Cocos Nucifera: An Abundant Renewable Source of Energy

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Introduction

Cocos Nucifera trees, otherwise known as coconut palm trees, grow abundantly along the coast line of countries within 15^o of the equator. They prosper in sandy, saline soil and in tropical climates. A healthy coconut tree will produce approximately 120 watermelon-sized husks per year, each with a coconut imbedded inside. There are three constituents of the Cocos Nucifera that can be used for fuel: the husk, the coconut shell, and the coconut oil that is in the white coconut "meat", or copra as it is usually called. Thus, the coconut tree is a very abundant, renewable resource of energy. We have been investigating the production of energy from these three constituents of coconuts and their husks.

Figure 1. Coconut tree with husks

Figure 2. A coconut husk with embedded coconut

Figure 3. Coconut and husk

Energy Conversion Options for Coconuts and their Husks

There are at least three ways that coconuts and their husks can be converted into useful energy. First, the oil in the copra of the coconut can be expelled and used to make coconut bio-diesel to fuel a diesel generator to make electricity. Alternatively, the coconut oil can be burned directly in a modified diesel generator. Second, the coconut husk and shell might be used in a biomass converter to produce combustible gases that can then be used in a gas turbine to produce both electricity and heat. Third, the coconut shell can be converted to charcoal and combustible gases to be used in cooking or heating. We will discuss each of these options in turn, beginning with the conversion of the energy in coconut oil into electricity.

Producing Electricity from Coconut Oil

The coconut oil is in the copra, or white "coconut meat", as seen in Figure 3. A typical coconut will have 0.36 kg of copra, including water, meal and coconut oil. Drying removes the 50% of the mass that is water, leaving 0.18 kg of dry copra, 67% of which is coconut oil, or 12kg. The most efficient extraction that can be done in a village using hand operated presses is 75% of this oil, or 0.09 kg/coconut. Coconut oil has a density of 890 kg/m^3, or .89kg/liter. Thus, 0.1 liter of coconut oil can be produced from each coconut. The cost of the coconuts and the labor to process them in a rural village setting in Papua New Guinea is about $0.07/coconut, or $.70/liter.[1]

There are two options for converting the coconut oil into electricity. First one can chemically process the coconut oil into bio-diesel, using standard procedures such as are used to convert other vegetable oils into bio-diesel. The process is called transesterification and uses methanol as a reactant and lye as a catalyst. The mixture is 1:5, methanol to coconut oil, with a yield of about 0.8 bio-diesel and 0.2 glycerin, which can be used to make soap. The equipment to make coconut bio-diesel is inexpensive to purchase and simple to operate. We have run the coconut bio-diesel in a diesel powered electric generator and it runs extremely well, with about 1/3rd the emissions that one gets from conventional petroleum based diesel fuel. No modification of the diesel engine is required. The additional cost of processing is about $.20/liter, but the sale of the glycerin should more than compensate for this additional cost.

Figure 4. Equipment to make bio-diesel at Baylor

Figure 5. Bio-diesel and glycerin made at Baylor

A second option is to burn the coconut oil directly in a diesel generator. This cannot be done without modification of the diesel engine. The coconut oil at room temperature is much too viscous to be processed by the fuel pump and fuel injection system of the diesel engine. However, if the coconut oil is preheated to approximately 70^{o}C, then the viscosity is similar to conventional diesel fuel and it can be burned directly in a diesel engine. This was first demonstrated by Timothy Kopial[2]. Thus, the options are to modify the fuel to make coconut bio-diesel or modify the diesel engine to allow for preheating of the fuel before it is used. The efficiencies of conversion of the energy in the coconut oil, coconut oil bio-diesel and conventional diesel fuel into electricity using the diesel generator were 19.7%, 20.3% and 22.4% respectively.[2]

The second approach is preferred because methanol will not be easily available in rural villages and it is both toxic and explosive, posing a danger to the village. However, there is a significant concern about the startup and shut down of the diesel generator when using pure coconut oil. At temperatures below ambient (22C), coconut oil can form a soft solid, much like butter. Thus, it is likely that it will plug either the fuel pump or the fuel injection system. A compromise approach might be to use a small amount of diesel fuel to start the generator, using the exhaust heat to heat the coconut oil to be used as fuel. Once the coconut oil is heated to a sufficient temperature (~70C) then, one could switch to coconut oil as the fuel. Just before shut down, the engine could be returned to diesel fuel to be sure to clear the fuel system of coconut oil before shut down. This will avoid startup problems.

