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JATROPHA AND KARANJ BIO-FUEL: AN ALTERNATE FUEL FOR DIESEL ENGINE

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ABSTRACT

The bio-diesel was produced from non-edible oils by using bio-diesel processor and the diesel engine performance for water lifting was tested on bio-diesel and bio-diesel blended with diesel. The newly developed bio-diesel processor was capable of preparing the oil esters sufficient in quantity for running the commonly used farm engines. The fuel properties of bio-diesel such as kinematic viscosity and specific gravity were found within limited of BIS standard. Operational efficiency of diesel pump set for various blends of bio-diesel were found nearer to the expected efficiency of 20 percent. Bio-diesel can be used as an alternate and non-conventional fuel to run all type of C.I. engine.

Keywords: fuel, jatropha, karanj, diesel, engine, performance.

INTRODUCTION

Fast depletion of the fossil fuels and some times shortage during crisis period directs us to search for some alternative fuel which can reduce our dependence on fossil fuels. The agriculture sector of the country is completely dependant on diesel for its motive power and to some extent for stationary power application. Increased farm mechanization in agriculture thus, further increase requirement of this depleting fuel source. Many alternative fuels like biogas, methanol, ethanol and vegetable oils have been evaluated as a partial or complete substitute to diesel fuel. The vegetable oil directly can be used in diesel engine as a fuel, because their calorific value is almost 90-95 percent of the diesel. The technology of production, the collection, extraction of vegetable oil from oil seed crop and oil seed bearing trees is well known and very simple. The development in this respect also provides much ecological balance. Due to pressure on edible oils like groundnut, rapeseed, musterd and soyabean etc. non-edible oil of Jatropha curcas and Karanja (Pongamia Pinnata) are evaluated as diesel fuel extender (Racheman *et al.*, 2003). The oil is extracted from the seeds and converted into methyl esters by the transesterification process. The methyl ester obtained from this process is known as bio diesel. Bio diesel is renewable source of energy which can be produced locally by our farmers by growing oil seed producing plants on their waste lands, barren land which is eco friendly also. In order to propagate and promote the use of bio-diesel as an alternate source of energy in rural sector, the bio-diesel was produced from non-edible oils by using bio-diesel processor and the diesel engine performance for water lifting was tested on bio-diesel and bio-diesel blended with diesel.

MATERIALS AND METHODS

Considering the availability of Karanja, Jathropha and other vegetable oils in the local areas bio-diesel processor based on the trans-esterification process was designed and fabricated at College of Agricultural Engineering and Technology, Parbhani.

Process requirements

1) Revolutions of stirrer	:	500-700 rpm
2) Temperature of reaction	:	55-60^{0}C
3) Thermostat setting	:	52 +2^{0}C
4) Oil sample	:	15 kg
5) Methanol used	:	200 ml/kg of vegetable oil
6) KOH / NaOH	:	0.5-1.0 gm/liter of vegetable oil
7) Time required	:	1.0-1.5 hours
8) Sulphuric acid	:	1.0 ml/liter of vegetable oil (pre-treatment)

Almost all bio-diesel is produced by using base catalysed trans-esterification process, as it is the simple process and requiring only low temperature. The trans-esterification process is the reaction of a tri-glyceride (fat/oil) with an alcohol to form esters and glycerol. The alcohol reacts with the fatty acids to form the mono-alkyl ester or bio-diesel and crude glycerol (Peterson *et al.*, 1991). In bio-diesel production process, the main reaction is transesterification of vegetable oil (Shay, 1993 and Agarwal, 2004). The important factor that affects the tranesterification reaction is the amount of methanol and sodium or potassium hydroxide, reaction temperature and reaction time (Demirbas, 2003). A molar ratio of 6:1 is normally used in industrial processes to obtain methyl ester yields higher than 98% by weight, because lower molar ratio required more reaction time. With higher molar ratios conversion increased but recovery decreased due to poor separation of glycerol. (Srivastava *et al.*, 2000).

The reaction temperature influences the reaction rate and yield of ester. Therefore, generally the reaction is conducted close to the boiling point of methanol, 60 to 70^{0}C at atmospheric pressure. Further increase in temperature is reported to have a negative effect on the conversion (Srivastava *et al.*, 2000).

Most researches have used 0.5 to 0.1% NaOH/KOH by weight of oil for bio-diesel production (ma *et al.*, 1998). If acid value is greater than 1, more alkaly is required to neutralize free fatty acids.

The methyl ester conversion rate increases with the reaction time. Different researchers have reported different reaction times for the transesterification process. The reaction mixture was stirred for 90 min during transesterification process (Foidl *et al.*, 1996).

