5th INTERNATIONAL BIOFUELS CONFERENCE

Feb. 7-8, 2008, Hotel Le Meridian, Janpath, New Delhi, India

INVESTIGATION ON SHORT BIOENERGY CHAINS BASED ON THE DIRECT USE OF PURE VEGETABLE OIL

D. Chiaramonti, M. Prussi, G. Braccio* and V.K. Sharma*

CREAR Department of Energetic "S. Stecco", University of Florence
Faculty of Mechanical Engineering, Florence, Italy

*** ENEA Research Centre Trisaia, TER-ENE-BIO Section**
75026 Rotondella (MT), Italy

E-mail: sharma@trisaia.enea.it

Trisaia Research Centre, Italy

Mr. Chairman, distinguished delegates, dear colleagues, ladies and gentlemen.

At the outset let me most heartily congratulate the organisers of this seminar for organising this important event in a very critical area of **Energy.**

Energy and, in particular, the clean energy, is certainly an important scientific topic that needs special attention by the scientific community World-wide and, more so, in the context of the developing countries.

JUSTIFICATION FOR THE WORK UNDERTAKEN

The main objective of the "VOICE-LIFE Project" is related to the investigation on the short bioenergy chains, based on the pure vegetable oil.

The direct use of the vegetable oils has positive environmental impacts and, if based on properly converted adequate technologies, allows easy energy generation from a renewable source. The main advantage with the pure vegetable oil chain is that the added value, of the end-product, remains to the farmer, and this creates the real bases for a rural development founded on bio-energies.

In order to select the best cultivars for energy production (based on sunflower crop) some experimental cultivation have been realized in Tuscany region (about 100 ha for the sunflower cultivation and two experimental fields, for the research activities).

To show farm-scale extraction feasibility, a small-scale pilot extraction plant has been installed in Tuscany, as well. Finally, to show the economical feasibility of the entire chain, some co-generators will also be modified during the project.

ISSUES RELATED TO THE USE OF VEGETABLE OILS FOR ENERGY PRODUCTION

Vegetable oil has different chemical-physical properties compared to the conventional diesel fuel; this poses many technical issues, especially in the combustion processes.

(From a chemical point of view, vegetable oil is a mixture of free fatty acid, di- and tri-glaciered, glycerol, phosphorus compounds and waxes. Considering sunflower oil, an important aspect is the ratio between linoleic and oleic acids. The linoleic acid increases the iodine number, which is a mean to measure the amount of in saturations present in the oil that is correlated with the formation of deposits in some parts of the engines)

Another important difference between VO and diesel oil is the kinematics viscosity.

(Vegetable oil is 11-17 times more viscous than conventional diesel fuel or biodiesel. Atomisation troubles are joined with high viscosity fuels and the combustion process is strongly affected by it. The main expected troubles are related to the injector blockage, higher exhaust emissions and reduction of the engine life)

POSSIBLE SOLUTIONS !!!!!

- Mixing with diesel;
- Blending it with an organic solvent additive;
- Single or two-tanks VO kits,
- Engine conversion etc.

are many different approaches in solving the problem.

For example, in Europe, several companies offer kits to convert engines.

IMPORTANT APPLICATIONS

PRODUCTION OF HEAT

Production of heat using VO have no complex problems except long-term demonstration probability. Oil viscosity needs to be adjusted to achieve both the efficient combustion and droplet SMD (Sautern Mean Diameter) similar to the diesel oil and all this doesn't require any modification of the combustion camber.

RURAL TRANSPORT

Use of VO in the transportation sector, especially, in the rural areas appears to be another potential application for the small bioenergy chains. The main problem of this potential application is the injector system; a component mainly affected by the use of this fuel.

POWER PRODUCTION

Usually, the production of electrical energy is performed by endothermic engines and, the related technical issues are more or less similar to the ones in the transport. The diesel engines used in this application usually have low and constant rotational speeds.

