Technology Updates on Filtered Crude Coconut Oil (FCCNO) as Biofuel

Gilles Vaïtilingom
Filtered Crude Coconut Oil as Biofuel

• Vegetable oil as Fuel

• Technology Updates

• Quality requirement of FCCNO as Biofuel for diesel engines

• FCCNO in the Pacific: examples
HISTORY OF VEGETABLE OILS AS FUEL

SINCE NEOLITHIC PERIOD : 9000 before J.C.

BUT: APARITION OF PETROL LAMPS IN 1853
HISTORY OF VEGETABLE OILS AS FUEL

Rudolf DIESEL (1858 – 1913)

1900: test of some vegetable oils in his engine
VEGETABLE OILS AS FUEL

- Characteristics close to diesel oil
  - LCV coconut oil: 41 MJ/kg
  - LCV Diesel oil: 44 MJ/kg
  - Density coconut oil: 0.92
  - Density Diesel oil: 0.83

- History:
  - Mr. Diesel himself in 1900
  - World War II
  - Banned from research in the 50’s
  - interest renewed at the end of 70’s
COCONUT OIL AS FUEL
Why so few applications?

• higher cost than diesel ← case of most renewable
  But new position with > USD 70/barrel

• too different to respect fuel standards
  New standards on the way: soon in Fiji

• Coconut Oil! Not to be compared to a cheap, common and stinking product
  New consideration → USD 70 for 159 liters

STOP Coconut oil Biofuel is not Diesel Fuel and must be used in adapted engines only!
VEGETABLES OILS AS FUEL FOR DIESEL ENGINES

Piston after 200 hrs. with diesel fuel at idle speed no load

Piston after 21 hrs. with sunflower oil at idle speed no load

WHY?
CONSEQUENCES (1)

CARBON DEPOSIT

MECHANICAL DAMAGES

Injection pumps, rings, cylinder....

Figure 10 - enroissement typique dû aux huiles végétales (platen de moteur à injection directe, 10 heures de reflux à vide, huile de tournesol raffinée)
CONSEQUENCES (2)

CARBON DEPOSITS

nozzle, valves,...
Technology Updates

Vegetable oils:

1. In standard Diesel engines by either:
   • adapting the “fuel” and making Biodiesel (esterification with methanol or ethanol).
   • using pure vegetable oils or mixtures under internal thermal conditions allowing their complete combustion (2- tank systems)
   • using IDI engines (Indirect injection system)

2. In specifically designed engines modified to burn vegetable oils at any percentage
Technology Updates

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ESTER OF VEGETABLE OIL

BIODIESEL

In any type of Diesel engines

50 % Diesel - 50 % Methyl Ester (rapeseed oil)

Reims - France
METHYL ESTER OF VEGETABLE OIL

Biodiesel Plant
Coconut oil Biodiesel Small scale Unit. 50 liters / 8 hours.
Tuvalu, TMTI, 2009.
(Green Fuels UK)

2 tonnes/day Biodiesel Unit
Cameroon, 2008.
(Ageratec Sweden)

Source: Cirad Vaïtilingom
Technology Updates

Vegetable oils:

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2. In specifically designed engines modified to burn vegetable oils at any percentage
Running on Diesel Fuel from 0 to 30 KVA (load < 50 %)
Running on pure Palm Oil from 30 to 60 KVA (load > 50 %)

**MARKET PROSPECTS OF COCONUT PRODUCTS IN THE PACIFIC COUNTRIES - Nadi, FJ, June 2009**
SYSTEM OF DOUBLE CIRCUIT or 2 TANKS SYSTEM

KIT for 2-TANK SYSTEM

Renault dci 270 Ch (2006)

Common Rail injection
SUNFLOWER OIL
SYSTEM OF DOUBLE CIRCUIT or 2 TANK SYSTEM

IVORY COAST

Genset 320 KVA – crude Palm Oil (2006)
MIXTURES OF COCONUT OIL
in STANDARD DIRECT INJECTION ENGINES

Filters, injectors, injection pumps, … have been designed for Diesel Fuel use (ref. 40°C). A too high viscosity may reduce flow and can damage injection pump.

