COMPARISON OF RAPESEED OIL FUEL MIXTURES

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Abstract. Traditional understanding of the bio-diesel composition is the methyl- and ethyl esters from vegetable oil, whose production technology is complicated and expensive. Practitioners used their knowledge and skills and proved that pure rape seed oil can be used as engine fuel, but the engine must be adjusted. This research shows how to use rape seed oil with different additives, which improve the main characteristics of fuel – reduce kinematics viscosity and flash point temperature. As a result several efficient mixtures of rape seed oil and additives were created. They are comparable with traditional bio-diesel fuel (RME, REE), when physical, energetic, ecological parameters are compared. At the same time minor diesel engine modifications are necessary in order to use the fuel mix.

Key words: rapeseed oil mixture, bio-diesel, co-generator, energy efficiency, ecology.

Introduction

Latvia as a world fuel market participant has already stated its dependence from fossil fuel (oil, gas, etc.) – delayed, unstable, politically risky deliveries, price increase. This is a reason why the biofuel production development in Latvia has become as very important topic. Biofuel at the current stage is the only technically and technologically possible way to use alternative energy sources instead of oil in the mobile transportation units (cars, lorries). Biofuel from vegetable oils is the most popular, and it can be used also after mixing it with fossil diesel fuel.

The most popular biofuel production technology from vegetable oil is transesterization using methanol or ethanol catalyst, receiving fatty acid methyl and ethyl esters to be used for biodiesel [*E. Gudriniece,* 1999]. Byproduct – raw glycerin, is being received during this process, utilization of which is not solved yet in Latvia. Storage and use of raw glycerin becomes serious problem for biofuel producers.

Serious attention is being paid currently to the use of pure (100%) vegetable oil as engine fuel. Relatively high viscosity and flash point temperature are the main restrictors [*M.E. Tat,* 1999]. Another way to change physical and chemical properties of vegetable oil to be able to use it as engine fuel is to add to it fossil fuels, e.g., reactive engines fuel, gasoline A95 [*A. Grundulis et al,* 2004]. For such fuels no chemical reactions take place and no byproducts are created. Total volume of biofuel/fossil fuel mix is equal to arithmetic sum of vegetable oil and fossil fuel volumes.

Materials and methods

Experimental research was made using 16 different samples of rape seed oil and fossil fuel mixes, made by mechanical mixing fossil fuel (reactive engines fuel, fossil diesel engine, gasoline A76 and A95) with rape seed oil (made by SIA "Iecavnieks") in different proportions, and 10 samples of biodiesel fuel made in Latvia (RME, REE), mixed with fossil diesel fuel (*Diesel Fortis*) in different proportions (Tab. 1).

Table 1. **Description of fuel mixes used in the experiments**

Nr.	Fuel content, in volume percents	Fuel abbreviation
	Diesel fuels with rape seed oil add-on	
1.	70% rape seed oil and 30% reactive motor fuel	RE+30RD
2.	80% rape seed oil 20% reactive motor fuel	RE+20RD
3.	90% rape seed oil 10% reactive motor fuel	RE+10RD
4.	60% rape seed oil 40% fossil diesel fuel (winter)	RE+40DD-Z
5.	70% rape seed oil 30% fossil diesel fuel (winter)	RE+30DD-Z
6.	80% rape seed oil 20% fossil diesel fuel (winter)	RE+20DD-Z
7.	77% rape seed oil 23% A76 gasoline	RE+23A76
8.	80% rape seed oil 20% A76 gasoline	RE+20A76
9.	82% rape seed oil 18% A76 gasoline	RE+18A76

