Study on the Utilization of Coconut Oil as a Substitute for Diesel Fuel

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ABSTRACT

Research on the possibility of and the potential for utilizing coconut oil as a substitute for diesel fuel is one of the most interesting works being undertaken in many coconut producer countries. Efforts have been made to extend the uses of the coconut plant, which would not only solve the problem of the depressed price of coconut but also alleviate the energy situation in the countries concerned. The Agricultural Engineering Division of the Department of Agriculture in Thailand has undertaken research along these lines since September 1982. Work was initiated to look for new formulae for fuel based on coconut oil by mixing coconut oil with different oils or fuels, such as diesel, parafin etc., in different ratios. It was found that a mixture of coconut oil and kerosene in a ratio of 20:1 by volume gave more or less the same engine performance as with the use of diesel fuel in operating an internal combustion engine. Two single-cylinder water-cooled diesel engines were tested, one using standard diesel fuel and the other blended coconut oil, at no load, and driving agricultural machines such as water pumps and soybean threshers, etc. for more than 500 operating hours. After the test, the engines were dismantled, and the wear and condition of the main components, such as the injection nozzle, the piston and the rings, and the combustion chamber, etc. showed insignificant differences. Tests were also undertaken with locally designed vehicles called "farm trucks" with a three-cylinder diesel engine, travelling from the north to the south of Thailand – a total distance of 6,000 kilometres. No critical troubles occurred during the journey and the truck operated quite well even on mountainous roads. Although blended coconut oil with kerosene in a ratio of 20:1 by volume can be used as a substitute for diesel oil, there are still some aspects of the process which need to be further investigated, such as the high freezing point of coconut oil, the economic feasibility and long-run effects on engine components, etc.

INTRODUCTION

Although currently problems of fossil fuel scarcity and price seems to have been alleviated, difficulties encountered in the past have nevertheless made most countries aware of the necessity to look for "alternative" energy sources. In view of this, a number of research activities to determine the feasibility of deriving energy from natural sources such as the wind, the sun, water and agricultural products have been undertaken in different countries.

Certain studies undertaken in the past have revealed that some plant oils, such as caster oil and groundnut oil, could be used to run diesel engines. However, these oils were not economically feasible. Therefore no concerted effort was made to develop these alternative energy sources.

During the last three to four years, scientists and engineers of the Department of Agriculture of the Royal Thai Ministry of Agriculture and Cooperatives, found that oil from a plant called *Jatropha curcas linn* (commonly known as physic nut or purging nut) had a high potential as a substitute for diesel fuel, both from a technical and economic point of view. This renewed a great interest in exploring alternative energy sources from agricultural products, especially the coconut.

Since new technology has boosted the yield of coconut considerably, its production has become a surplus for the world market, with the result that the growers are getting a very low price for this commodity. The problem became critical during the last three years, especially for countries who were big suppliers of coconut, such as the Philippines. The Philippine government tried to solve this problem by encouraging research to expand and broaden the scope of utilization of coconut plant products. One of the significant efforts was a study to mix coconut oil with diesel oil for use in diesel engines.(1) The results were quite encouraging. The news of the study in the Philippines in 1982 motivated the "Marketing Organization for Farmers" of Thailand who were facing equally serious problems, and requested the Ministry of Agriculture and Cooperatives to undertake research in Thailand. Eventually, the Agricultural Engineering Division of the Department of Agriculture was assigned the responsibility of studying the feasibility of using coconut oil as a substitute for diesel fuel.

