Non-Esterified Plant Oils as Fuel
-Engine Characteristics, Emission Behaviour and Health Impact of PM-

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1. INTRODUCTION

Engine	Purpose
Diesel engine OPEL 1.7 CDTI ECOTEC®	Basic investigation: ➢ Detailed analysis of particle emission ➢ In cylinder pressure indication Different plant oils in comparison to gas oil: ➢ Rape seed oil ➢ Sun flower oil ➢ Soya oil ➢ Peanut oil
Diesel engine MAN D2066 LF36	Generation of particulate matter from gas oil and rape seed oil operation for AMES test. The particulate matter was sampled under well defined conditions over a longer period of time.

Table 1: Overview of experiments

Plant oils may be used as a sustainable, nearly CO_2 neutral fuel for diesel engines. Plant oils do not require any chemical treatment so do not cause secondary pollution. This work investigates experimentally the particulate and gaseous emissions of diesel engines fuelled with non-esterified, pure plant oils fulfilling the quality standard of DIN V 51605 (Weihenstephan RK-Qualitätsstandard 05/2000). The emissions of two different engines have been investigated to cancel out engine specific effect. Table 1 lists the engines and the measurements performed with the individual engine.

The engines have been properly adjusted to plant oils, i.e. the fuel was pre-warmed to 80-90^{0}C prior to the high pressure pump and injection. This reduces the high viscosity of plant oil so that a reasonable injection can be expected, avoiding engine damage due to coke formation.

2. MEASUREMENT TECHNIQUES

Measurement data	Measurement devices
Speed of revolution, torque, temperatures and fuel volume flow	Conventional devices
Pressure indication	AVL Indimaster
Gases: NOx, HC, CO, CO_2, O_2	AVL DiGas 440
Particulate matter	Gravimetry, partial flow Transmission electron microscopy LPME Long path multi-wavelength from WIZARD Zahoransky KG
AMES test	Fluctuation assay from Xenometrix GmbH

Table 2 provides the overview of the measurement and measurement techniques.

Table 2: Applied measurement techniques

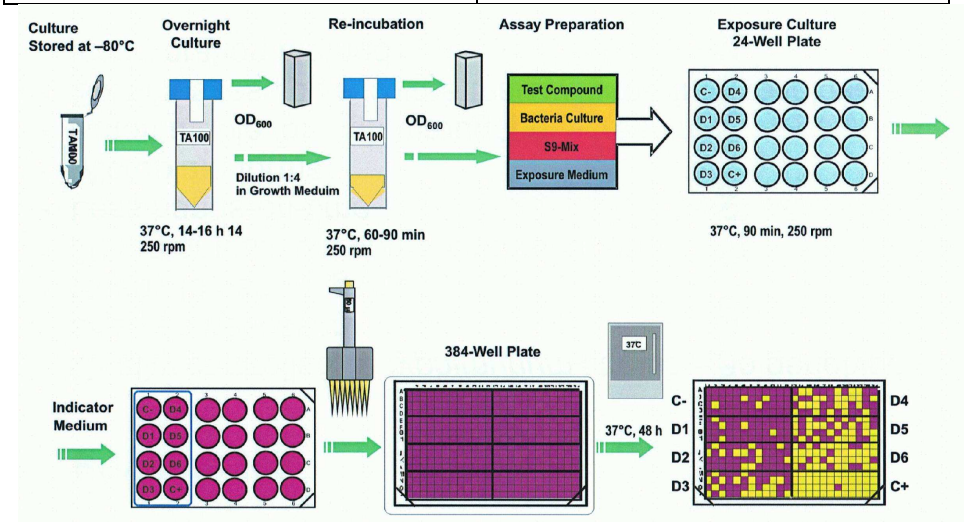

Fig. 1 displays schematically the laboratory procedure of the AMES test. The AMES fluctuation assay with micro plates and ager plates was applied.

Fig. 1: Laboratory procedure of the AMES test

3. EXPERIMENTAL SET-UP

The OPEL engine is installed on the dynamometer of the University of Applied Sciences Offenburg [1]. The installed equipment is chosen to get the basic engine and combustion data and the emission values, including particulate matter, see Table 2. The big MAN engine is installed to collect PM samples for the AMES tests.

