Small Developing Island Renewable Energy Knowledge and Technology Transfer Network

Project DIREKT – 4th meeting Mauritius
12 –16 April 2011

Biofuels in Fiji and the Pacific - research, production and possibilities

Anirudh Singh and Pritika Bijay

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences
University of Mauritius
USP THE UNIVERSITY OF THE SOUTH PACIFIC
The University of the West Indies
ACP S&T PROGRAMME
Project is funded by the European Union

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Talk outline

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1. Introduction – why biofuels?

Energy challenges of the Pacific

- lack of indigenous fossil fuel sources
- imported fuel for transportation and power generation – adds to high import bills

Renewable energy and energy efficiency possible solutions

- interest in biofuels for transportation and power generation

Introduction (cont.)

- Biofuels for
  - diesel engines include blended fuels – diesel and coconut oil (CNO)
  - petrol engines include ethanol–petrol blends
- Other vegetable oils (jatropha, pongamia, castor) also being considered for diesel engine fuels, and ethanol for petrol engines in Fiji.

2. Biofuels initiative in Fiji

- Increasing interest by the private sector to produce blended fuels (dubbed "renewable diesel" by FDoE – now 20% max CNO and 80% minimum diesel) and trans-esterified bio-diesel (probably CME).
- Also production of feedstock for vegetable oils.
- – Niue Industries (renewable diesel)
- - Biodiesel Group Company Ltd (trans-esterified biodiesel)
- - Biofuels International (yet to begin production) – pongamia biodiesel

Biofuels (cont.)

- government initiatives increase blended biofuel production
- - Koro Island (renewable diesel) 757,000 l capacity
- Rotuma and Cicia islands proposed plants – May this year (2011)

3. Biofuel resources – Fiji case study

Feedstock production potential:

- Land area: 1800,000 ha
- Total forest cover – 1,054,400 ha (58% of total) of which

  - 85% is natural forest, 11% is plantation forest, 4% is mangrove forest

Total wood production

~ 500,000 m^3, of which

- 20% is from native forest, 20% from mahogany, 60% from pine

Biofuel resources – sugarcane production

- Sugar production has been falling steadily in recent years – an industry in deep trouble

Year	Area harvested (ha)	Sugarcane (tonnes)	Sugar exported (tonnes)
2000	66,000	3,786,000	302,000
2006	58,000	3,226,000	250,000
2008	51,000	2,321,000	260,000
2009	49,000	2,247,000	153,000

Copra and other biofuel feedstock

- Copra production has also been declining. In 2008, 9069 tonnes of coconut oil (CNO) was produced. This compares to 17,000 tonnes in 1970
- Jatropha oil – recent interest by a number of entrepreneurs in the cultivation of feedstock
- Pongamia and caster – one business enterprise now engaged in cultivating feedstock plantations
- Cassava – a surge of interest two years ago, but this has died down.

4. Biofuels for diesel engines

- Range of biofuels currently known for diesel engines include
- vegetable oils – coconut oil (CNO), palm oil, other edible oils, pongamia oil, jatropha oil
- vegetable oil-diesel blends
- biodiesel (produced from the trans-esterification of long-chain vegetable oils)

5. Fuel properties of biofuel for diesel engines

The fuel properties of diesel engines are kinematic viscosity, carbon residue, cetane number, higher heating value or gross calorific value, iodine value and saponification value.

Fuel property	Definition	Desired value	Typical value for CNO/ soybean	Value for Diesel
1.Kinematic viscosity	Viscosity per unit density	low	31.6/33.1	4.3
2.Carbon residue	Tendency to form carbon deposit in engine	low	- /0.24	-
3.Cetane number	Measure of ignition delay (large CN = small delay)	high	70.0/38.1	47.0
4.Higher heating value	Energy content of fuel	high	38.3/39.6	45.5
5. Iodine value	Degree of unsaturation of fatty acids	low	10.0/69.8	-
6. saponification value	Average mol wt (i.e. chain length) of fatty	high	252.0/220.8	-

Properties of biofuels – fuel emissions

The emissions produced by fuels have environmental consequences.

The emissions include CO_2, CO, NOx, SOx, Hydrocarbons (HC).

These need to be monitored for new biofuels.

