



Advantaged performance of tractor engine fuelled with dewaxed-degummed jatropha oil on long-run evaluation under loads

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ABSTRACT

A tractor engine was fuelled with blends of dewaxed-degummed jatropha oil and diesel up to 50:50 (v/v) ratio. Higher power was obtained with treated oil than raw oil for all fuel blends. The engine operated well up to the blend ratio of 30:70 with treated oil and then there was sudden drop in engine speed under overload conditions. It was also found that there was sharp power drop with treated oil for the blends above 20 per cent, and hence the blend ratio of 20:80 (treated jatropha oil: diesel) was optimized for long duration operation. Power increase of 11.8 per cent with treated oil over raw oil was obtained at rated speed with optimized blend ratio, in spite of 5.5 per cent power drop with treated oil over diesel due to lower calorific value of plant oil. There was 2.8 per cent increase in torque with treated oil than raw oil. Brake thermal efficiency reduced with the percentage of plant oil in the blend and there was 2.5 per cent reduction with treated oil over diesel. A saving of 4.3 per cent in specific fuel consumption was achieved by using treated oil over raw oil. While CO, CO₂, and HC decreased with blend ratio up to 25 per cent and then increased, NO and NO₂ increased with blend ratio. The SO₂ reduced with the increase in blend ratio due to the fact that plant oil contains no sulphur. There was no significant difference in smoke density between operation of engine with diesel and 20:80 blend at rated engine speed. Noise level and mechanical vibration had declining trend with the treated oil up to 25 per cent blend. There was no adverse effect with the operation of tractor engine up to 200 h during long-run evaluation with optimized blend (20:80). Operation of tractor with treated jatropha oil is encouraging in spite of slight hike (7.3%) in cost of operation with respect to decrease in CO, CO₂, HC, and SO₂. The study revealed that treated jatropha oil has promising potential as a fuel substitute up to 20 per cent blending in diesel.

Key words : Degumming, Dewaxing, Engine performance, Jatropha oil

Vegetable oil is one of the alternatives, which can be used as fuel in diesel engines either in the form of straight vegetable oil, or in the form of ethyl or methyl ester. The biodiesel, which can be generated from natural, renewable sources such as new or used vegetable oils or animal fats, may have the potential to reduce our nation's reliance on imported oil and to improve air quality. In addition, it is compatible with petroleum diesel fuel in compression ignition engines, meaning that an existing diesel engine can be fuelled by biodiesel blends.

Generally some problems are associated with the utilization of jatropha oil for running of conventional diesel engines. This includes injector coking, carbon deposits in the combustion chamber, filter gumming problems and excessive

wear on the rings, pistons and cylinder. The raw jatropha oil contains impurities loosely termed 'gums' and 'waxes'. These impurities are mixture of phosphatides, sugars, resins, proteinaceous components, and trace metals and they are present in the oil at approximately 2 per cent by weight. The one of the promising method of applying jatropha oil to diesel engine is dewax and degum the crude jatropha oil and mix it with diesel to form fuel blends. This fuel blend can have a viscosity low enough to allow a conventional diesel engine to utilize it. Hence the study aims to utilize the dewaxed degummed jatropha oil to the internal combustion engine of tractor.

The paper deals with the study conducted at biofuel laboratory in Central Institute of Agricultural Engineering, Bhopal for analyzing technical feasibility and economic viability of utilization of dewaxed-degummed treated jatropha oil with petro-diesel in internal combustion engine of tractor. It also deals with the optimization of treatment parameters for physical refining of jatropha oil.

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MATERIALS AND METHODS

Dewaxing was carried out before the degumming process. The raw jatropha oil was refrigerated at 10°C for certain duration. There duration of refrigeration was considered for the study, viz. 10 h (T1), 20 h (T2), 30 h (T3). The refrigerated oil was centrifuged for 30 minutes at 5000 rpm at room temperature, and then filtered to separate the precipitated wax from the oil. The observations were replicated thrice.

There are number of ways attempted by many researchers to physically modify the vegetable oils through dewaxing and degumming processes to make it most suitable for engine application, among which three methods were attempted for this present study. The physical properties of the degummed jatropha oil after the each process was studied and the best method, which led to appreciable physical properties was selected for the engine application. Three degumming processes were taken for the study, viz i) hot water treatment, ii) acid degumming, and iii) dry degumming.