MIXTURES ARE USEFUL ONLY TO REDUCE VISCOSITY
EXAMPLE OF MIXTURES OF COCONUT OIL in STANDARD DIRECT INJECTION ENGINES

BUT RUNNING ON 10 to 20 % CNO only WHEN LOAD > 50 % => > 200 KVA

Cummins genset, 400 KVA, 10-20 % CNO in DIESEL FUEL

Savai’i EPC Power station, Samoa (2005)
EXAMPLE OF MIXTURES OF COCONUT OIL in STANDARD DIRECT INJECTION ENGINES

Figure 21: UNELCO Generators in Port Vila running on coconut oil fuel blend (Source: UNELCO)

4 MW MAN 9L32/40 generators on blends fuel/coconut oil
UNELCO Port Vila – 2006
Coconut oil is mixed or not to diesel fuel according to the load. (similar to a 2 tank-system)

BUT RUNNING ON 15 to 20 % CNO only WHEN LOAD > 50 %
Vegetable oils:

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2. In specifically designed engines modified to burn vegetable oils at any percentage.
ARCHITECTURE OF DIESEL ENGINES

TWO TYPE OF DIESEL ENGINE

INDIRECT INJECTION

DIRECT INJECTION

DEUTZ AIR COOLED ENGINES: 912, 914 AND 912W
PURE VEGETABLE OILS

INDIRECT INJECTION (IDI)

No modifications, only adaptation
Up to 100 % vegetable oil.
Heat exchanger and/or mixture with diesel fuel to reduce vegetable oil viscosity
& Some settings
DieSEL INDIRECT INJECTION

EXAMPLE

settings

• injectors opening pressures: 200 bars

Photo: Rabaul Hotel car

IDI coconut oil powered car in PNG. (Atul Raturi, 2006)
Vegetable oils:

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PURE VEGETABLE OILS

Modification of pistons

Example of combustion chamber
PURE VEGETABLE OILS

In specifically designed engines

DIESEL DIRECT INJECTION
In specifically designed engines

Tractor Biocombustible Yumz D-65 M, Sunflower or soja

In specifically designed engines
Tractor Yumz (Camagüey - Cuba)

Spare Piston
modified Piston
Filtered Crude Coconut Oil

Quality requirement as Biofuel for diesel engines
QUALITY OF COCONUT OIL BIOFUEL

1. reducing viscosity

Filters, injectors, injection pumps, ... have been designed for Diesel Fuel use (ref. 40°C)
A too high viscosity may reduce flow and can damage pumps

![Graph showing the viscosity of coconut oil vs. temperature. The graph indicates that coconut oil must be at 100°C to match the viscosity of Diesel fuel at 40°C.](image)

