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Evaluation of Cotton seed oil ratios as alternative diesel fuel

A. I. Moussa   A. A. Nada**   A. A. El-Gwadi***

Abstract

Farm tractor was fueled with 5, 10, 15, 20, 30, 40 and 50 percent cottonseed oil/diesel fuel blends. The engine exhaust was analyzed using portable exhaust emissions testing equipment. These exhaust emissions were compared with emissions taken from engine fueled with 100 % diesel fuel. All fuels performed satisfactorily in a direct injection diesel engine, with the fuels derived from cottonseed oil giving somewhat lower pollution than diesel fuel. Performance and emission characteristics of the different fuels were comparable and the blended fuel gave lower smoke readings.

Introduction

The use of vegetable oils in diesel engines has received considerable attention lately due to the forcible depletion of world oil supplies. The use of vegetable oils in diesel engines dates back to 1900, when Dr. Rudolph Diesel used peanut oil as a fuel at the Paris Exposition (Nitschke and Wilson. 1965). Recent research has shown that hybrid vegetable oil fuels have improved fuel properties over straight vegetable oil and have performed well in diesel engines. The hybrid fuels produced greater thermal efficiency than diesel fuel (Goering, et al., 1982). According to Francese et al., (1992), the presence of oxygen atoms in the fuel assures more complete combustion in the engine. This reduces the carbon monoxide (CO), unburned hydrocarbons (HC) and particulate matter (PM) in the exhaust when comparing the same engine when fueled on #2 diesel fuel. Wagner et al., (1985) and Schumacher et al., (1992) reported similar findings. Faletti

*Senior Researcher in Agricultural Engineering Research Institute

** Researcher in Agricultural Engineering Research Institute

(1983) studied heat release rates from soybean oil hybrid fuels to determine why they produced higher thermal efficiency than diesel fuel. The hybrid soybean oil fuels were shown to have longer ignition delays than No. 2 diesel fuel. The longer ignition delay caused the hybrid soybean oil fuel to have higher levels of premixed burinig and a more efficient combustion process than diesel fuel. Cottonseed oil has also received attention as a possible alternative fuel.

The purpose of this investigation was to compare the effects of fueling diesel engines with different percentage of cottonseed oil and diesel fuel under variables investigation: (1) horsepower, (2) Specific fuel consumption and (3) engine exhaust emission levels.

Materials and Methods

The test was located at Tractor Test Station in Alexandria. The fuels tested were pure diesel fuel and blended cottonseed oil with diesel at 5. 10. 15. 20. 30. 40 and 50%. Each blend was prepared by using graduate cylinder (1 liter). For instance 400 cm^3 of cottonseed oil was mixed with 1600 cm^3 of diesel fuel to prepare the mixture of 20 % and put in additional fuel tank. time for fuel consumption at certain volume (37 cm^3) was measured. After data for a given fuel had been obtained the engine was shut off and the fuel was bled from the fuel system. The fuel filter on the test was changed for each new percentage of cottonseed oil and the engine was run long enough to remove all of the previous fuel.

Each oil percent was analyzed to determine. density. viscosity. heat generation and cetane no. These characteristics were evaluated in accordance with ASTM procedures for petroleum products. Viscosity was measured by viscosimeters at 21 °C. Oil was analyzed to its fatty acid content.

Horsepower determinations were made using a hydraulic dynamometer instrumented with a tractor 65 hp Jiangsu model JjS 650, four cylinders. The engine has a bore of 105 mm, a stroke of 125 mm, an engine speed of 2200 revolutions per minute (rpm) and a compression ratio of 16:1. The Engine speed was controlled by a throttle positioner. The side view of PTO dynamometer is illustrated in Fig. 1. The constant torque number is 10; maximum RPM 3500, maximum torque 1360 N.m and maximum power 220 kW.

The tractor was coupled to P.T.O dynamometer for appling varying loads according to the A.S.A.E. Standard of tractor PTO performance at rated engine speed.

Combustion efficiency was measured by a stack analyzer while thermal efficiency was assessed by the following formula.

$$\text{Thermal efficiency} = \frac{BHP \times 60 \times 60 \times 75}{F.c \times C.v \times 427} \times 100$$

Where:

BHP = break horsepower

F.c = fuel consumption, kg/h

C.v = Caloric value

Exhaust temperatures were also measured by a chromel alumel thermocouple. Torque were measured at rated speed and different loads.

