Hawaii:

New biodiesel frontier

Project evaluates local crops for suitability in fuel production

by Warren Dominy, Lee Litvin, Joseph Shacat and Adria Estribou

With 93% of its energy coming from fossil fuels and almost no local energy production of its own, Hawaii is the single most petroleum-dependent state in the U.S.

Hawaii's dependency on imported energy leaves the state extremely vulnerable to price and availability fluctuations, resulting in decreased energy security. Suitable, available agricultural land and increasing demands for biodiesel have resulted in a unique opportunity to significantly reduce pollution caused by petroleum diesel and offer a new means to sustain agricultural commerce in the region.

A project for Honolulu Clean Cities (HCC) funded by the U.S. Environmental Protection Agency (EPA), "Biodiesel from Fuel Crops in Hawaii," evaluated crop materials currently grown in Hawaii (kukui, coconut and jatropha) to determine their suitability as feedstock for making an American Society for Testing and Materials (ASTM) grade biodiesel.

The purpose of the project was to develop an understanding of the quality and yield of biodiesel produced from a variety of different island feedstock sources and measure the emissions generated. HCC members Oceanic Institute, Pacific Biodiesel Technologies and Grace Pacific Corp. partnered to undertake this project.

As well as energy, Hawaii is also largely dependent on food from the U.S. mainland and overseas. The state's livestock industries are rapidly disappearing, with the cost of importing animal feed a major contributor to the decline. The project also looked at the potential economic value of using biodiesel coproducts as animal feed ingredients, to help reduce the feeding costs for Hawaii's farmers.

PROCESSING AND ANALYSIS

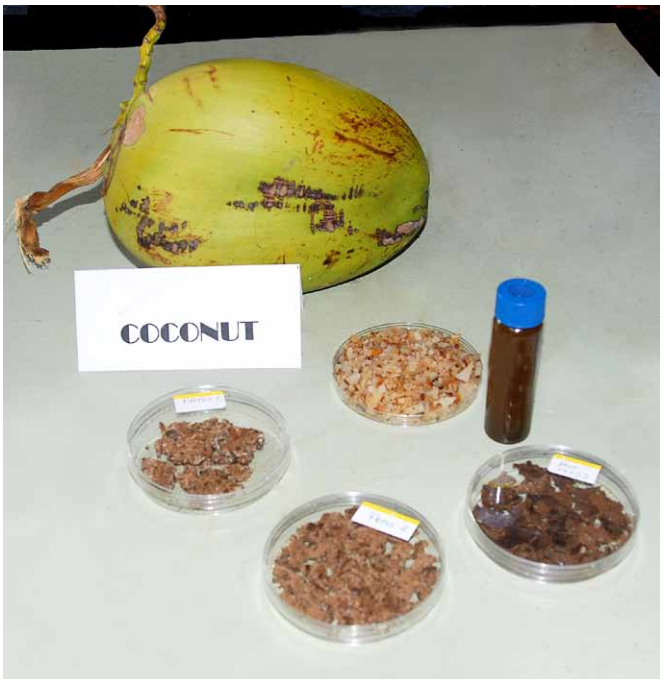
Oceanic Institute's feed processing complex extracted oil from coconut, kukui nut and jatropha seeds. Whole soybeans were also processed and extracted as a control oilseed.

Oil yield measured by weight recovery from the original raw material was 10.04% for soybeans, 27.39% for coconut, 12.39% for kukui nut, and 32.75% for jatropha seed. Oceanic Institute's analytical lab characterized the crude oil extracted and the press cake co-products generated from the oil extraction process.

Fatty acid profiles of the crude oil and press cake were determined for each feedstock. The press cakes were also characterized for use as an animal feed by determining their crude protein content, which ranged from 7% to 46%, crude fat from 6% to 10%, ash from 2% to 6%, moisture from 8% to 9.5%, and crude fiber content that ranged from 7% to 76%.

Additional analysis of the protein quality was determined

Diesel engine used in emission testing. Photos by Warren Dominy.



On the left, coconut in various stages of the extraction process including diced coconut meat, press cakes and oil. On the right, jatropha seeds in various stages of processing including seeds, press cakes and oil.

by amino acid content. Yields of oils from extracted feedstock material were from 10% to 33%, while electrical consumption per kilogram of crude oil extracted ranged from 1.1kWh to 4.5 kWh. All extracted oils — soy, coconut, kukui and jatropha — were filtered and delivered to Pacific Biodiesel for conversion into ASTM biodiesel.

Biodiesel production in the state currently relies solely upon waste cooking oil for feedstock and has a total production capacity of approximately 1.2 million gallons per year. When compared to the estimated 50 million gallons of petroleum diesel that are consumed in Hawaii (2006), there is a great deal of potential for expansion of this resource.

While waste-derived biodiesel has provided an important opportunity to convert a large portion of otherwise landfilled waste into a valuable energy source, the recent boom in biodiesel interest has resulted in a much larger demand than can be satisfied by this feedstock source alone.

