Proceedings 6th International Colloquium Fuels. Technische Akademie Esslingen (TAE)
10-11 January 2007 • TAE Ostfildern (Stuttgart), Germany

Production and Utilisation of Rapeseed Oil Fuel in Germany

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Summary

Growing energy consumption and decreasing fossil records are reasons for increasing prices of fossil diesel fuel. High prices for fossil fuels, associated with favourable general regulations for biofuels, which are well-founded in many ecological and economical advantages, led to a high demand on vegetable oils, used for fuel application. Today 13 industrial and more than 300 decentral oil mills produce predominantly rapeseed oil, mainly for energetic use in Germany. The demands on quality of rapeseed oil, used as a fuel in compatible diesel engines are defined in the new national prestandard DIN V 51605. Quality assurance systems for decentral processed rapeseed oil are being developed and established. In Germany over 60 mainly small sized enterprises offer solutions for the technical adaptation of conventional diesel engines for the use of pure rapeseed oil. Experiences in field tests with rapeseed oil fuelled engines are better than expected. Prior applications for rapeseed oil fuel are niche markets, such as environmental sensitive areas and agricultural machines, due to a limited number of engine types and the advantage of closed economic and material flow loops.

1 Introduction

The primary energy consumption in the world has increased from 8,3 to 10,2 Mio. t oil equivalent between 1994 and 2004. The growth mainly takes place in Asia, especially in China and India (Figure 1). The most important primary energy source is oil (37 %). However, conventional mineral oil production will reach its maximum within the next decade.

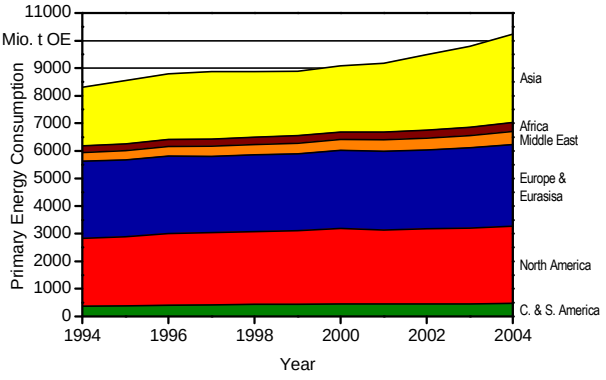

Figure 1: Worldwide Primary Energy Consumption in Tons of Oil Equivalent (OE) (Reference: BP Statistical Review of World Energy, 2005)

More than 60 % of the oil reserves are located in the Middle East, which results in a high dependency for oil importing countries. Besides limited availability, the contribution to the greenhouse effect is another problem of fossil fuels. Moreover, there is the danger of environmental pollution during production, transport and utilisation.

Apart from saving energy resources by higher energy conversion efficiency, alternative energy sources can help to solve the problems. Especially biomass as accumulated solar energy in gaseous, solid and liquid form has a big potential. Liquid biomass such as vegetable oils, that are characterised by high energy density, are appropriate to be used as fuels in combustion engines to substitute fossil diesel fuel. Vegetable oils can be produced out of more than 2000 plant species all over the world in both industrial or small decentralised oil mills.

There is a growing demand on pure rapeseed oil, used as a fuel for adapted automotive and stationary diesel engines in Germany. Reasons therefore are increasing prices for fossil diesel fuel and heating oil, advantageous regulations for biofuels as well as the public awareness of the excellence of rapeseed oil fuel, regarding environmental impacts and the development of regional

markets. However, pure rapeseed oil used as a fuel raises important questions about deficits and chances of extended utilisation.

2 Purpose

It is the purpose of this work, to show the state of the art of pure rapeseed oil fuel production and utilisation in Germany. Therefore comprehensive results of various research works are combined. Based upon these facts conclusions for future relevance of rapeseed oil fuel applications in Germany will be drawn.

3 Results

3.1 Framework for Biofuels

The EU directive 2003/30/EC, which aims at a minimum proportion of biofuels by 31st of December 2010 of 5,75 % and the council directive 2003/96/EC, which enables excise tax reduction on biofuels are basis for extended utilisation in the member states.