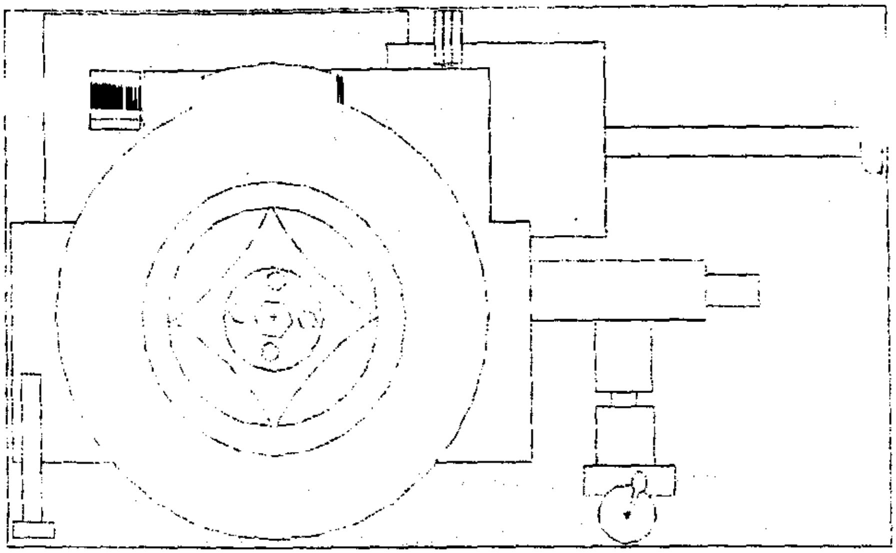

Fig. (1). The side view of PTO dynamometer.

Power was calculated by the following equation:

$$P = \frac{2 \times \pi \times N \times T}{C}$$

Where:

P = Horsepower

N = Revs per second

T = Torque in kg.m

C = 75 kg.m/sec

Soot emissions were evaluated gravimetrically by isokinetic sampling from a probe in the exhaust pipe. Air samples were withdrawn from the stack by a vacuum pump with a rate of 1.5 L/min. and the soot was collected on a membrane filter, which was further weighed, and its concentration expressed in mg/m^3.

For each set of blends exhaust measurements for carbon monoxide CO, nitrous oxides NOx, carbon dioxide CO_2, and O_2 at different load ratings were conducted using a stack analyzer. The emission stack measurement system consisted of a probe to sample gaseous emissions from direct reading combustion gas analyzer. In each test series CO, NOx, CO_2 concentration, excess O_2 percent, combustion efficiency and exhaust temperature were recorded. In the mean time particulate matter (PM) was sampled via another probe in the stack pipe. Air samples were withdrawn from the stack by a vacuum pump with a rate of 1.5 L/min. and the PM was collected on a membrane filter, which was further weighed, and its concentration expressed in mg/m^3.

The engine rated at 2200 rpm. Power, $N0_x$, CO, CO_2 and O_2, and engine exhaust temperature were measured. Baseline data were taken on diesel fuel before random fueling with the cottonseed fuel blends.

RESULTS

cottonseed oil in different percents dissolved readily in diesel fuel. The oil mixture was completely homogeneous with no sediment formation. Engine in this study performed well when fueled with cottonseed oil/diesel blends and no related fuel problems were observed during tests. No engine or fueling system modifications were made on the tractor to run on cottonseed oil/diesel. The engine has been left running for 8 continuous hours with no engine problems. The chemical analysis of the cottonseed oil/diesel at the different ratios was tabulated in table 1.

Table 1. Some properties of the fuel used in the tests at different percent

Fuel	Cetane no.	Viscosity, mm^2/s	Density, kg/L	Hg, kcal/kg
Diesel	47	2.7	0.84	10829
Cottonseed oil 5 %	46.7	4.25	0.844	10759
Cottonseed oil 10 %	46.48	5.78	0.847	10689
Cottonseed oil 15 %	46.22	7.33	0.851	10619
Cottonseed oil 20 %	45.96	8.86	0.855	10549
Cottonseed oil 30 %	45.44	11.94	0.861	10408
Cottonseed oil 40 %	44.92	15.02	0.87	10268
Cottonseed oil 50 %	44.4	18.1	0.875	10128

It is clear that increasing oil percent to diesel fuel increase viscosity and density; however, cetane no. and heat generation decreased. The vegetable oils are 7 to 9 % heavier than diesel fuel;contain only 94 to 95 % as much energy per liter; have viscosities 11 to 17 times higher than that of diesel fuel; and the ash content was found to be less than diesel Peterson (1983).