Nr.	Fuel content, in volume percents	Fuel abbreviation
10.	77% rape seed oil 23% A76 gasoline	RE+23A95
11.	80% rape seed oil 20% A76 gasoline	RE+20A95
12.	82% rape seed oil 18% A76 gasoline	RE+18A95
13.	85% rape seed oil 15% A76 gasoline	RE+15A95
14.	88% rape seed oil 12% A76 gasoline	RE+12A95
15.	91% rape seed oil 9% A76 gasoline	RE+9A95
16.	100% rape seed oil	RE
Biodiesel fuels (RME, REE) and mix with fossil diesel fuel		
1.	100% fossil diesel fuel	100FD
2.	100% rape seed oil methylester (SIA "Naukšēni")	100RME-N
3.	100% rape seed oil methylester (SIA "Mežrozīte")	100RME-M
4.	100% rape seed oil ethylester (RTU MLĶF)	100REE-RTU
5.	35% RME-N and 65% fossil diesel fuel	35RME-N
6.	35% RME-M and 65% fossil diesel fuel	35RME-M
7.	35% REE-RTU and 65% fossil diesel fuel	35REE-RTU
8.	5% RME-N and 95% fossil diesel fuel	5RME-N
9.	5% RME-M and 95% fossil diesel fuel	5RME-M
10.	5% REE-RTU and 95% fossil diesel fuel	5REE-RTU

In cooperation with scientific polygon "Vegas", located in the agriculture farm, special co-generation system usable for scientific experiments was built (Fig. 1). Co-generation system allows to produce electricity and heat energy. It consists of diesel engine from *Volkswagen Golf 1.6,* year of production 1991, and asynchronous electrical generator with output power 15 kW.

Table 2. **Engine technical characteristics**

Engine type	Diesel engine
Number of cylinders, positioning	4 cylinders, vertical position, in line
Max. output power at 4800 min^{-1}	40 kW
Total cylinder volume	1588 cm^3

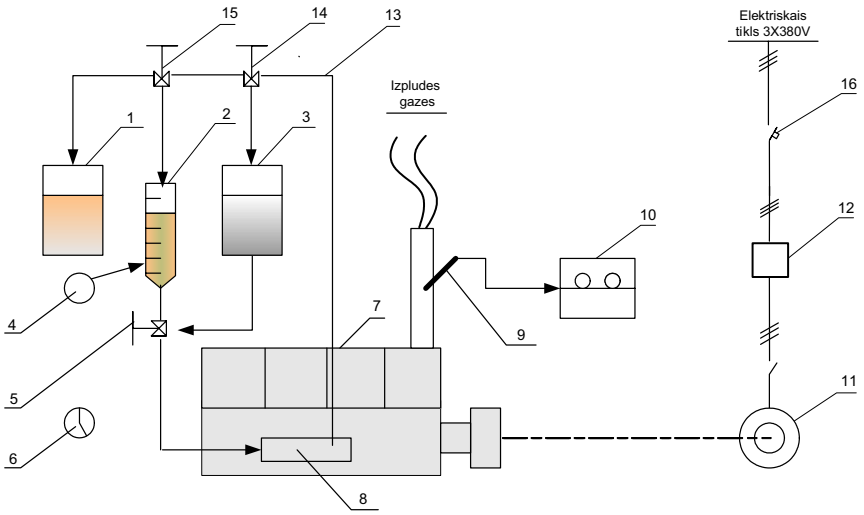

Fig. 1. **Technological scheme of fuel comparison experimental co-generation system**: 1 – reservoir for returned fuel; 2 – measuring cylinder; 3 – reservoir for fossil fuel; 4 – used fuel control unit; 5 – three-way valve; 6 – time control; 7 – diesel engine; 8 – fuel system; 9 – exhaust gases analysis probe; 10 – exhaust gases analyzer; 11 – asynchronous generator; 12 – electrical parameters control device; 13 – returned flow; 14 and 15 – three-way valve; 16 – automatic switch; 17 – contactor

Experiments with co-generation system using different vegetable oil and fossil fuel mixes were made, and the following measurements were registered:

- fuel consumption;
- time;
- electrical energy produced;
- components of exhausts – CO, NO_x, CO_2.

During experiments the co-generation system engine had constant load. Electrical energy produced was delivered to the electrical net.

The block diagram of experimental device is provided in the Fig. 1. Diesel engine (7) in this system is connected directly to the asynchronous generator (11). Connection of the generator to the electrical net is automatic – with the launch of diesel engine via contactor (17).

