Evaluation of rape-seed oil production, extraction and use as fuel in modified diesel engines

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INTRODUCTION

It is now well established that rape-seed oil can provide a sustainable source of renewable fuel for diesel engines. The main problem is a high viscosity and vaporisation temperature, which could lead to pumping, atomisation and combustion difficulties. These problems can be overcome in either of two ways: by further processing of the oil to improve its pumping and combustion properties (usually achieved by esterification and layer separation to produce biodiesel) or by some peripheral modifications to the engine to allow it to cope with the more viscous fuel. Engine conversion kits for this purpose are widely available. The second option has attractions in Ireland, at least in the short-term, for a number of reasons. Plants can be established quickly, and so could make an immediate if small contribution to the achievement of Ireland's substitution target in the Transport Biofuels Directive (Commission of European Communities, 2003). The small operating scale of cold-pressing oil extraction plants could be achieved without undue difficulty, and the capital investment required to launch such a project is relatively low. In the event of a biodiesel plant being established at some stage in the future, the option of sourcing some of the oil requirement from these extraction plants would still be available.

The initial aim of this project was to evaluate on a practical scale the production of rape-seed, the extraction of the oil and its utilisation as a fuel in road vehicles with modified diesel engines. However, an intended monitoring of a number of vehicles running on rape-seed oil could not be carried out due to delays in the implementation of the Motor Oils Tax Relief programme. Instead, work was concentrated in the following areas:

- A study of the quality of the oil from small extraction plants and the controls needed to ensure that oil of a quality acceptable for fuel use is produced.
- Participation in a strategic study of Irish options for the achievement of the transport biofuels substitution target set out in the Transport Biofuels Directive.

OIL QUALITY STUDY

Introduction and objectives

For a successful production and use of unprocessed rape-seed oil as fuel, recent German research is showing that the quality of the oil is very important (e.g. Thuneke and Kern, 2002; Remmele, 2002). This is particularly the case when the oil is extracted in small cold-pressing plants, since there are no post-extraction processes other than filtration to improve its quality. Much information on the effect of seed quality, plant specification and plant operating parameters on oil quality is now being established for these plants. Initially a voluntary trading standard for fuel-grade rape-seed oil (the RK Standard, Remmele et al, 2000) was drawn up in Germany, based on considerable research and practical experience. This standard specified limits for 15 oil properties and test procedures for their measurement. More recently a DIN standard largely based on the RK Standard has been produced and is in the ratification process (Deutsches Institut fur Normung, 2005).

If vehicles are to run without problems on the fuel produced in small cold-pressing units, the quality of the oil must be assured. This requires that the key oil quality factors that are affected by the extraction/filtration process and that in turn affect engine performance need to be clearly identified, limits for the values of these properties need to be determined and simple methods of measuring or estimating these values need to be established.

The objectives of the present work were as follows:

1. To identify the key process-dependant oil properties that need to be measured frequently and the facilities and equipment needed to make these measurements.
2. To assess the possibility of making the tests on site.
3. To make occasional measurements of the quality of the oil produced at the two commercial plants in operation.
4. For properties whose rigorous measurement following the appropriate standard is not possible on site, to explore the possibility of substituting simple indicative or qualitative tests.

Procedure

Oil samples from three press units were included in the survey; an experimental-scale unit at Teagasc, Oak Park and two small commercial cold-pressing units.

The two commercial units each had a screw press with a seed throughput of 100-150 kg/hour (Straehle 130), a high-capacity filter press to remove most of the suspended solids, and a final candle filter to complete the oil clarification process. Various heaters and/or heat-exchange units were used to raise the seed temperature before pressing and the oil temperature before filtration, and to cool the oil-seed cake prior to storage. The Oak Park unit was a small 10 kg/hr screw press (IGB Monforts, S-87G); oil clarification was achieved by allowing the oil to cascade through a series of sedimentation tanks.

A total of 17 oil samples were taken from three oil presses. Background data on seed quality, press settings, filtration system and oil storage were recorded at each sampling. Oil sampling was carried out to include as many variations as possible in operating conditions. The results of these analyses were compared with the quality limits set in the voluntary German RK Standard.

Crop-dependant properties were measured at Teagasc, University of Limerick and Carlow Institute of Technology. For these parameters, the measurements were made mainly to ensure that values for Irish crops were similar to those reported in overseas literature, and to identify laboratories with the facilities and expertise to make the measurements.

Where possible, the process-sensitive properties such as suspended solids, water content, acid value, phosphorus content and ash content were measured at more than one laboratory. Suspended solids and acid values were measured at all three laboratories. Water and ash contents were measured at Carlow Institute of Technology and University of Limerick. Phosphorus content was measured at Teagasc. Quick-test analyses of suspended solids, water content and acid value (using a kit supplied by ASG, Germany) were made by Teagasc.