6. Disadvantages of vegetable oils as biofuels

- High viscosity
- - leads to problems of atomisation
- Lower volatility
- Reactivity of unsaturated hydrocarbons chains
- -i.e. Iodine Value too high
- These properties lead to plugging of filters, fuel lines and injectors, formation of carbon deposits, sticky piston rings, failure of engine lubricating oil etc.

Vegetable oils as biofuels cont.

- Ways of producing biofuel derivatives that reduce these problems are
- **Dilution** or **blending**
- - blending vegetable oil with diesel
- **Pyrolysis**
- - breaking down the large vegetable oil molecules to smaller ones by heating in the absence of oxygen
- **Trans-esterification**
- - production of new esters with shorter hydrocarbon chains by reacting with alcohol
- **Microemulsification**
- - formation of miscible fuel mixtures through the use of surfactants

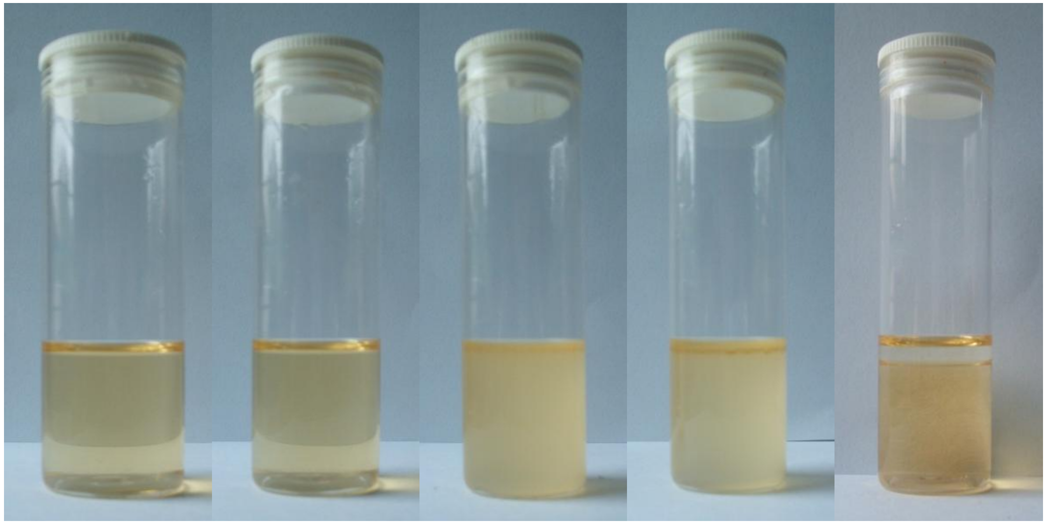
7. Work at USP: Ethanol-CNO micro-emulsions for diesel engines

- Our work consists of
- (A) Biofuel blends for diesel engines through micro-emulsification – ethanol-coconut oil(CNO)
- hybrid fuels by micro-emulsification
- (B) Biofuel blends for petrol engines – E10 and E20 from cassava ethanol – work still in progress.
- We will present the first work.

8. Production and testing of ethanol-CNO micro-emulsions at USP - preparation

- **Preparation of ethanol-CNO micro-emulsions**
- It was found that ethanol was miscible in commercially-produced coconut oil (CCO) up to a volume fraction of 8%. Beyond this value, a surfactant had to be used to achieve miscibility.
- Two surfactants studied were 1-butanol and 1-octanol.

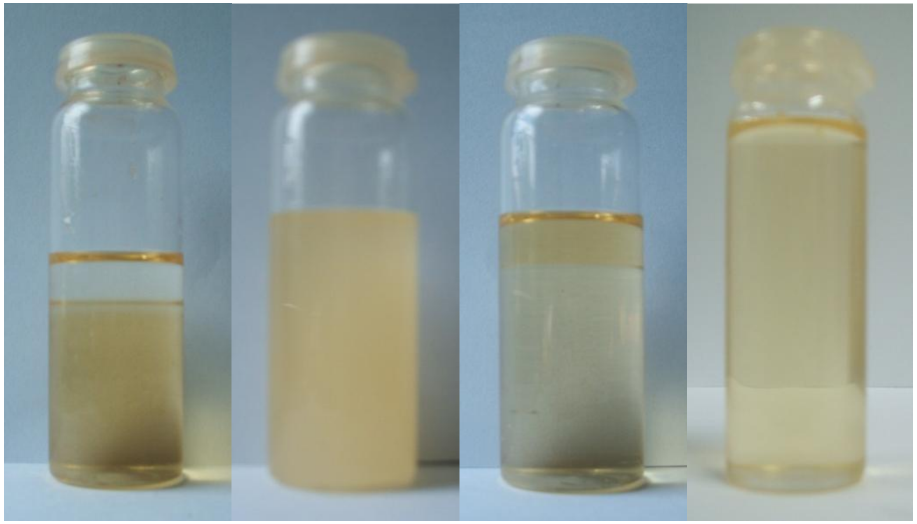
Miscibility of ethanol in CNO (no surfactant)



