In: Proceedings 1st World Conference on Biomass for Energy and Industry, 5-9 June 2000 in Sevilla, Spain (in press)

# STANDARDISATION OF RAPESEED OIL AS A FUEL

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**ABSTRACT:** Rapeseed oil can be used as a fuel in suitable diesel engines to minimise environmental impact. To guarantee a reliable operation and low exhaust gas emissions, fuels must fulfil specified quality aspects. In three working sessions, experts discussed all relevant fuel quality criteria and combined the results in a quality standard for rapeseed oil as a fuel. This standard comprises 15 important fuel properties with corresponding limiting values and testing methods. The parameters can be distinguished in those, that are naturally given and characterise rapeseed oil, like density, flash point, heating value, viscosity, low-temperature behaviour, cetane number, carbon residue, iodine number and sulphur content and parameters, that can be influenced by the production process with effects on engine operation. Examples are contamination, acid value, oxidation stability and the content of phosphorus, ash and water. After verifying all limiting values by numerous oil analyses and after an evaluation of the testing methods, if they are applicable for rapeseed oil, the quality standard is now accepted by both, the engine manufacturers and oil producers as a common basis to assess quality criteria of rapeseed oil as a fuel.

## 1. INTRODUCTION

The use of rapeseed oil as a fuel in adapted diesel engines has become very important. The reasons therefore are that vegetable oils help saving resources and have - compared to fossil fuels - major environmental benefits (e.g. reduced $CO_2$-increase in the atmosphere and low sulphur emissions). In comparison to transesterfied oil (fatty-acid methylester) also known as "biodiesel", native vegetable oil has a better energy balance because of the missing step of transesterfication and less transportation effort, when being produced in decentral plants for regional use. Due to their high biodegradability and low ecotoxicity, fuels based on vegetable oil are especially appropriate to be used in environmental sensitive areas (e.g. farm land, alpine regions or near waters).

Besides the environmental benefits, the present increasing prices for fossil fuels, as well as the reduced subsidy of diesel fuel for agricultural use in Germany, make rapeseed oil fuels more competitive to fossil fuels and often profitable.

Fuels based on vegetable oil can be used in vehicles or stationary engines. However, a reliable operation is only possible with fuels of constant high quality. Biomass fuels vary in property because of their biological variability and various production process parameters.

## 2. PROBLEM

- Rapeseed oil of poor quality can cause problems in engine's operability by blocking filters and injection nozzles or severe motor damage
- Different specifications complicate the procedure in cases of warranty
- Varying properties of rapeseed oil make it difficult to co-ordinate the mutual demands of both, the engine and the fuel, for further technical progress
- Fuel contents can increase exhaust gas emissions and hinder the application of catalyst converters

## 3. PURPOSE

It is the purpose of the work to lay down a commonly accepted quality standard for rapeseed oil as a fuel in adapted diesel engines or purpose built vegetable oil engines that guarantees a reliable operation with low environmental impact.

## 4. APPROACH

Previous work for the standardisation of rapeseed oil was done by K. MAURER at the University of Hohenheim, Germany. In 1996, a working session on „Decentral Vegetable Oil Production" at the Bayer. Landesanstalt für Landtechnik, Weihenstephan (Technische Universität München) was hold. In three conferences 60 experts (engine manufacturers, vegetable oil producers, fuel analysing institutes, scientists and representatives of responsible associations and the state government) discussed all relevant fuel quality criteria. From a list of 39 parameters, 15 relevant were selected, that characterise rapeseed oil sufficiently or affect engine operation. After that, limiting values were fixed with regard to the effects on the engine, the emissions, the bandwidth in practise and the possibility to be adjusted by the production process. Finally, testing methods were committed. Here it was intended to choose methods, that are also applied for diesel fuel or fatty-acid methylester (FAME). In two following working sessions and within a present project financed by the Bayerisches Staatsministerium für Ernährung Landwirtschaft und Forsten, with the title „Standardisierung von Rapsöl als Kraftstoff", which is conducted by the Bayerische Landesanstalt für Landtechnik (Freising-Weihenstephan, Germany) in co-operation with the company ASG (Augsburg, Germany), an accredited analysis institute for vegetable oil fuel, the suitability of limiting values and testing methods was verified by analysis of numerous oil samples of different origin.