CROP CULTIVATION

Amongst different issues affecting quality of the sunflower oil for non-food applications, content of oleic (18:1) and linoleic (18:2) acids that correspond to nearly 85 - 90 % of the total acid quantity in sunflower oil is of significant importance.

Insaturation grade presents in the oil, depends on the cultivar used in the plantation. The conventional cultivar generates oil with 20-30% of oleic acid, while in case of “high oleic” cultivar, the percentage increases up to 70- 90%. The ratio between oleic and linoleic acid is also affected by cultivation parameters, such as minimum temperature of the cultivation and the period of the seeding.

Low temperatures promote the production of linoleic acid while high temperatures affect the production of oleic acid. VO with high oleic acid content can be obtained even with winter seeding and, this particular feature, decreases with possible delay of seeding.

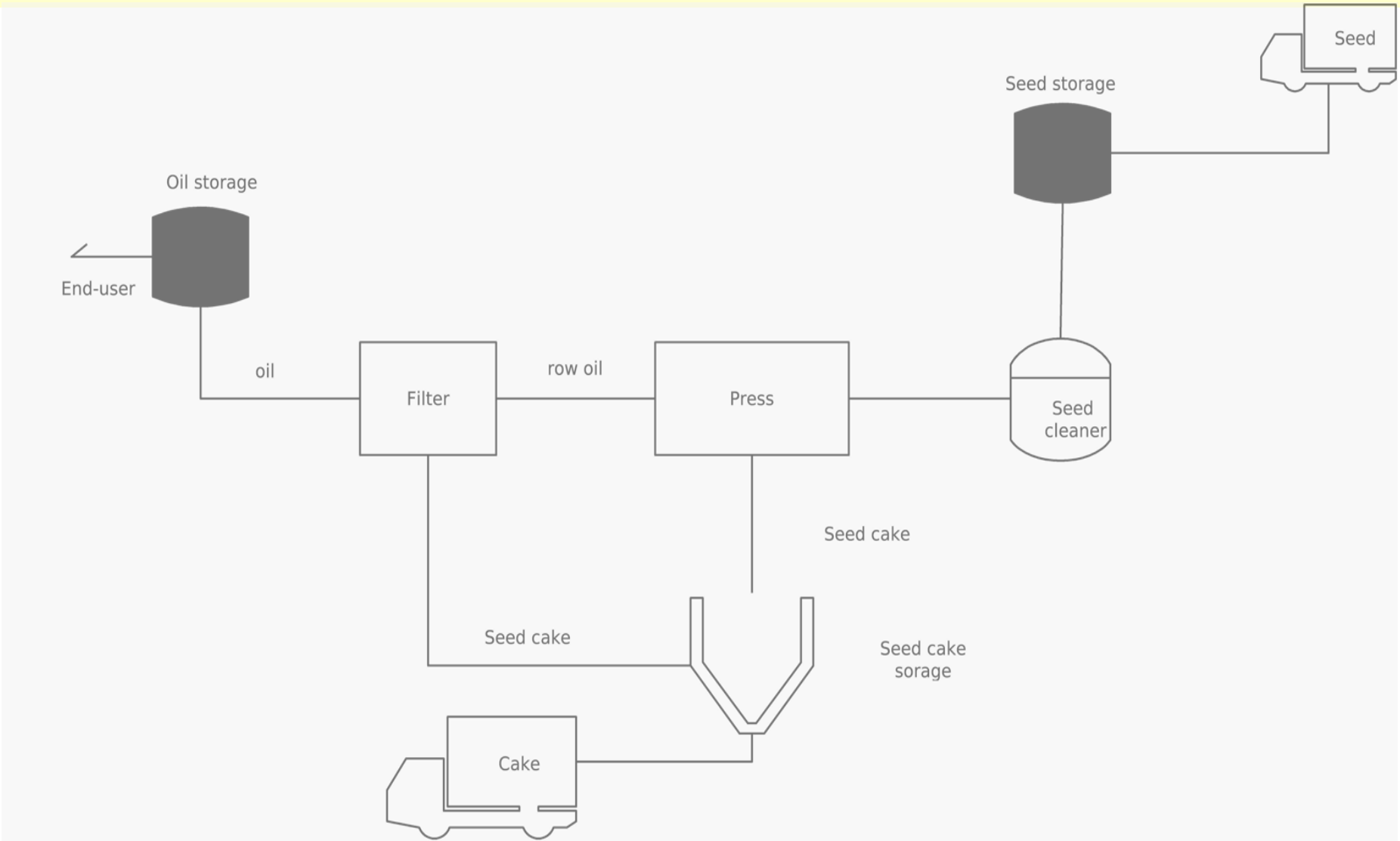
Some hectares of land has been reserved in the VOICE project solely for the purpose of cultivar demonstration.

