Reducing CO₂ emissions from tractor engines by using the diesel fuel and rapeseed oil blend

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Abstract. The paper presents the results of some experimental research that led to the conclusion that diesel engines that fit agricultural tractors can reduce CO₂ emissions by using a fuel oil mixture made up of 50% diesel and 50% refined rapeseed oil. Following the experimental determinations made and presented in the paper, both in load and idle operation, using a fuel mixture consisting of diesel and rapeseed oil, a reduction of up to 25% of CO₂ emissions was obtained. Such a reduction in CO₂ emissions is important because this gas belongs to the greenhouse effect category, and at the moment, a large number of U650 tractors are still being used in agriculture.

1. Introduction
Since the 1970s, the interest in the use of vegetable oils as alternative fuels for diesel engines has been renewed [1]. The rapid increase in the number of diesel vehicles has led to an increase in the "greenhouse effect" due to the pollution of the surrounding air with CO₂, CO, NOₓ, HC, PM. Plant oil based fuels have been used as diesel fuel extension agents, which could mitigate environmental pollution, contributing to reducing CO₂ emissions in a closed cycle [2].

CO₂ emissions from transport will continue to increase as the world's number of vehicles is expected to double by 2030 [3]. Under the Kyoto Protocol, developed countries have pledged and succeeded in reducing greenhouse gas emissions over the period 2008-2012 by about 5% compared to 1990 levels [4]. To achieve this objective, it was necessary to further reduce CO₂ emissions from cars [5], therefore very demanding targets were set around the world. Emissions from diesel engines are related to diesel quality, engine operating regimes and also to its design.

Legislation on emissions, the need to reduce CO₂ emissions and fuel consumption will lead to more and more complex engines compared to those in the past. New passive and active technologies have led to the reduction of pollutant emissions (CO (carbon monoxide), HC (hydrocarbons), NOₓ (nitrogen oxides) and particles emissions) [6]. CO₂ emissions are not classified as harmful pollutant emissions but they favour the "greenhouse effect". The CO₂ concentration of the exhaust gases depends on the operating mode of the engine and is directly proportional to the fuel consumption caused by the engine load. When running the engine with pure rapeseed oil, the CO concentration is higher, which characterizes the incomplete combustion process of the rapeseed oil-air fuel mixture [7].

The main purpose of the widespread use of vegetable oil fuels should be seen as a measure taken to resolve environmental problems, create new jobs, and suspend the rise in prices for mineral fuels [8].
Significant progress has been made over the last 20 years within the European Union in the area of emissions and air quality. Directive 2001/81/EC has made a key contribution to this progress by setting maximum emission limits from 2010 [9].

Vegetable oil produced from oilseeds, crude or refined but not chemically modified, may be used as biofuel in cases where its use is compatible with the type of engine involved and with the corresponding emissions requirements [10].

At the University of Hohenheim, rapeseed fuel was used in a direct injection engine between 1992 and 1995. The performance of the test engine was unsatisfactory for a low engine load that can be encountered frequently to agricultural tractors. At a higher load, satisfactory results were obtained [11]. Cultivation of rape has expanded quite a lot in Romania too; the surface on which the oilseed plant has come to be grown is at this moment the highest recorded in our country since 2010, reaching 460 thousand hectares. In Romania, more and more farmers include rapeseed in their mix of crops. The rapeseed is growing steadily on the national market, and the upward trend is still maintained, the harvested area exceeding 590,000 hectares [13].

2. Equipment used for experimental studies
All the experimental measurements presented in this study were performed on a 4 cylinder, naturally aspirated, watercooled, D103, four-stroke, diesel engine. U 650 type tractors are equipped with this diesel engine and it has a power output of 65 HP at 1800 rpm. Although they are from an older generation, U 650 tractors are still widely used in agriculture in Romania.

The engine laboratory equipment (figure 1 and figure 2) was equipped with a Froude hydraulic brake. The coupling between hydraulic brake and diesel engine is directly, without transmission gear.

![Figure 1. The scheme of experimental laboratory equipment.](image)

The elements specified in Figure 1 are: 1 – Diesel engine D 103; 2 - fuel tank; 3 - fuel supply pipe; 4 - three-way valve; 5 - Calibrated fuel consumption measurement; 6 - electronic weighing; 7 - exhaust gases outlet pipe; 8 - expansion tank for coolant; 9 - oil cooler; 10 - coolant cooler; 11 - fuel filter battery; 12 - injection pump with speed regulator; 13 - supply pump; 14 - cooling liquid pump; 15 - hydraulic brake; 16 - coupling; 17 - signaling and warning panel; 18 - suction air tank; 19 - air filter; 20 - diaphragm used for measuring air flow; 21 - Diaphragm used for measuring the flow rate of the coolant.
The fuel mix that was used consists of 50% diesel with cetane number (CC) 51 and 50% refined rapeseed oil (straight oil) commercially available. In Table 1 are presented the main physical-chemical properties of rapeseed oil and diesel fuel [2, 9].