**Coconut oil must be at 100°C**

**Diesel fuel at 40°C**
QUALITY OF COCONUT OIL BIOFUEL

2. Respecting a standard of quality

<table>
<thead>
<tr>
<th>Properties / Contents</th>
<th>Unit</th>
<th>Limiting Value min.</th>
<th>Testing Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (15 °C)</td>
<td>kg/m³</td>
<td>900 000</td>
<td>DIN EN ISO 3875</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DIN EN ISO 12185</td>
</tr>
<tr>
<td>Flash Point by P.-M.</td>
<td>°C</td>
<td>220</td>
<td>DIN EN 22719</td>
</tr>
<tr>
<td>Calorific Value</td>
<td>kJ/kg</td>
<td>250 000</td>
<td>DIN 51990-3</td>
</tr>
<tr>
<td>Kinematic Viscosity (40 °C)</td>
<td>mm²/s</td>
<td>36</td>
<td>DIN EN ISO 3104</td>
</tr>
<tr>
<td>Low Temperature Behaviour</td>
<td></td>
<td>Rotational Viscosity Testing Method will be reviewed</td>
<td></td>
</tr>
<tr>
<td>Carbon Residue</td>
<td>Mass-%</td>
<td>0.40</td>
<td>DIN EN ISO 10370</td>
</tr>
<tr>
<td>Iodine Number</td>
<td>g/100 g</td>
<td>100 120</td>
<td>DIN 53241-1</td>
</tr>
<tr>
<td>Sulphur Content</td>
<td>mg/kg</td>
<td>20</td>
<td>ASTM D5453-83</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable properties</th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Contamination</td>
<td>mg/kg</td>
<td>25</td>
<td>DIN EN 12882</td>
</tr>
<tr>
<td>Acid Value</td>
<td>mg KOH/g</td>
<td>2.0</td>
<td>DIN EN ISO 660</td>
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<tr>
<td>Oxidation Stability (110 °C)</td>
<td>h</td>
<td>5.0</td>
<td>ISO 6886</td>
</tr>
<tr>
<td>Phosphorus Content</td>
<td>mg/kg</td>
<td>15</td>
<td>ASTM D3231-89</td>
</tr>
<tr>
<td>Ash Content</td>
<td>Mass-%</td>
<td>0.01</td>
<td>DIN EN ISO 6545</td>
</tr>
<tr>
<td>Water Content</td>
<td>Mass-%</td>
<td>0.075</td>
<td>pr EN ISO 12937</td>
</tr>
</tbody>
</table>
QUALITY OF COCONUT OIL BIOFUEL
Proposal of a quality standard

<table>
<thead>
<tr>
<th>Properties/content</th>
<th>Unit</th>
<th>Min.</th>
<th>Max.</th>
<th>Test method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristic properties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density at 25°C</td>
<td>Kg/m³</td>
<td>0,915</td>
<td>-</td>
<td>ASTM D1298</td>
</tr>
<tr>
<td>Flash Point</td>
<td>°C</td>
<td>210</td>
<td>-</td>
<td>ASTM D93</td>
</tr>
<tr>
<td>Calorific value</td>
<td>MJ/kg</td>
<td>37</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Viscosity (Kin. @ 40°C)</td>
<td>mm²/s</td>
<td>-</td>
<td>30</td>
<td>ASTM D445</td>
</tr>
<tr>
<td>Carbon residue</td>
<td>Mass %</td>
<td>-</td>
<td>0,40</td>
<td>ASTM 4530</td>
</tr>
<tr>
<td>Sulphur content</td>
<td>mg/kg</td>
<td>-</td>
<td>20</td>
<td>ASTM D5453</td>
</tr>
<tr>
<td>Cetane Index</td>
<td></td>
<td>40</td>
<td>-</td>
<td>ASTM D4737</td>
</tr>
<tr>
<td><strong>Variable properties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total contamination</td>
<td>mg/kg</td>
<td>-</td>
<td>25</td>
<td>ASTM 5452</td>
</tr>
<tr>
<td>Acid value</td>
<td>mg KOH/g</td>
<td>-</td>
<td>10</td>
<td>ISO 660</td>
</tr>
<tr>
<td>Oxidation stability (110°C)</td>
<td>h</td>
<td>4</td>
<td>-</td>
<td>ASTM D2274</td>
</tr>
<tr>
<td>Phosphorous content</td>
<td>mg/kg</td>
<td>-</td>
<td>15</td>
<td>ASTM D323</td>
</tr>
<tr>
<td>Ash content</td>
<td>Mass %</td>
<td>-</td>
<td>0,02</td>
<td>ISO 6245</td>
</tr>
<tr>
<td>Water content</td>
<td>Mass %</td>
<td>-</td>
<td>0,075</td>
<td>ISO 12937</td>
</tr>
</tbody>
</table>

QUALITY OF COCONUT OIL BIOFUEL

3. Taking chemical constraints in account

MINOR COMPONENTS: GUMS, WAXES, ...

- partial Glycerides:

- Free Fatty Acids:

- non-saponifiables, pigments...

- Phosphatides:

SENSITIVITY to COLD COND.

Begining of solidification:

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Sensitivity to (\text{Cold Cond.})</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIESEL</td>
<td>- 35 (\degree) C</td>
</tr>
<tr>
<td>RAPESEED</td>
<td>- 11 (\degree) C</td>
</tr>
<tr>
<td>Coconut Oil</td>
<td>+ 23 (\degree) C</td>
</tr>
</tbody>
</table>

If Cno can solidify under local condition:

- Start up and stop on diesel fuel (2 tank system,...)

