Dr. eng. Piotr Pasyniuk
Institute for Building, Mechanization and Electrification of Agriculture
Warsaw, Poland

Pure Vegetable Oil, the alternative fuel for agriculture

Introduction

Pure vegetable oil is one of the most promising of all renewable fuel sources. Especially in agricultural transport and other agricultural applications, pure vegetable oil could play a key role in future farming strategies. Besides the obviously broad ecological benefits due to carbon-dioxide neutrality, pure vegetable oil offers an enormous economic potential for agricultural farms in the field of energy production. This is especially true in decentralized supply chains or for fuel self supply in farms. The production process has only small energy losses and provides potential for additional income generation on farms, thereby strengthening rural economic structures.

All other biofuels have a longer production chain and higher associated energy losses. E.g. ethanol production shows high energy losses because of the required distillation step and synthetic biofuels produced by the thermo-chemical pathway can hardly be produced with efficiency higher than 50% due to high thermal losses of the gasification stage and the fuel synthesis (Fischer-Tropsch or similar). All biofuels except pure vegetable oil also present a more or less pronounced risk for the environment or for safety due to some degree of toxicity and the generally high flammability.

The presently most used vegetable oil for transport is rapeseed oil. However, rapeseed can hardly be cultivated organically, thus not allowing fully sustainable fuel production. Sunflower oil is an alternative and *camelina sative* oil as well. Camelina sative is a co-crop in mixed-cropping cereals and/ or fodder peas. Mixed-cropping, the cultivation of tow or more plant species at the same time on the same field, allows to switch from conventional to organic agriculture without yield losses. The oil from camelina sative is an additional yield and 100-300 liters can be obtained per hectare. Other really promising crop is jatropha which increases considerably the fuel potential in hot arid and tropical countries without harming the environment.

Objects and method

Since 1993 German enterprise VWP has been developing engine and fuel technologies for plant oil fuel operations in series diesel engines (passenger cars, tractors, trucks and stationary engines). In cooperation with JDWM these technologies were also developed and tested on John Deere tractors. Within this cooperation the plant oil capability has been achieved for the third generation of engines (exhaust gas regulation level 3A/Tier 3). Today this technology is available for plant oil operation. Plant oil capability is achieved by technical adaptations according to the patented VWP-plant oil combustion process, a modified fuel supply system and optimized engine management. The systems allows for plant oil operation in all operating conditions including engine starting. The tractor can be started without any additional preheating equipment at temperatures above +5°C. Using the JD cold start package (engine preheating with external 220 V supply) makes cold starts with pure plant oil possible even at temperatures below +5°C. By mixing diesel into the plant oil fuel to a certain percentage, the tractor can be started and operated at temperatures clearly below zero. Engine runs on vegetable oil, diesel or biodiesel . External appearance not different from standard model, only little modifications required, vehicle handling is same and familiar. No additional fuel stops, no additional on-site diesel station, no manual switchover from vegetable oil to diesel operation is mounted.

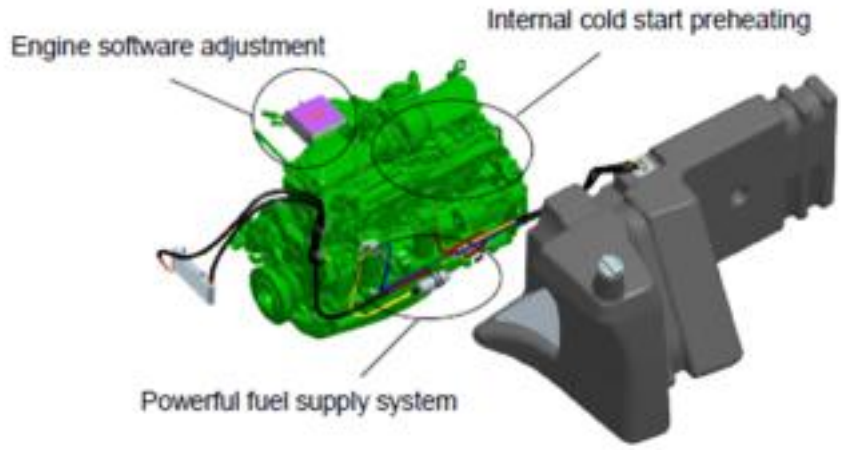

Figure 1. Basic changes in standard John Deer engine

For further engine and oil improvement John Deere Works Mannheim (JDWM) are leading a project called "2nd VegOil" runs within the EU 7th Framework Funding Programme. The project covers research and demonstration on 2nd generation vegetable oil fuels in advanced

engines. Project partners are: Vereinigte Werkstätten für Pflanzenöltechnologie – VWP (D), Technical University of Munich, Chair for Internal Combustion Engines(D), Lubrizol Ltd. (UK), Waldland Vermarktungsges. m.b.H. (AU), Rhônalpénergie-Environnement (F), Fédération Régionale des CUMA Rhône-Alpes – FRCUMA (F), Instytut Budownictwa, Mechanizacji i Elektryfikacji Rolnictwa – IBMER (PL) and Nederlands Normalisatie-Instituut NEN (NL)

