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Mutagenic Potential of Particulate Matter Emissions from Rapeseed Oil Fuelled Tractors

Particulate matter emissions of plant oil compatible tractors fuelled with standard-compliant rapeseed oil fuel show lower mutagenic effects in comparison to diesel fuel. This is the result of a study conducted by the Technologie- und Förderzentrum (TFZ), Straubing. Particle samples were taken at the exhaust gas test rig of the TFZ by operating a Deutz-Fahr tractor during idle mode and at eight representative test modes according to the European particle measurement guideline. The bifa Environmental Institute analysed the samples for mutagenic potential with the AMES test.

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Keywords

Rapeseed oil fuel, tractors, exhaust gas emissions

The use of rapeseed oil fuel in tractors adapted for vegetable oil can make a significant contribution to the climate protection. In addition, the use of rapeseed oil as fuel offers other benefits in soil and water protection, the improvement of supply security and an improvement of the value-adde by on-farm production of both feed and fuel at the same time. Also since rapeseed oil used in agriculture in Germany is free of energy tax, there is the possibility to reduce fuel costs compared to the use of diesel. A pre-requisite for the successful use of a plant oil suitable engine with rapeseed oil is a high quality fuel that meets the standards set in DIN V 51605. Tractors with engines compatible with rapeseed oil are now brought onto the market directly from the machinery industry; thus, an increase of importance of rapeseed oil use is expected.

With an increased use of rapeseed oil in practice, any unanswered questions about the emissions from rapeseed oil engines have an increased significance. In particular the mutagenic and carcinogenic effects of the engine emissions on human organs have to be considered. Media reports claiming that the use of rapeseed oil has an extremely increased potential of causing cancer have led to a great feeling of uncertainty about its safety.

Therefore the purpose of this work was to investigate the mutagenicity of particle emissions from a rapeseed oil suitable tractor. To allow a more complete interpretation of the results, in addition the composition of the particles relevant to mutagens and carcinogens i.e. the polycyclic aromatic hydrocarbons (PAH) and nitrated PAH (nitro-PAH), was measured.

Methodology

Analyses were carried out on particle emissions collected on filters under the conditions defined for the test cycle according to EU-Directive 2000/25/EG. The particle samples (each about 30 mg) were made up from a total of 8 test points within the engine power-speed map (8-mode-test). Additionally the idle running performance was examined. A Deutz-Fahr tractor Agrotron TTV 1160 fitted with an one-tank rapeseed oil conversion system of the company Hausmann was used for the tests. The particle samples were collected at the test rig of the Technologie- und Förderzentrum (TFZ) at Straubing, while operating the tractor with standard-compliant rapeseed oil and diesel fuel (*Fig. 1*). The legally restricted exhaust gas emissions and the test conditions during sampling were monitored with a continuous data logging system.

Fig. 1: Particle sampling for mutagenicity analysis

The genotype mutation (mutagenicity) as well as the concentration of the PAH and nitro-PAH in a total of 8 samples were measured at the bifa Umweltinstitut in Augsburg by means of AMES-Tests and chemical analyses.

Results

In spite of particle sample masses of about 30 mg, the mutagenic effect on all the test samples was at a very low level and in some cases under the detection threshold.

A comparison of the results between rapeseed oil and diesel showed that the mutagenic potential of the particles derived from

rapeseed oil operation was 10 to 60% lower than those from diesel fuel operation over the whole test cycle and 50 to 80 % lower in idling mode (*Fig. 2*). Expressed in relation to exhaust gas volume, the mutagenicity of the rapeseed oil particles were 30 to 70% lower over the full cycle and from 20% higher to 50% lower in idling mode. But it has to be considered that the use of a standard (instead of an adapted) engine with mineral diesel might give different results.

The presented results are verified by three further autonomous studies of the year 2007 [3, 4, 7] (*Table 1*). In contrast to the above results, e.g. [1] obtained in an unadapted engine of another manufacturer and a different test cycle using unspecified rapeseed oil and a different particle sampling process, a significantly higher mutagenicity with rapeseed oil than with diesel fuel. The difference between results is possibly due to the test conditions.

The results of the chemical analysis of the particles showed that the total nitro-PAH in the particles was much higher with diesel fuel than with rapeseed oil. In particular the strongly mutagenic components 2-nitropyren and 3-nitrofluoranthen are to be found in greater amount in the diesel fuel samples. The higher mutagenicity with the diesel fuel could be at least partly due to this higher concentration of nitro-PAH.

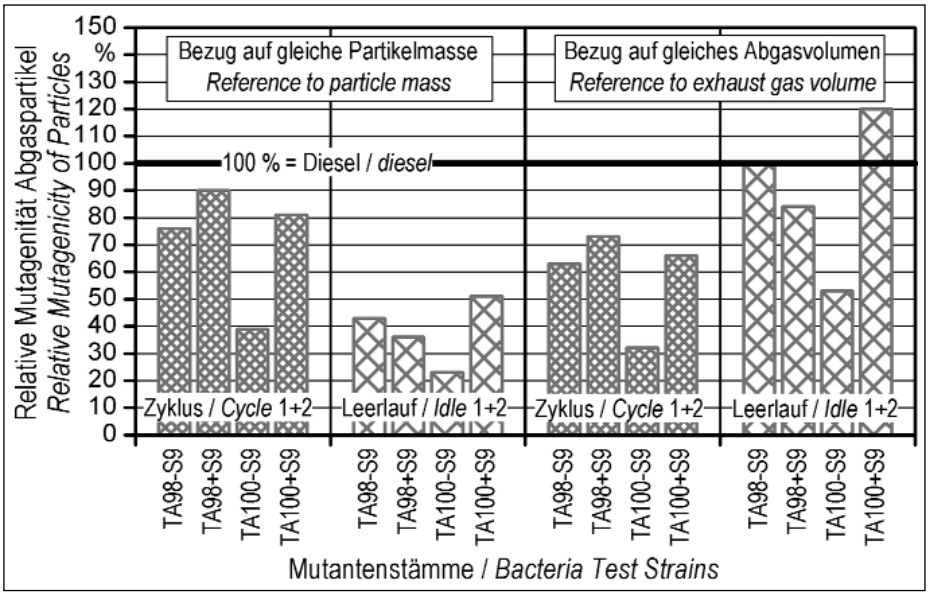

Fig. 2: Mutagenicity of exhaust gas particles from a Deutz-Fahr tractor, operated with rapeseed oil and Diesel fuel at the 8-mode-cycle according to 2000/25/EC and at idle