Principles of operation

The operations of the experimental system can be divided into four parts:

- co-generator launch using fossil fuel;
- switching to the fuel to be tested, engine operations regimes setup;
- experiments with the new fuel – measuring, data collection;
- engine fuel system cleaning cycle, using fossil fuel, switching to fossil fuel feeding.

Co-generation system launch using fossil fuel. Engine is being prepared for working with fossil diesel fuel. Three-way valve (5) opens the fuel flow from fossil fuel reservoir to the engine fuel system (8). Three-way valve (14) opens the returned fuel flow from fuel system to the fossil fuel reservoir. Diesel engine (8) is being launched, and heated to the nominal working temperature 80 °C.

Transition to the fuel to be tested, engine operations regimes setup. Engine is being prepared for working with particular fuel mix. Three-way valve (5) opens the fuel flow from measuring cylinder (2) to the fuel system (8). Three-way valve (14) opens the returned fuel flow from fuel system to the measuring cylinder (2). The sample portion of fuel mix to be tested is filled in the measuring cylinder (2). Electrical parameters control device is being used to set up engine regimes during the test. Exhaust gases analysis probe placed in the exhausts emission pipe (9).

Experiments with the new fuel – measuring, data collection. Engine is working using the sample of the fuel mix to be tested. When fuel level in the measuring cylinder (2) reaches the stated level, timer (4) is being launched, and time count starts. At the moment of time count start, electrical energy counter readings are registered. The overall length of the experiment – 6 minutes. After three minutes of experiment the readings from exhaust gases analyzer are printed out. After three minutes more the engine is switched off, and the level of fuel mix in the measuring cylinder and readings from electrical energy counter are registered. Difference between the registered values of electric power counter final and start states is the volume of electrical energy sent into the electric net. The difference in the start and end levels in the measuring cylinder is the fuel mix consumption by the diesel engine.

Engine fuel system cleaning cycle. At the end of the experiment, three-way valve (5) opens the fuel flow from fossil fuel reservoir to the engine fuel system (8). Three-way valve (14) opens the returned fuel flow from fuel system to the return fuel reservoir (1). Engine runs on the fossil fuel until the fuel system (8) is cleaned from fuel mix.

Results

During the experiment, constant power of electrical generator – 7.5 kW, was stated. Data collected from the experiments were compared.

Experiments showed that when working with pure rape seed oil, the fuel consumption was in average 38.9% higher than with fossil diesel fuel. The results can be explained by the fact that rape seed oil has substantially lower heating capacity and high viscosity. When working with pure rape seed oil, engine worked in the overload regime, and substantially reduced output power, which at some part was compensated by increased fuel supply and consumption.

After adding in average 20.5% fossil fuel to the rape seed oil, fuel consumption decreased by 20.1%.

When engine operation on the rape seed oil diesel fuel was compared with 100RME fuel, mean fuel consumption was higher by 346.15 ml/h or by 11.2%, but with 100REE – by 245.8 ml/h or by 7.9%. Fuel mix of pure biodiesel (RME, REE) and 65% fossil diesel fuel, the fuel consumption decreased – for 35RME in average by 11.1%, but for 35REE – by 9.2%. Consumption of the biodiesel mix with 35% fossil diesel fuel (35RME, 35REE) is comparable with rape seed oil diesel fuels consumption (Fig. 2).