Vegetable oil (trans fatty acids) + Methanol + Sodium Hydroxide → Methyl Ester (Bio-diesel + Glycerine & Soap

$$\begin{matrix} CH_2 - OCOR \\ CH - OCOR \\ CH_2 - OCOR \end{matrix} + 3\ CH_3OH \xrightarrow{KOH\ /\ NaOH} 3\ RCOOCH_3 + \begin{matrix} CH_2 - OH \\ CH - OH \\ CH_2 - OH \end{matrix}$$

Products of the reaction are the bio-diesel and glycerol. The mixture was then allowed to settle. The glycerin phase is much denser than bio-diesel phase. The bio-diesel and glycerine can be gravity separated with glycerin simply drawn off from the bottom of the settling vessel. The bio-diesel is then purified by washing gently with warm water to remove residual catalyst or soap, dried, and sent to storage. This is normally the end of the production process resulting in clear liquid with viscosity near to petro-diesel.

Bio-diesel processor was fabricated as per the design consideration and need to produce bio-diesel on farm level. This processor has been used for preparation of methyl esters from raw Karanja oil and Jatropha oil.

Jatropha and Karanja seeds were collected from the local area. The chemical analysis of the seed sample was carried out. The oil was extracted using screw expeller in local market. The oil recovery percentage of Jathropha and Karanja by using local oil expeller was calculated. Oil was pre-heated to remove water contents at about 100^0C for 10 min. in cylindrical stainless steel tank. Potassium methoxide was prepared by mixing methanol and potassium hydroxide. The methanol was 99.6% and sodium hydroxide was 86% pure. For preparation of 1 liter of bio-diesel, 200ml methanol and 10gm of potassium hydroxide used. Methanol and potassium hydroxide were mixed to form potassium methoxide.

CH3 – OH (Methanol) + NaOH (Sodium Hydroxide) → $CH_3 - O - Na$ (Sodium Methoxide) + H_2O (Water)

The potassium methoxide was added to the pre-heated oil of Karanja and Jatropha. The mixture was stirred at 550 rpm for one hour. The temperature of reaction was maintained at 55^0C. The batch wise mixture of Karanja and Jatropha methyl esters were allowed to settle for 8 hours in the setting flask. Glycerin was heavier as compared to oil so it settles down while oil floats up. After 8 hours glycerin settles down while methyl ester floats at top. The Crude bio-diesel obtained from Karanja and Jatropha had some impurities which were then separated by using bubble washing method. The bio-diesel was again heated to remove moisture at about 100-110^0C temperature.

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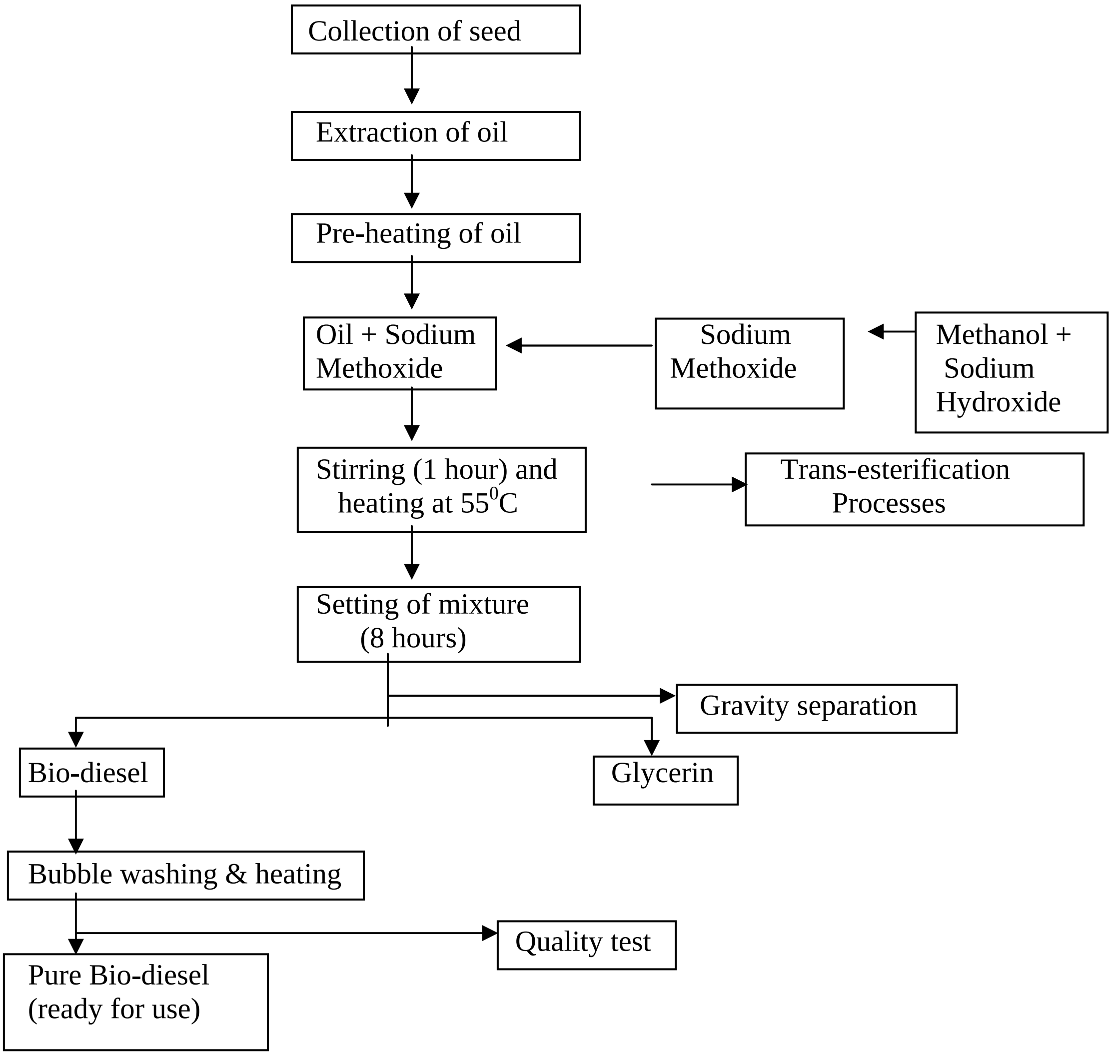