The hot water treatment is one to the finest processes for degumming of plant oil for utilization in engines. The gums are hydrophilic and hence can be removed by hot water treatment easily. The de-waxed jatropha oil was heated up gradually up to 65°C. Later water of 1 per cent (T1), 2 per cent (T2), and 3 per cent (T3) (v/v) at 65°C was added. It was kept for 45 min and then filtered (McDonnell *et al.* 1995). Then the oil was centrifuged for 30 minutes at 5000 rpm at room temperature, and then filtered to separate the precipitates from the oil. The weight of oil taken and weight of gum separated to remove the gums. Then the oil was centrifuged for 30 minutes at 5000 rpm at room temperature, and then filtered to separate the precipitates from the oil. The weight of oil taken and weight of gum separated was noted.

The dewaxed jatropha oil was heated up to 75°C gradually. The oil was acidified with 0.2 per cent (T1), 0.6 per cent (T2), and 1.0 per cent (T3) (v/v) of 85 per cent phosphoric acid at 75°C, and then 2 per cent of water (v/v) was added. Then the oil was cooled for 45 minutes and then filtered to remove the gums. Then the oil was centrifuged for 30 minutes at 5000 rpm at room temperature, and then filtered to separate the precipitates from the oil. The physical



Fig 1 Tractor engine test set up under laboratory condition

properties of this degummed oil were studied.

A known amount of raw jatropha oil was taken and acidified by phosphoric acid. Then 1% (T1), 2% (T2), and 3% (T3) (w/w) bleaching absorbent was added. The observations were replicated thrice. The weight of oil taken and weight of gum separated was noted. The physical properties of this degummed oil were studied.

Jatropha oil was tested in tractor engine (35 hp) in test set-up at laboratory with different blend ratios with diesel, at different power ratings (Brown R H (1988), Anon (1999)). During the engine test, water inlet temperature, water outlet temperature, lubrication oil temperature, air inlet temperature, exhaust gas temperature, dynamometer water outlet temperature, dynamometer water inlet temperature, lubrication oil pressure, torque were measured for the set engine speed.

RESULTS AND DISCUSSION

Physical properties of raw jatropha oil

The basic properties of jatropha oil were measured. The viscosity and specific gravity of jatropha oil were measured before and after thermal cracking process. The effect of temperature on jatropha oil was also observed.

Table 1 Physical properties of raw jatropha oil

Property	Jatropha oil											Diesel
	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	100%	
Density (g/cc)	0.852	0.856	0.859	0.863	0.867	0.871	0.875	0.878	0.882	0.886	0.922	0.849
Viscosity (cS)	7.87	9.92	12.12	14.21	16.29	18.43	20.62	22.75	24.87	26.99	48.23	5.76
Flash point °C	83	92	101	112	121	129	137	146	155	164	252	75
Fire point °C	96	105	116	128	138	147	151	161	170	180	276	84
Cloud point °C	9	8	8	7	6	5	5	3	2	2	-4	10
Pour point °C	5	4	3	2	1	0	3	3	2	1	-15	6
Calorific value (MJ/kg)	47.1	46.7	46.4	46.0	45.7	45.4	45.0	44.7	44.4	44.0	40.6	47.4

Table 2 Physical properties of dewaxed degummed jatropha oil

Properties	Hot water treatment			Acid degumming			Dry degumming		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
Density (g/cc)	0.908	0.909	0.908	0.892	0.906	0.902	90.9	90.9	91.2
Viscosity (cS)	43.9	43.8	43.9	43.2	43.1	43.2	43.7	43.9	44.0
Flash Point °C	253	250	253	254	254	249	252	249	254
Fire Point, °C	276	275	274	275	276	274	276	274	275
Cloud Point °C	-4	-4	-4	-4	-4	-4	-4	-4	-4
Pour Point °C	-15	-14	-15	-14	-15	-15	-16	-14	-15
Calorific value (MJ/kg)	40.7	40.6	40.7	40.8	40.6	40.5	40.7	40.6	40.6
Cetane Number	49.5	50.6	49.9	49.8	50.1	49.8	50.4	50.9	49.8

Physical refining of jatropha oil

Dewaxing: The physical properties, viz density, viscosity, flash point, fire point, cloud point, pour point, calorific value, and cetane number were measured after dewaxing process. All the physical properties remained unchanged among the treatments of the dewaxing process, except density and viscosity. Treatment 2 performed well among the treatments based on the extent of reduction of density and viscosity of the jatropha oil after dewaxing process. Hence, Treatment 2 (20 hr duration) was optimized for the dewaxing process.