a b c d e

(a) 6% ethanol (e) 14% ethanol. Note the clear miscible samples (a) and (b), and the phase-separated sample (e).

Ethanol-CNO mixture with surfactant



a b c d

With surfactant: increasing amounts of surfactant added to a 20% ethanol blend: (a) no surfactant; (d) 13% surfactant.

Engine testing

The engine testing consisted of

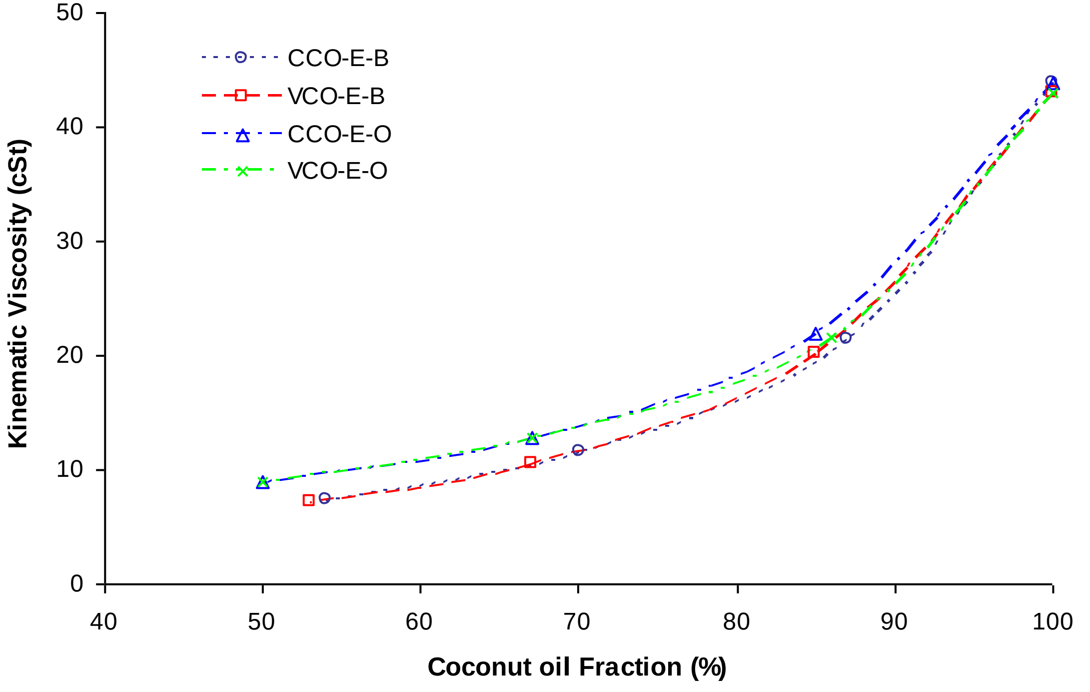
- determining load-efficiency curves, and
- emissions testing