Fuel structure and characteristics have been shown to have great influence on engine performance and emission behavior. Ordinary diesel fuel is a mixture of hydrocarbon molecules of differing lengths and structures. These molecules contain no oxygen atoms. They may have double-bonded carbons that cause the chains to bend. The characteristics of the hydrocarbons affect how they burn. Cottonseed oil, on the other hand, consist primarily of triglycerides with fatty acid chains 16 to 22 carbons in length. Classification of the vegetable oil by its predominant fatty acid is shown in Table 2. Vegetable oils are mixtures of fatty acids molecules that contain carbon, hydrogen, and oxygen atoms. The fatty acids may be saturated, monounsaturated, or polyunsaturated. Length of carbon chains and number of double bonds in the fuel molecules affect low temperature suitability, spray formation and carbon residue Corinna (1998).

Table 2: Fatty acid composition of the cottonseed oil

Mystric (C_{16}:0)	Meristolic (C_{14}:1)	Palmitic (C_{16}:0)	Palmitolic (C_{16}:1)	Stearic (C_{18}:0)	Oleic (C_{18}:1)	Linoleic (C_{18}:2)	Linolenic (C_{18}:3)	Erucic (C_{22}:1)
1.4	0.1	23.0	2.0	1.1	22.9	47.8	0.3	1.3

Cottonseed oil consists of 26% saturated acids, 26% monosaturated and 48% polyunsaturated acid.

It is shown that cetane no. and heat generation for diesel fuel is higher than cottonseed oil at 20 % by 1.04 and 280 kcal/kg respectively, while viscosity of cottonseed oil at 20 % is higher than diesel fuel about 3 times.

Specific emissions analysis obtained at peak power and peak torque for the engine are reported in Tables 3.

Table 3. Exhaust emissions readings for engine at rated RPM (2200rpm).

Cotton seed oil. %	Max. Power, (kW)	N0x, (ppm)	CO, (%)	$C0_2$ (%)	O_2 (%)	Combustion efficiency, %
0	47.82	1735	406	6.4	11.1	75.9
5	44.42	1561	385	5	12.9	76.3
10	44.83	1701	376	5.7	12.2	77.3
15	44.6	1662	326	7.4	15.7	77
20	45.54	916	252	4.5	14	80.4
30	44.85	821	257	5.3	12.5	80.1
40	44.34	741	261	6.3	11.7	79.7
50	44.11	982	239	6.5	10.5	80.8

It has been shown from the previous table that the maximum power obtained for the pure diesel fuel was 47.8 kW, while it was dropped about 4.77 % for blend of Cottonseed oil at 20%. Increasing the percentage of cottonseed oil decrease the power in kW. Schumacher et al., (1992) reported a five percent drop in power for a 5.9 L direct injection turbocharged Cummins engine.

Exhaust emissions readings for a tractor 65 hp Jiangsu model JjS 650, four cylinders. engine at peak power (2200 rpm). NO_x emissions are reported in ppm. Although diesel fuel was nearly 13 % more NOx emissions than the 20 % cottonseed oil blend. Fueling engine on diesel fuel at rated power resulted in more ppm Carbon monoxide exhaust emissions than when the engine was fueled on a 20 percent blend of cottonseed oil with 80 % diesel fuel by 48.5 %. The Carbon Dioxide (ppm) emissions for the 20 percent blends was also lower 31 % than when the engine was fueled on diesel fuel. The O_2 (ppm) exhaust emission was higher 35 % on a 20 percent blend of cottonseed oil than diesel fuel when the engine was operated at peak torque. Fig 2.

Reduction of PM (soot) can be attributed to the lower aromatic and sulfur content of cottonseed oil. Aromatic content is widely known to contribute to PM formation Wang WG et al (2000). As shown previously, in case of cotton oil blend NOx emissions were lower than diesel oil, which is probably related to the lower exhaust combustion temperature 353 °C (at cotton seed oil 20 %) compared to 376 °C for diesel oil. Table (3) shows the combustion efficiency percents of diesel and cottonseed oils. It is evident that cottonseed oil revealed the highest percent of combustion efficiency (81.2%) at 40 % cottonseed oil compared to diesel 75.9 %. Specific fuel consumption for cottonseed oil at the percentage of 20 % is about 7 % higher than diesel fuel.