4. MEASUREMENT RESULTS

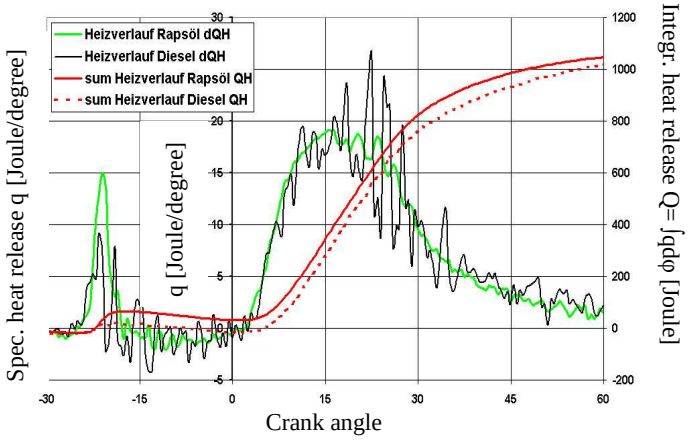

Fig. 2: Heat release, rape seed oil compared to gas oil

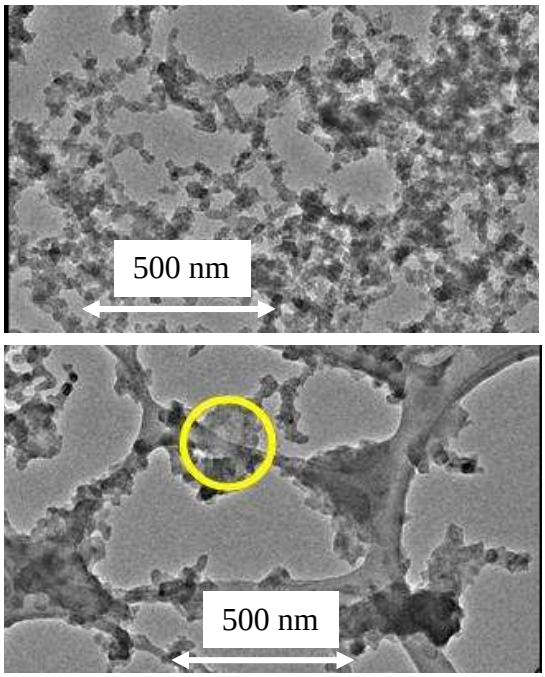

Fig. 3: PM emission of gas oil (top) and of rape seed oil (bottom)

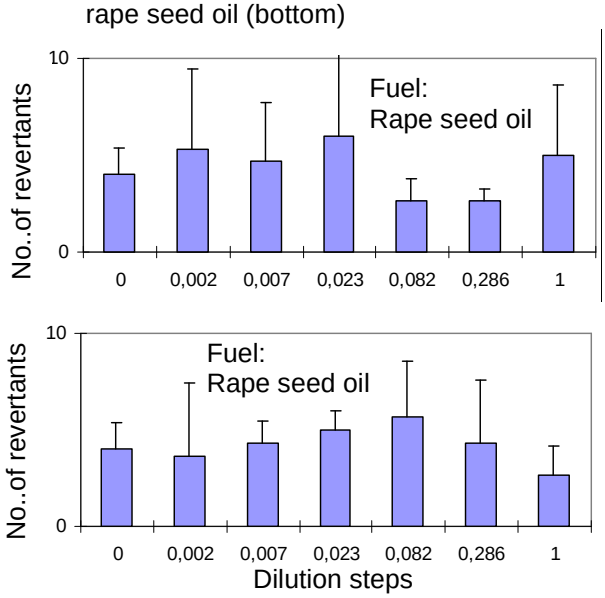

Fig. 4: Typical sample result of AMES test
Number of revertants w/ bacteria phylums TA100+S9 for PM for gas oil & rape seed oil

Fig. 2 reflects the basic difference in the combustion behaviour leading finally to different emission characteristics. The burning of the plant oil is much smoother and can qualitatively explained by the homogeneous content of plant oils with fatty acids, i.e. large carbon dioxides, missing highly volatile components. The plant oils release relatively more heat, the temperature and the pressures are higher in the combustion chamber. Consequently, the NOx emission is higher.

The primary particles emitted by gas oil formed more chain like aggregates whereas the rape seed oils emit more compact, baked together aggregates, as shown in Fig. 3. One can be speculated if this leads to a different biological impact. Further investigations are needed.