The German act for excise tax on fuels, which secured a tax exemption for biofuels until the 31st of July and the amendment of the act on granting priority to renewable energy sources (Renewable Energy Sources Act), which guarantees power feed-in tariffs for biomass plants paved the way for the present competitiveness of biofuels for automotive and stationary engines. However, since August 2006 a new act on taxation of energy products will lead to a stepwise taxation of biodiesel, (beginning in August 2006) and rapeseed oil fuel (beginning in January 2007) until full taxation of 0,45 €/l will be reached in 2012. The future market relevance of biofuels is depending on the development of mineral oil prices. However, in case of very low prices for fossil fuels an adjustment of the tax rates for biofuels is proposed. Additionally, since January 2007 a new regulation will dictate a minimum share of biofuels for diesel and petrol producers. For biofuels, that are used in agricultural machines, an entire tax relief is being continued. Thereon the presently very high demand for rapeseed oil fuelled tractors and machinery can be deducted.

3.2 Growing Rapeseed

Rapeseed is the most important oil crop in Germany, because growing rapeseed is well established in agricultural practice and high oil yields from 1,0 to 1,5 t/ha are achieved. Growing rapeseed has been extended during the last years and reached an acreage of 1,4 Mio. hectares in 2006 (Table 1). The total yield increased to 5,3 Mio. t, which is a plus of 25 % compared to the average yield of the last 6 years.

Winter Rapeseed	2006	∅ 2000-2005
Acreage	1,40 Mio. ha	+ 16,2 %
Yield per hectare	3,75 t/ha	+ 7,8 %
Total yield	5,27 Mio. t	+ 25,2 %

Table 1: Acreage and Yield of Rapeseed in Germany (Reference: BMELV, Referat 425; Statistisches Bundesamt)

Rapeseed oil can be produced in small agricultural production units (decentral oil mills) and used for many different applications, such as edible oil, lubrication agents or fuel for adapted engines. Important fuel properties, such as cold flow properties and oxidation stability are more favourable for rapeseed oil, than for other plant oils.

3.3 Production of Rapeseed Oil

Today 13 industrial and more than 300 decentral oil mills produce rapeseed oil, mainly for energetic use in Germany (Figure 2).

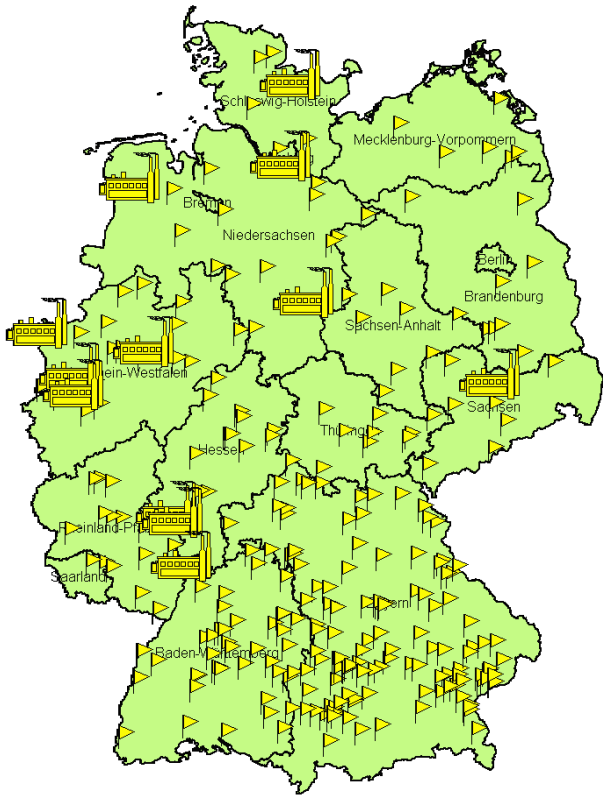

Figure 2: Location of Industrial and Decentral Oil Mills in Germany

Processing in industrial oil mills is done by “warm pressing” with solvent extraction, which leads to high oil yields of up to 99 %, but on the other hand requires several steps of refining (Table 2, Figure 3). Due to high expenditure, only plants with high production capacities of up to 3000 t oilseed per day operate economically successful.

Plant type	Industrial	Decentral
Number of plants	13	322
Processing technology	"warm pressing" solvent extraction refining	"cold pressing" filtration
Processing capacity	up to 3000 tons seed per day	0,5 to 25 tons seed per day
Energy consumption	1,7 GJ per ton seed	0,1-0,5 GJ per ton seed
Oil yield	99 %	75-85 %