Equipment used for the engine testing

Typical sample series used in this study

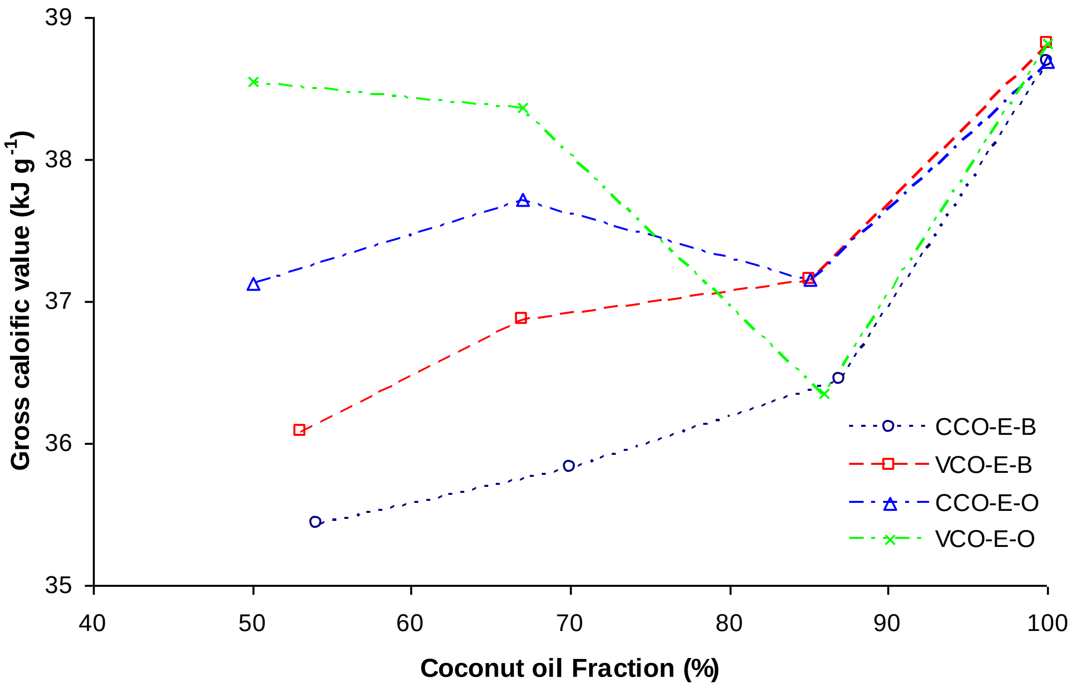
Sample label	%CNO	%Ethanol	% Butanol
HF1	**87**	**10**	**3**
HF2	**70**	**17**	**13**
HF3	**54**	**23**	**23**

9. Results: Blending and viscosity



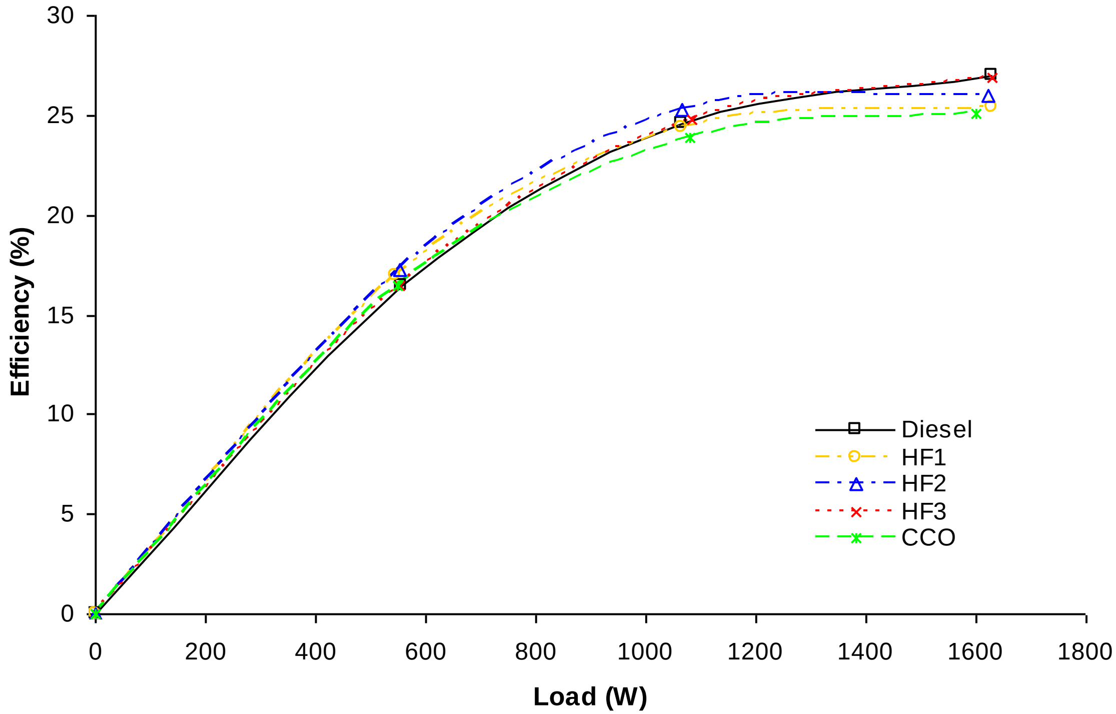
Viscosity reduces towards the diesel value (~4 cSt) for both commercial (CCO) and virgin (VCO) oils as more ethanol is added

