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Research Article

THE ANALYSIS OF THE MANUFACTURING AND USING ALTERNATIVE FUEL – A MIXTURE OF RAPESEED OIL AND ALCOHOL

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ABSTRACT

The following article is an analysis of designed process of manufacturing a mixture of 50% rapeseed oil and 50% alcohol and using it as a fuel. The analyzed eco-fuel is completely based on renewable sources, and can be a good alternative to diesel fuel. The analysis was made according to the assumptions of Life Cycle Assessment, which is a method that divides the whole life cycle of the product into the unit processes. It is used especially for measuring the environmental impact of the product. The life cycle of fuel mixture in an amount of 10 000 l was divided into six unit processes: the production of oilseed and biomass on the farm, transport of rapeseed to oil extraction works, oil production, the production of alcohol from biomass, the transport of mixture into a transport company and the use of total fuel delivered by the company. The use of energy and the amount of pollutants emitted were particularly important in the analysis. Fuel mixture, the same as the analyzed, was used during the whole designed process. In the production of rape on a farm the tractor and the harvester were used, and caused highest emissions of pollutants during all steps involved in the production of fuel. Alcohol, the component of the mixture, was produced through the fermentation of biomass that cames from waste from rapeseed processing, which caused no energy consumption or emissions. The analysis shows that total emissions of harmful gases is lower than that of conventional diesel, which proves that the tested fuel mixture is more environmentally friendly.

Keywords: alternative fuel, mixture, rapeseed oil, alcohol, unit process, biomass.

INTRODUCTION

Traditional fuel for powering diesel engines is diesel oil. As a product derived from petroleum it belongs to non-renewable energy sources. It's price, alike the price of petroleum, has been rising for years, and is highly dependent on political issues. In addition, its combustion emits a number of compounds hazardous to the environment.

Alternative fuel that can replace diesel oil, should be primarily produced with renewable sources, and also should be characterized by lower price for similar performance and lower emissions of harmful substances during combustion. The fuel that could be a mixture of rapeseed oil and alcohol, which is still under development. The fuel is the subject of the following analysis.

SUBJECT AND METHOD OF THE ANALYSIS

The analyzed alternative fuel consists of 50% rapeseed oil and 50% alcohol produced in biomass fermentation. The analysis is carried out for 10 000 liters of fuel.

The materials used for the designed production process are from fully renewable sources, it is mainly rape, grown in farms. Rapeseeds are

converted into the oil, and the waste (e.g. straw) is used as biomass to obtain alcohol.

Basing on previous studies it can be stated that, compared to conventional diesel, the mixture of rapeseed oil and the alcohol will be characterized by only a few percent lower energy value, which results in a little lower efficiency [2].

The study was based on assumptions of Life Cycle Assessment, which are to divide the whole life cycle of product info unit processes and to analyze each one of them. This method is mainly used to assess the environmental risks posed by the product. Unit processes may be associated with the production, transport, use or disposal, and for each of these, the use of raw materials, energy, emissions or waste volume is determined, depending on the purpose of analysis [3].

The following analysis focuses primarily on emissions of pollutants and energy consumption in each of the phases of the whole designed process, which led to information on total emissions and energy consumption for the life cycle of the fuel mixture.