Table 4. Measurements for diesel engine at different percentage of cotton seed oil and diesel fuel under rated RPM (2200 rpm).

Blend	Diesel 100%	Cotton 5%	Cotton 10%	Cotton 15%	Cotton 20%	Cotton 30%	Cotton 40%	Cotton 50%
Fc_lit/h	13.32	13.32	13.32	13.32	14.17	13.32	13.59	12.33
SFC_cc/kW.h	279	300	297	299	311	300	310	294
Tg (°C)	376	354	362	279	353	320	319	336
Loss, %	24.1	23.7	22.7	23	19.6	20.3	18.8	19.2
Ex. Air. %	2.05	2.61	2.13	1.92	3.03	2.13	1.85	1.8
Combustion Efficiency. %	75.9	76.3	77.3	77	80.4	79.7	81.2	80.8
Thermal Efficiency, %	30.44	28.28	28.54	28.39	27.25	28.55	27.69	30.33
Soot, mg/m^3	188	48.5	49.1	48.7	47.8	48.8	49.3	48.2

All measured and calculated operating characteristics power, torque, fuel consumption and efficiency prove that when using these novel fuels there are only slight power and consumption disadvantages in comparison to diesel fuel.

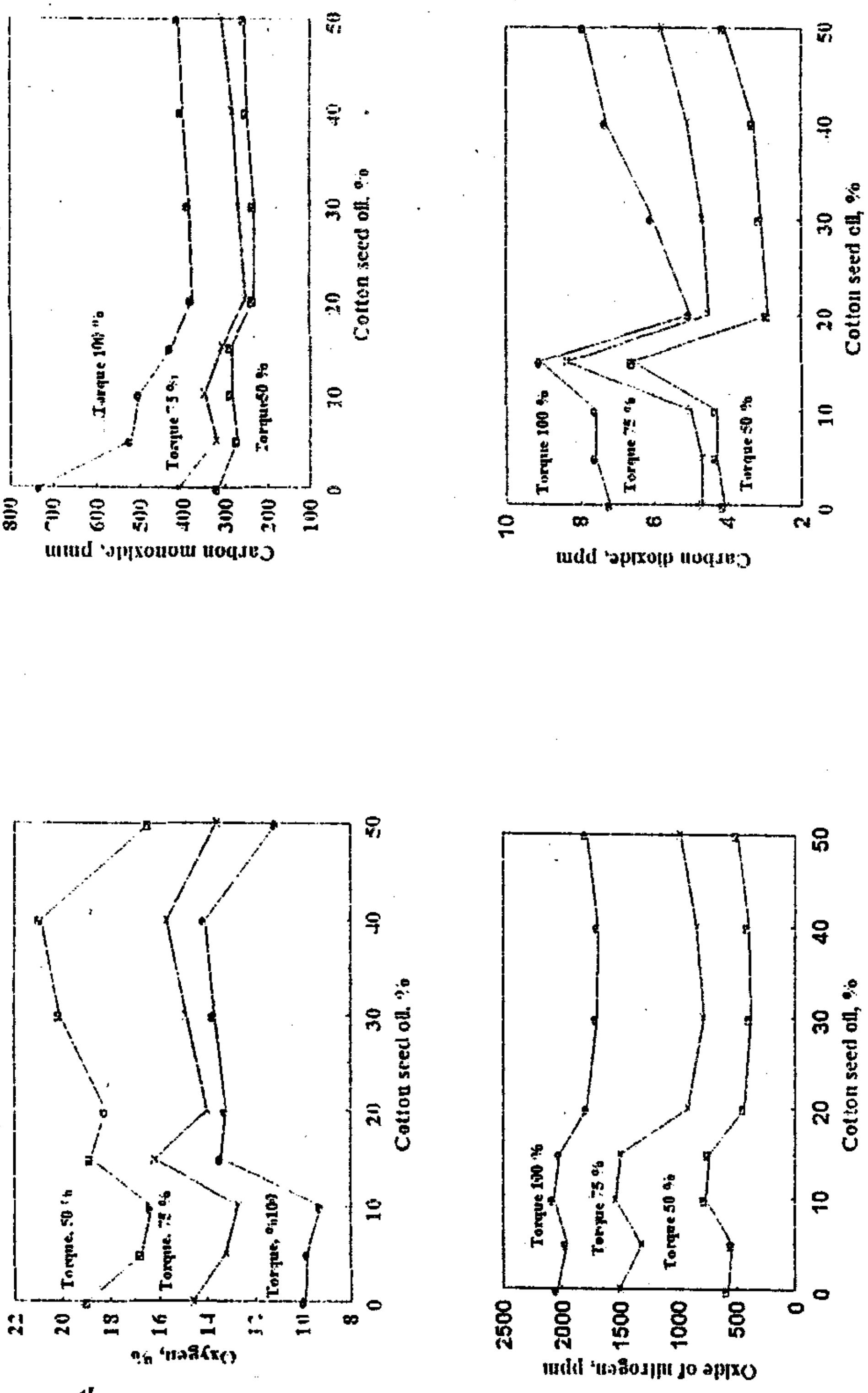

Fig.(1): Exhaust emission as affected by different cottonseed oil ratios

It can be seen that the seven different cottonseed oil blends gave thermal efficiency and exhaust gas temperature slightly lower than diesel fuel as a result of the lower heating values of the cottonseed oil compared to the diesel fuel, the specific fuel consumption increased as the amount of diesel fuel used was decreased. Since the efficiencies were essentially identical for all of the fuel blends, one would not expect substantial differences in the combustion behavior of the fuel shows, however, that there were indeed some differences in combustion behavior as the fuel composition changed.

CONCLUSIONS

The following conclusions were made based on the findings of the investigation:

1. The fueling of a compression ignition engine on cottonseed oil/diesel does not reduce the torque of the engine much when fueled with cottonseed oil at any ratio.

2. A compression ignition engine fueled on cottonseed oil/diesel developed approximately five to fifteen percent less power.