Energy content (Gross calorific value)



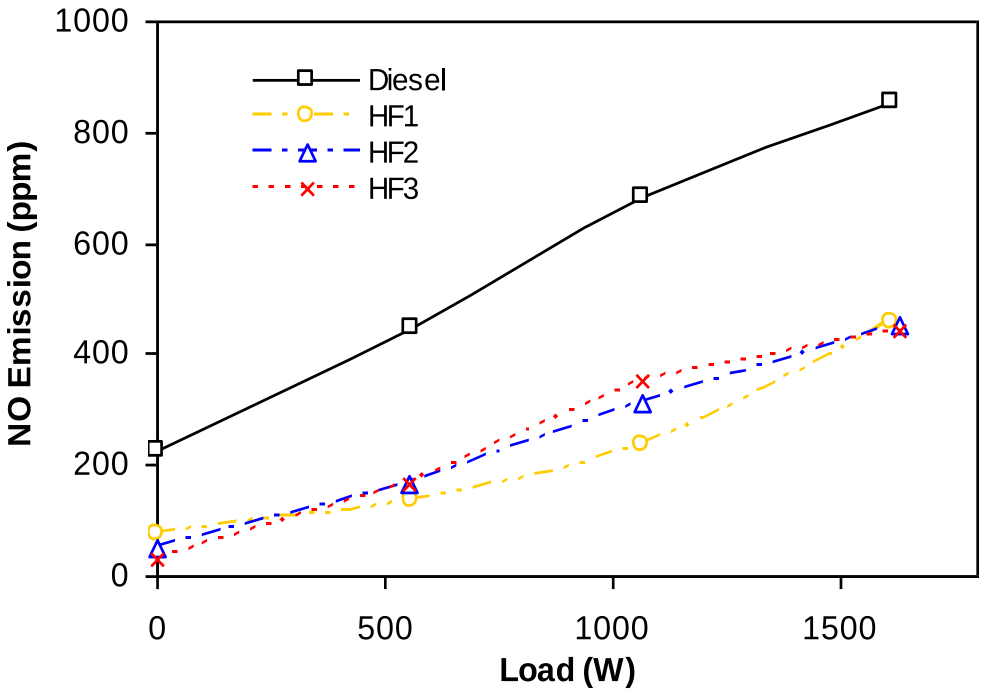
The energy content generally tends downwards toward the ethanol value (27.3 kJ/g) as more is added– spurious rise is due to energy content of surfactant (34.2 for butanol, 44 for octanol)