Table 2: Features of Industrial and Decentral Oil Mills

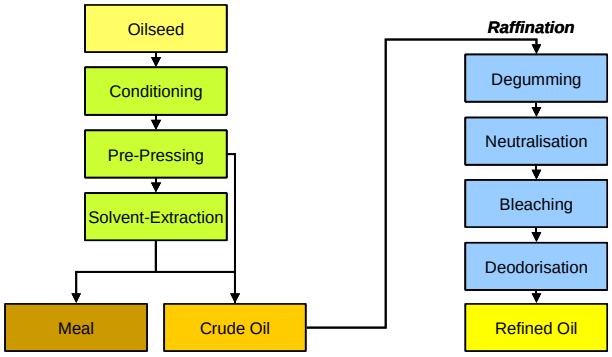

Figure 3: Oil Production Steps in Industrial Plants

Like for industrial plants, also for decentral plants, oil processing technology is state of the art. Equipment is provided by many suppliers. The production is characterised by "cold pressing" with processing capacities from 0,5 to 25 tons seed (and more) per day without the need of refining, with low energy consumption, but also with lower oil yields from 75 % to 85 %. (Figure 4).

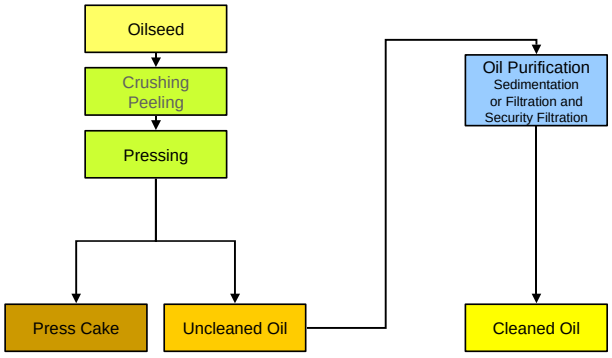

Figure 4: Oil Production Steps in Decentral Plants

Due to the lack of refining steps, oil seed quality and pressing parameters have big influences on the characteristics of vegetable oil fuel. Important requirements for the production of high quality rapeseed oil fuel are:

- Full ripeness of the rapeseed
- No germinated seeds
- Low share of contamination in the oilseed
- Low storage temperature (< 12 °C)
- Aeration during storage
- Low energy impact on seed and oil during pressing
- Precise adjustment of the press (e.g. screw rotation speed, nozzle diameters, steel bar gaps)
- Sophisticated oil clearing systems, including safety filtration

Despite plenty of experiences, process optimisation is still possible and necessary for both, high production efficiency and high product quality. Furthermore, an effective quality management system for rapeseed oil fuel has to be established.

3.4 Demands on Rapeseed Oil Fuel Quality

The demands on rapeseed oil fuel quality were first defined in the Quality Standard for Rapeseed Oil as a Fuel (05/2000), which was the basis for the pre-standard DIN V 51605 (Figure 5). Therein the latest cognitions, regarding rapeseed oil production, analytics and engine applications are incorporated. According to DIN V 51605 the production of rapeseed oil fuel can either be done by mechanical extraction with or without solvent extraction. Thus, both cold-pressed rapeseed oil and chemically extracted and refined rapeseed oil can be used, as long as limiting values are fulfilled. It is not allowed to use rapeseed oil, which has gone through any prior application (e.g. cooking oil or lubrication oil). Denaturation can be done by adding a maximum share of 2,9 mass-% rapeseed oil methyl ester according to DIN EN 14214. For this purpose diesel is not applicable, in order to guarantee the German classification „not hazardous to waters" for rapeseed oil.


Juli 2006

DIN V 51605

DIN

ICS 75.160.20

Vornorm

Kraftstoffe für pflanzenöltaugliche Motoren – Rapsölkraftstoff – Anforderungen und Prüfverfahren

Fuels for vegetable oil compatible combustion engines – Fuel from rapeseed oil – Requirements and test methods

Combustibles pour moteurs adaptés aux huiles végétales – Combustible à base d'huile de colza – Exigences et méthodes d'essai

Figure 5: Pre-Standard DIN V 51605 for Rapeseed Oil Fuel (www.beuth.de)

Besides others, like ignition behaviour, the main difference between rapeseed oil and diesel fuel is viscosity. Whereas the viscosities of both fuels are similar at high temperatures, viscosity from rapeseed oil increases overproportional with decreasing temperatures (Figure 6). This is the reason, why conventional diesel engines have to be adapted to the special needs of rapeseed oil fuel, before rapeseed oil can be used properly.