Comparing Coconut Oil to Other Vegetable Oils for Generation of Electricity

It is interesting to determine the relative merits of coconut oil relative to other vegetable oils as a potential fuel for diesel generators. This information for some common vegetable oils is summarized in Table 1. The vegetable oils are listed in order of yield per hectare (note: a hectare = 1000 m^2 ~2.5 acres). Palm oil and coconut oil have extremely high yields compared to the other vegetable oils. The iodine number measures the number of unsaturated bonds, which gives an indication of the tendency of the oil molecules at elevated temperatures to chemically react with other oil molecules, producing high viscosity sludge that can gum up a diesel engine's fuel injection system or values. Here a low number is desirable, and coconut oil is by far the lowest of the vegetable oils, meaning it should burn without gumming up the diesel engine.

Vegetable Oil	liters oil/hectare	Iodine Number	Centane Number	Melting Point -deg C
Palm Oil	5950	52	65	34
Coconut Oil	2689	9	70	23
Sunflower Oil	952	130	52	-18
Soybean Oil	446	132	53	-12
Cotton Seed Oil	325	108	55	0
Corn Oil	172	120	53	-5

Table 1. A comparison of properties of various vegetable oils[3]

The centane number is a measure of the ease with which fuels will spontaneously combust, since diesel engines do not have spark plugs. Here the higher the number the greater the ease of spontaneous combustion. Again, coconut oil is the highest of the vegetable oils. Finally, the melting point is important as the fuel needs to be liquid to be processed by the fuel pump and fuel injection system. A low melting point is obviously the best, and it is only here that coconut oil is deficient. As previously noted, it is anticipated that this can be overcome by preheating the coconut oil or by converting it into bio-diesel, which lowers the melting temperature to -9^{o}C. In summary, coconut oil seems to be superior to other vegetable oils in its yield and its physical properties for use in diesel engine generation of electricity.

What Advantages does Coconut Oil Offer Over Diesel Fuel in Rural Villages?

The information provided above gives a price point for coconut oil that is similar to the price of conventional diesel oil in some rural villages such as on the island of KarKar in Papua New Guinea.[4] What advantage would their be to setting up the necessary facilities to extract coconut oil from coconuts when one can purchase petroleum based bio-diesel at a similar price? First, the electrification of a village using coconut oil should be sustainable long-term as the natural resources, namely coconuts, are readily available and renewable and the additional costs of extracting the coconut oil are primarily wages paid to people in the village rather than as a flow of capital from the village to the outside world. This also produces employment in the village, allowing more people to be able to afford the electricity generated.

There is another extremely important advantage that is missed in just comparing the cost of the coconut oil to bio-diesel. The production of one liter of coconut oil also generates 10 coconut shells and husks, each of which has potentially significant value if subsequently processed. The shells and husks can also be used as fuel or converted into other types of value added products.

Coconut shells have a specific gravity of 1.1, which is extremely high. As one would expect they have a very high energy density. A coconut shell can be burned directly as fuel, though it tends to burn extremely hot, which may not make it idea for cooking. However, it can be easily processed into charcoal and combustible gases. Whereas 10 kg of wood makes only 1 kg of charcoal, 10 kg of coconut shells, makes 3 kg of charcoal and 5.5 kg of combustible gases.[5] Since 65% of the fuel consumption of people in developing countries is in cooking, this makes the coconut shell a very valuable source of cooking fuel.

The large amount of biomass in the husks that are “waste” from the production of coconut oil can also be utilized as fuel by processing it through a biomass gasification unit that converts it to combustible gases that can then be used in a gas turbine to produce electricity and heat. Work is now under way by David Hagen[6] to explore how well coconut husks can be used in this way.

Alternative Uses for Husk, Coconut Shells, and Meal

While the coconut shells and husks may also be used for fuel, it seems likely that they can be converted into more value-added alternative products. For example, we are currently exploring the hot pressing of husks into particle board that could be used for housing in the village or sold outside the village. There are encouraging reports in the literature that this is feasible.[7] We are also exploring the use of finely ground coconut shells as reinforcement in engineering plastics, and again, others have show that this seems like a feasible application for coconut shells.[8]

Particle board that is 250 cm by 125 cm sells for $15 in Papua New Guinea, which is a very large sum of money in this country.[4]

Chopped glass is a common reinforcement in filled engineering plastics, but the bonding between the glass and the polymer is only fair. Since coconut shells are organic, one would expect a much better bonding and therefore a better utilization of the ground coconut shell as reinforcement. Filler for engineering plastics often sells at $1-$2/lb, which would generate a great revenue stream for a village processing coconuts to make electricity.

Summary

Preliminary work done at Baylor University and reported by other in the literature suggests that coconuts can be a very attractive renewable resource for rural electrification in developing countries. This approach is much more sustainable than just importing diesel fuel and the byproducts, shells and husks, can be processed into value-added products that create jobs and income for the village.

References

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