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Use of straight vegetable oil mixtures of rape and camelina as on farm fuels in agriculture

Hans Marten Paulsen[a,*], V. Wichmann[b], U. Schuemann[b], B. Richter[b]

[a] *Institute of Organic Farming of the Johann Heinrich von Thunen-Institute (vTI), Federal Research Institute for Rural Areas, Forestry and Fisheries, Trenthorst 32, 23847 Westerau, Germany*

[b] *Chair of Piston and Internal Combustion Engines, Faculty of Mechanical Engineering and Marine Technology, Albert-Einstein-Str. 2, 18051 Rostock, Germany*

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ABSTRACT

Possibilities for using straight vegetable oil (SVO) from *Camelina sativa (L.) Crantz* (camelina or false flax) and its mixtures with *Brassica napus* (rape) SVO as fuel in adapted diesel engines are described with chemical parameters, measurements in a test engine and a field test in a tractor. Camelina as a crop is attracting attention in organic farming and is often used in mixed cropping systems with low competition to food production area. Camelina SVO has low oxidation stability. Its polymerization affinity limits the storage time and increase the risk of coking at hot motor components and of thickening processes in the lubricant oil of the engine. In mixtures with rape and camelina SVO, threshold limits for Conradson Carbon Residues and for oxidation resistance were exceeded. The oxidation resistance could be prolonged by the addition of commercial antioxidants. Camelina and rape SVO showed very similar burning characteristics at full-to-medium partial engine loads. Under low partial loads and idle load, the burning function of the various fuels was increasingly delayed, beginning with diesel fuel over pure rape SVO, then a mixture containing 700 $dm^3\ m^{-3}$ rape SVO, and 300 $dm^3\ m^{-3}$ camelina SVO, through to pure camelina SVO. The exhaust emissions of NO_x-, CO-, particles and HC of rape SVO, camelina SVO and their described mixture were not significantly different. The typically higher NO_x- and lower HC-emissions of SVO compared to diesel fuel were apparent. The results principally reveal the usability of a cold pressed, non-refined camelina-rape SVO mixture in adapted diesel engines.

1. Introduction

The use of straight vegetable oils (SVO) as a fuel is a tool toward the energy self-sufficiency of farms. The oil crop *Camelina sativa L. Crantz* (camelina or false flax) was identified as a suitable partner in mixed cropping systems with legumes or cereals, especially for organic farms. This cropping system is described as 'mixed cropping with oil crops' [1,2] and allows the simultaneous production of food and fuel with moderate area competition. Agricultural benefits of the cropping systems are described as weed suppression, lodging resistance and elevated land use efficiency values [3–5]. Life cycle assessments (LCA) for the co-production of the oil crops generally showed low energy and environmental loads when the seed bed preparation was allocated to the main crop and whether the drilling procedures of both crops were combined

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[*] *Corresponding author*. Tel.: +49 4539 8880 316.
E-mail address: hans.paulsen@vti.bund.de (H.M. Paulsen).

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[6,7]. The efficiency of the production of renewable fuels with *Brassica napus L.* (rape) is seen critically worldwide, because of the competition between food and energy crops and the low energy efficiency of the whole production line in comparison to heat and combined heat and power generation. Additionally, unbalanced political demand for biofuels increases impairments of the environment in exporting countries [8–12]. In organic farms, the energy input in rapeseed cultivation is much lower than in conventional production [13], but the high yield risk caused by insects and pests makes the cultivation of rape impracticable at many sites [4,14]. However, rape could be combined with undersown clover (*Trifolium repens L.*) in organic crop rotations. This cropping concept shifts the yield risk of rape, but also its yield potential to the required leguminous fallow year in the crop rotation and is described as 'intensified fallow' [15]. The cropping systems 'intensified fallow' and 'mixed cropping with oil crops' deliver between 350 and 850 kg ha^{-1} a^{-1} rape SVO and between 100 and 300 kg ha^{-1} a^{-1} camelina SVO. With an average fuel consumption of 100 kg ha^{-1} for farm machinery [16] these two crop rotation elements would supply fuel for 4.5–11.5 ha and could significantly contribute to the fuel demand of the whole crop rotation without competition to food production, and with minimized area competition and low environmental costs.

Quality of rape SVO (refined or unrefined) is standardized for use as fuel by the DIN 51605, the standard on fuels for SVO compatible combustion engines [17]. The use of vegetable oils as fuel in diesel engines is widely described in the literature and has been summarized by [18] and [19]. First results concerning the use of pure camelina SVO in a car with an unadapted diesel engine are described by [20]. Various technical adaptations of diesel engines to vegetable oil as fuel have been developed to improve cold starting, to perfect combustion, to prevent coking and deposits at injection nozzles, pistons and cylinders and to minimize the permeation of vegetable oil in the mineral lubricating oil of the engine (Fig. 1).