Yield of the sunflower production

Province	Surface (hectares)	Sunflower Variety	Production (ton)	Yield (ton/ha)
SI	25	KWS_logisol	30	1.2
AR	5.0	KWS_logisol	4	0.8
PI	10.0	PIONEER_H41	15	1.5

SMALL SCALE EXTRACTION PLANT

The conceptual scheme of a decentralized oil extraction plant can be defined trough a flow chart.



The seeds transported from the fields (and stored into silos) are made to pass through a seed cleaner that removes dirt and eventually metal fragments. Subsequently, they are pressed to produce raw oil (about 30% of the inlet mass flow). The solid part, called seed cake, is sent to buffer storage, prior to its final use. The raw oil is subjected to a process of decantation and then filtered. Solid part produced in filter can be added to the cake. The filtered oil can so be stored and supplied to the end-users.

In order to help the local integration and easy maintenance, main idea is to create simplest possible plant. Seed storage, screw for seed charging, seed cleaner, oil press, storage and the filter, are the main components of the plant.

The seed pressing unit is a machine sensible to the start-stop intervals and so mainly because of this reason attention has been paid to its integration with other plant components. Many solutions have been considered in order to guarantee the continuous working, even if troubles with the filter or with the oil storage will occur. The system has been designed to have a high level of automation.

PRELIMINARY TESTS ON A MODIFIED TRACTOR

From technical point of view, the main problem of this potential application, i.e. use of VO in the transportation sector, is the injector system of the machine. This was evident from the experimental results obtained by Bruwer while working on a tractor fed by 100% VO fuel, with net decrease in output power of nearly 8% after about 1000 working hours.

Engines inspection showed deposits both on injectors and filters. Successive studies further confirmed these macro-observations and, depending on the engine type, current kits available on the market are based on the substitution of filters, injectors, fuel pump, valve/valve seats, and addition of a fuel heating element. In order to perform efficient fuel combustion, some modifications concerning working parameters of the engine, could easily be modified.

Agricultural tractor to be fed with pure VO has been modified. The modified kit has been installed by a project partner (VWP) on a machine. The machine is an “AgroPlus 85” produced by Deutz Fahr, engine a direct injection, liquid cooled, BF4M 1012 with characteristics as reported in Table.

Deutz Fahr engine characteristics

Net power	[kW]	63
Displacement	[cm^3]	3192
Volume Compression ratio	[-]	17.5
Pressure level	[bar]	28-33

The kit installed has been developed for the rapeseed oil. It is because of this reasons that tests needs to be conducted using sunflower oil. Based on the precedent experiences, two main issues have been considered: design performances in term of power output and fuel consumption will be maintained through appropriate tractor capacity contamination of the lubrication oil.