The goals of project are: demonstration the reliability throughout the entire project period of various John Deere tractors (off-road exhaust emissions standard Stage 3A) that run on vegetable oil fuel on a day-to-day basis, optimising and test engines and exhaust gas after-treatment components conforming to exhaust emissions standards Stage 3B and 4 for operation with vegetable oil fuels, developing and optimise a local production process for 2nd generation vegetable oil fuels with a view to future exhaust emissions standards and exhaust gas after-treatment technologies, achievement sustainable solutions beyond the current exhaust emissions standards.

From april 2009 in Poland started to work 4 tractors John Deer 6830 Premium powered with pure rapeseed oil.

Figure 2. Polish farmer Mr. Zajkowski and his JD powered with pure rapeseed oil

Average farm area is about 60 ha. Level of tractor exploitation was 70 to 100 operating hour (oh) per month. First engine oil change was made after 100 oh next elective service time is after each 250 oh.

Results

For tractors run on vegetable oil decline power was expected. The tractor might show up to 15% reduced power due to the minor energy content of rapeseed oil fuel. But farmers never complain of this situation. Decision about power measure with mobile dynamometer was made, however. The findings are shown on figure 3.

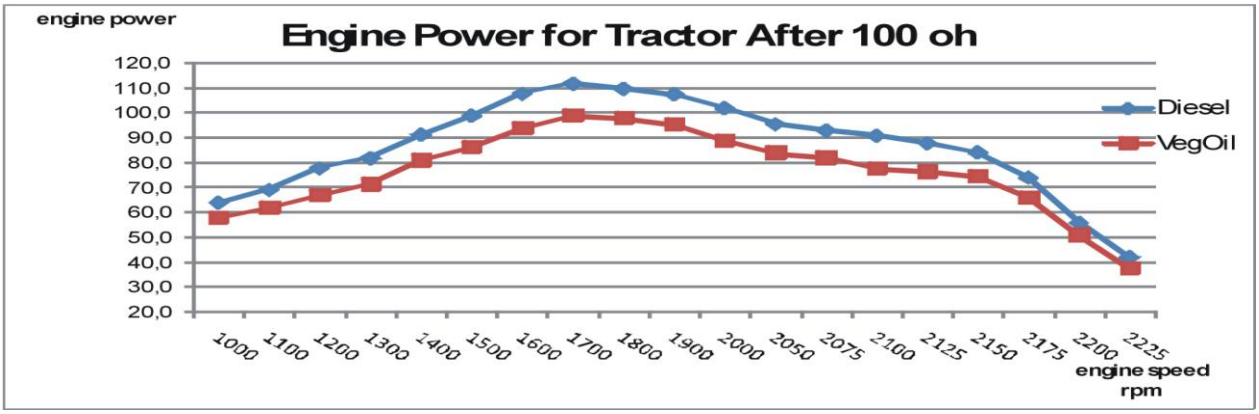

Figure 3. Engine Power for tractor run on diesel or on vegoil

Average power decline was 11.8% with maximum on level 14.6% at 2 110 rpm. For maximum power at 1 780 rpm difference was 12%. Fuel consumption level was measured at once.