Table 1. Physical and chemical properties of refined rapeseed oil and diesel fuel.

| Parameter                           | Rapeseed oil | Diesel fuel |
|-------------------------------------|--------------|-------------|
| Kinematic viscosity, 20°C [mm²/s]   | 60-72        | 4-6         |
| Lower Calorific value - LCV [MJ/kg] | 37.4-38      | 41.5-42     |
| Density, 20°C [kg/dm³]              | 0.91-0.92    | 0.82-0.84   |
| Cetane number                       | 40           | 51          |
| Flash point, [°C]                   | 270-321      | 65-80       |
| Freezing point [°C]                 | -18 … 0      | -12… 0      |

Fuel viscosity directly influences the spraying of the fuel into the combustion chamber, the efficiency of blending and vaporising the fuel together with its calorific value, determining the maximum power the engine can develop at a given injection pump rate [14].

In the present case, no modifications were made to the diesel fuel injection system and no equipment was installed to correct the viscosity of the fuel mixture. The viscosity of the fuel mixture (diesel and refined rapeseed oil at 50%) measured with the Hoppler viscometer was 18.4 mm²/s at 20°C, about 3.8 times higher than diesel fuel and 3.5 or less than refined rapeseed oil. The values measured with the Hoppler viscometer at 20°C were for diesel fuel of 4.8 mm²/s respectively for the refined rapeseed oil of 64.5 mm²/s.

Using the Multilayer STX gas analyzer, the CO₂ emissions (%vol.), CO (%vol.) and the residual oxygen content O₂ (vol%) of the exhaust gases were measured. The measurement of the temperature of the combustion gases was carried out on the exhaust pipe at a distance of about 1.5 m from the engine exhaust manifold, a distance similar to the displacement of the exhaust manifold of the engine the U650 tractor is equipped with.

3. Experimental determinations and results
A significant reduction in the effective engine power was noticed at loads greater than 0.75. According to the results presented in figure 3, the reduction is between (6-20)%, the higher values being at the full load and close to the nominal speed, and the lower values at lower loads and revolutions ranging...
between (1200-1700) rpm. The reduction in power is mainly due to a drop in the calorific value of the fuel mix by about (8-10)%, but this can be accepted under conditions where a reduction in CO₂ emissions is found using the indicated fuel mix, taking into account that for most of the operating time it is not exceeded 0.8 of the full load.

For the idle regimes, there is a clear reduction of CO₂ emissions, which is a positive aspect, especially as it will also be confirmed in the case of medium and high load operation. CO₂ emissions are reduced by 12-24% for idling, with lower cuts at lower speeds, according to the variations shown in Figure 4.

At the same time, CO emissions increased 4-23% at revolutions above 1200 rpm, according to the variations in Figure 5, the larger increase being around the nominal speed of 1800 rpm. This is explained by the reduced combustion rate of the fuel mixture relative to the engine speed and a shift of the combustion on the expansion, which leads to the formation of a larger amount of CO emissions.

If, in the case of the use of diesel fuel, CO emissions account for (1-2)% of CO₂ emissions, in the case of 50% diesel fuel and 50% rape oil, CO emissions represent (1.5-2.5)% of the CO₂ emissions.

In the case of engine idling, there is a reduction of up to 24% of CO₂ emissions but also an increase of up to 23% of CO emissions. However, taking into account that CO emissions account for only a maximum of 2.5% of CO₂ emissions, we can assume that the use of the specified fuel mixture will have a positive effect.

For load regimes, at least for loads ranging from 0.6 to 0.8, the CO₂ reduction is noteworthy and it ranges from 5 to 25%, with higher values at low speeds and lower values of (4-8) % at loads above 0.8, as shown in Figure 6.

![Figure 3. Effective Power with diesel fuel compared with mixed fuel.](image-url)
At the same time, the emission of CO in the exhaust gases, according to Figure 7, increases on average by (30–40)% at partial loads and has an increase of less than 8–10% in the full load when using the diesel fuel with rapeseed oil blend compared to the classic diesel fuel.