EXHAUST GAS
VALVE
INLET
VALVE

Chemical analysis of the deposits

	N%	C%	S%	Weight (mg)
Inlet valve	0,53	61,92	0,522	3,25
Exhaust gas valve	0,62	60,09	0,822	4,83
injector	0,54	53,89	0,00	1,19

	Ca	Mg	P	
	ppm	ppm	ppm	
Inlet valve	3577	243,2	938,3	
injector	---	---	---	Not enough material

Injector: The injectors were in optimal conditions. Pin of the component (free of deposits), seals and other components of the injection system resulted to be clean. Only, the part directly located into the combustion chamber presents a thin layer of deposits. No signs of corrosion are present.

Valves: Though the valves appeared free from the fuel combustion deposits, nevertheless, some deposits were present on the upper part of the inlet valve. The deposit could lead to some troubles of leakage of lubricating oil, in the turbo-charger group.

Head of the piston: The head of the piston showed some deposits. However, such deposit is of scarce interest for the engine operational condition.

Filters: The fuel filter group has been cut. These elements contain a relevant part of wax and margarines, probably due to a non-checked bench of oil used.

RESULTS AND DISCUSSION

With the use o f VO, reduction in maximum power (about 2.2%) with corresponding increase of fuel consumption (3.0% vs. 15% w/w) was observed. This is in good agreement with the lower calorific value of the VO, about 10% w/w respect to the diesel one.

VO is soluble in the lubricant oil, and alters its lubrication properties.

After 100 working hours, a small percentage increase of Si and metals (due to wear) was found.

The preliminary conclusions confirm that the use of sunflower oil should not significantly modify the performance of the installed conversion kit. After 200 hours of working with the VO feeding, the engine has been inspected. The general status of the engine was good; some components have been deeply analysed.

The VO has the tendency to pass through the piston sealing, into the lubricating oil, altering its chemical-physical performances. This effect seems to be important at low engine regimes. Monitoring of lubricating oil has been carried out as indicator of the kit conversion validity.

As shown below, no significant variation in the main parameters, such as oil viscosity, suggest that the installed kit guarantee good performances also for the sunflower oil.

Viscosity ASTM D7042-04	
Nominal value	99
Actual value	102
Precedent value	102
Perceptual variation	0,0

Form first working experience, it can be concluded that the Kit installed on the Deutz Fahr tractor seems to work well even with the sunflower oil.

Considering chemical-physical differences in the two fuels, such as the LHV, power output and general behaviour of the machine is satisfactory.

No significant troubles have been found by the engine investigation.

Monitoring of lubricating oil (due to tendency of the VO to pass into lubricating oil) showed no significant modifications in its chemical-physical parameters.