Results of the AMES tests:
Fig. 4 suggests that the number of revertants may be slightly higher for PM from gas oil emissions. But all samples are in the range of the negative control sample. Furthermore, a dose effect could not be detected as the different dilution samples did not reveal any significant change in the detected revertant number. Consequently, no quantitative statements to different health impacts of the different fuels can be made. But it can be stated that there is no significant difference between the biological influences of the emitted particulate matter. This is in strong contrast to [2], where the test engine was not converted to plant oil operation – in such a case, the atomization is bad and the combustion incomplete so that a variety of hydrocarbons are emitted. Such emission behaviour with a lot of unburned carbon hydrogen emission was also found in [4] where the incomplete combustion was forced by an old DEUTZ industrial engine. This bad emission behaviour can not occur in correctly adjusted engines. Our results are in line with the careful study of [3] where no elevated health risk is found by plant oil fuels.

5. CITED LITERATURE

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[2] J. Bünger, J. Krahl et al.; Strong mutagenic effects of diesel engine emissions using vegetable oil as fuel; Archives of Toxicology, 2007
[3] K. Thuneke et al., Mutagenität der Partikelemissionen eines mit Rapsöl- und Dieselkraftstoff betriebenen Traktors, Berichte aus dem TFZ 14, Technologie- und Förder-zentrum Bayern, ISSN 1614-1008, Straubing, 2007
[4] R.A. Zahoransky, B. Dorn; Influence of different biological fuels on particle emissions of diesel engine; 9th ETH-Conference “Combustion Generated Nanoparticles” (Conference CD), Zürich, Aug. 2005

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Introduction

Plant oils may be used as a sustainable, nearly CO_2 neutral fuel for diesel engines. This work investigates experimentally the particulate and gaseous emissions of diesel engines fuelled with different non-esterified, pure plant oils. The data are collected from three engines:

a) Common rail 1.7 liter passenger car engine from Opel AG b) 12.8 liter truck engine from VOLVO c) Truck engine from MAN AG

The emissions of the MAN engine have been used to perform AMES tests to analyze possible health impacts of plant oil operation. Finally, all emission results with plant oils have been compared to traditional gas oils.

Engine	***Purpose***
Diesel engine OPEL 1.7 CDTI ECOTEC®	Basic investigation: ➢Detailed analysis of particle emission ➢In cylinder pressure indication Different plant oils in comparison to gas oil: ➢Rape seed oil ➢Sun flower oil ➢Soya oil ➢Peanut oil
Diesel engine VOLVO FH 480	Real traffic cycle Measurement of NOx, HC, CO, CO_2, O_2 emis. With two representative plant oils in compari-son to gas oil: ➢Rape seed oil ➢Soya oil
Diesel engine MAN D2066 LF36	Generation of particulate matter from gas oil and rape seed oil operation for AMES test. The particulate matter was sampled under well defined conditions over a longer period of time.

Measurements:

- All conventional engine data like speed of revolution, torque, temperatures and fuel volume flow.
- Pressure indication by AVL Indimaster.
- Gaseous emissions by DiGas 440 of AVL: NOx, HC, CO, CO_2, O_2.
- Particulate matter: Gravimetry, Transmission electron microscopy, LPME Long path multi-wavelength ext. from WIZARD Zahoransky KG.
- AMES fluctuation assay from Xenometrix GmbH.

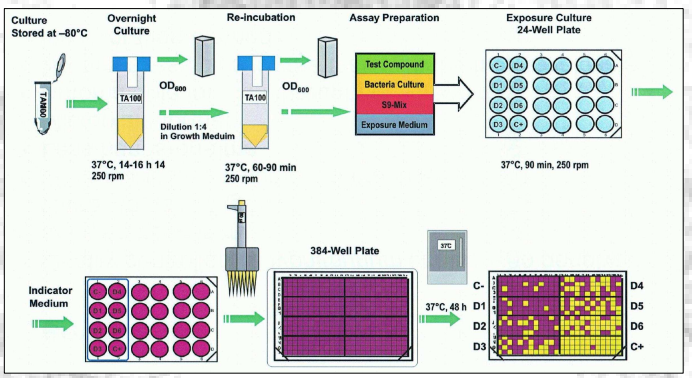

Fig. 1: Visualization of the AMES fluctuation test

Measurement Results :

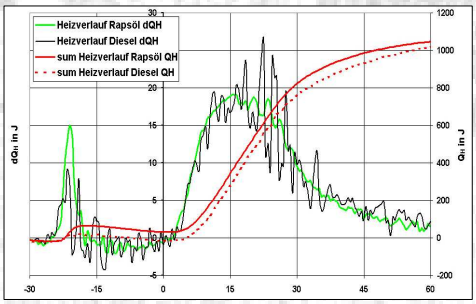

Fig. 2: Heat release, rape seed oil vs conventional gas oil

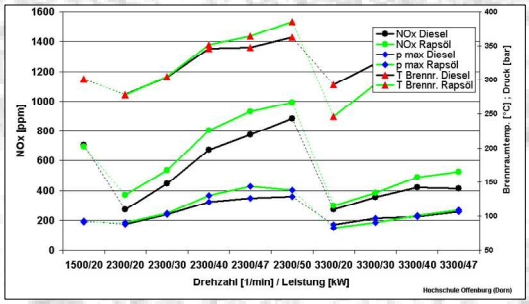

Fig. 3: NOx emission, max. ind. pressure & temperature, rape seed oil vs conventional gas oil