EXPERIMENTAL PROCEDURE

Experiences from the Philippine research, which concentrated on mixing coconut oil with diesel oil in different ratios, revealed that there were some serious constraints in the utilization of the so-called "cocodiesel oil". High viscosity and specific gravity, and low ignition quality, seemed to be the main problems. Therefore the research in Thailand aimed at improving the blended coconut oil quality by mixing it with natural fossil fuel, which has a higher ignition quality but lower viscosity than diesel fuel. An important factor is that the price of the newly blended oil should be moderate and remain approximately at par with diesel fuel. Preliminary studies showed that kerosene seemed to be the most suitable fuel to blend with coconut oil, since it costs almost the same but has a higher ignition quality and lower viscosity than diesel fuel. The research was undertaken step by step as follows:

1. The possibility and extent of blending coconut oil with kerosene was studied by mixing them together in a flask in different ratios, and leaving them for a week at room temperature to find out if any separation occurs or any other changes take place.

2. The completely blended coconut oil with kerosene obtained from the first step was used to operate a diesel engine in order to compare the characteristics and performance of each blending ratio. At the same time diesel fuel was also used to operate another engine of the same specifications and under similar conditions. Trials were carried out at different engine speeds, such as maximum, minimum and continuous speeds.

3. The most promising blend of coconut oil with kerosene found from the second step was used to operate a diesel engine at no load, and loaded with agricultural machines, and the performance was compared with another engine operated with diesel fuel under similar conditions. After being operated for about 350 hours, the engines were dismantled and some important components, such as the injection nozzle, the piston, the cylinder head and bore, etc., were checked.

4. The most promising blend of coconut oil and kerosene was used to operate 3-cylinder diesel engine fitted to a farm truck. Tests were carried out by running the truck for a long dis-

tance to find out the potential of blended coconut oil with kerosene in operating diesel engines of agricultural machines for a long continuous period.

RESULTS

1. The coconut oil could mix thoroughly with kerosene in any ratio. Blending with kerosene not only reduced the viscosity of pure coconut oil but increased its ignition quality as well.

2. In a no-load test, an old 12 HP diesel engine (Dongfeng-Chinese brand) was operated with various energy sources, viz: pure diesel fuel, pure coconut oil, coconut oil blended with diesel fuel at 98:2 by volume, and coconut oil blended with kerosene at 10:1, 20:1, 30:1, and 40:1 by volume. No modification of the engine was made during the trials. The result showed that coconut oil blended with kerosene at 20:1 by volume had the most promising efficiency in both engine performance and fuel consumption. A summary of the results is given in Tables 1 and 2.

During this trial, a shortcoming was noted, namely that coconut oil has a very high freezing point. The specific gravity of coconut oil increases rapidly when the ambient temperature falls below 25°C, and begins to freeze at temperatures around 15°-17°C. This creates a problem in utilizing it in normal winter conditions or in the morning, because the fluidity of coconut oil decreases considerably, which seriously effects the performance of the engine. Some remedies were made during the test by coiling a brass tube around the exhaust manifold of the engine, and then the tube supplying the blended coconut oil was fixed to the coil, and the outlet of the coil was joined to the inlet of the fuel pump. By this method, blended coconut was heated to about 55°-60°C

Table 1
Properties of blended coconut oil with kerosene at 20:1 by volume

Properties	Testing Method	Blended oil
API gravity at 60°F	ASTM – D – 1298	22.5
Specific gravity at 60/60°F	ASTM – D – 1298	0.918
Flash point (°F)	ASTM – D – 93	212
Heating value (BTU/1b)	ASTM – D – 240	16084
Carbon residue	ASTM – D – 189	0.18
Viscosity 104°F (cst. % wt.)	ASTM – D – 445	22.2
Pour point (°F)	ASTM – D – 97	60
Distillation test	ASTM – D – 86	
Initial boiling point (°C)		182
5 percent (°C)		266
10 percent (°C)		277
15 percent (°C)		288
20 percent (°C)		296
25 percent (°C)		299
30 percent (°C)		302 Cracked
35 percent (°C)		305

Maximum specific gravity of kerosene = 0.83

Note: Analysis carried out with the apparatus of the laboratory of the Petroleum Authorities of Thailand.