Degumming: The physical properties, viz density, viscosity, flash point, fire point, cloud point, pour point, calorific value, and cetane number were measured after degumming process. All the physical properties were remaining unchanged among the treatments of the degumming process, except density and viscosity. Treatment 2 performed well among the treatments based on the extent of reduction of density and viscosity of the jatropha oil after degumming process. Hence Treatment 2 (0.6% by volume of 85% phosphoric acid) of the acid degumming process was optimized and selected for the operation of engine.

Engine testing at laboratory

The tractor was tested with different blends of treated jatropha oil with diesel, viz 5:95, 10:90, 15:85, 20:80, 25:75, 30:70, 35:65, 40:60, 45:55, 50:50. The engine speed, torque and power were monitored during the engine test. The specific fuel consumption, smoke density, exhaust gas temperature, and exhaust constituents (O_2 , CO, CO_2 , SO_2 , HC) were determined for all the fuel blends.

Power and torque: The maximum power was attained at the 85 per cent of rated speed for all the blends investigated. The power was decreasing with the blend ratio due to the lower heating value of the jatropha oil compared to diesel. The power of treated jatropha oil was higher than that of raw jatropha oil for all the blends. This may be due to the viscosity reduction occurred by dewaxing and degumming process. However the power of both treated and raw jatropha oil was drastically reduced for the blends above 20 per cent. Hence the blend of 20:80 was optimized for long duration evaluation

Table 3 Engine performance at rated speed

Blend (%)	Raw JO			Treated JO		
	Torque (Nm)	Power (kW)	SFC (g/kWh)	Torque (Nm)	Power (kW)	SFC (g/kWh)
0 (Diesel)	350	20.0	312.8	350	20.0	312.8
5	339	19.4	317.2	346	19.7	315.3
10	333	18.9	326.4	340	19.4	320.6
15	330	18.2	326.1	337	19.2	324.1
20	322	16.9	348.2	331	18.9	333.4
25	267	16.0	396.1	280	16.0	375.5
30	259	14.1	430.2	265	15.1	415.8
35	246	13.7	450.2	258	14.7	437.3
40	232	13.3	486.1	250	14.3	464.8
45	218	11.8	512.8	242	13.8	506.7
50	209	11.0	561.7	233	13.3	520.9

of the engine. The power reduction with raw jatropha oil was 11.2 per cent compared to diesel, whereas that of treated jatropha oil was 6.7 per cent. Hence considerable improvement in power was achieved by the treated jatropha oil.

Specific fuel consumption: The SFC was computed for rated power, 85, 75, 50, 25 per cent of rated power and for no load condition for different blend ratios. The SFC for the maximum torque and SFC for the maximum power were also computed for different blend ratios. The SFC decreased with the power up to 85 per cent of rated power and then increased at 100 per cent load. The SFC also increased with the percentage of jatropha oil in the blend. During the over load condition the SFC increased further above the blend ratio of 25 per cent. The SFC increased drastically for all power ratings above the blend ratio of 20 per cent. The SFC of the raw oil was 23.5 per cent higher than diesel, whereas that of treated jatropha oil was only 9.6 per cent higher than diesel.

Brake thermal efficiency: The brake thermal efficiency increased with the power rating up to 85 per cent of rated power and then reduced slightly. The brake thermal efficiency of the engine reduced with the percentage of jatropha oil in