The project showed that island nuts and oilseeds can be processed into oils for conversion into biodiesel fuel, and there are uses for the presscake, probably as a ruminant (cattle) feed.

BIODIESEL PROCESSING

Three raw oils (coconut, kukui, and jatropha) were successfully processed into methyl esters using a process developed by Pacific Biodiesel Technologies. The coconut methyl ester was the only sample to pass the ASTM D6751 specification for biodiesel quality. The jatropha methyl ester had high sulfur content, and the kukui methyl ester had a high carbon residue value and a low cetane number.

Analysis of the raw oils included tests for water content, moisture and volatile content, insoluble impurities content, unsaponifiable matter content, sulfur content, phosphorus content, free fatty acid content, and fatty acid profile.

There were processing difficulties with the raw jatropha and raw kukui oils. Both oils had a very high insoluble impurities (sediment) component that had to be settled and separated before the oil could be processed. The kukui oil also required a water degumming step to help the ester-glycerin phase separation during production.

Process yields varied between the samples. The coconut oil had the highest conversion yield to methyl ester with a range of 90% to 92%, jatropha oil had a conversion yield of 89% to 91%, and kukui had a conversion yield of 84% to 89%.

Overall, coconut oil is a fine feedstock for biodiesel production. The kukui methyl ester sample failed two ASTM D6751 parameters, cetane number and carbon residue, and cannot be considered biodiesel. Other than the high sulfur content, jatropha oil would be a fine feedstock for biodiesel production.

The information regarding kukui as a feedstock will be highly useful. Little information on processing kukui into biofuel was available before the project. For agricultural and cultural reasons, this may prove to be a viable feedstock for larger-scale production. The project demonstrated that kukui is more difficult to process into biodiesel. However, the finished fuel showed excellent cold-flow properties which could make

A full report on the "Biodiesel from Fuel Crops in Hawaii" project is available from Honolulu Clean Cities. Contact Robert T. Primiano or Sherry Goya at 1.808.768.3500 for more information.

kukui-based biodiesel a premium fuel or fuel additive on the international market.

EMISSIONS TESTING

Grace Pacific Corp. performed biodiesel emission testing through SCEC, an environmental consulting firm, on five different fuels: the #2 diesel used to blend the biofuels to a concentration of 20% (B20); coconut oil B20; jatropha oil B20; kukui nut oil B20; and recycled fryer oil B20. The gas sample was then analyzed for oxygen, carbon dioxide, nitrogen oxide, carbon monoxide and sulfur dioxide following USEPA 40CFR Part 60 methods 3a, 6c, 7e and 10.

The purpose of the testing was to determine if these various biofuels can be a viable alternative compared to commercially available diesel fuel and to document and compare emissions resulting from an engine that is running on the various biofuels.

Emissions of nitrogen oxide, carbon monoxide, and sulfur dioxide were higher for petroleum diesel fuel than for B20 blends of coconut oil biodiesel, jatropha oil biodiesel and recycled fryer oil B20.

Emissions reductions for nitrogen oxide ranged from 12% to 17%, reductions for carbon monoxide ranged from 5% to 13%, and reductions for sulfur dioxide ranged from 1% to 24%.

The nitrogen oxide emissions associated with the biodiesel blends tested showed significant reductions compared to petroleum diesel. The reduced carbon monoxide emissions associated with the biodiesel blends tested support previous studies that show lower carbon monoxide emissions for biodiesel.

Sulfur dioxide emissions are largely a function of the sulfur content of the fuel itself. Jatropha oil biodiesel had a sulfur content of 56.5 parts per million (ppm), which exceeds the ASTM 6751 limit of 15 ppm as well as the federal limit for the sulfur content of highway diesel fuel of 50 ppm. It would need further processing to be used for biodiesel.

Insta-Pro Model 750 Oil Press used to extract the oilseeds and nuts.

INDUSTRY LESSONS

The quantities of coconut, kukui nut and jatropha seeds available in Hawaii were not enough to get a sustained processing run. An estimate of a ton more of product was needed to get accurate readings for these various feedstocks. To become an economic reality, there is still a long way to go before the use of locally grown oilseeds and nuts can be pressed into oil for the conversion of biodiesel fuels.

An important industry application was learned about the processing of kukui nut. There is no need to hand crack kukui shells (which take considerable time and energy) because the oil content of these nuts is so high that additional fiber is needed to use the oil press efficiently. A best future practice would be to process the whole nuts in a hammermill and put the entire contents through the oil press. Further testing would be needed to see if shell content in resulting press cake would be useable for animal feed. If not, other uses such as mulch are a possibility.

"The nitrogen oxide results were surprising, as high nitrogen oxide content is typically cited as a reason against the use of biofuels," said Joseph Shacat of Grace Pacific Corp. The ramifications for industry are the ability to operate plants longer with biodiesel, since nitrogen oxide is one of the two main limits to operational hours. **BB**

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