Table 2
Comparison of fuel consumption of different fuels (no load)

Fuels	Minimum idle speed (RPM)	Maximum speed (RPM)	Cooling water temp. (°C)	Fuel consumption at continuous speed (Litre/min)	Fuel consumption at maximum speed (Litre/min)	Experimental condition and time	Engine performance
1-D Diesel fuel	450	1840	66	0.0059	0.020	At different speed for 120 minutes	Normal
Pure coconut oil	550	1800	67	0.0066	0.027	At different speed for 240 minutes	High fluctuation of speed especially at high speed
Coconut oil + diesel fuel (2:98 by volume)	450	1840	66	0.0059	0.0208	At different speed for 180 minutes	Normal
Coconut oil + kerosene (10:1 by volume)	410	1930	66	0.0062	0.0208	At different speed for 10 hours	Normal
Coconut oil + kerosene (10:1 by volume)	420	1930	66	0.0057	0.0185	At different speed for 10 hours and additional test at minimum and maximum speed for 8 hours each	Normal
Coconut oil + kerosene (30:1 by volume)	430	1910	66	0.0059	0.0185	At different speed for 10 hours	Normal
Coconut oil + kerosene (40:1 by volume)	450	1900	66	0.0059	0.0192	At different speed for 10 hours	Normal

before entering the engine. This remarkably reduced the specific gravity and viscosity of the blended coconut oil. The result was very encouraging. Subsequently another experiment was carried out by heating 100 cc of blended coconut oil with kerosene in the ratio of 20:1 by volume and 100 cc of diesel fuel up to 100°C, which is still below the boiling point of both the fuels. No change was observed in the case of diesel fuel, but for the blended oil the volume was extended by about 10 percent. This meant that heating up blended coconut oil with kerosene would not only increase its fuel properties but also increase its volume, leading to a reduction in fuel consumption.

3. The testing of the engine components for wear and fuel consumption, both in the case of engines using diesel fuel and those using blended coconut oil with kerosene at 20:1 by volume, was carried with two new 4-stroke single-cylinder 10 HP diesel engines (Yanmar brand). Volumetric bottles were used instead of a fuel tank. In the case of engines using diesel fuel, the fuel was directly connected to the pump; but for engines using the blended oil the fuel was passed through the heating coil around the exhaust manifold before connecting it to the pump. Both engines were operated simultaneously alongside each other at no load and at different engine speeds: maximum, continuous (1500 RPM) and minimum speed, with a total operative time of about 350 hours. No significant differences were observed during the performance tests on both engines, but blended coconut oil with kerosene showed slightly less fuel consumption. As investigation of the wear of the ignition components of both engines showed that the wear was the same in both cases. After 120 operating hours from the engine operated with blended coconut oil, the used lube oil was still in good condition and reusable. Results are tabulated in Tables 3, 4 and 5.

Table 3
Comparison of engine performance between 1-D diesel fuel and blended coconut oil with kerosene at ratio of 20:1 by volume (at no load)

Data	1-D diesel	Blended coconut oil
Engine speed (RPM)	2630	2640
Fuel consumption (litre/min)	0.0122	0.0106
Cooling water temperature (°C)	70	63
Exhaust gas temperature (°C)	110	113
Temperature of fuel before entering injection pump (°C)	Normal (32-38)	60
Engine speed (RPM)	1500	1500
Fuel consumption (litre/min)	0.0050	0.0047
Cooling water temperature (°C)	70	58
Exhaust gas temperature (°C)	70	73
Temperature of fuel before entering injection pump (°C)	Normal (32-38)	55
Engine speed (RPM)	600	600
Fuel consumption (litre/min)	0.0022	0.0020
Cooling water temperature (°C)	62	58
Exhaust gas temperature (°C)	62	55
Temperature of fuel before entering injection pump (°C)	Normal (32-38)	45

Table 4
Comparison of components wear between engines operated with 1-D diesel fuel and blended coconut-kerosene oil