Conclusions and Outlook

The results of this research show a reduced mutagenicity of particle emissions with the use of standard-compliant rapeseed oil fuel in suitably adapted engines, when compared with diesel fuel. This can be verified by three of four further studies. In future works the relevant mutagenic substances are to be identified, influences of engine and exhaust gas aftertreatment systems, engine operation mode and fuel quality on mutagenic effects of emissions need to be examined. Finally different methodologies of particle sampling and AMES-Test analysis have to be tested.

Table 1: Overview about studies on mutagenicity of exhaust gas particles of rapeseed oil fuelled engines

Quelle *Reference*	Stalder et al. (1994) [5]	Bünger et al. (2007) [1]	bifa i.A.v.*) bioltec evolv-ram (2007) [4] [7]	Univ. Rostock / BSL i.A.v.*) John Deere (2007) [3]	bifa / TUM i.A.v.*) Flughafen München (2007) [2]	TFZ / bifa (2007) [6]
Testzyklus bei Probenahme	Nennlast	13-Phasen-Zyklus	13-Phasen-Zyklus	8-Phasen-Zyklus Phasen einzeln	13-Phasen-Zyklus	8-Phasen-Zyklus und Leerlauf
Test-cycle for sampling	*nominal load*	*13-mode-cycle*	*13-mode-cycle*	*8-mode-cycle single cycles*	*13-mode-cycle*	*8-mode-cycle and idle*
Maschine Motor Motortyp Abgasstufe	Traktor KHD; Deutz F4L912W	LKW Mercedes-Benz OM 906 LA Euro III	LKW DAF Euro V	Traktor John Deere John Deere 6068 HL Stufe IIIa	-- Mercedes Benz OM 602.900 Euro I	Traktor Deutz-Fahr Deutz BF6M 1013EC Stufe II
Machine Engine Engine type Exhaust stage	*tractor KHD; Deutz F4L912W*	*truck Mercedes-Benz OM 906 LA Euro III*	*truck DAF Euro V*	*tractor John Deere John Deere 6068 HL stage IIIa*	*-- Mercedes Benz OM 602.900 Euro I*	*tractor Deutz-Fahr Deutz BF6M 1013EC stage II*
Anpassung an Rapsölbetrieb	Pflanzenöl-tauglichkeit	Rapsölvorwärmung im Tank (70 °C)	Zweitank-System „bioltec“	Eintank-System “John Deere/VWP“	Eintank-System „VWP“	Eintank-System „Hausmann“
Adaptation for rapeseed oil use	*plant oil fuel suitability*	*fuel pre-heating in tank (70 °C)*	*dual fuel system “bioltec”*	*single fuel system “John Deere/VWP“*	*single fuel system “VWP“*	*single fuel system “Hausmann“*
Kraftstoff	Rapsöl, Diesel	Rapsöl, Diesel	Rapsöl-/Dieselmix, Diesel	Rapsöl DIN V 51605, Diesel DIN EN 590	Rapsöl DIN V 51605, Diesel DIN EN 590	Rapsöl DIN V 51605 Diesel DIN EN 590
Fuel	*rapeseed oil, diesel*	*rapeseed oil, diesel*	*rapeseed oil-/diesel-mixture, diesel*	*rapeseed oil DIN..., diesel DIN EN 590*	*rapeseed oil DIN..., diesel DIN EN 590*	*rapeseed oil DIN..., diesel DIN EN 590*
Mutagenität mit Rapsöl bezogen auf die Partikelmasse	--	--	**0,4 bis 0,6** x Diesel	--	**0,4 bis 1,1** x Diesel	8-Phasen-Zyklus: **0,4 bis 0,9** x Diesel Leerlauf: **0,2 bis 0,5** x Diesel
Mutagenicity with rapeseed oil referring to particle mass	--	--	***0,4 to 0,6** x diesel*	--	***0,4 to 1,1** x diesel*	*8-mode-cycle : **0,4 to 0,9** x diesel idle: **0,2 to 0,5** x diesel*
Mutagenität mit Rapsöl bezogen auf das Abgasvolumen	**0,1 bis 4** x Diesel	ohne Vorwärmung: **5 bis 18** x Diesel mit Vorwärmung: **13 bis 59** x Diesel	--	Prüfphasen 1-6, 8: **0,1 bis 0,9** x Diesel Prüfphase 7: **0,9 bis 2** x Diesel	--	8-Phasen-Zyklus: **0,3 bis 0,7** x Diesel Leerlauf: **0,5 bis 1,2** x Diesel
Mutagenicity with rapeseed oil referring to exhaust gas volume	***0,1 to 4** x diesel*	*without pre-heating: **5 to 18** x diesel with pre-heating: **13 to 59** x diesel*	--	*test modes 1-6, 8: **0,1 to 0,9** x diesel test mode 7: **0,9 to 2** x diesel*	--	*8-mode-cycle : **0,3 to 0,7** x diesel idle: **0,5 to 1,2** x diesel*

*) i.A.V. = im Auftrag von / by order of

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