3. NOx, CO and CO_2 exhaust emissions tend to be lower when a diesel engine is fueled with a 20 % cottonseed oil/diesel blend as compared to 100% diesel fuel

4. O_2 exhaust emissions tend to be higher when a diesel engine is fueled with a 20 % cottonseed oil/diesel blend as compared to 100% diesel fuel

* The blending stock of 20% meets ASTM requirements and definitely showed good engine performance and exceedingly high soot reduction.

*cotton oil revealed the highest combustion efficiency, lower emissions of CO, NOx, PM compared to diesel oil and other biodiesel blends. In addition, torque and HP reduction and fuel consumption of cotton oil are very close to those of diesel oil. Besides, cotton oil is considered the cheapest type of oil in Egypt. On the other hand, a 20% blend showed minimal difference with respect to 40% or 60% blends and it is universally recommended as the most appropriate percent blend

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زيت بذرة القطن بديل لوقود الديزل

علي ابراهيم موسى   أنور ندا   عادل الجوادي**

تم استخدام زيت بذرة القطن بنسب خلط ٥ , ١٠ , ١٥ , ٢٠ , ٣٠ , ٤٠ , ٥٠ % مع الوقود الديزل. تم تحليل ناتج الوقود من أول أكسيد الكربون وثاني أكسيد الكربون والاكاسيد النيتروجينية ودرجة حرارة العادم وكفاءة الاحتراق باستخدام جهاز التحليل وتم مقارنته بناتج احتراق وقود الديزل. أداء المحرك مع جميع نسب الوقود منتظم. التلوث الناتج من احتراق الوقود مع جميع نسب الخلط للزيت مع الديزل أقل من ناتج التلوث الناتج من احتراق وقود الديزل

أوضحت النتائج أن خلط الديزل وزيت بذرة القطن أعطي نواتج عادم أقل خطرا على البيئة بينما قلت قدرة المحرك بنسبة ٤,٧ ? عن استخدام وقود الديزل فقط كما إن أكاسيد النيتروجين وأول أكسيد الكربون في حالة استخدام وقود الديزل فقط أعطت أكثر من ضعف المتحصل علية في المزيج) وقود الديزل وزيت بذرة القطن.

أعلى قدرة للمحرك مع الديزل ٤٧.٨٢ كيلووات أعطت نسبة كربون من عادم المحرك ١٨٨ ملليجرام/ متر مكعب بينما كانت أعلي قدرة للمحرك مع نسبة ٢٠ ? زيت بذرة القطن إلى ٨٠ ة? ديزل ٤٥.٥٤ كيلووات ونسبة كربون من عادم المحرك ٤٧ ملليجرام/ متر مكعب. تساوي استهلاك الوقود تقريبا في جميع الحالات.