Engine with 1-D diesel fuel	Engine with coconut-kerosene oil (20:1 by volume)
1. Grey to black with some brown spot deposits on piston and cylinder head.	1. Comparatively more deposits of same colour on piston and cylinder head.
*2. Injection nozzle worked normally with little deposits.	*2. Injection nozzle worked normally with comparatively less deposits.
*3. Fuel pump pressure 137 kg/cm^2 (Manufacturing standard is 140 kg/cm^2)	*3. Fuel pump pressure 138 kg /cm^2 (Manufacturing standard is 140 kg/cm^2)
4. Fuel filter was in normal condition.	4. Fuel filter was in normal condition.
5. Cylinder bore wear measured at top ring travel level (lip) – 1.0 feeler. (0.001 inch).	5. . . . . .same. . . . .
6. Piston rings wear (Measured ring gap with feeler gauge).	6. Piston rings wear (Measured ring gap with feeler gauge).
a) First compression ring – 0.021 (Standard – 0.020)	a) . . . . .same. . . . .
b) Second compression ring – 0.021 (Standard – 0.020)	b) . . . . .same. . . . .
c) Oil ring – 0.018 (Standard – 0.016)	c) Oil ring – 0.017 (Standard – 0.016)

Note *Inspected by private specialist of a service shop.

Table 5
Properties of used lube oil from engines using diesel and blended coconut-kerosene oil (20:1 by volume) – about 500 hours running (at no load)

Data	Test method	Diesel fuel	Blended coconut -kerosene
Viscosity 104°F (cst.)	ASTM – D – 445	138.84	143.98
Viscosity 212°F (cst.)	ASTM – D – 445	14.03	14.49
Viscosity index	ASTM – D – 445	97	99
Total acid number (mg KOH/2)	ASTM – D – 664	2.345	2.908
Total base number (mg KOH/2)	ASTM – D – 664	4.201	4.962
Pentane insoluble (%)	ASTM – D – 893	0.1942	0.1656
Benzene insoluble (%)	ASTM – D – 893	0.1448	0.1250

Remarks – In both cases, the lube oils were still in good condition and usable
Total base number 1.0
Total acid number – still low
Pentane and benzene insoluble – still very low
– Analysis carried out with apparatus of the laboratory of
The Petroleum Authorities of Thailand.

Besides testing at no load, experiments were also carried out by operating a diesel engine as the prime mover of a 10-inch diameter propeller pump, lifting water at a suction head of one metre and driving a soybean thresher. Some modification was made to the fuel system. A three-way valve adapter was fitted to the fuel pump inlet, which provided a two-fuel source system in one engine. Fuel could be changed from diesel to blended coconut oil spontaneously as required, and vice versa. Each fuel volumetric flask was fitted with check valves. A heating chamber for blended coconut oil was designed, fabricated and fitted to the engine replacing the exhaust muffler. Its features were almost the same as the engine exhaust muffler except that it was designed to have two separate parts. The upper part was about 100 mm height and was designed as an oil container for the heating chamber. The lower part still acted as an exhaust muffler of the engine and simultaneously acted as the heater of the heating chamber. The exhaust muffler heating chamber is illustrated in Figs. 1 and 2.

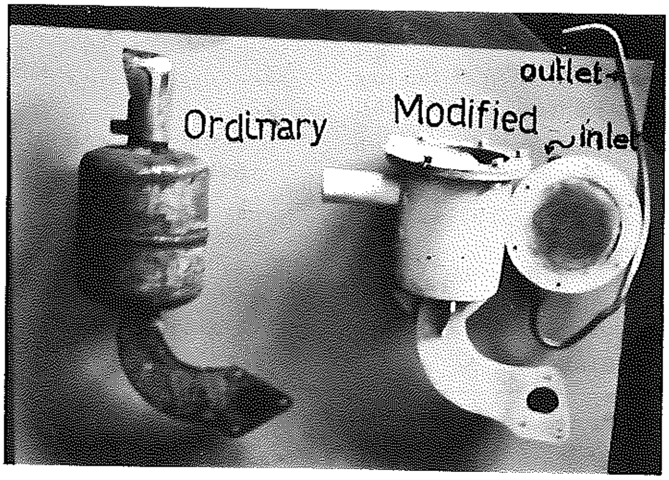

Fig. 1 Comparison of ordinary muffler and a modified muffler to be used as a heater.

