oil is a mixture of triglycerides of a variety of fatty acids. On the basis of GC analysis, six types of fatty acids were determined and quantified. These fatty acids showed vary in carbon chain length and in the extent of unsaturation. Fatty acid profile of T. bellirica seed oil was palmitic acid, 11.6%; stearic acid, 3.9%; ecosanoic acid, 0.8%, oleic acid, 61.5% and linoleic acid, 18.5% which was determined by GC agrees with the earlier literature on T. bellirica (Bera et al., 2007). T. bellirica seed oil is contain about 20% and 80% of the total saturated and unsaturated fatty acid composition respectively. It is very resemble to rapeseed oil in oleic and linoleic glyceride content and resemble to soybean oil in saturated acid glycerides. Physico-chemical properties of T. bellirica seed oil and other four oils are also given in Table 1. The table shows that the acid value of the crude T. bellirica oil and jatropha were higher (3.36 and 3.80 mg KOH/g) The density of T. bellirica seed oil is moderately higher (929 kg/m3) than other oils. The cloud point and pour point of T. bellirica oil and jatropha oil are (8 o C and 3 o C/ 6 o C), which is higher than sunflower, soybean and rapeseed oil. Oils which are more unsaturated are oxidized more quickly than less unsaturated oils as shown in the Table 1.T. bellirica seed oil oxidation stability is found to be 8.68 h. The presence of Gallic acid (3, 4, 5-trihydroxy benzoic acid) which acts as antioxidant (Bera et al., 2007). Unsaturation of oil is described by the iodine value and the determination of iodine value of vegetable oils and methyl ester of some oils from fatty acid composition as per AOCS Cd 1c-85 method has reported earlier (Petursson et al, 2002).

In this method, iodine value measured is about 85 (Table 1), which embraces dominantly octadecenoic triglyceride (oleic acid) vis-a-vis jatropha, sunflower, soybean and rapeseed oil. The iodine value is correlated with viscosity, which narrates that the viscosity decreases linearly with the iodine value increases (Abramovic and Kloufutar et al., 1998). The viscosities of vegetable oil were positively correlated with the amounts of monounsaturated fatty acid (i.e., viscosity increased with increase in fatty acid) and negatively correlated with the amount of polyunsaturated fatty acid, respectively (i.e., viscosity decreased with increase in fatty acid) which was reported by (Fasina et al., 2006). The values of viscosity of the respective vegetable oil methyl esters are reduce after transesterification process.

5 c) T Bellerica Methyl Ester Characterization

The synthesized methyl ester (Biodiesel) properties were determined and compared with Jatropha and Sunflower methyl ester as shown are in Table 2. The fuel properties of methyl esters synthesized ume XIII Issue XI Version I ( )A Year 013 2

In general, the properties of biodiesel meet the standard of all the important properties estimated. The acid value of T. bellerica methyl ester is 4.5544 mg KOH/g, higher than the estimated acid value 0.014 mg KOH/g. Also it is higher than the acid value of jatropha (0.48 mg KOH/g), sunflower (0.20 mg KOH/g) and soybean (0.15 mg KOH/g). The flash point of synthesized biodiesel is 162 0 C.The variation of flash point of Jatropha and sunflower methyl ester is in a specified limit. Where, the flash point of jatropha is higher in 1 0 C than that of T.bellirica. The value of kinematic viscosity of T. bellirica methyl ester at 40 0 C is 5.936 mm 2 /s, jatropha (4.40 mm 2 /s) and sunflower (4.10 mm 2 /s) are less viscous under the same temperature condition, which is reasonable for a biodiesel. Cloud point of it higher also in 1 0 C than that of those are compared in the table. The pour point of T. bellirica is 10C; the standard value of biodiesel is 0 0 C. the cetane number provides a measure of the ignition characteristics of diesel fuel. The table exhibits that the cetane number is slightly higher than standard of the respective value. The oxidation stability of fuel is 2.09 h, comparable with jatropha 3.23 h slightly more stable and 1.73 h less stable than T .bellirica. Fuel meets the free (.003%) and total (0.11%) glycerol content with the standard 0.02% for free glycerol and 0.25% for total glycerol which is lower than jatropha and sunflower. Density of fuel at 150C is 0.9077 g/cc, in line with the standard 0.88 g/cc. The key properties of biodiesel is boiling range, the last value of the range indicates the initial boiling point which for the fuel is 84-338 0 C.