The production of oils in local oil mills, e. g., in single farms or those owned by farmers' associations would contribute to the diversification of the agricultural product range, is estimated as suitable option to stimulate rural economics with good LCA values [23–25] and would address the demand of organic farming to close local energy cycles in farms [26].

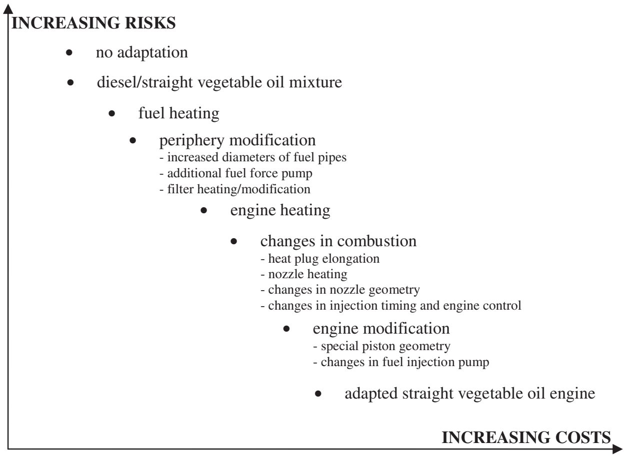

Fig. 1 – Adaptation of diesel engines on straight vegetable oil, risk assessment and costs according to [21,22].

Fuel characteristics of native cold pressed rape SVO and of camelina SVO are described in the following. Possibilities for the use of SVO mixtures as fuel for agricultural machinery are analyzed in detail on the basis of chemical analyses and of runs in a test engine. First field results on the use of a suitable mixture of both SVO as pure biofuel in a tractor with an adapted engine are reported.

2. Materials and methods

Various SVOs were used in the different experiments. All SVO charges were analyzed on quality parameters with the methods given in the DIN 51605 [17]. The parameters and standard values are given in Table 1. The Cetane numbers were analyzed with a Fuel Ignition tester (Fuel Tech As, Trondheim) according to the method given by [27]. The ignition delays were determined as a mean from 20 single injections at 525 °C and 0.2 MPa pressure. Both latter values were determined at the Technologie- und Foerderzentrum (TFZ) Straubing, Germany.

The range of the quality parameters of camelina SVO and its mixtures with rape SVO are described on basis of cold pressed SVO produced in a local oil mill: After treatment in a screw press (Straehle Co., 350 kg h^{-1}, 40–50 °C oil temperature), the oil was stored in a raw oil tank, pumped through a chamber filter press (Schenk Co.) with variable plate numbers and was finally filtered with a candle filter (AMA Co.) to reach purity according to the DIN 51605. Seeds of the harvests in 2005 and 2007 from different origin and age and storage conditions were processed (camelina: Steiermark, Austria (Graz area: 47°4′N, 15°26′E), Bayern, Germany (Pfaffenhofen area: 48°32′N, 11°25′E) and Schleswig-Holstein, Germany (Trenthorst: 53°47′N, 10°30′E), rape: purchased from European Union by the local oil mill). All SVO were pressed between January and March 2008 and stored in plastic containers at room temperature in farm buildings. They were used as fuel in a tractor between February and October 2008. Both SVO and their mixtures were analyzed immediately before their use as biofuel at that time (Table 1). The camelina SVO used for the test engine runs was pressed in December 2007 with the same technology (Seed origin: North Germany, harvest 2007) and used immediately. The P, Ca and Mg contents of this oil were higher than the range given for camelina SVO in Table 1. The other quality parameters for camelina and rape SVO used here were within the reported quality range. In the test engine the combustion behavior and the exhaust emissions of the different fuels (rape SVO, camelina SVO, mixtures of both with 700 dm^3 m^{-3} rape SVO and 300 dm^3 m^{-3} for camelina SVO) were assessed at different motor loads in comparison to diesel fuel, without replications. No fuel additives were used. The fuels were examined at five engine load levels. A residual fuel oil test engine with one piston (brand 'Elbe Werk Roβlau', Type 1VDS18/15, four stroke cycle diesel operation, direct injection, forced induction, 72 kW, compression pressure 17 MPa, maximum indicated mean effective pressure (IMEP) 2.4 MPa, stroke 180 mm, bore