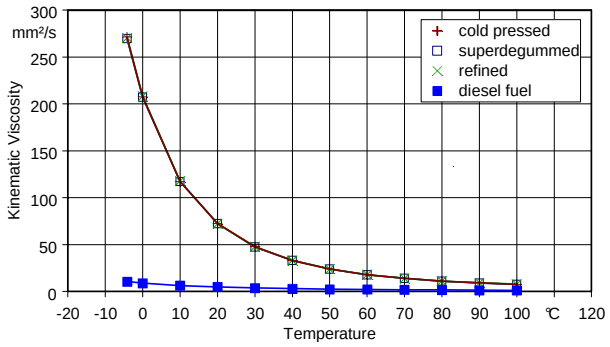

Figure 6: Viscosity of Diesel and Rapeseed Oil Fuel

3.5 Blends of Rapeseed Oil and Diesel Fuel

Depending on the share of added rapeseed oil, the characteristics of the blends differ widely from diesel fuel. Especially the deviant kinematic viscosity and combustion behaviour can lead to insufficient fuel dispersion in the combustion chamber, to incomplete combustion during cold starts and low engine load operation as well as to fuel-entry into the motor oil. Thus, the use of blended diesel fuel with a high share of rapeseed oil in modern conventional diesel engines is connected with a high risk of engine damage.

Systematic tests on two Deutz engines (BF4M2012), fuelled with blends of different shares of rapeseed oil in diesel fuel (0 %, 25 %, 50 %, 75 %) at a test stand by the University of Hohenheim, Germany showed severe coking on valves and injection nozzles, deposits at the piston and abrasion of the top piston ring after 300 operating hours. With increasing share of rapeseed oil, the problems get worse, which results in a higher engine wear and lower engine durability. The blend with 75 % rapeseed oil led to an engine breakdown after 67 operating hours.

Thus, for a long term reliable and low emission operation of diesel engines with diesel blends or pure rapeseed oil fuel, adaptation of the engine is required.

3.6 Rapeseed Oil Fuelled Engines

Purpose built rapeseed oil fuelled engines of recent times were developed in the 1980s. The most famous designer was Ludwig Elsbett. Today adaptation of conventional diesel engines is typical. Structural measures for adaptation can be (among others):

- Preheating of the fuel
- Exchange of fuel and injection system components
- Modification of injection pressure and time
- Modification of combustion chamber
- Adaptation of engine management system
- Additional diesel fuel system (for cold start and low load operation)

In Germany more than 60 mainly small sized enterprises offer solutions for the technical adaptation of conventional diesel engines for the use of pure rapeseed oil. Adaptation costs vary from 1.000 to 7.000 €, depending on adaptation technology and engine size. Converted engines are used in cars, busses, trucks, tractors, agricultural and construction machinery, stationary engines, trains and boats.

Today far more than 12 000 vehicles and stationary engines are operated with pure rapeseed oil fuel (approximately 50 % cars and 50 % trucks, tractors and others) in Germany. Operational reliability is high for many engine types with aligned adaptation systems.

Within a field survey 107 rapeseed oil fuelled tractors of 10 different manufacturers and 7 adaptation companies were tested for their technical and economic feasibility in practical use for three years. Scientific monitoring was done by the University of Rostock. Results are [2]:

- Tractor malfunction depends mainly on tractor and engine type but also on adaptation measures
- Functional efficiency is best for Deutz engines in Fendt and Deutz-Fahr tractors (50 of 66 tractors showed no or only marginal failures)
- Fuel lubricated distributor-type fuel injection pumps are not suitable for rapeseed oil fuel
- Low load operation leads to deposits and fuel entry into the motor oil (danger of motor oil thickening)
- Engine performance, limited exhaust gas emissions and fuel consumption are similar to diesel fuelled tractors.

Promising results encourage the agricultural machinery industry to consider own developments of rapeseed oil fuelled tractors. After the field survey 92 tractors are still being operated with rapeseed oil fuel, which shows a high satisfaction of the users and the capability in practice.

3.7 General Aspects for Successful Engine Operation with Rapeseed Oil Fuel

For a successful engine operation with rapeseed oil fuel, following works before adaptation are advisable [1]:

- Inspection and adjustment of start of fuel delivery and injected fuel amount
- Inspection and maintenance of injection nozzles
- Control of compression pressure of each cylinder
- Control of motor oil pressure
- Control of seals and pipes of the fuel system (hardenings, leakages)

Besides the works prior to adaptation, some aspects during the operation with rapeseed oil fuel have to be considered [1]:

- Driver instruction
- Motor oil control daily before start; when motor oil level is increasing: location of fuel entry and elimination

- Immediately after adaptation: analyses of motor oil samples every 50 operating hours
- Annual control of injection nozzles
- Before a longer period without operation: last application with diesel fuel