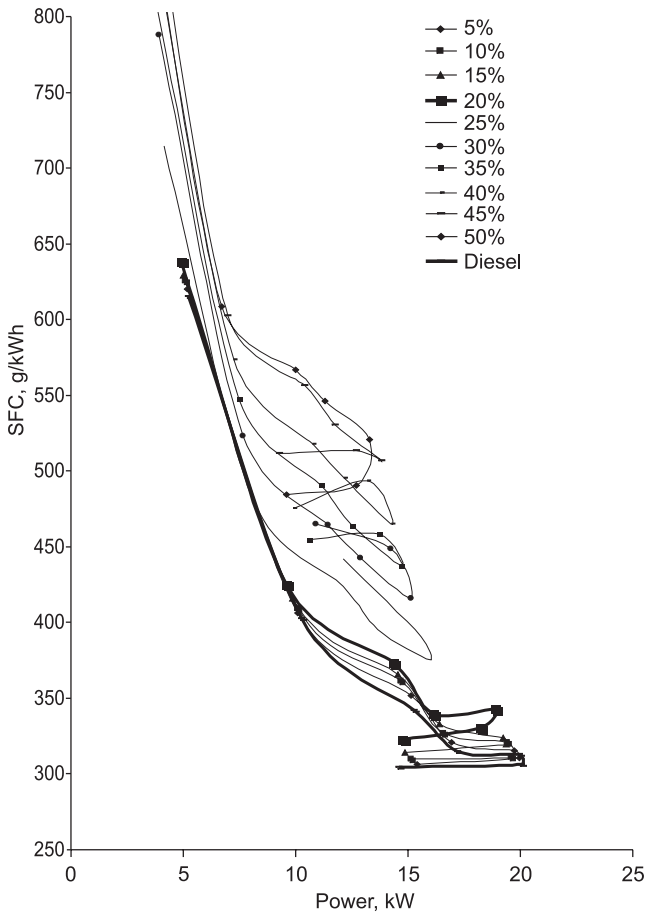


Fig 2 Relationship between p.t.o. power and SFC

the fuel blend. The brake thermal efficiency of diesel was observed as 27.7 per cent and that of 20:80 blend was found to be 27.1 which works only 2.5 per cent reduction by using the treated jatropha oil. But there was 9.7 per cent of reduction in brake thermal efficiency was observed while using raw

jatropha oil. Lower heating value of the jatropha oil is the cause of reduction in brake thermal efficiency.

Exhaust gas temperature: The exhaust gas temperature increased with the increase in blend ratio. It increased drastically for the blend ratios above 30 per cent. The exhaust gas temperature also increased with power ratings. The exhaust gas temperature ranged between 234 to 620°C for the optimized blend (20:80) from no load to rated power. The maximum exhaust gas temperature of diesel at rated speed was 602°C and that of treated jatropha oil was 620°C. Due to the higher viscosity of jatropha oil the ignition lack is occurring which results in poor ignition and higher ignition temperature.

Smoke opacity: The smoke opacity increased with the power rating. The smoke opacity slightly decreased with the treated jatropha oil up to 25 per cent blend, and then increased with the blend ratio. The reduction in smoke opacity in lower blend ratios might be due the oxygen content in the jatropha oil. The smoke opacity at rated power with diesel was observed as 74.8 per cent and that of treated jatropha oil was 73.5 per cent. Hence there is no significant difference in smoke opacity between operation of engine with diesel and treated jatropha oil. However the smoke opacity of raw oil was observed as 91.9 per cent at rated speed of engine.

Noise level: The noise level increased with the power rating. The noise level slightly decreased with the treated jatropha oil up to 25 per cent blend, and then increased with the blend ratio. The reduction in noise level in lower blend ratios might be due the proper combustion with the jatropha oil (Anon 1996, Anon 2000). The noise level at rated power with diesel was observed as 89.1 dB(A) and that of treated jatropha oil was 87.3 dB(A). Hence there is slight difference in noise level between operation of engine with diesel and treated jatropha oil. However the noise level of raw oil was observed as 91.2 dB(A) at rated speed of engine.

Mechanical vibration: The vibration level was measured

Table 4 Exhaust gas temperature and smoke opacity with treated jatropha oil

Blend (%)	Exhaust gas temperature (°C)							Smoke opacity (%)					
	No load	25% Load	50% Load	75% Load	85% Load	100% Load	Max. load	No load	25% Load	50% Load	75% Load	85% Load	100% Load
0 (Diesel)	178	204	256	320	430	602	610	58.1	60.3	66.8	69.5	72.5	74.8
5	201	213	265	329	447	610	613	59.3	59.4	65.7	67.9	72.4	74.2
10	206	220	272	336	454	612	615	59.5	56.7	64.5	66.8	72.3	74.0
15	211	229	279	343	462	618	620	59.6	54.6	63.7	65.1	72.2	73.6
20	234	238	291	355	467	620	630	60.1	49.8	58.7	62.4	72.0	73.5
25	256	249	312	376	478	621	634	60.2	45.8	53.8	61.9	72.9	74.8
30	267	284	328	392	508	625	635	60.4	44.7	51.8	59.9	74.8	82.0
35	294	300	333	397	526	627	638	60.5	43.9	49.7	54.7	80.6	87.0
40	305	315	349	413	558	629	645	60.7	41.5	48.1	52.8	82.6	89.4
45	309	334	370	434	585	635	650	60.7	40.9	46.5	49.7	84.1	91.8
50	320	345	409	473	603	638	651	60.8	40.0	46.1	48.6	88.3	92.6

at steering wheel, seat bottom and seat back. The mechanical vibration also showed same trend as noise level. The vibration level increased with the power rating. The vibration slightly decreased with the treated jatropha oil up to 25 per cent blend, and then increased with the blend ratio. The reduction in vibration in lower blend ratios might be due to the proper combustion with the jatropha oil. Hence there is no significant difference in vibration between operation of engine with diesel and treated jatropha oil. However the vibration of raw oil was observed higher than diesel and treated jatropha oil at rated speed of engine.