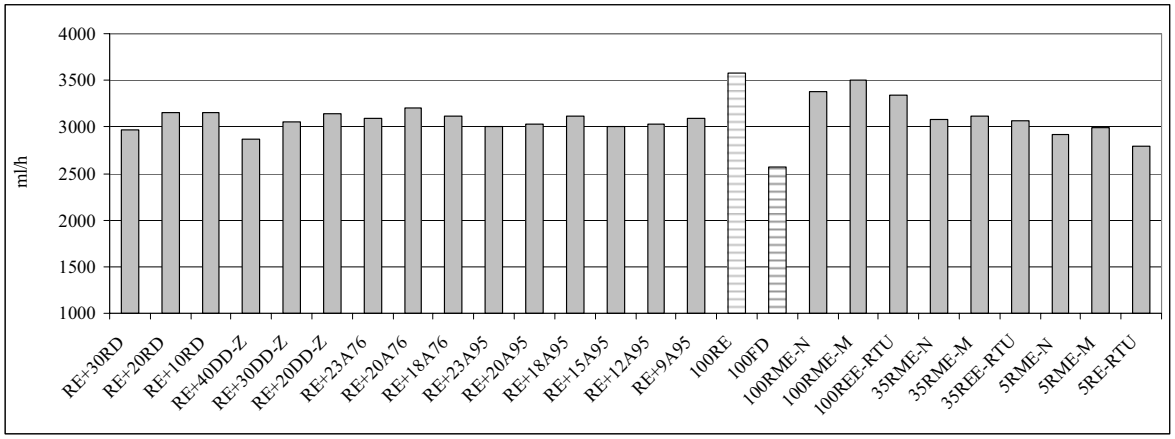

Fig. 2. **Co-generator engine fuel consumption, using different rape seed oil and biodiesel fuel mixes** (P_{el} *= 7.50 kW, n = 1550 min*$^{-1}$)

Similar trend is being observed when the specific fuel consumption to produce 1 kW of electric energy is being compared. Average fuel consumption increased by 12.7%, when 100RME fuel was used instead of rape seed oil mix biodiesel fuels, and by 9.3%, when 100REE was used. This shows that rape seed oil diesel fuels have significantly higher efficiency.

In comparison with pure rape seed oil, use of 100RME reduced average fuel consumption only by 3.8%, and use of 100REE – by 6.9%, showing significant advantages of ethyl ester use. Biodiesel fuel produced by SIA "Mežrozīte" (100RME-M) was consumed a bit more (by 3.7%) than the one produced by SIA "Naukšēni"(100RME-N) (Fig. 3). The difference in the consumption patterns is because of different production technologies and different raw materials use in the mentioned companies.

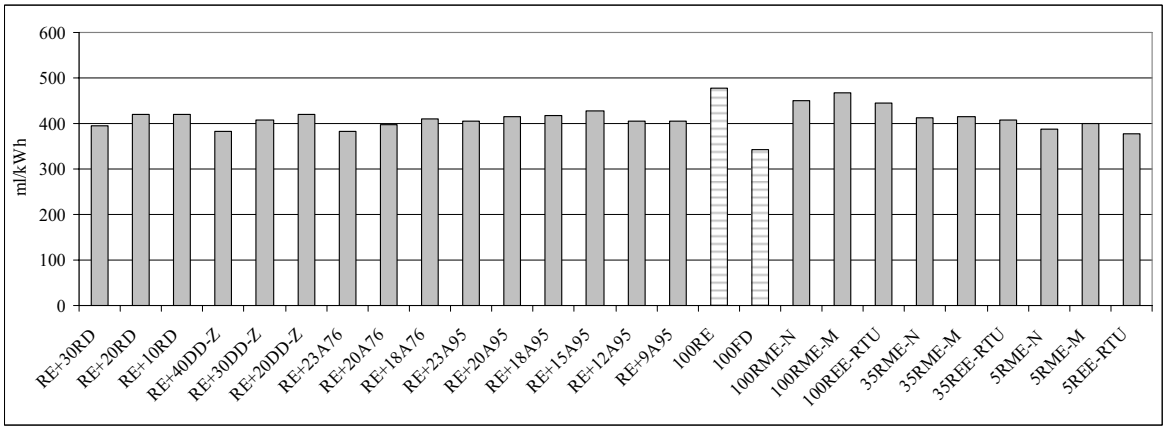

Fig. 3. **Co-generator engine specific fuel consumption comparison, using different rape seed oil and biodiesel fuel mixes** (P_{el} *= 7.05 – 8.15 kW, n = 1550 min*$^{-1}$)

Evaluation of energo-economic parameters of the co-generator system with different fuel mixes under stated constant motor load shows that rape seed oil biodiesel mixes are more efficient than biodiesels (RME, REE).