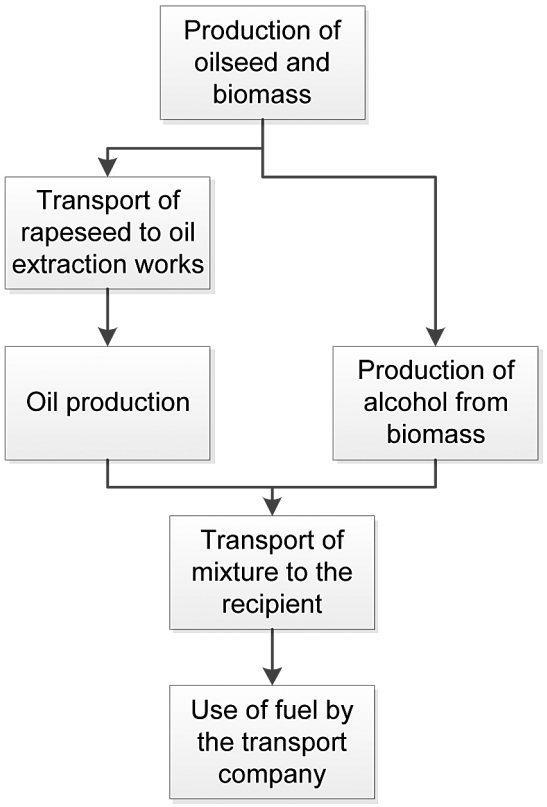

Figure 1. Processes of the production of life cycle of fuel mixture

UNIT PROCESSES IN THE MIXTURE FUEL LIFE CYCLE

The following analysis includes all unit processes making up the finished product, including the emissions they cause. The process of using the fuel is also included.

Figure 1 illustrates successive processes making up the life cycle of a mixture of vegetable oil and alcohol.

Single processes making up the whole designed process of production and use of tested alternative fuel are characterized below.

Production of oilseed and biomass

In order to obtain raw materials which are necessary to produce elements of the mixture, it is needed to cultivate appropriate intermediates. Vegetable oil is produced from rapeseed, and alcohol is formed in the fermentation of biomass.

It was assumed that the production of the two components is carried out on the farm located in Lower Silesia.

For the production of 5000 liters of rapeseed oil the area of 5 hectares required. This value was estimated basing on average yields and the amount of oil obtained from one tone of rapeseed. It can be gained on average 2.5 tones of rapeseed from one hectare, while one tone can be processed into around 400 liters of oil [1].

Biomass intended to be used in the fermentation process to produce alcohol is derived from wastes from the production of rapeseed (straw, oil cake). Therefore, the production of components for the production of rapeseed oil and the alcohol is treated as a single process. During the fermentation of one ton of biomass 220 liters of alcohol are produced, and one hectare can produces 5 tons of biomass. Therefore, to produce 5000 liters of alcohol 4.55 ha is required, so cultivation area will remain the same as in the case of rape crops – 5 ha.

It is assumed that an agricultural machinery (tractor and harvester) is used in the production process of these materials, also powered by a mixture of rapeseed oil and alcohol. Previous experiments showed that this fuel is characterized by 10% higher consumption than conventional diesel fuel. For the production of necessary raw materials (12.5 t rapeseed and 22.75 t rape straw) the estimated total fuel consumption is 494 liters (Table 1). It takes into account such processes

as skimming, plowing, tillage, seeding, fertilization, protective treatments, seed harvest and commuting.

Table 1. Fuel consumption during rapeseed and straw production

Type of activity	Fuel mixture consumption [dm^3]
Skimming	63
Plowing	110
Tillage	104
Seeding	29
Fertilization	42
Protective treatments	42
Seed harvest	104
Commuting	33
Sum	494

Because the energy value of the fuel used is similar to that of diesel oil, it is assumed that it is 36 MJ/L. Therefore, the energy value of whole fuel used were as follows:

$$E_{zon} = 36 \text{ MJ/l} \times 494 \text{ l} = 17784 \text{ MJ} \quad (1)$$

When cultivating, it was also necessary to usesome fertilizers and pesticides, which is shown in Table 2.

Energy value of fertilizers and pesticides was calculated 37 390 MJ. Therefore, total energy value is:

$$E_{pr} = 17784 \text{ MJ} + 37390 \text{ MJ} = 55174 \text{ MJ} \quad (2)$$

The combustion of fuel by a tractor and combine harvester, issues a certain amount of air pollution. It was assumed that a tractor (Zetor 12245) workes on average power 63 kW. Operating time of the tractor on 5 ha of land in the whole process of cultivation of rape is 43.75 h. Therefore, the tractor uses 2756.25 kWh.

The combine harvester (Bison Rekor workes for 18.75 hours, and its average power is 75 kW. Thus, the energy consumption is 1406.25 kWh. Therefore, the total energy consumption in the production of 12.5 tonnes of rape is 4162.5 kWh. Emission level for the combustion of a mixture of rapeseed oil and the alcohol is shown in Table 3.