Jatropha, Karanja bio-diesel blends were used in diesel engine coupled water pump. The specification of the diesel engine used during the test run was as under:

Engine specification

Make	:	Field marshal
Horse Power	:	5 HP, 5.7 KW
R. P. M.	:	1500
Specific fuel consumption	:	236 gm/Kw-h
Cooling system	:	Water cooled

The bio-diesel prepared from Karanja, Jatropha and its blends with diesel as B_{20}, B_{40}, B_{60}, B_{80} and B_{100} by volume were used as a fuel to run diesel engine. This engine was run for water pumping from the sump well. Fuel consumption, engine rpm, water discharge /water output were measured for each blend. The standard instrumentation was used to measure the fuel consumption, engine rpm and water output. The engine performance was tested for water pumping using diesel and blends of bio-diesel with diesel on the diesel pump available at College of Agricultural Engineering and Technology, Marathwada Agricultural University, Parbhani.

The operational efficiency of pumping system was determined as the ratio of the power output to power input. The water horse power or output was calculated as (Sondhi *et al.*, 1994):

$$WHP = Q \times H / 75.8$$

Where, Q = Discharge (liter per second)
H = Total head (meter)

The discharge was measured volumetrically during the specific time for specific blends of karanja and Jatropha bio-diesel with petroleum diesel in the proportion of B_{20}, B_{40}, B_{60}, B_{80} and B_{100}.

Water Horse Power was calculated after considering suction delivery head and frictional losses for each blend of bio-diesel for water discharge. Input horse power was measured for each test run on the basis of consumption of fuel in specific time duration and on basis of Water Horse Power and 1 Horse Power, operational efficiency for each test run was calculated.

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RESULTS AND DISCUSSIONS

Bio-diesel processor was tested for production of bio-diesel from Karanja and Jatropha oil. Oil recovery percentage from Jatropha and Karanja seeds found to be 22.5% and 25%, respectively Karanja and Jatropha oil was processed in the bio-diesel processor. Base catalyzed trans-esterification process was selected for bio-diesel production. During bio-diesel productions following processor were adopted:

1) Pre-treatment 2) Trans-esterification 3) Settling and 4) Washing.

Trans-esterification reaction was carried out at 60^0C. Auto heating arrangement was provided in the processor therefore it was observed that the required temperature range of 60^0C was achieved within 10-15 min and then reaction temperature remained constant through out the trans-esterification process. During trans-esterification process the required revolution of the stirrer stirring rpm was to be maintained within the range of 550-700 rpm. In the trans-esterification vessel motor rpm of 1440 was stepped down to 570 rpm by using 12.5cm pulley. The stirrer was rotated by means of pulley and belt drive. The auto heating and stirring mechanism found to work as per the desired and estimated values. Increase in process temperature beyond 65^0C will cause formation of vapours of methyl alcohol, because it boils above 70^0C temperature and therefore reaction would be altered. Further increase in the speed of stirring would disturb the process by excessive splashing in the trans-esterification process. Therefore, the process parameters, such as constant heating at 60^0C and 550-700 rpm were recommended.