6 ND: Not Determined

Table 3 exhibits the comparative study of T. bellirica methyl ester with diesel and standard biodiesel. Carbon composition of T. bellirica methyl ester (C 12 -C 22) is in reasonable range of standard biodiesel. It has the specific gravity 0.9077 which is higher than standard value of diesel and biodiesel experiencing a lower level of atomization. The flash point 162 0 C is too high than diesel which represents the higher combustion temperature requirement for proper and complete combustion due to the flash point close to the upper limit of the range of biodiesel. Cloud and pour point are 5 0 C, 1 0 C respectively directing the storage of T. bellirica biodiesel at a temperature above the standard value of diesel and biodiesel. The amount of carbon presence is not determined. Water is determined by volume percentage that is of about 0.07% which is also in a higher portion. Cetane number 53.4 is in the middle within the range of cetane number of standard biodiesel, which results a modified and reasonable hydrocarbon emission and noise levels accepting by the concerning authority. Also less sulphur indicates less sulphur related emission. The O 2 and H 2 amount in T. bellirica methyl ester are not determined. T. bellirica biodiesel was blended with diesel at 5%, 10%, 15% and 20% (v/v) dosages and tested for key physico-chemical properties as per IS 1460:2005 BS III Diesel specification and data are presented in Table 4. Blends of biodiesel with diesel were found to be completely miscible and gave stable mixtures. In table 4, it is noticed that by addition of biodiesel to diesel, the total acidity raises from 0.015 to 0.09 mg KOH/g. Kinematic viscosity and density values increases with increase in the concentration of biodiesel in the respective bends, while flash point of diesel gets marginally affected on blending up to 20% dosage, but remains within specified limit. Diesel water content was unaffected even up to 20% blending of T. bellirica biodiesel. The pour point of all the three blends was found in the range of 6 to 9 0 C meeting the specification limit. The diesel biodiesel blends were also found to be non-corrosive to copper. d) Performance evaluation of T. bellirica biodiesel and DF blends T. bellerica biodiesel was blended with diesel at 5% (BME 5), 10% (BME 10), 15% (BME 15) and 20% (BME 20) (v/v) dosages and its performance test was done in single cylinder peter diesel engine having the following specification. Figure 1 illustrates the variation of brake thermal efficiency with engine speed at load 55.6 N with diesel. From the figure it is seen that the brake thermal efficiency of engine increases with increase of engine speed. After reaching the maximum value, the efficiency of the engine also decreases. This is due to the fact that, initially with the increase of engine speed the torque produced by the engine increases, hence the efficiency also increases. But at higher rpm (>900) more amount of fuel is injected into the engine cylinder per cycle and due to higher engine speed these fuel doesn't get sufficient time to burn completely which reduce the efficiency of the engine. Hence the maximum efficiency obtained at 900 rpm.

Then the engine was run at the fixed rpm (900) and brake power was varied from 0.43 KW to 1.02 KW.