Therefore, a total production of rapeseed and biomass to produce 5000 liters and 5000 liters of alcohol requires 55 174 MJ. It uses 494 liters of fuel, 1400 kg of nitrogen fertilizer, 570 kg of phosphate fertilizer, 630 kg of potassium fertilizers and 15 kg of pesticides. 3330 g of carbon monoxide and 29 137.5 g of nitrogen oxides are emitted.

Transport of rapeseed to oil extraction works

The next step is to transport the produced rapeseed oil to an oil mill, located at a distance of 50 km from the farm. It is assumed that transportation is done by already used Zetor 12 245 with two trailers with total capacity of 20 000 kg. During transport to the oil mill and return to the farm the tractor uses 841 liters of fuel mixture, which energy value is 36 MJ/l. So total energy consumption of the process is 3042 MJ.

During the transportation, the average tractor power is 70 kW, and the transportation time is 6 h. Therefore, the energy consumption is 420 kWh. In total, in this process 841 liters of fuel are used, which causes an emission of 336 g carbon monoxide and 2940 g nitrogen oxides (Table 4).

Table 2. Consumption and energy value of fertilizers and pesticides

Fertilizer / pesticide	Consumption [kg]	Conversion coefficient [MJ/kg]	Energy value [MJ]
Nitrogen fertilizers	1400	20	28 000
Phosphate fertilizers	570	7	3990
Potassium fertilizers	630	5	3150
Pesticides	15	150	2250
Sum	2615	182	37 390

Table 3. Emission of pollutants during rape production

Pollutants	Average emission [g/kWh]	Emission for 4162.5 kWh [g]
CO	0.8	3330
NO_x	7	29 137.5
SO_x	0	0

Table 4. Emission of pollutants during the transportation of rapeseed

Pollutants	Average emission [g/kWh]	Emission for 420 kWh [g]
CO	0.8	336
NO_x	7	2940
SO_x	0	0

Oil production

The next step is the extraction of 5000 liters of oil from the rapeseed provided. For this purpose, the oil press TLS-30 may be used. Total power of this machine is 120 kW (including auxiliary drives) and it processes 25 tons of rapeseed per day.

Therefore, the press running time to process 12.5 tons of rape is 12 hours. So the energy consumed is 2106 MJ. The device uses 1440 kWh during the process (Table 5).

Table 5. Emission of pollutans during rapeseed oil production

Pollutants	Average emission [g/kWh]	Emission for 1440 kWh [g]
CO	0.014	20.16
NO_x	0.088	126.72
SO_x	0.338	486.72

Source: own elaboration, based on user's manual of the oil press.

Therefore, the process of producing 5000 liters of oil consumes 12.5 tons of rapeseed and issues 20.16 g of carbon monoxide, 126.72 g of nitrogen oxides and 486.72 g of sulfur oxides.

Alcohol production from biomass

For the manufacturing of the fuel mixture, it is also necessary to produce 5000 liters of alcohol. Alcohol is produced by the fermentation of biomass acquired earlier, involving bacterium Clostridium acetobutylicum.

In order to produce the required amount of alcohol, 22.75 tons of biomass has to be used. The process does not require any energy and does not cause the emission of harmful substances into the environment.

Transport of fuel mixture to recipient

After the combination of the components, 10 000 l of alternative fuel is made. Then, it is transported to the transport company, established in Wrocław, which is located at a distance of 10 km from the factory.

It is assumed that in the process of transport, the tractor unit Mercedes-Benz Actros with tank-type trailer NPA-33 is used. The vehicle is supplied with a mixture of rapeseed oil and alcohol. The entire vehicle, including the filled trailer has a weight of 21.2 tons.

The total process energy consumption is 127.57 MJ. Fuel consumption over a distance of 10 km is 3.5 liters. The average power of the tractor is about 250 kW, therefore, the journey lasts 0.166 hours (assuming average vehicle speed of 60 kph) and the energy consumption is 42 kWh.