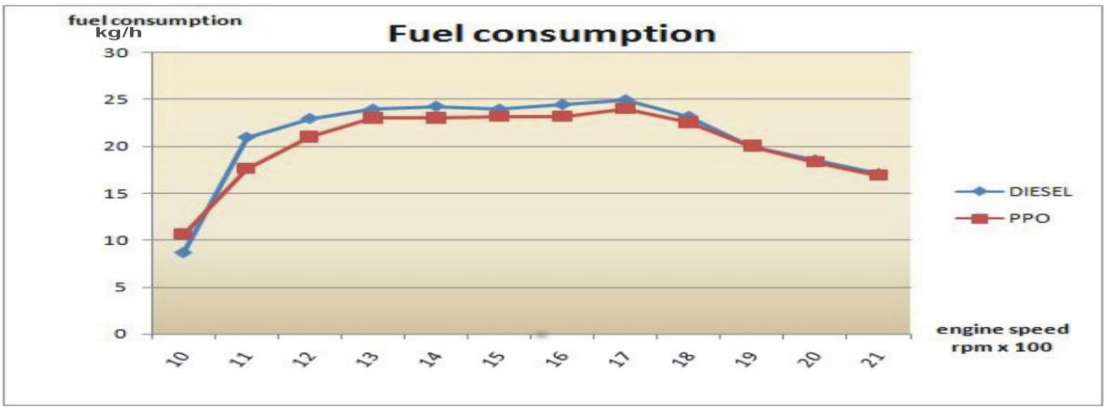

Figure 4. Fuel consumption for different engine's load

Maximum difference was 16.2% for 1 200 rpm and approximate 5.0% for revolution range from 1 300 to 1 800 rpm. Median rapeseed fuel consumption for normal field work logged since march 2009 was about 18 l/oh. The lowest surroundings registered temperature was +5^{0}C.

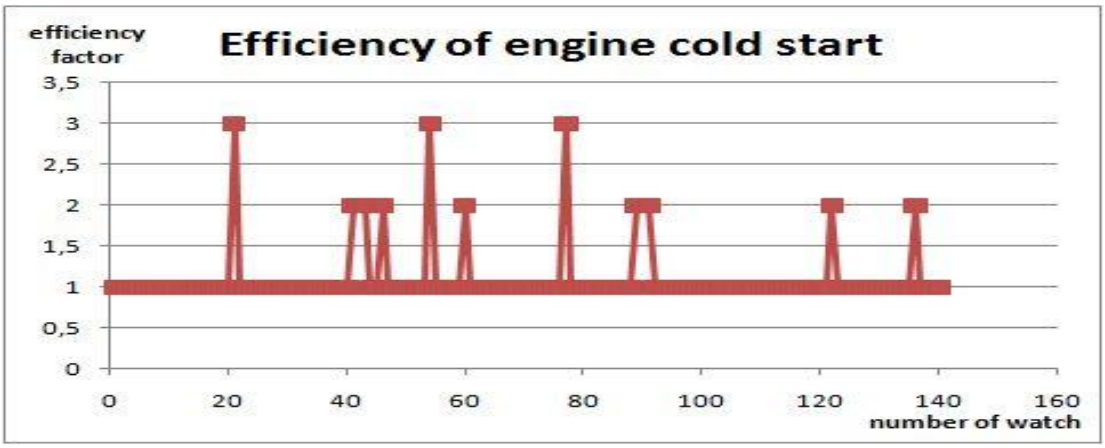

Figure 5. Efficiency of engine cold start

In test duration most of morning engine starts trouble-free. Even after long term tractor park, for example during 14 days, engine starts at once. In whole period during 140 observations 8 times engine started after third trial and twice after second.

Conclusions

1. Pure vegetable oil use as engine fuel has the potential for the most comprehensive ecologic, economic and social benefits of all biofuels. The production involves few process steps and can be done economically with small production units. The production process has only small energy losses and provides potential for additional income generation on farms, thereby strengthening rural economic structures.

2. Is possible to achieve EU stage 4 / US Final TIER 4 emission levels and even achieve forthcoming EURO 6 emission levels what needs further engine and fuel improvement.

3. The relatively short term investigation show that John Deer engines modified together with VWP are fully adapted to work with pure plan oil. Drivers did not complain small engine power decrease for powerful tractor working under maximum load.

4. Based material and labor costs in Poland in first quarter 2009 replacemen diesel by rapeseed oil can makes profit for farmer up to 25 % of annual fuel expenditure.

References

1. Lotko W.: Zasilanie silnikow wysokopreznych paliwami weglowodorowymi i roslinnymi. Wydawnictwa Naukowo-Techniczne, Warszawa 1997
2. Niewiadomski H.: Rapeseed Chemistry and Technology. PWN, Warszawa 1990
3. Pasyniuk P.: Czysty olej roślinny do konstrukcyjnie zaawansowanych silników wysokoprężnych. AgroImpuls, Warszawa lipiec 2009
4. Pasyniuk P.: Pure vegetable oil as an alternative fuel for second generation engines in sustainable farming – economic aspect. Problemy Inzynierii Rolniczej, Warszawa, No 1/2009
5. Szlachta Z.: Zasilanie silnikow wysokopreznych paliwami rzepakowymi. Wydawnictwa Komunikacji i Lacznosci, Warszawa, 2002