## 5. RESULTS

On May, 23rd 2000 all engine manufacturers and oil producers agreed in a common quality standard for rapeseed oil as a fuel.
The physical and chemical properties of rapeseed oil can be distinguished in those that characterise the oil and vary only little, and those which depend on the production process (growing, pressing, cleaning, transport and storage) and can have effects on the operation of the engine or the exhaust gas emissions.

### 5.1 Characteristic Properties of Rapeseed Oil

The **Density** of rapeseed oil is genetically fixed and varies only little around 920 kg/m³ (at 15 °C). The determination is conducted according to the testing methods, described in DIN EN ISO 3675 or DIN EN ISO 12185.
**Flash Point** is that temperature level, where inflammable smoke is being formed. It is an important criterion for assigning fuels in risk classes, resulting in safety requirements for storage and transport. Since rapeseed oil has a flash point above 220 °C, no safety restrictions for inflammable goods (e.g. diesel fuel) need to be observed. However, only little admixtures of other fuels result in an immediate drop of the flashpoint. Fig. 1 shows that a share of 1 % diesel fuel in rapeseed oil causes a decrease of the flash point from about 240 °C to 168 °C. Thus, the flash point can be used to indicate fuel-mixtures. As testing method DIN EN 22719 (Pensky-Martens) is being applied.

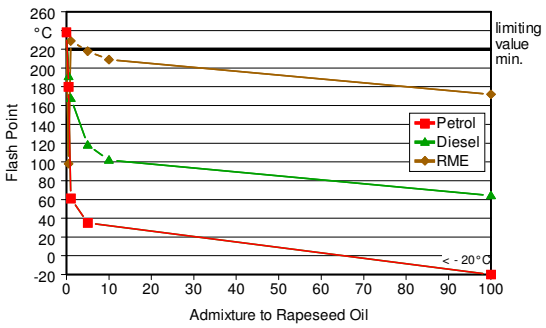


**Figure 1:** Flash Point of Mixtures of Rapeseed oil with other Fuels

The **Calorific Value** is a fuel quality criterion and important for an optimum engine adjustment. The calorific value of rapeseed oil is usually higher than 35000 kJ/kg. It is determined according to the testing method DIN 51900-3.
Like the density, also the **Kinematic Viscosity** is naturally given and characterises rapeseed oil. With 38 mm²/s at a temperature of 40 °C it is about 10times as viscous as diesel fuel. High viscosity affects the pumpability and can reduce injection spray quality, both are important features to be considered when constructing diesel engines for vegetable oil use. The kinematic viscosity is highly dependent on temperature. Fig. 2 shows the viscosity-temperature behaviour of rapeseed oil of three different stages of refining. The

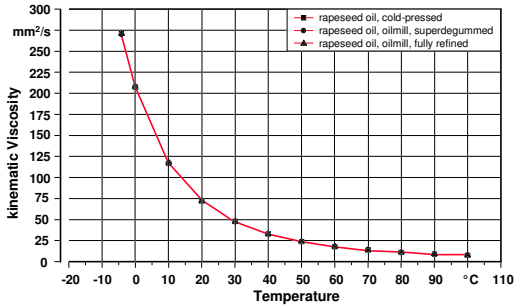


**Figure 2:** Viscosity-Temperature Graph of Rapeseed Oil

congruent three graphs illustrate that the process of pressing and refining has no influence on viscosity. As testing method DIN EN ISO 3104 is applied.
For diesel fuel the **Low Temperature Behaviour** can be described by various parameters such as Cloud Point (CP), Cold Filter Plugging Point (CFPP) or Pourpoint (PP). The tests for the first two parameters, which base mainly on the precipitation of paraffin are not representative for rapeseed oil, due to the absence of paraffin in rapeseed oils. The latter instead does not show correlation with the operability in praxis because of a complex crystallisation process of vegetable oil at low temperatures. Therefore another testing method by using a rotational viscometer is being applied. Here the dynamic viscosity is being measured, following a practicable temperature gradient. The temperature, where the dynamic viscosity hits the value for the demanded minimum viscosity for operability of all fuel system components (such as injection pumps or fuel pumps) can be determined as the limiting value. Some more investigations are necessary before the exact testing conditions can be determined.
The ability of ignition of the fuel is described by the **Cetane Number**. It is an important parameter for engine performance and has effects on exhaust gas emissions ($NO_x$, particles) and the emitted noise level. The cetane number is fairly constant in fresh rapeseed oil, but can rise during storage. The ignition of diesel fuel is determined by ISO/DIS 5165. Because the test engines are conventional diesel engines, which are not suitable for rapeseed oil, the cetane numbers of diesel and vegetable oil fuel cannot be compared. Thus a purpose developed vegetable oil test engine or a different testing method is required, which are not available, yet.
The testing method according to DIN EN ISO 10370 for the parameter **Carbon Residue** simulates the combustion of the fuel on a surface without oxygen. The limiting value of 0,4 Mass-% is not comparable with diesel fuel. This is because rapeseed oil can not be distilled completely without the appearance of pyrolysis products, which make the distillation impossible. Carbon residue can cause deposits on injection nozzles or in the combustion chamber. Experiences show that no operational failures occur in practise with a maximum value of 0,4 Mass-%.
The **Iodine Number** is a measure for the number of double bondings and characterises the type of vegetable oil. Fuels with high iodine numbers can