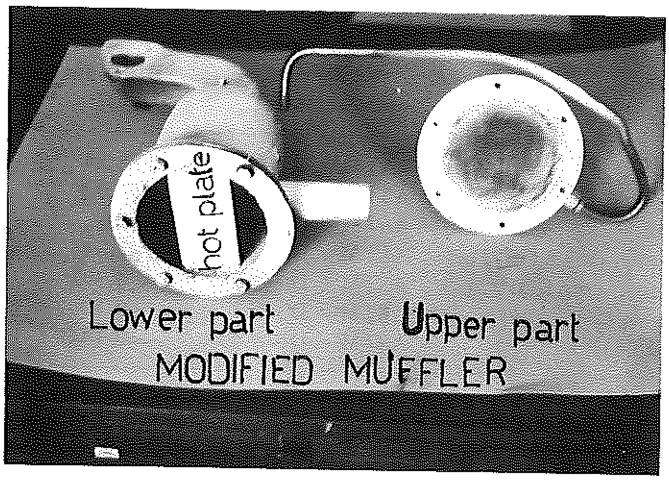

Fig. 2 Modified muffler has two parts, the upper acting as oil container and the lower as heater.

Tests on the propeller pump, mostly at an engine speed of 1500 RPM for about 100 hours, gave a smooth performance and encountered no problems. Trials were also carried out by changing the fuel source suddenly from the blended coconut oil to diesel and vice versa. The engine ran normally without any speed fluctuation or any other adverse phenomenon. This obviously showed that blended coconut oil with kerosene at 20:1 by volume could be used as a substitute in a diesel engine perfectly, and had the advantage of a lower cooling water temperature (about 5-7°C) and slightly less fuel consumption. However, it required a heating system for the blended oil before allowing it to enter the injection pump. The results are given in Table 6.

Table 6

Comparison of engine performance between 1-D diesel fuel and blended coconut oil with kerosene at 20:1 by volume driving a 10-inch diameter propeller pump

Data	1-D diesel fuel	Blended coconut -kerosene oil
Maximum engine speed (RPM)	2360	2400
Fuel consumption (litre/min)	0.0154	0.0144
Cooling water temperature (°C)	78	72
Exhausted gas temperature (°C)	110	113
Fuel temperature before entering injection pump (°C)	40	68
Continuous speed (RPM)	1500	1500
Fuel consumption (litre/min)	0.0066	0.0064
Cooling water temperature (°C)	75	60
Exhausted gas temperature (°C)	72	75
Fuel temperature before entering injection pump (°C)	40	60

4. Tests were conducted on a farm truck fitted with a Kubota diesel engine model DH 110 B., with an engine displacement of 1115 cc from 3 vertical cylinders, providing 24 HP at a maximum engine speed of 3000 RPM and produces a maximum torque at 2800 RPM. The total weight of the farm truck was 1800 kg. The test was carried out by running the farm truck with an additional load of 600 kg from Pitsanuloke, a northern province, to the far-southern province of Narathivas and back, a total travelling distance of about 6000 km over a period of 3 weeks. No problems were encountered. The truck travelled smoothly and normally even when the fuel was changed suddenly (a two-fuel source system was used with the engine). The fuel consumption, the acceleration rate, the driving torque and the maximum ground speed were found to be nearly the same, but the engine or cooling water temperature when using the blended coconut oil was slightly lower than when using diesel fuel. This result indicated again that blended coconut oil with kerosene at 20:1 by volume can be used to operate a diesel engine. The results are given in Table 7. However, during the experimental journey some minor problems were noted and are listed below along with suggested solutions:–

a) The heating chamber which was designed for this experiment required a person to control the temperature of the blended coconut oil, so as to maintain it at about 60-70°C before it