Results and discussion

Of the many oil properties that might have a bearing on engine performance, two emerged as of prime importance:

- Suspended solids, an excess of which can lead to blocked filters and injectors. Initial samples from all units had levels outside the RK Standard, but these levels fell with experience and management improvements.
- Acid value, excessive levels of which may lead to corrosion and abrasion of engine parts as well as degraded lubricating oil. Again early results were poor, mainly due to long delays between pressing and filtration and weed seeds mixed with the rape-seed (Fig. 1). Results began to improve when these problems were overcome.

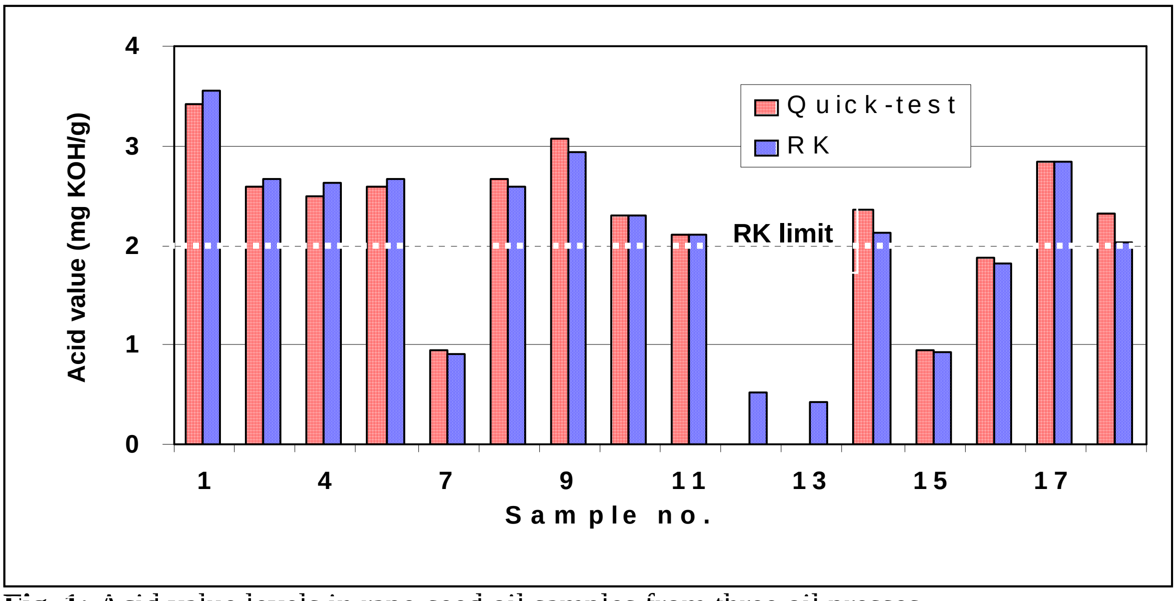

Fig. 1: Acid value levels in rape-seed oil samples from three oil presses

To control these two properties, the results showed that the first requirement is clean seed, which in turn requires effective weed control and good seed cleaning before pressing. The oil should be filtered as soon as possible after pressing, and then allowed to cool. It should be stored in cool conditions as near to airtight as possible. It is also important to ensure that no re-contamination occurs due to solids residues in pumps, pipelines or storage tanks. The press should be set and operated in a way that avoids excessive oil temperatures.

Suspended solids, acid value and the other process-dependent properties such as ash, phosphorus and water contents and oxidation stability should all remain within acceptable limits if these recommendations are put into effect.

A monitoring programme is needed at each press site for suspended solids, acid value and water content. The ASG Quick-test kit is adequate for these measurements, with occasional verification tests by an outside laboratory.

Many of the oil quality deficiencies that were measured in this work can be attributed to start-up problems with the plants involved, e.g. excessive delays between pressing and filtration, inadequate seed cleaning facilities, and lack of experience in the management of the plants. The specification of both of the Irish commercial plants is adequate for the production of high-quality oil, but careful operation and regular monitoring will be required for this to be achieved on a consistent basis.

This study was commissioned by Sustainable Energy Ireland. The complete report has been published on their web-site (www.sei.ie).

LIQUID BIOFUELS STRATEGY STUDY FOR IRELAND

Introduction and objectives

The Transport Biofuels Directive requested member states to substitute 2% (energy basis) of their transport fossil fuels by biofuels by 2005 and 5.75 % by 2010 (Commission of European Communities, 2003). To assist in the formulation of goals and strategies for compliance with this Directive, Sustainable Energy Ireland commissioned a study from a consortium of Ecofys (co-ordinator), Teagasc and the Fraunhofer Institute. The objectives of the study were to establish the raw material resource for biofuel production in Ireland, to quantify the financial and environmental impacts of the establishment of an Irish biofuel industry and to identify the most strategic routes towards the implementation of the Transport Biofuels Directive. The complete report has been published on the SEI web-site (www.sei.ie).

Materials and methods

The focus in this study was on the short-term production of of mainstream biofuels, i.e. biofuels or blends that would not require any adaptations to the common transportation fleet, and that could be sold at the forecourts of filling stations. These fuels have to meet official standards and directives e.g. EN 590 for fossil diesel, (European Committee for Standardisation, 1999), EN 14214 for biodiesel (European Committee for Standardisation, 2003), EN 228 for petrol (European Committee for Standardisation, 2004) and prEN 15376 for ethanol in blends (European Committee for Standardisation, 2006). Biofuels that cannot be considered a mainstream fuel, such as pure plant oil, are therefore not included in this report. Several biofuels that may be used within official standards and directives mentioned, are technically fully proven and can be implemented on a commercial scale at this moment are selected for this study.