Figure **??** : Variation of brake specific fuel consumption with brake power (Engine speed 900 rpm) Fig. **??** illustrates variation of brake thermal efficiency of engine with respect to brake power. It presents that the efficiency of the engine increases with the increase in brake power. The maximum brake thermal efficiency of diesel fuel is 22.86% at brake power 1.02 KW. Higher brake thermal efficiency is due to better mixing of fuel with air which results in better combustion. At higher brake power (> 1.02 KW) more amount of fuel is injected into the engine cylinder which not completely burned. It causes higher BSFC and low Variation of brake thermal efficiency with brake power is illustrated in Fig. 3. From this figure it is observed that the brake thermal efficiency increases with the increase in engine load (brake power) for all fuels/ blends. It is interesting to note that compared to DF, BME 15 blends almost coincide with DF showing higher brake thermal efficiency than BME 5 and lower than BME 10 and BME 20. The maximum value of brake thermal efficiencies with BME 5, BME 10,BME 15, BME 20 blends and DF were found to be 20.29%, 19.81%, 17.94% , 18.8% and 19.73% respectively at brake power 1.02 KW. Figure **??** compares the fuel consumption of diesel, blends of BME at various brake power in the range of 0.43 KW-1.02 KW. It can be seen from the figures that the BSFC decreases with the increase in engine brake power. It is interesting to note that the BSFC is lower with all BME blends relative to DF. with brake power Figure4 : Variation of brake specific fuel consumption with brake power Brake specific energy consumption (BSEC) is lower with BME blends compared to DF. We know thermal efficiency is the reciprocal of fuel consumption and heating value. So that the brake thermal efficiency increases and BFSC decreases with the increase in engine load (brake power) for all fuels/blends. Thus, as the BSFC is lower with the BME blends the BFSC will also be lower with all BME blends the value of BFSC with BME 5, BME 10, BME 15, BME 20 blends and DF were found to be 0.40 kg/KW-hr, 0.41 kg/KW-hr,0.47 kg/kW-hr, 0.43kg/kW-hr and 0.413 kg/KW-hr respectively at brake power 1.02 KW. However, for the BME 5 blend, the fuel consumption was lower when compare to other blends of BME and DF, when the applied load was 1.02 KW. The DF100 had the highest specific fuel consumption. However, as the brake power of the engine increases the specific fuel consumption for all BME blends and diesel. A slight variation of exhaust gas temperature of various DF and BME blend is investigated in Fig. 5. The exhaust gas temperature of BME 5, BME 10, BME 15 and BME 20 are 82 o C, 89 o C, 93 o C and 88 o C respectively whereas diesel is 84oC. The reason is may be due to high auto ignition temperature for increase in exhaust gas temperature. Due to this, the heat that is generated due to the compression stroke gets shifted its direction toward the exhaust side and increases the exhaust gas temperature. BME20@900rpm BME20@730rpm BME20@1000rpm

Variation of thermal efficiency with brake power is illustrated in Fig. 6. From the above figure it observed that the brake thermal efficiency increases with the increase in engine load (brake power) for all fuels /blends. But relatively BME 20 at speed 900 rpm gives higher thermal efficiency because of proper combustion of fuels. Due to the fact that at higher speed and lower speed more amount of fuel is injected into the engine cylinder which is not completely burned so thermal efficiency lower. BME20@900rpm BME20@730rpm BME20@1000rpm

Figure **??** : Effect of BME on BSFC at low and high speed condition Fig. **??** represents the variation of BSFC with brake power. Thermal efficiency is the reciprocal of fuel consumption and heating value, So that the brake thermal efficiency increases and BSFC decreases with the increase in engine load (brake power) for all fuels/blends. It is observed. At speed 900 rpm BSFC is lower because a minimum amount of fuel is injected into the engine cylinder which is completely burned. So BSFC becomes lower. On the other hand at low and high speed condition engine remain idle so BSFC is higher than that of optimum speed. Fig. 8 shows the variation of exhaust gas temperature of various DF and BME blend. The exhaust gas temperature of BME 20 at speed 900 rpm is maximum. The reason is may be due to high auto ignition temperature for increase in exhaust gas temperature. At high or low speed the heat that is generated to the compression stroke is lower due to uncompleted combustion so less heat that is generated due to the compression stroke gets shifted its direction toward the exhaust side less.

IV.