Table 7
Comparison of 3-cylinder diesel engine performance between 1-D diesel fuel and blended coconut oil with kerosene at 20:1 by volume (load – farm truck)

Data	1-D diesel fuel	Blended coconut -kerosene oil
Maximum engine speed (RPM)	Not available (No speedometer)	Not available (No speedometer)
Maximum ground speed (km/h)	70	70
Fuel consumption (litre/min)	10.5	10.8
Cooling water temperature (°C)	80	75
Fuel temperature (°C)	38	65
Exhaust gas temperature (°C)	100	103
Continuous engine speed (RPM)	(Not available (No speedometer)	Not available (No speedometer)
Ground speed (km/h)	50	50
Fuel consumption (litre/min)	14	14.7
Cooling water temperature (°C)	77	65
Fuel temperature (°C)	35	65
Exhaust gas temperature (°C)	95	96

entered the fuel pump. If this was not done a vapour lock would occur in the fuel tube at a temperature of about 80°C. This could cause the engine to stop. Modifications could be made by fitting a thermostat to control the heating temperature or by redesigning the heating chamber. The new heating chamber should be larger and exhaust gas should be used as the heating source.

b) The coconut oil available in the market has no standard quality. The specific gravity and viscosity varied; but the biggest problem was the cleanliness. Some samples were found to be highly contaminated. Such contamination will shorten the working life of the fuel filter considerably. During the test, the fuel filter had to be changed after running for about 4500 km, or only 125-130 operating hours.

c) The 24 HP engine used as the prime mover of the farm truck with a total load of 2400 kg, was insufficient. The engine had to run at maximum speed instead of at a continuous speed during the long distance test. Naturally, the engine consumed more fuel and there was more wear on the engine components. The selection of appropriate matching power and load should be considered before testing.

GENERAL OBSERVATIONS AND DISCUSSION

Efforts have been made in many countries by various means to use coconut oil as an alternative energy for fossil fuel. For instance, the Honda Motor Co. Ltd. had blended coconut oil with gasoline to use with motorcycles but the results were not very encouraging.[2, 3] In the Philippines, the largest supplier of coconuts in Asia, a blend of 5 percent coconut oil and 95 percent diesel fuel has been used with big diesel engines in trucks and buses, etc.[1]

In the early stages of development, the use of cocodiesel seemed to be encouraging, but it was found later that there were problems of fuel filter clogging.[4] In Thailand, experiments were also undertaken by blending coconut oil with diesel fuel at a ratio of 80:20 by volume with some special chemical additive. This was carried out by the Working Group on Energy of the Industrial Works Department of the Ministry of Industry. Trials with a small diesel "pick up" truck showed that the new formula fuel could work quite satisfactorily.[5] It can be seen that all the experiments still relied heavily on petroleum fuel and expensive chemical additives. Therefore, the aim of the work reported here was to use coconut oil as a substitute for diesel oil with a minimum mixing of fossil fuel. From the experiments, it was found that blending coconut oil with kerosene in a ratio of 20:1 by volume was suitable for operating a diesel engine and had a higher potential than any other formula. However, some hindrances were found during the trials. These should be investigated and studied in more detail in order to assure that utilization of the newly blended coconut oil formula will be beneficial to farmers and to the nation. Some of the hindrances which need to be investigated are as follows:

1. Although the problem of the high freezing point of blended oil could be remedied, a shortcoming still remains at the starting period of the engine because the blended oil might be in solid form. Therefore a two-fuel source system was designed. The engine can be started with diesel fuel first, and the exhaust gases can be used to heat up and melt the blended oil for some time before changing to blended oil. From the experiments this worked very well provided the fuel system is so arranged that it can supply sufficient fuel instantaneously when the engine has sudden overloading. Another alternative is to solve this problem by using a chemical additive. However, this would increase the cost considerably.