Engine efficiency



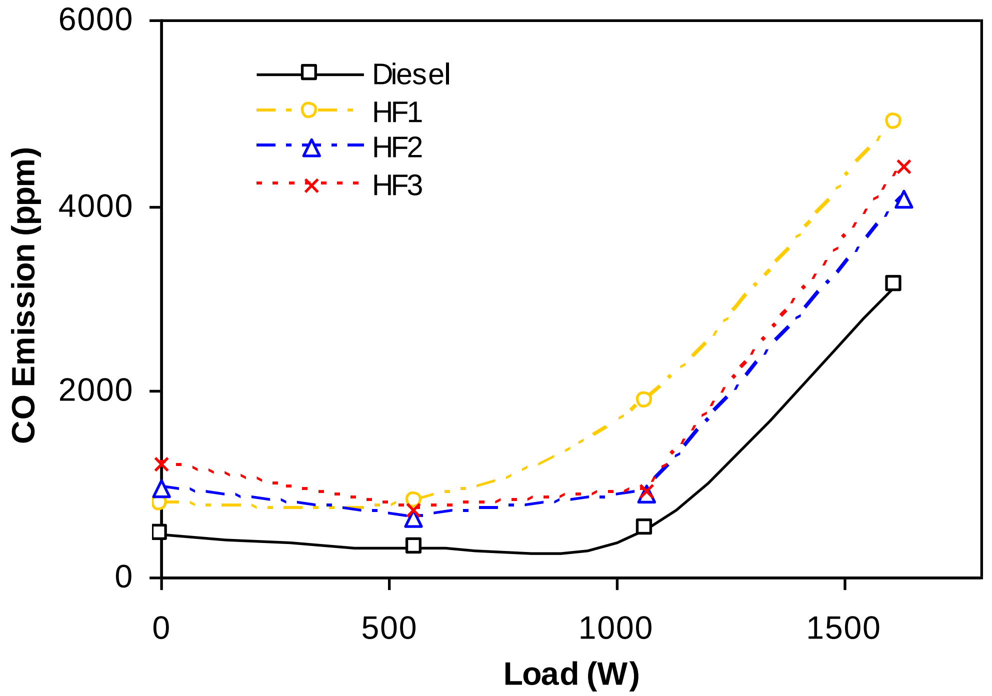
Engine efficiencies are very close to those of diesel

Engine emissions - NO



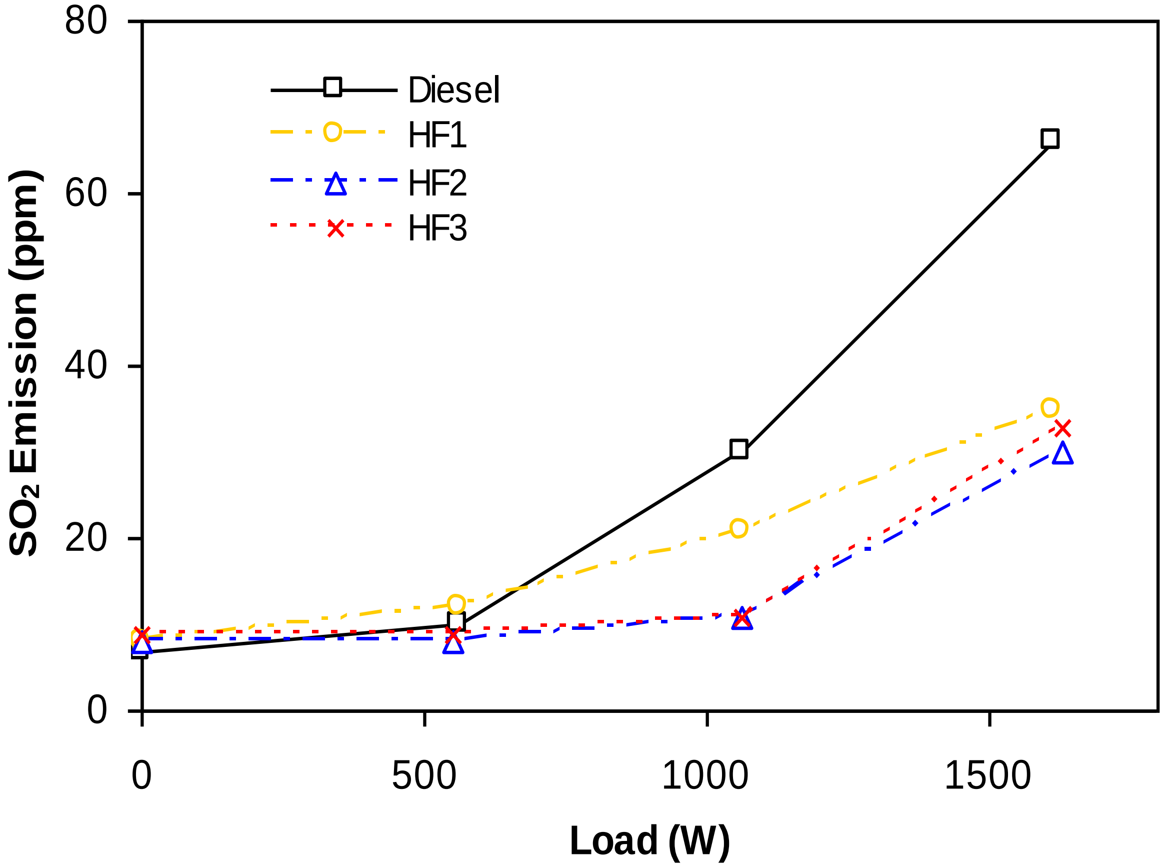
All series of samples produce much less NO than diesel