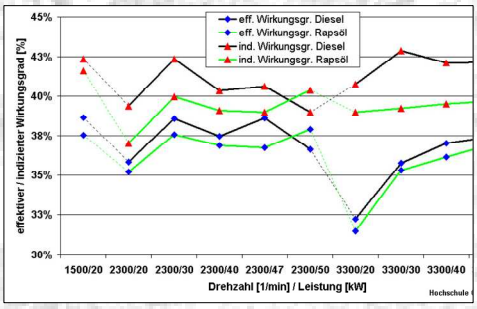

Fig. 4: Efficiencies, rape seed oil vs conventional gas oil

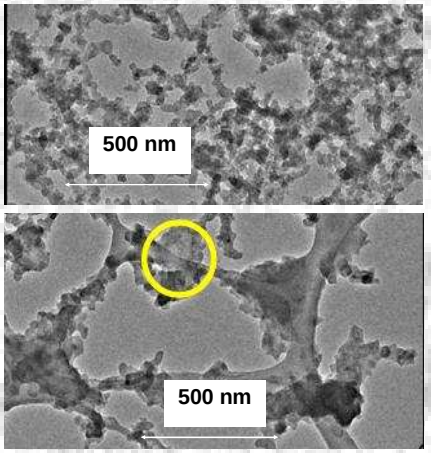

Fig. 5: Particulate matter from gas oil and (top) & gas rape seed oil (bottom)

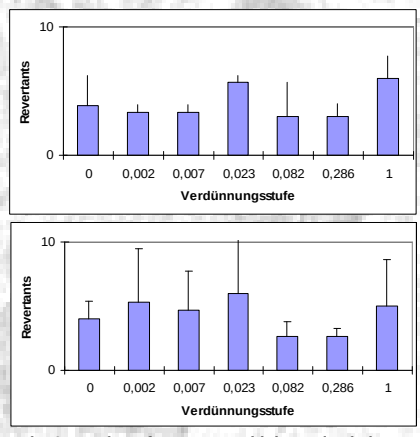

Fig. 6: Number of revertants with bacteria phylums TA 100 - S9 (top) & TA 100 + S9 (bottom) for PM from rape seed oil

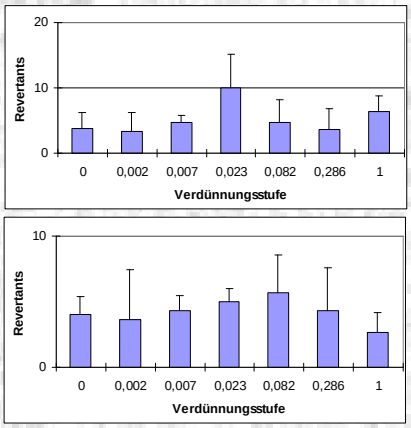

Fig. 7: Number of revertants with bacteria phylums TA 100 - S9 (top) & TA 100 + S9 (bottom) for PM from conventional gas oil

Conclusion :

The emissions from plant oil operations achieved generally lower values compared to the operation with conventional fuel. The CO, HC and PM emissions were appreciably lower. NOx is the exception – this emission was typically 10 % higher for plant oils compared to gas oil.

The indicated pressures have been higher for plant oils. Consequently, the in-cylinder temperature is higher which is assumed to be the main cause of the higher NOx emissions for plant oil fuels.

The measured effective efficiencies and the indicated efficiencies were found to be higher with gas oil fuel compared to rape seed oil. The difference was approx. 5 %.

The primary particles emitted by gas oil fuel formed more chain like aggregates whereas the plant oil particles formed more compact, baked together aggregates, i.e. less chain like.

The AMES test revealed no significant difference in the mutagenic effect of the emitted particulate matter. Even so the concentration of the PM was selected like in a previous investigation with a tractor engine, the number of detected revertants (measure of mutagenic effect) was not above the negative control substance. Therefore, it has to be concluded that PM from plant oil fuels do not have a higher health effect than the PM from gas oil fuel.

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