2. The cleanliness of the coconut oil is a critical factor in the effectiveness of blended coconut oil. It was found that coconut oil extracted directly from copra without refinement was highly contaminated, thus reducing the working life of the fuel filter. Therefore, before blending coconut oil with kerosene, contamination should be removed by using a filter.

3. No serious wear of engine components was found throughout the study. But the study of Honda Motor Co. Ltd. revealed that 100 percent coconut oil caused some green deposits on copper alloy parts, though these could be wiped off with a cloth without any corrosion.[2] However, further study about the effects of the newly blended coconut oil with kerosene on various metals needs to be undertaken.

4. The critical issues for the adoption of plant oil as an alternative energy source for the internal combustion engine are economic feasibility and engine wear. There are many factors affecting the usage of plant oil as an energy source, such as the price of agricultural products, the distance and difficulty in getting petroleum fuel, etc. Therefore, it may be feasible for farmers in some remote areas, such as islands where coconut farming is the prime source of income, but it will not be feasible for areas where petroleum fuels are readily available. During this research, a feasibility study was carried out comparing Ko Samui District, the largest coconut planting island in Thailand, in Surat Thani province (above 900 kilometres from Bangkok), and Thap Sakae District of Prachuap Khiri Khan province, about 280 kilometres from Bangkok. The results given in Table 8 reveal that, blended coconut oil with kerosene would be more economical for Ko Samui than for Thap Sakae. However, this is not so significant. Research on alternative energy from plant oil will be most valuable in future when fossil fuel is scarce or the price of coconut products becomes very depressed. In that case the blended coconut oil with kerosene will immediately be justified. As regards engine wear, although the results are encouraging, this problem may require more detailed investigation.

Table 8
Comparison of production cost of coconut oil in Ko Samui (Island), Surat Thani and Amphoe Thap Sakae, Prachuap Khiri Khan

General information

- Copra generally provides about 60-65 percent of extracted coconut oil.
- A coconut fruit consists of 10 percent by weight of husk.
- 1 litre of coconut oil = 0.85-0.90 kg.

Considered factors	Production cost in Ko Samui	Production cost in Thap Sakae
1. Price of fresh coconut fruit (Baht/piece)	1.20 (Mid 1982–0.90)	3 (Mid 1982–1.80)
2. Price of copra (Baht/kg)	5.50 (4-5 fresh coconut fruits give 1 kg of copra)	6.30 (3-4 fresh coconut fruits give 1 kg of copra)
3. Selling of coconut husk (by product) at 0.60 Baht/kg (Baht)	0.27 (0.45 x 0.6)	0.27
4. Selling of extracted copra residues at 2.60 Baht/kg (Baht)	0.975 (0.375 x 2.6)	0.975 (0.375 x 2.6)
5. Real raw material cost of coconut oil (Baht/kg)	4.255 (2) – (3) – (4)	5.055
6. Real raw material production cost of coconut oil (Baht/litre)	3.723 (0.875 x 4.255)	4.423 (0.875 x 5.055)
7. Overhead cost including profit (estimated at 50 percent of raw material cost) (Baht/litre)	1.861	2.211
8. Production cost including profit (Baht/litre)	5.584	6.634
9. 1-D diesel price (Baht/litre)	8.00	7.80

Notes: a) All estimation made at average values.
Notes: b) Production cost would be lower if farmers extracted coconut oil by themselves.
c) All prices based on marketing information available during February 1983.
d) Blended coconut – kerosene oil at 20:1 by volume will be slightly cheaper than pure coconut oil (kerosene costed 6.80 Baht/litre).

CONCLUSION

This study achieved the objective of the project. It was found that blending coconut oil with kerosene at a ratio of 20:1 by volume can be used as a diesel-fuel substitute. However, there are still some minor problems which should be remedied in order to make the utilization of blended coconut oil as an alternative energy source beneficial to farmers and to the nation as a whole.

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