Research on the performance characteristics of rapeseed oil for its use as a diesel fuel additive

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Abstract. Traditionally used fuels can be replaced with one of the possible alternatives such as rapeseed oil. With the development of Industry 4.0 and the high environmental requirements, research into reducing carbon dioxide emissions continues. To this end, research has been carried out on the performance characteristics of rapeseed oil, diesel and mixed fuel - 8% rapeseed oil and 92% diesel. In order to optimize the process, a study and in-depth analysis of the results of the use of diesel with the addition of biodiesel by end-customers has been carried out.

1. Introduction

The rapid pace of development in the fields of artificial intelligence, biotechnology and energy conservation rearranges production and transcends traditional boundaries, creating new opportunities for reducing carbon dioxide emissions. This contributes to the development of technology and is defined as the Fourth Industrial Revolution [1, 2]. It is seen as a model that supports business and society, drives the radical changes and also environmental protection that result from the introduction of new technologies [3, 4].

The reduction of available stocks of traditional fuels in recent decades has led to an increase in the use of renewable sources for the production of biofuels [5, 6]. Unlike other renewable energy sources, biomass can be converted directly into liquid biofuels for transport [7, 8]. The two most common types of biofuels are ethanol and biodiesel [9]. The great advantage of biodiesel over other fuels is that the raw materials it produces are renewable and inexhaustible [10]. When burned, the emissions of exhaust gases, and especially carbon dioxide, are drastically reduced [11]. Its technical structure is similar to that of diesel. It can be used as an additive to diesel to reduce vehicle emissions or in its pure form as biofuel. In recent years, the EU has set itself the goal of reducing harmful emissions from transport, leading to an increase in biofuels produced from food or feed crops [12]. Since the 1990s, the EU has started a course to reduce harmful gases, adopting a directive in 2003 promoting the use of biofuels in transport [13]. Transport emissions are expected to decrease by 20% by 2020 and between 30 and 40% by 2030. The European car fleet is mainly made up of diesel vehicles and this, coupled with the rise in prices of conventional liquid fuels, necessitates an increase of the production of biofuels from vegetable oils. Biofuels can also be mixed with petroleum products [14, 15]. For the production of vegetable oils, it is necessary to use traditional EU-specific raw materials such as rapeseed in Bulgaria. This study...
identifies both the performance of rapeseed oil and consumers' views on the use of biodiesel as an additive to petroleum-based diesel in vehicles.

2. Exposition
The object of this study is rapeseed oil, which can be successfully used as biodiesel. For the purpose of the study, the performance characteristics affecting the quality of rapeseed oil were determined: density, kinematic viscosity, calorific value, flash point and cetane number. A comparative analysis was made between rapeseed oil, diesel and a mixture of diesel and rapeseed oil.

2.1. Raw material for the production of rapeseed oil in Bulgaria
The cultivation of rapeseed in Bulgaria has become increasingly urgent in recent years in connection with its use as a raw material for the production of rapeseed oil. Rapeseed is characterized by a relatively high oil content of 33 to 42%. This makes rapeseed a preferred raw material for oil production mainly for technical purposes. For maximum yield of rapeseed oil and at the same time high quality of the resulting oil, it is necessary to comply with all technological requirements regarding the collection, storage and preparation of the seeds for oil extraction in them. To extract the oil, the seed is pressed, filtered and cooled. Biodiesel is produced from organic oils by chemical reaction with alcohol (ethanol or methanol) in the presence of a catalyst. Ethyl and methyl esters are obtained, respectively. The yield of alcoholic esters (100% biodiesel) is increased when the reaction proceeds with excess alcohol and accelerates with increasing temperature. The process is called trans-esterification and pre-esterification of fats to produce biodiesel and glycerine. The rapeseed oil molecules are transformed into molecules similar to diesel hydrocarbons. Samples for testing rapeseed oil were taken from a production facility. Petroleum-based diesel oil and rapeseed oil were tested individually and then mixed at a ratio of 92% petroleum-based diesel and 8% rapeseed oil. The tests were performed in laboratory conditions and the results are presented as mean.

2.2. Testing Methods for diesel and biodiesel fuels
Diesel, rapeseed oil and blend performance tests have been performed based on European Testing Methods. Table 1 gives the values of the performance characteristics of diesel and biodiesel according to the methodologies and studies of the authors in [16, 17, 18, 19, 20].

| Unit               | Testing Method                  | Diesel  | Biodiesel |
|--------------------|---------------------------------|---------|-----------|
| Density at 15°C    | kg/m³                           | 820-845 | 860 - 900 |
| DIN EN ISO 3675,   | DIN EN ISO 12185                |         |           |
| Viscosity at 40°C  | mm²/s                           | 2 – 4,5 | 3,5 – 5,0 |
| DIN EN ISO 3104    |                                  |         |           |
| Calorific Value,   | MJ/kg                           | 37-44   | 33-40     |
| DIN 51900-3        |                                  |         |           |
| Flash point,       | °C                               | min 55  | min 101   |
| DIN EN ISO 2719    |                                  |         |           |
| Cetane number      |                                  | min 51  | min 51    |
| DIN EN ISO 5165    |                                  |         |           |

3. Results and discussion
Based on the research performed on rapeseed oil, diesel and mixed fuel - 92% diesel and 8% rapeseed oil, the following results were obtained for determining performance.