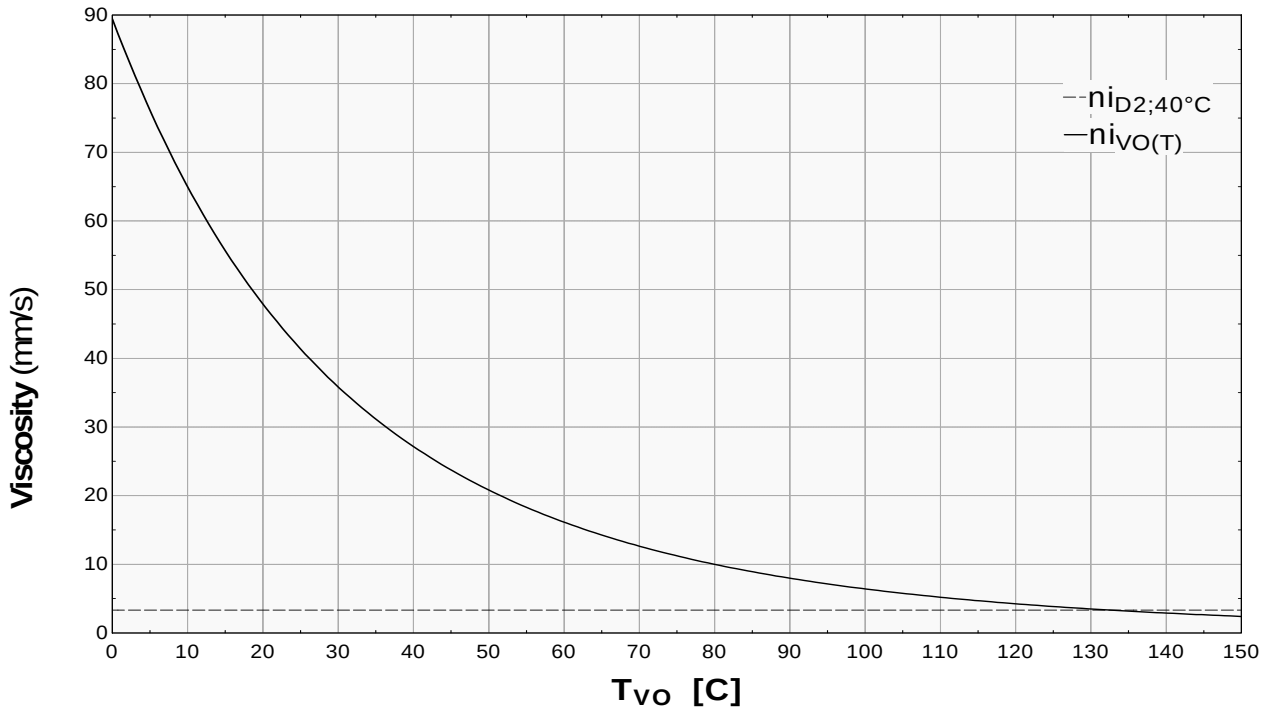
MINOR MODIFICATIONS FOR MICRO GAS TURBINE (MGT) FEEDING WITH PURE VEGETABLE OIL

As regard MGT, modifications needed relevant to C30 with VO feeding, have been investigated. At the first instance, a comparison between the physico-chemical properties between vegetable oil and standard D#2 has been carried out.

Viscosity of the VO results the main trouble; comparing the DIN-standard for VO (i.e. first quality target for VO production) with CAPSTONE requests for liquid feeding. Using values obtained from mechanically extracted VO, Ca, Mg and P contents are really high with respect to the CAPSTONE indicated values. Also, the amount of water is high.

The process of atomization, mixing/evaporation and combustion has been investigated, for VO feeding. In order to have the same operative conditions of the machine as the nominal values (even with VO), the basic idea is to modify the operative parameters of C30 and oil feeding temperature. For atomization process, a correlative approach (Rizk-Lefebvre's correlation has been used, and the SMD (Sautern Mean Diameter) dependency as function of the fuel temperature has been investigated.

High temperature help reducing the SMD, increasing atomization and combustion performance of this fuel, but technical barriers put limits to this parameter: maximum temperature of fuel pump and the chemical stability of the fuels are the main issues. Combustion stage will be next analysed, as the ratio between stoichiometric ratio and LHV, for the two fuels, strongly affects combustion temperature, and consequently, the thermal field in the combustion chamber. For similar thermal fields, similar emission levels can be awaited, in particular for the NOx and CO polluting.



VO cinematic viscosity on fluid temperature

CONCLUSION

A reduction in maximum power reduction (about 2.2%) with corresponding increase of fuel consumption (3.0% v/v 15% w/w) was observed, when a modified agricultural tractor was fed with pure VO.

No significant variations in the main parameters, such as the oil viscosity, suggest that the installed kit guarantee good performances also for the sunflower oil.

After 200 working hours with VO feeding, general status of the engine was good. Preliminary conclusions confirm that the use of sunflower oil should not significantly modify the performance of the installed conversion kit.

First preliminary tests gave promising results, both for the cultivar screening as well as for the tractor testing. The conversion of other generators, such as MGT and creation of a decentralized extraction plant offer opportunity to investigate entirely present new model of bioenergy generation.

WISHING YOU ALL

A VERY SUCCESSFUL CONFERENCE

THANK YOU !!!!