Almost all fossil and vegetable oil fuel mixes produce less CO emission than 100FD. This means that biodiesels with substantially different chemical composition are burning completely, and do not make toxic exhausts.

Engine working using rape seed oil mix diesel fuel, has in average 21% less CO emission in comparison with pure biodiesel (RME, REE) use.

Few experimental mixes of biofuels showed high CO concentration in the exhaust gases. It was observed that with these fuel mixes engine worked in the overload regime, and partial burning of fuel took part there (Fig. 4). Exhaust gases analysis showed that rapes seed oil diesel fuel use reduces NO_x emission by 5.3%, when compared with pure biodiesel (RME, REE). When compared to fossil diesel fuels, NO_x emission from rape seed oil mix biodiesel in the exhaust is in average 16.7% higher, and from biodiesel (RME, REE) – 10.8% higher (Fig. 5). CO_2 emission analysis from co-generator using rape seed oil mix biodiesel shows 2.3% reduction in comparison with use of pure biodiesel fuel (RME, REE). In comparison with fossil diesel fuel, use of rape seed oil biodiesel fuel increases of CO_2 emission is 20.5%, and using biodiesel fuel (RME, REE) – by 23.3% (Fig. 6).

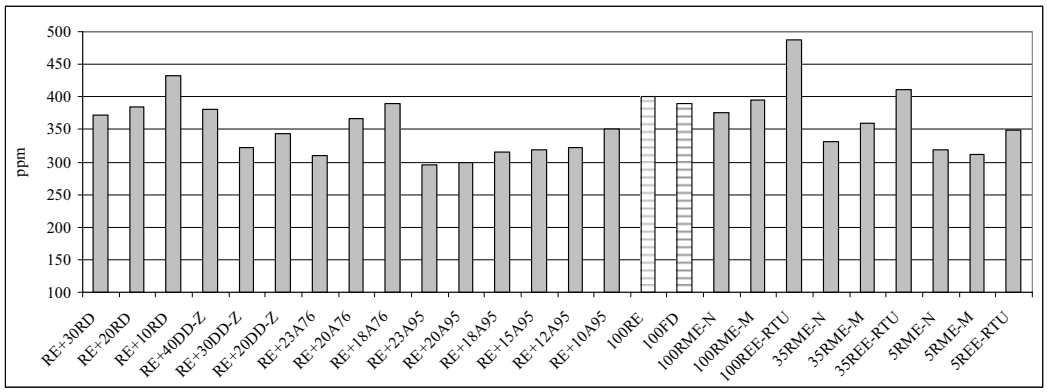

Fig. 4. **CO emission comparison in the exhaust of the co-generator engine, using different rape seed oil and biodiesel fuel mixes** (P_{el} *= 7.05 – 8.15 kW, n = 1550 min*$^{-1}$)

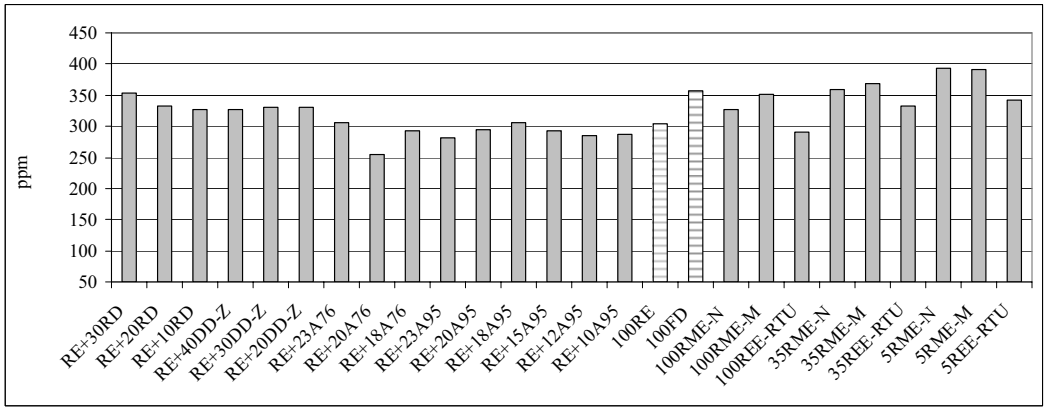

Fig. 5. **NO_x emission comparison in the exhaust of the co-generator engine, using different rape seed oil and biodiesel fuel mixes** (P_{el} *= 7.05 – 8.15 kW, n = 1550 min*$^{-1}$)