3.1. Results and analysis of the results obtained for the performance of rapeseed oil, diesel and mixture fuel.
Table 2 shows the results obtained for the performance characteristics of rapeseed oil, diesel and mixture fuel.
The results obtained for the density of the tested fuels indicate that rapeseed oil is higher than that of diesel and a mixture of 8% rapeseed oil and 92% diesel. The viscosity of rapeseed oil is much higher than that of diesel and mixture. The calorific value of rapeseed oil is lower than that of diesel and mixture. The flash point of rapeseed oil is many times higher than that of diesel and mixture. Cetane number for diesel and blend is higher than rapeseed oil. Comparative analysis of the results showed that the resulting values for the mixture of 8% rapeseed oil and 92% diesel were closer to those of diesel than to rapeseed.

### Table 2. Performance of rapeseed oil, diesel and mixture.

| Distance (m)          | Unit     | Rapeseed oil | Diesel | 8% Rapeseed oil and 92% Diesel |
|-----------------------|----------|--------------|--------|-------------------------------|
| Density at 15°C       | kg/m³    | 919          | 841    | 858                           |
| Viscosity at 40°C     | mm²/s    | 37.3         | 4.66   | 4.79                          |
| Calorific Value       | MJ/kg    | 37.1         | 42.5   | 41.8                          |
| Flash point           | °C       | 270          | 56     | 65                            |
| Cetane number         |          | 42           | 49     | 48.1                          |

The study shows that over the past two years, biodiesel supplementation has become increasingly popular with customers. This is also due to the fact that the EU has started a course to reduce the harmful emissions of gases into the atmosphere and into diesel fuel so Bulgaria has started adding 6% biodiesel.
Figure 2. Are you satisfied with the quality of the biodiesel additive diesel?

Customer responses indicate that they are satisfied with the biodiesel supplement. But there will always be sceptics who, for obvious reasons, do not accept the new.

Figure 3. What is your opinion on the EU measure to add biodiesel to diesel?

Data from the answers to this question clearly show that the end customer is following the changes in the EU's environmental programs. This is confirmed by the answers to the following question:

Figure 4. Does the use of the biodiesel additive to diesel lead to a reduction in carbon monoxide emissions?
From the following two questions, it is clear that a large percentage of end users are aware of the main benefits and advantages of using biodiesel as an additive to diesel:

**Figure 5.** What arguments would you make to support the addition of biodiesel to diesel and the environment?

**Figure 6.** What are the benefits of adding biodiesel to the end-customer diesel?

**Figure 7.** What is your opinion on increasing the amount of biodiesel additive in diesel?

80% of end customers agree that it is necessary to increase the amount of biodiesel additive in diesel. 8% use biodiesel, but do not have an opinion due to the fact that they automatically trust the service station staff and do not seek information from outside sources.
89% of the respondents strongly hope that the price for them will not increase. They share that everything related to environmental protection should not affect the price for the end customer. However, 11% are absolutely convinced that the end customer always pays the price. This is dictated by the frequent upward shift in fuel prices.

The analysis of the survey shows that the end customer is positive about using biodiesel as an additive to conventional diesel. The personal experience of most of the responders shows that the addition of biodiesel to the diesel does not impair the quality of the diesel engine, and even leads to its improvement. The customer seeks and receives the necessary information through various distribution channels and is inclined to believe that the benefits of adding biodiesel to the diesel are enormous both in reducing diesel engine wear and in protecting the environment. A large percentage of end users rely on the fact that their price will not change. However, there is always one group that is sceptical about pricing questions.

4. Conclusions

The following conclusions can be drawn from the analysis of the rapeseed, pure diesel and 8% rapeseed oil and 92% diesel blend, performance studies and questionnaires for the use of biodiesel as a diesel additive:

1. The rapeseed oil density is 919 kg/m$^3$ and is higher than the diesel 841 kg/m$^3$ and the mixture of 8% rapeseed oil and 92% diesel, which is 858 kg/m$^3$.
2. The viscosity of rapeseed oil is 37.3 mm$^2$/s and is much higher than that of diesel and the mixture, which is about 4.79 mm$^2$/s.
3. The calorific value of rapeseed oil is 37.1 MJ/kg and is lower than that of diesel and the mixture 41.8 MJ/kg.
4. The flash point of rapeseed oil is 270ºC and is many times higher than that of diesel and the 65ºC mixture.
5. Cetane number for diesel and blend is 48.1 and higher than rapeseed oil 42.
6. Consumers are positive about using biodiesel as an adjunct to petroleum diesel. Experience has shown that the addition of biodiesel to diesel does not impair the quality of the diesel, and even leads to its improvement. They tend to believe that the benefits of adding biodiesel to diesel are enormous in reducing harmful gases into the atmosphere.

The conclusions presented above are grounds for claiming that rapeseed oil can be blended seamlessly and used as an additive to petroleum diesel. The benefits of adding biodiesel to diesel are enormous in reducing harmful gases into the atmosphere.

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