cause deposits on injection nozzles or in the combustion chamber more frequently and impair storage stability. The limiting value is set at 100-120 g/100g. As testing method DIN 53241-1 is applied.

Due to the very low **Sulphur Content** of usually less than 10 mg/kg the use of vegetable oil reduces $SO_x$ and sulphate emissions in comparison to conventional diesel fuel. Besides this, the application of catalytic converters, which tolerate only limited sulphur, is particularly appropriate when using vegetable oil fuels. However decreasing sulphur content in the atmosphere now often requires sulphur fertilising, when growing rapeseed. The effect can be a sulphur content in the oil slightly higher than 10 mg/kg (Fig 3). So the limiting value is determined at 20 mg/kg maximum. The analysis is done after ASTM D5453.

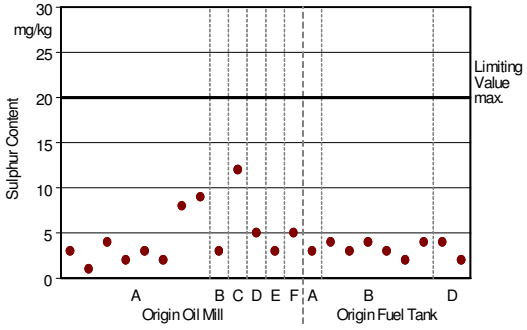


**Figure 3:** Sulphur Content of Rapeseed Oil of Different Origins

5.2 Variable Properties of Rapeseed Oil

A very important parameter of fuel property is the **Contamination**. Particles can plug fuel filters or injection nozzles and cause abrasion or deposits in the combustion chamber. It is expected that contamination also can have influences on particle emissions. Preliminary tests have shown that a limiting value of 25 mg/kg can be achieved with both, fully refined and cold pressed rapeseed oil. However, the cleaning process is very important. As testing method DIN EN 12662 is applied. Here rapeseed oil is being passed through a 0,8 µm wide filter diaphragm. The filter is washed with a solvent and then dried and weight.

The **Acid Value** or Neutralisation Number is a measure for the share of free fatty acids in the oil. The occurrence of free fatty acids is higher under conditions, that advance the fatty hydrolysis, like water, micro-organisms, high temperature and catalytic active metals (e.g. copper). Free fatty acids can cause corrosion and react with basic components of the engine oil, resulting in oxidation or polymerisation. The consequence are shorter oil change intervals or severe engine damage. The critical acid value can vary with the type of engine but with a maximum of 2,0 mg KOH/g determined by DIN EN ISO 660 the demands of modern engines are widely fulfilled.

**Oxidation Stability** describes the stage of previous aged vegetable oil and is very likely an indicator for a disadvantageous interaction between the fuel and the engine oil. Conditions like high temperature and oxygen exposition during the production, transport or storage process accelerate oil ageing, which is usually connected with an increase of viscosity. However, latter is not sensitive enough for exact assessment of the parameter. With the testing method ISO 6886 a stream of purified air is passed through the sample, which has been brought to a temperature of about 100 °C. Volatile oxidation products are collected in a flask, containing distilled water and an electrode, for measuring the conductivity. The inductive time until a rapid increase of conductivity can be noted (dissociated volatile carboxylic acids) correlates with the oxidation stability of the sample. As a minimum oxidation stability of good quality rapeseed oil 5.0 hours were fixed.

A high **Phosphorus Content** in vegetable oil can contribute to the building of deposits in the combustion chamber. Engines with direct injection and low load operation cause more problems than indirect injecting engines and heavy load operation. Especially modern engine and catalytic technology request low phosphor contents. Thus the limiting value of 15 mg/kg was determined, which can be obtained by nearly all investigated (mainly cold-pressed) oil samples (Fig. 2). Testing method ASTM D3231-99 enables a determination of the phosphor content as precise as 0,2 mg/kg.