Reduction of CO$_2$ emissions occurs even when the exhaust gas temperature is slightly increased by up to 8–10% (especially at lower loads) as shown in Figure 8, because the combustion moves to the releasing cycle (mixture used have a diminished cetane number as against diesel fuel) and that increase the CO emissions. Certainly, a reduction in the temperature of the gas could be achieved in the case of increased injection rate when using the diesel fuel and rapeseed oil blend and possibly a decrease of CO emissions, but these will be verified in experimental determinations which will follow.

**Figure 4.** Emissions of CO$_2$ for idling regimes.

**Figure 5.** Emissions of CO for idling regimes.
In case of load engine running, there is a reduction of up to 25% of CO₂ emissions but also an increase of up to 40% of CO emissions; however, taking into account that CO emissions represent only (1.5-2.5)% of CO₂ emissions, we can assume that when using the specified fuel mixture, the effect is still a positive one, especially considering that most of the time the engine will work at loads up to 0.8, in which case we have set that CO₂ emissions drop by as much as 25%.

**Figure 6.** Emissions of CO₂ depend of load and rotation.

**Figure 7.** Emissions of CO depend of load and rotation.
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In principle, the use of the diesel fuel with rapeseed oil blend increases the amount of O₂ in the exhaust gases due to the presence of the oxygenated compounds in the refined rapeseed oil used in the fuel mixture in a ratio of 50%, the amount of O₂ in the combustion gases being anyway higher at the partial loads of 0.5-0.8 irrespective of the type of fuel, as shown in figure 9.

The experimental results, carried out on the laboratory stand (within the Department of Thermal Systems and Automotive Engineering at the Faculty of Engineering, Galati), with the D103 diesel engine used to equip U650 tractors, led to the following results regarding the CO₂ and CO emissions
from the combustion gases in the situation of using the fuel mixture made up of diesel and refined rapeseed oil in a ratio of 50%, compared to the normal operation with diesel fuel with a cetane number of 51:

- For idling, there was a 12-24% reduction in CO₂ emissions, with lower cuts at lower engine speeds.
- CO emissions increase by 4-23% at revolutions above 1200 rpm, with higher rises around the nominal speed of 1800 rpm.
- For load operation, at 0.6-0.8 loads most frequently encountered in operation, the CO₂ emissions reduction is in the range of 5-25% with higher values at low speeds.
- For workloads above 0.8, the reduction of CO₂ emissions is lower, being only 4-8%, with the lowest values at full load.
- CO emissions from combustion gases increase on average by 30-40% at partial loads of 0.6-0.8 and have a smaller increase of only 8-10% on the full load when using the fuel mixture compared to the classic fuel (diesel). As we can see, CO emissions represent only 1.5-2.5% of CO₂ (which is a greenhouse gas) emissions.

4. Conclusion
Following the experimental determinations carried out and presented in the paper, both in load and idle modes, using diesel fuel with rapeseed oil blend (diesel and refined rapeseed oil in a ratio of 50%), a decrease of up to 25% of CO₂ emissions was obtained, higher values being obtained at 0.6-0.7 loads of the engine, and lower values of up to 8% at loads higher than 0.8. Such a reduction in CO₂ emissions is important precisely because at the moment there is still a large number of U650 tractors used in Romanian agriculture.

In the determinations made, it was found that the CO emissions in the combustion gases increase on average by 30-40% at the partial loads of 0.6-0.8 of the engine and they have an increase of only 8-10% at the load full when using the fuel mixture compared to classic fuel (diesel). Taking into account that CO emissions represent only 1.5-2.5% of CO₂ emissions, we can assume that if the diesel fuel with rapeseed oil blend is used, the effect is still a positive one, especially considering that in most operating times, the engine will work at loads up to 0.8, in which case we have established that CO₂ emissions decrease by as much as 25%.

Given that CO₂ is considered a greenhouse gas, a reduction of up to 25% CO₂ emissions to partial load operation when using the 50% fuel oil and refined rapeseed oil blends can be considered an important one.

Taking into account the price of refined rapeseed oil, which is about 0.9 Euro / litre compared to diesel fuel of 1.24 Euro / liter, the authors recommend the use of this fuel mixture made up of 50% diesel with the cetane number 51 (CC 51) and 50% refined rapeseed oil, as it has been found to have a reduced decrease of up to 10% of power in the payload of 0.6-0.8 most commonly encountered in operation, but at the same time a reduction of up to 25% of CO₂ emissions.

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