Exhaust emission: The CO, CO₂ and HC slightly decreased with the blend ratio up to 25 per cent and then increased. However the NO and NO₂ increased with the blend ratio. The increase in NO and NO₂ might be due to the higher temperature in the combustion chamber owing to higher viscosity of the jatropha oil. The SO₂ reduced with the increase in percentage of jatropha oil in the fuel blend. The reduction in SO₂ occurred due to the fact that the jatropha oil contains no sulphur.

Table 5 Exhaust emission with treated jatropha oil

Blend (%)	CO (ppm)	CO ₂ (%)	SO ₂ (ppm)	NO (ppm)	NO ₂ (ppm)	HC (ppm)
0 (Diesel)	4 123	12.3	21	198	350	486
5	4 015	10.8	20	211	358	438
10	3 915	10.5	18	221	389	430
15	3 829	10.1	17	226	393	421
20	3 841	9.2	15	239	400	409
25	3 828	10.6	12	280	430	397
30	4 205	10.7	11	283	432	392
35	4 537	10.8	10	291	440	381
40	5 211	10.9	9	292	448	380
45	5 727	11.2	8	297	452	375
50	6 245	11.2	8	319	461	371

Long duration test of tractor engine

The long duration test of tractor engine with the optimized blend shows that the results were similar to those of laboratory results. There was no reduction in power, no increase in SFC, no increase in exhaust gas temperature and no increase in smoke opacity as compared to those in laboratory. Hence the optimized blend (20:80) confirmed its ability to run the tractor engine without sacrificing power, torque, emission and other operational parameters.

Cost economics

The cost of operation of tractor by operation with blend of jatropha oil and petro diesel was calculated and compared with cost of operation by diesel. The cost of operation of tractor was calculated by using the procedure recommended by RNAM test code (Anon 1995). The cost of operation of tractor (35 hp) with 20 per cent blend of jatropha oil and

Table 6 Performance of treated jatropha oil in long duration test

Cumulative duration (hr)	Power (kW)	SFC (g/kWh)	Exhaust gas temperature (°C)	Smoke opacity (%)
10	16.1	352	473	72
20	16.1	342	462	73
30	16.0	352	465	72
40	15.9	350	468	71
50	16.0	337	462	78
60	16.1	333	459	79
70	16.1	332	460	75
80	16.1	343	458	74
90	16.0	341	456	76
100	16.1	338	457	72
110	16.0	339	469	74
120	16.0	341	470	69
130	16.2	342	492	81
140	16.0	352	468	74
150	15.9	338	469	71
160	15.8	341	468	71
170	16.0	342	465	73
180	16.1	345	482	71
190	16.1	336	463	68
200	16.1	334	465	68
Mean	16.0	342	468	73
Optimized blend (20:80)	16.12	340	467	72.0

diesel was ₹ 464.18 and cost of operation of tractor with pure diesel was ₹ 432.44. Hence, it is found that the cost of operation of tractor with 20 per cent blend of jatropha oil and diesel was 7.3 per cent costlier than the operation of tractor with pure diesel. On summarizing the operation of tractor with 20 per cent blend of jatropha oil and diesel is promising in spite of slight hike in variable cost.

CONCLUSION

The performance evaluation of tractor engine fueled with different blends of raw and treated jatropha oil revealed that the optimum blending ratio of treated JO and diesel is 20:80 without scarifying the power developed with nominal increase in specific fuel consumption. There was no adverse effect with the tractor engine up to 200 hours of operation during the long-run evaluation of 20:80 blend of treated jatropha oil and diesel. No problem in starting of the engine was faced during the operation of engine on 20:80 treated jatropha oil and diesel blend. These results revealed that treated jatropha oil has great potential as a fuel substitute up to 20 per cent blending in petro-diesel.

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