The above-mentioned short-term biofuels could be produced and marketed immediately. However, there is also a range of very promising biofuels, that may be implemented in the medium (e.g. towards 2010) to long term. Two examples of these fuels that have potential to substitute for gasoline or diesel are also discussed in the report.

In this study, the main focus is on the introduction of biofuel via blends with fossil fuels. The main advantage of blends, as compared to pure biofuels, is that existing transportation fuel specifications can be met, allowing the fuel to be used in all cars without the need for vehicle adaptations. This would facilitate a relatively fast transition towards biofuels.

To illustrate the differences between biofuels and fossil fuels, the “neat fuel comparison basis” is used in the analyses in this report. This means that the study is confined to that part of the blend that is affected by the introduction of biofuels.

Results and discussion

The total and realistic Irish potential liquid biofuel production resource was estimated as in Table 1.

From this resource, Ireland could produce about 12 PJ of biofuels, i.e. the 2010 target. However, that would imply that some of the crops currently fed to animals be used for energy purposes. This might be expected to lead to additional feed imports. If these imports are to be avoided, a realistic estimate of the Irish biofuel resource availability (2.8 PJ) comprises about 79 % of the 2005 and 23 % of the 2010 target. Larger amounts of liquid biofuel (12 PJ) could be produced from straw and wood residues when the conversion technologies become available.

Table 1: Summary of the potential amount of liquid biofuel feedstocks in Ireland.

	Area (kha)			Potential (ktonne)			biofuels yield
	Potential	Realistic	Set-aside	Potential	Realistic	National	(l/tonne)
Cereals total	320	320	15	2455	565	140	356
Beet	95	50		4665	2455		90
Potato	14	14		476	476		90
Molasses				55	55		610
Beet pulp				110	110		90
Straw residues				1096	325		
S. Rape-seed	80	15		216	41		450
W. Rape-seed	80	15					
RVO*				11	11	11	1000
Tallow				15	15	15	900

*Recovered vegetable oil

Within current transport fuel standards and directives, it would be possible to meet the 2005 target with all biofuels considered. However, these standards and directives do not give sufficient latitude to meet the 2010 target. One could only meet this target by:

- Using biofuels that do not meet the current gasoline directive regarding ethanol or the current diesel standard.
- Adapting the standards to increase the permissible ethanol and biodiesel percentages
- Introducing new biofuels (other than ethanol and biodiesel) that meet the current gasoline and diesel directives and standards

The best estimate of the well-to-wheel (WTW) greenhouse gas (GHG) emission for biodiesel from rape-seed is about 50% of that of conventional diesel. Biodiesel from recovered vegetable oil emits about 16% of the diesel WTW GHG emission. Bioethanol from sugar-beet emits about 45 % as compared to gasoline; from wheat it emits about 33% of the gasoline emission.

Because of different heating values, costs of biofuels and fossil fuels are best compared on the basis of their energy content. The delivered cost of biodiesel from rape-seed at the filling station was estimated at €25/GJ (€0.80/l). Biodiesel produced from tallow or RVO costs about €17/GJ (€0.56/l). Ethanol (from wheat) could be delivered at about €27/GJ (€0.58/l), as compared to €11 /GJ (€0.33 /l) for gasoline.

In the long term, it is expected that Fischer Tropsch diesel can be produced for a cost that is roughly 30% higher than current fossil diesel costs. Long-term estimates for ligno-cellulosic biomass indicate cost levels of about €16 /GJ (€0.33/l).

To get the same price per litre at the pump for rape methyl ester (RME) an excise duty exemption is required of about €0.47/l (being higher than the actual excise, €0.37/l). In the case of biodiesel produced from recovered vegetable oil (RVO), the required excise exemption would be about €0.22/l. In the case of ethanol from wheat, the excise exemption needed would be about €0.25/l (as compared to an excise of €0.44/l).

Greenhouse gas emission reduction costs about 340 €/tonne CO_2-eq. when using RME. With RVO-based biodiesel this is about 100 €/tonne. In the case of bioethanol, this is 300 - 450 €/tonne.

Most EU countries currently choose excise duty exemption as the central policy instrument for the implementation of the biofuel directive. It is relatively easy to implement. Disadvantages to this instrument are the fact that it generally gives no long-term guarantee, which is a disincentive for investments and innovation. Another disadvantage is that the cost to government is relatively high. An alternative is an obligation in combination with a certificate system. The sellers of transport fuel are then obliged to redeem a certain amount of biofuel certificates at the end of the year. An advantage of this system is that one has the guarantee that the target will be obtained using the market mechanism as a driver. Furthermore, it is a flexible system, which could incorporate other elements, such as information about the sustainability of (imported) biofuels, in the longer term.

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