Table 6. Emission of pollutans during the transportation do the recipient

Pollutants	Average emission [g/kWh]	Emission for 42 kWh [g]
CO	0.8	33.6
NO_x	7	294
SO_x	0	0

In the process of transport of 10 000 liters fuel for the company, 3.5 liters of fuel is consumed. The process generates 33.6 g of carbon monoxide and 294 g of nitrogen oxides (Table 6).

Use of fuel by the transport company

The transport company uses the tractor Mercedes-Benz Actros with trailers. The energy value of the whole fuel delivered is 360 GJ.

$$E_{wemor}=10\ 000\ l\times 36\ MJ/l=360\ 000\ MJ=360\ GJ \quad (3)$$

Assuming an average speed of 75 kph and consumption of 35 liters per 100 km it can be calculated that 10 000 liters of fuel enable to drive 28 571 km during 381 h. Therefore, if the average engine power is 335 kW, then power consumption is 127 635 kWh.

Table 7. Emission of pollutants during the use of fuel mixture

Pollutants	Average emission [g/kWh]	Emission for 127 635 kWh [g]
CO	0.8	102 108
NO_x	7	893 445
SO_x	0	0

Table 8. Summary of the energy consumption in the production of a mixture of rapeseed oil and an alcohol

Process	Energy consumption [MJ]
Rape production	55 174
Rapeseed transportation	3024
Rapeseed oil production	2106
Transport of fuel mixture to the recipient	127.57
Sum	60 431.57

Table 9. Summary of emissions of pollutants for the production and use of a mixture of rapeseed oil and alcohol as a fuel

Process	Emission [g]		
	CO	NO_x	SO_x
Rape production	3330	29 137.7	0
Rapeseed transportation	336	2940	0
Rapeseed oil production	20.08	126.72	486.72
Biomass fermentation to produce alcohol	0	0	0
Transport of fuel mixture to the recipient	33.6	294	0
Use of fuel mixture	102 108	893 445	0
Sum	105 827.68	925 943.42	486.72

In total, 10 000 liters of rapeseed oil mixture with alcohol are used by the transport company, generating the 102 108 g of carbon monoxide and 893 445 g of nitrogen oxides (Table 7).

CONSLUSIONS

In the designed process, the manufactured fuel delivered 360 GJ of energy. Table 8 shows the power consumption in processes of fuel production and total energy. In conclusion, with the effort of 60 GJ, there was nearly six times more power provided – 360 GJ.

Although the designed process of production of mixture of rapeseed oil and alcohol used environmentally friendly methods, it is inevitable to emit some pollutants, mainly associated with the burning fuel.

In the life cycle of fuel mixture it more than 100 000 g of carbon monoxide, more than 900 000 g of nitrogen oxides and almost 500 g of sulfur oxides were emitted (Table 9). This emission appears to be high, but it is lower than the production and use of conventional diesel, tested previously according to the same method (carbon monoxide 235 376 g, nitrogen oxides 944 921 g, sulfur oxides 83 287 g).

The unit process that caused the highest emission was the production of rapeseed on the farm. This may be an indication for further improvement of the manufacturing process.

The fuel consisting of rapeseed oil and alcohol produced from biomass has similar energy to that of diesel oil, but it is more environmentally friendly and made from entirely renewable sources.

REFERENCES

1. Bieniek J., Molendowski F., Kopa D. 2010. Analiza opłacalności produkcji estrów metylowych oleju rzepakowego na przykładzie wytwórni rolniczej W-400. Instytut Inżynierii Rolniczej, Uniwersytet Przyrodniczy we Wrocławiu, Inżynieria Rolnicza, 1(119).
2. Bocheńska A., Bocheński C. 2008. Olej rzepakowy paliwem do silników Diesla. Czasopismo Techniczne, Wydawn. Politechniki Krakowskiej, z. 8-M.
3. Grzesik K. 2006. Wprowadzenie do oceny cyklu życia (LCA) – nowej techniki w ochronie środowiska. Inżynieria Środowiska, 11(1).