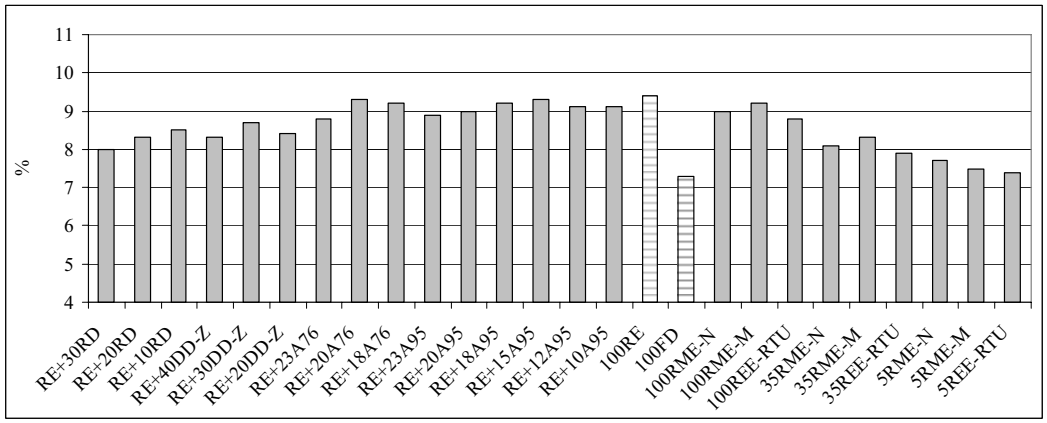

Fig. 6. **CO_2 emission comparison in the exhaust of the co-generator engine, using different rape seed oil and biodiesel fuel mixes** (P_{el} *= 7.05 – 8.15 kW, n = 1550 min*$^{-1}$)

Conclusions

1. Vegetable oil fuels are renewable energy source. Use of fuels based on vegetable oils is important and necessary prerequisite to fulfill norms and statements mentioned in the Kioto protocol and directives of European Union.
2. Research showed that adding 20.5% fossil fuel to the rape seed oil, fuel consumption reduces by 20.1%. In addition, specific fuel consumption to produce 1 kW of electrical energy using rape seed oil fuels is by 12.7% lower than using 100RME, and by 9.3% lower than using 100REE.
3. Experiments results showed that co-generation system under stated constant load working with rape seed oil biodiesel fuel consumes 11.2% less fuel than working on 100RME, and 7.9% less than working on 100REE.
4. Exhaust gases analysis shows that rape seed oil biodiesel fuel burning produces in average 21% less CO and 5.3% less NO_x than burning pure biodiesel (RME, REE). When comparing with 100FD, rape seed oil biodiesel fuel burning produces in average 16.7% more NO_x, and biodiesel (RME, REE) – 10.8% more NO_x. When comparing with 100FD, rape seed oil biodiesel fuel burning produces in average 20.5% more CO_2, and biodiesel (RME, REE) – 23.3% more CO_2.

References

1. E. Gudriniece. Rapšu eļļas racionālas izmantošanas iespējas. Simpozija. Alternatīvā enerģija Latvijā. Referātu krājums. Jelgava: LLU, 1999, 10-14.
2. M.E. Tat, J.H. Van Gerpen. The Kinematic Viscosity of Biodiesel and Its Blends with Fossil Diesel Fuel. Journal of the American Oil Chemists'Society 76(12), 1999, 1511-1513.
3. A. Grundulis, Ar. Grundulis, A. Galiņš, K. Zihmane. Bioloģiskās dīzeļdegvielas sastāvs, iegūšanas paņēmiens un iekārta paņēmiena realizācijai. Patents, LV 13150 B, 2004.