On the contray, speed of stirrer less than 550 rpm would affect the transesterification process. In this case the mixture will not be mixed together and mixing will be improper. Pre-treatment of oil was carried out for 2 hour and it was found that transesterification process was completed in 2 hour at 55^0C and stirring at 570 rpm.

The batch wise mixture after transesterification was allowed to settle for at least 8 hours in the setting flask. The rate of settling, amount of bio-diesel received and glycerin produced were analyzed. The rate of glycerin settling of was faster during first hour. The rate of setting slowed down afterward in each case. The total time required for setting was nearer to 8-8.5 hrs in all the mixture of transesterified Karanja and Jatropha oil. During the process of settling glycerin was settled down and bio-diesel floated up. Glycerin settled down because it was heavier than bio-diesel. The amount of glycerin and esterified Karanja and Jatropha oil obtained by this process are given in Table-2. From the table it is clear that the per liter bio-diesel recovery from Karanja and Jatropha oil was 910ml, and 908.30ml, respectively. Glycerin recovery per liter Karanja and Jatropha oil was 107ml and 106ml, respectively. The quantity of glycerin produced from jatropha was more than karanja. The bio-diesel recovery by using the developed bio-diesel processor was nearly 90%. Difference was observed in the amount of glycerin produced is due to the feed stock quality of processed oil. Jatropha oil was found more viscous than the Karanja oil and therefore glycerin level after transesterification was more in Jatropha than Karanja oil. After transesterification process, the viscosity of Karanja and Jatropha oil reduced. Reduction in viscosity will over come the problems associated with the direct use of vegetable oil as a viscous fuel in diesel engine. It's viscosity further reduced with increase in petroleum diesel amount in the blend. The values of kinematic viscosity are given in Table-1.

Table-1. Chemical properties of Karanja and Jatropha raw oil.

S. #	Properties	Karanja oil	Jatropha oil
1.	Acid value (mg/ KOH)	1.52	3.5
2.	Saponification value	185	195
3.	Iodine value	89	101.7
4.	Viscosity (mm^2/sec)	41.06	40.4
5.	Viscosity after TES	5.7	5.85
6	Specific gravity	0.909	0.9136

It is obvious from Table-1 that the kinematic viscosity 41.06 mm^2/sec of Karanja oil changed to 5.7 mm^2/sec. after transesterification process. Similarly, kinematic viscosity of Jatropha oil (40.4 mm^2/sec) changed to 5.85 mm^2/sec which was nearer to the viscosity of for petroleum diesel (2.60 mm^2/sec).

From the above discussion, it is clear that the newly developed bio-diesel processor was capable of preparing the oil esters sufficient in quantity for running the commonly used farm engines.

The engine test was conducted using specified blends of Karanja and Jatropha bio-diesel with diesel in order to study their effect on performance parameter. Engine rpm, fuel consumption and water discharge by the pump were measured and the results are given in Tables 3 and 4. The performance of engine was compared on bio-diesel blended fuel and pure petro-diesel. Fuel consumption and water discharge were 1352 rpm, 1.09 kg/hrs and 4.8 lps, respectively. When 100% bio-diesel of Karanja and Jatropha were used, engine rpm was 1340 against 1352 rpm with diesel. The marginal difference was observed, in the engine speed, which may be due to change in calorific value of the fuel.

When engine operated on 100% Karanja and Jatropha bio-diesel fuel consumption was observed to be 0.543kg and 0.684kg, respectively. Fuel consumption of diesel was 1.094kg. Fuel consumption of Karanja and Jatropha bio-diesel were 49.54% and 62.75% of diesel. Fuel consumptions for Karanja bio -diesel was found less than Jatropha bio-diesel. The less fuel consumption of bio-diesel as compared with diesel may be due to complete

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combustion of bio-diesel fuel in the engine since bio-diesel is called as an oxygenated fuel and it contains approximately 1% oxygen (Korbitz, 1998).