Engine emissions - CO



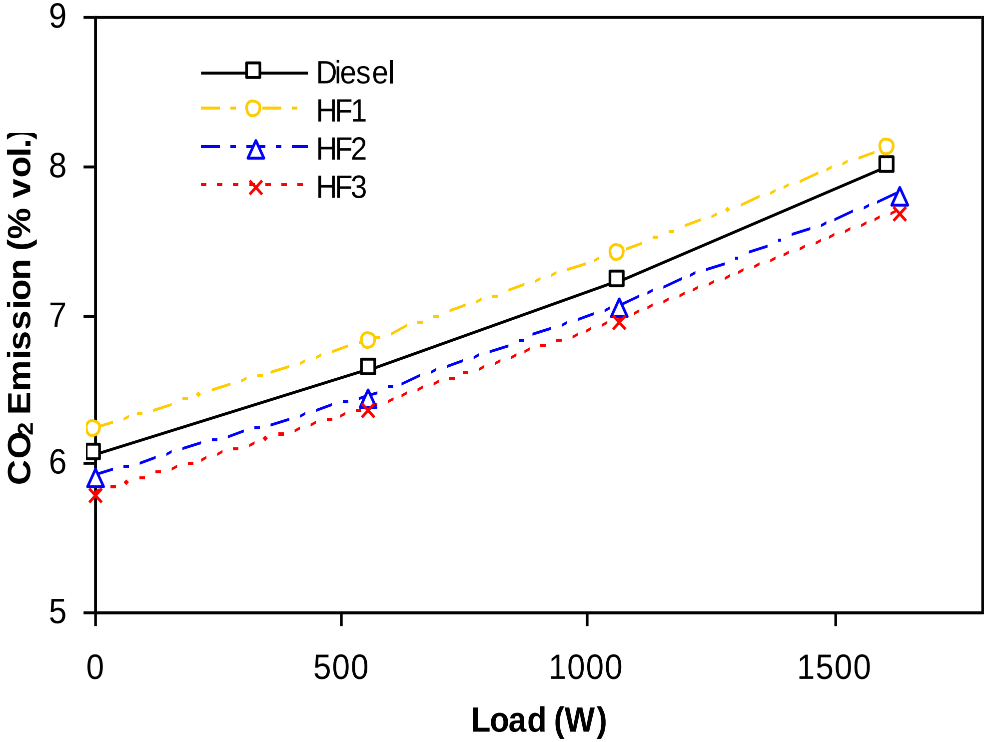
Carbon monoxide emission is generally higher than diesel

Engine emissions - SO_2



Sulphur Dioxide emissions are suppressed except for the lowest load conditions

Engine emissions - Carbon dioxide



CO2 emissions are (except for HF1) generally lower than diesel

10. Conclusions from the USP work

- Ethanol-CNO micro-emulsions containing up to 23% ethanol can be prepared with the help of surfactants
- The diesel engine efficiency is not affected to any great extent when these fuels are used as alternatives
- Except for carbon monoxide emissions (which are slightly higher for the hybrid fuels), these fuels emit lower amounts of harmful substances such as NO and SO2 to the atmosphere.
- The disadvantages of these hybrids are the large amounts of surfactants needed for the higher ethanol ratios, and the slightly inferior fuel consumption due to the lower energy values of CNO(38.7 kJ/g), and ethanol (27.3 kJ/kg) than diesel (45 kJ/kg).
- An extended engine testing (over several hundred hours) is required to determine the deleterious effects, if any, these fuels will have on the engine and its performance.

12. Future work

- We intend to investigate new surfactants that are better at producing miscible systems
- Extended engine testing to determine what effects these fuels have on the engine
- Extend the work to other vegetable oils and to vehicle engines

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Thank you for your attention!