3.8 Exhaust Gas Emissions

The Technologie- und Förderzentrum in Straubing is investigating together with the LVFZ Kringell, subsidised by the Bavarian State Government for Agriculture and Forestry, two rapeseed oil fuelled tractors in practical use. The aim is - among others - to determinate emission characteristics by recurrent measurement. Objects of investigation are a Deutz-Fahr Agrotron TTV 1160 and a Fendt Farmer Vario 412 tractor. The measurement of exhaust gas emissions takes place at the TFZ test stand according to EU-Directive 2000/25/EG. Thereby, eight test stages within the engine operating map are run through in one trial. The results of every single test stage are added up with specified weighting factors. Result discussion is done in terms of emission standards and differences between rapeseed oil fuel and diesel fuel operation.

Prior to engine adaptation the limiting values of European exhaust gas stage 2 are proven to be fulfilled with diesel fuel (Figure 7). The demands on nitrogen oxides emissions (NO_X) are met accurately. By adaptation emission behaviour is changed significantly. With diesel fuel about 50 % higher particulate mass and 4 % higher nitrogen oxides emissions are determined. Running on rapeseed oil NO_X-emissions increase, exceeding the limiting value at 14 %. However, particulate mass and hydrocarbons emissions are less with rapeseed oil fuel compared to diesel fuel prior and after adaptation.

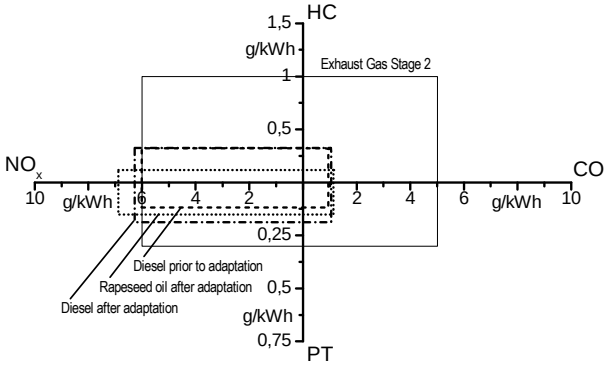

Figure 7: Emissions of a tractor with diesel and rapeseed oil fuel compared to the European exhaust gas stage 2

4 Conclusions and Outlook

Favourable general framework, which resulted in high price differences between diesel and rapeseed oil fuel led to a high demand on rapeseed oil production facilities, rapeseed oil fuel and rapeseed oil fuelled engines in Germany. Prior applications for rapeseed oil fuelled engines are either fleets, with only a limited number of different engine types or machines, that are operated in environmental sensitive areas, like tractors and cogeneration plants.

For further development of rapeseed oil fuel utilisation with all advantages for the environment and regional economy, existing framework conditions need to be continued. The present bottleneck in rapeseed oil supply needs to be removed by higher rapeseed acreage, more rapeseed imports and enlargement of plant capacities. Also other vegetable oil fuels might be an option, provided that the minimum requirements of the vegetable oils will be worked out and sustainable production is secured.

Quality demands for rapeseed oil fuel are well known and defined in the new pre-standard DIN V 51605, which is widely introduced in practice already. Although rapeseed oil fuel producers and users are mainly aware of the need of quality assurance, only few act sufficiently. Thus, quality assurance systems for decentral processed rapeseed oil need to be established for better engine operation reliability and fulfilment of emission demands.

Engine adaptation technique is widely available and further developed, companies for adaptation arise and have full order books. In Germany the demand is especially high in the transport sector and for agricultural machines, latter due to high agro-diesel costs, continuing tax relief for biofuels, used in agriculture and the possibility of self-supply.

Experiences in field tests with rapeseed oil fuelled engines are all in all better than expected. This applies for operation reliability, emissions and efficiency. The agricultural machine industry consider the chances of rapeseed oil technology and engage in the development of rapeseed oil fuel compatible tractors.

Besides further improvement of engine adaptation technique and development of the adaptation of modern engines, insecurities regarding warranty agreements for rapeseed oil fuelled engines need to be abolished. This can be solved either by close co-operations between engine adaptation companies and the automotive industry or series-production of rapeseed oil compatible engine systems. Further systematic tests with modern engines are necessary and exhaust gas aftertreatment, like particulate filter systems have to be designed for rapeseed oil fuel application, accompanied by fuel optimisation.

With continuing great demand of potential users, rapeseed oil fuelled trucks and tractors may soon be sold industrially with high product quality and economic benefits for both producers and users.

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