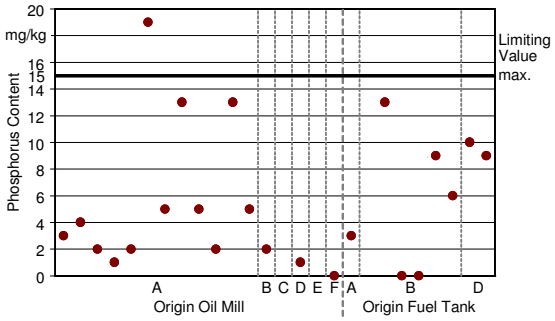


**Figure 4:** Phosphorus Content of Rapeseed Oil of Different Origins

**Ash** is an indicator for abrasive matter in the fuel. The limiting value is set at 0,01 Mass-% and determined by DIN EN ISO 6245.

**Water Content** in vegetable oil is basically not disadvantageous for the engine. Due to the reduction of the combustion temperature, water/fuel emulsions can reduce $NO_x$ emissions. However, within high pressure injection systems water can be severed from the fuel and cause problems like cavities in the injection system. Nevertheless water is less critical in vegetable oil than in diesel fuel, concerning the building of a water/fuel layer during storage. These layers are a culture medium for micro-organisms. The maximum value for rapeseed oil is 0,075 Mass-%, determined by prEN ISO 12937. A high moisture content of the rapeseed and varying storage temperatures of the vegetable oil are factors, that increase the water content in the fuel.

## 6. CONCLUSIONS AND PROSPECT

The results show that relevant parameters for the use of rapeseed oil as a fuel are defined. They are presented in a quality standard (Fig. 5), which can be used as a common basis for the oil producer, the engine manufacturer and the engine operator. This will guarantee a high quality fuel for a reliable and environmentally low impact operation of vegetable oil engines. With this quality standard further development of vegetable oil engines can be made. Moreover it could be the foundation for standardisation in national and international organisations (e.g. DIN, CEN, ISO). Nevertheless additional investigations are necessary to revise the standard in about two years. They will focus on the bandwidth of more analysis results in practice due to possible changes in both, the plant material and the production process as well as on the effects of relevant oil properties on exhaust gas emissions. At the same time testing methods for low temperature behaviour and the cetane number need to be adapted or developed.

## 7. REFERENCES


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LANDTECHNIK WEIHENSTEPHAN

**LTV-Work-Session on Decentral Vegetable Oil Production, Weihenstephan**

**Quality Standard for Rapeseed Oil as a Fuel (RK-Qualitätsstandard)**

05/2000

in Cooperation with:

| Properties / Contents | Unit | Limiting Value min. | Limiting Value max. | Testing Method |
|---|---|---|---|---|
| ***charcteristic properties for Rapeseed Oil*** | | | | |
| Density (15 °C) | kg/m³ | 900 | 930 | DIN EN ISO 3675<br>DIN EN ISO 12185 |
| Flash Point by P.-M. | °C | 220 | | DIN EN 22719 |
| Calorific Value | kJ/kg | 35000 | | DIN 51900-3 |
| Kinematic Viscosity (40 °C) | mm²/s | | 38 | DIN EN ISO 3104 |
| Low Temperature Behaviour | | | | Rotational Viscometer (testing conditions will be developed) |
| Cetane Number | | | | Testing method will be reviewed |
| Carbon Residue | Mass-% | | 0.40 | DIN EN ISO 10370 |
| Iodine Number | g/100 g | 100 | 120 | DIN 53241-1 |
| Sulphur Content | mg/kg | | 20 | ASTM D5453-93 |
| ***variable properties*** | | | | |
| Contamination | mg/kg | | 25 | DIN EN 12662 |
| Acid Value | mg KOH/g | | 2.0 | DIN EN ISO 660 |
| Oxidation Stability (110 °C) | h | 5.0 | | ISO 6886 |
| Phosphorus Content | mg/kg | | 15 | ASTM D3231-99 |
| Ash Content | Mass-% | | 0.01 | DIN EN ISO 6245 |
| Water Content | Mass-% | | 0.075 | pr EN ISO 12937 |

**Figure 5:** Quality Standard for Rapeseed Oil as a Fuel