During water pumping test with 100 percent bio-diesel of Karanja and Jatropha, water discharge was found to be 3.175 lps and 3.046 lps against 4.8 lps with diesel fueled engine. Water discharge of pump operated on Karanja and Jatropha bio-diesel were 66.15 and 63.46 percent respectively of diesel fueled engine. Reduction in water discharge was observed to be 24-33 percent due to less fuel consumption. Engine test was carried out on Karanja and Jatropha biodiesel blending proportion of B_{20}, B_{40}, B_{60}, B_{80} and B_{100}. The observed values of engine rpm, fuel consumption and water discharge through pump are summerised in the Tables 5 and 6. The results showed that bio-diesel blends B_{20} and B_{40} gave comparatively better water discharge.

Water horsepower, input horsepower and operational efficiency of the engine were determined for specified blends of Karanja and Jatropha are presented in (Tables 5 and 6). The pump set efficiency was evaluated on the engine run in diesel fuel and found to be 12.93%. Operational efficiency on 100 percent bio-diesel fuel was calculated for Karanja and Jatropha bio-diesel as 12.86 and 9.88 percent compared with 12.93 percent on diesel. The operational efficiency of diesel pump set run on Karnaja bio-diesel was found to be more than Jatropha bio-diesel and slightly less with engine run on 100 percent diesel (12.93%). In case of Karanja blends, operational efficiency for B_{20} and B_{40} were found to be maximum 15.8% and 14.2 % respectively than values calculated for B_{60}, B_{80} and B_{100}. Maximum efficiency was due to the less IHP correlated with less fuel consumption. The maximum WHP was due to the more water discharge for B20 and B40 blends as compared to B60, B80 and B100 blends. The maximum operational efficiency in Jatropha biodiesel blends of B_{60} and B_{80} were found to be 10.7 % and 11.2 % respectively. The maximum operational efficiency was due to the less fuel consumption and IHP. The expected pump efficiency was about 20 per cent. The efficiency of pump set evaluated under field condition ranged from 5.32 to 12.81 percent as reported by Sondhi *et al.*, (1994). The efficiency of pump set using specified blends of bio-diesel was found in the range of 8.0 to 17.56 %. The maximum operational efficiency was found on B_{20} and B_{40} blends in Karanja and for B_{80} Jatropha blends (11.2 %).

Table-2. Biodiesel recovery in transesterification reaction.

Particulars	**Jatropha oil** (ml)		**Karanja oil** (ml)	
	Biodiesel	**Glycerin**	**Biodiesel**	**Glycerin**
Batch 1	920	105	915	103
Batch 2	905	110	910	108
Batch 3	900	103	906	110
Mean	**908.3**	**106**	**910**	**107**

Table-3. Performance of diesel engine for water pumping on Karanja bio-diesel.

Blending proportion	**Engine R.P.M.**	**Fuel consumption** (kg/hr)	**Water Discharge** (lps)
B20	1345	0.594	4.08
B40	1340	0.561	3.63
B60	1342	0.615	3.38
B80	1340	0.686	3.445
B 100	1340	0.543	3.175
B 0	1352	1.09	4.8

Table-4. Performance of diesel engine for water pumping on Jatropha bio-diesel.

Blending proportion	Engine R.P.M.	Fuel consumption (kg/hr)	Water Discharge (lps)
B20	1342	0.705	3.389
B40	1340	0.684	3.338
B60	1341	0.684	3.442
B80	1340	0.648	3.3389
B 100	1340	0.684	3.046
B 0	1352	1.09	4.8

Table-5. Operational efficiency of diesel engine for water lifting using Karanja bio-diesel and blends with diesel.

Blending proportion	W.H.P.	I.H.P.	Operational efficiency %
B20	0.2377	1.501	15.8
B40	0.201	1.412	14.2
B60	0.1833	1.523	12.02
B80	0.1805	1.66	10.83
B 100	0.1679	1.304	12.86
B 0	0.303	2.34	12.93

Table-6. Operational efficiency of diesel engine for water lifting using Jatropha bio-diesel and blends with diesel.

Blending proportion	W.H.P.	I.H.P.	Operational efficiency %
B20	0.1839	1.906	9.6
B40	0.1839	1.778	10.3
B60	0.184	1.71	10.7
B80	0.1839	1.64	11.2
B 100	0.159	1.608	9.88
B 0	0.303	2.34	12.93

CONCLUSIONS

- Bio-diesel processor is capable of producing bio-diesel from edible and non-edible oils by using base catalyzed transesterification process.
- The fuel properties of bio-diesel such as kinematic viscosity and specific gravity were found within limited of BIS standard.
- Operational efficiency of diesel pump set for various blends of bio-diesel were found nearer to the expected efficiency of 20 percent.
- Bio-diesel can be used as an alternate and non-conventional fuel to run all types of C.I. engines.

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