7 Conclusions

This work discusses the production of BME in Bangladesh, characterization of BME and its blends and the influence of its blends on diesel engine performance. All results were compared with those of DF. The results of this work were summarized as follows: a) Bangladesh can reduce diesel import from foreign countries by 17% if Bahera is cultivated in the unused land of Bangladesh. b) Production of T. bellirica oil and its biodiesel was done and properties were compared with other vegetable oils, biodiesels and pure diesel. c) Compared to Jatropha oil, sunflower oil, Soybean oil and Rapeseed oil the viscosity, density, cloud point, pour point and oxidation stability are higher with T. bellirica oil. Rest of the physicochemical properties of tested T. bellirica oil was reasonable with those of other vegetable oil. d) The acid number, viscosity, cloud point, pour point, density and glycerin content of T. bellirica methyl ester were higher compared to Jatropha and Sunflower methyl ester. The cetane number and flash point were lowered by a limited value of those properties. e) The fuel properties of T. bellirica methyl ester were approximately similar to that of standard biodiesel. Whereas compared to pure diesel fuel properties of T. bellirica were varied in a considerable limit. f) T. bellirica biodiesel was tested in a single cylinder, 4-stroke diesel engine. Compared to DF the brake thermal efficiency and BSFC with DF and BME blends were almost unchanged. g) The results of above investigation revealed the possibility of T. bellirica as a potential source of biodiesel.

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Figure 1: Figure 1 :

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Figure 2: Table 1 :

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Property(units)	T.billerica		Jatropha	Sunflower
Acid number(mg KOH/g)	4.5544		0.48	0.20
Free fatty acid (%)	0.87		ND	ND
Flash point(0 C)	162		163	180
Viscosity at 40 0 C (mm 2 /s)	5.936		4.40	4.10
Cloud point(0 C)	5		4	4
Pour point(0 C)	1		0	ND
Cetane number	53.4		57.1	55.6
Oxidation stability(h)	2.09		3.23	1.73
Free glycerin(% mass)	0.003		0.01	0.02
Total glycerin(% mass)	0.011		0.02	0.02
Density at 15 C(g/cc)	0.9077		ND	ND
Boiling range(0 C)	IBP *	90	ND	ND
	10	280		
	20	284		
	30	286		
	40	286		
	50	290		
	60	296		
	70	304		
	80	338		
	84	338		

*[Note: * IBP : Initial Boiling Point ND: Not Determined]*

Figure 3: Table 2 :

3

Property		Diesel	Standard biodiesel	T. bellirica
Composition		Fatty acid methyl ester(c 10 -c 21)	Fatty acid methyl ester(c 12 - c 22)	Fatty acid met ester(c 12 - c 22)
Specific gravity(g/ml)		0.85	0.88	0.9077
Viscosity (mm 2 /sec)	at 40 o C	1.3-4.1	1.9-6.0	5.936
Flash point(0 c)		60-80	100-170	162
Cloud point (0 c)		-15 to 5	-3 to 12	5
Pour point (0 c)		-30 to -15	-15 to 16	1
Carbon (wt.%)		87	77	ND
Water(vol.%)		0.05	0.05	0.07
Cetane number		40-55	48-60	53.4
Sulphur(wt.%)		0.05	0.05	0.05
Oxygen(wt.%)		13	12	ND
Hydrogen(wt.%)		0	11	ND

Figure 4: Table 3 :

4

Test property	IS 1460 standard	Test method	Diesel	T. bellerica methyl ester blended with diesel at. %			
				5%	10%	15%	20%
Acidity, inorganic	Nil	IS 1448 [P:2]	Nil	Nil	Nil	Nil	Nil

[Note: Reported by S. Rakesh., Meeta S., Arif A. K.(2010).]

Figure 5: Table 4 :

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Engine type	4-stroke CI engine
Number of cylinders	one
Bore * stroke	80*110 mm
Cooling	water cooling
Compression ratio	16.5
Rated power	4.476 Kw@1800 rpm
Injection pressure	14 Mpa (low speed, 900-1099 rpm) 20 Mpa (high speed, 1100-2000 rpm)0
Injection timing	24 o BTDC

Figure 6: Table 4 :

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