- running on diesel fuel during cold weeks,...

\(\Rightarrow\) Copra quality and process + filtration,...
Environmental Impact

<table>
<thead>
<tr>
<th></th>
<th>Petrol</th>
<th>Diesel</th>
<th>Biodiesel Rapeseed</th>
<th>Biodiesel sunflower</th>
<th>Rapeseed oil pure</th>
<th>Sunflower Oil pure</th>
<th>Coconut Oil</th>
<th>Ethanol sugar cane</th>
<th>Ethanol wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy balance</td>
<td>0.879</td>
<td>0.913</td>
<td>3.3</td>
<td>3.44</td>
<td>5.09</td>
<td>5.78</td>
<td>15</td>
<td>7.34</td>
<td>3.57</td>
</tr>
<tr>
<td>(Output / Input fossil)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green House Gas indicator (g. equiv CO2/kg)</td>
<td>3560</td>
<td>3390</td>
<td>1332</td>
<td>1117</td>
<td>990</td>
<td>747</td>
<td>185</td>
<td>670</td>
<td>505</td>
</tr>
</tbody>
</table>

coconut plantations are assumed to use traditional, non-intensive farming practices with virtually no mechanization or utilization of chemical aids such as fertilizers and pesticides
Filtered Crude Coconut Oil

In the Pacific:

text

examples
CRUDE FILTERED COCONUT OIL 
ESTERIFIED WITH METHANOL 
⇒ BIODIESEL

GENSET 30 KVA.
TUVALU, 2009;
MIXTURES OF FCCNO with DIESEL FUEL
IN STANDARD DIRECT INJECTION ENGINES

BUT RUNNING ON CNO only WHEN LOAD > 50%

4MW MAN 9L32/40 generators on blends fuel/coconut oil
UNELCO Port Vila - 2004
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CRUDE FILTERED COCONUT OIL
IN IDI DIESEL ENGINE

1995, first Ouvea GENSET. 90KVA
New Caledonia
CRUDE FILTERED COCONUT OIL IN IDI DIESEL ENGINE

© Aliennard - France 1999 - Tous droits réservés.

1999, GENSET 200KVA DESALINATION PLANT, OUVEA-NEW CALEDONIA

© Aliennard - France 1999 - Tous droits réservés.
FILTERED CRUDE COCONUT OIL AS FUEL
IDI ADAPTED ENGINES + DUAL FUEL SYSTEM

RURAL ELECTRIFICATION:
Coconut Oil as fuel (10 nuts = 1 litre equivalent Diesel Fuel)

* First place in the World to produce grid electricity with its own vegetable oil (April 2000).
The pre-filtered coconut oil (drum on the left) is pumped by an electrical driven-pump (between drum and filter) and pushed through a flow line bag-filter (on the right). The hose at the bottom right is connected to the coconut oil main tank of the generator.
CRUDE FILTERED COCONUT OIL

In specifically designed engines

2004 GENSET. 300KVA
Power Station of ENERCAL (Utility)
CRUDE COCONUT OIL IN MODIFIED DIESEL ENGINE

2004 GENSET. 300KVA
Power Station of ENERCAL (Utility)
CRUDE COCONUT OIL IN MODIFIED DIESEL ENGINE

2004 GENSET. 300KVA
Power Station of ENERCAL (Utility)
COCONUT OIL FOR ELECTRICITY GENERATION

GOOD TRAINING
COCONUT OIL FOR ELECTRICITY GENERATION

AND GOOD MAINTENANCE
COCONUT OIL FOR ELECTRICITY GENERATION

MAKE PEOPLE HAPPY!

DoE staff at the very starting of Welagi genset with coconut oil (July 2001)
Vinaka!
ETHANOL BIOFUEL FROM TODDY

Example of BioEthanol production

1 TREE CAN PRODUCE UP TO 25 LITERS OF TODDY/DAY
Or from 2 to 2.5 LITERS OF ETHANOL BIOFUEL / DAY