Operating parameters and emission evaluation of tractors running on diesel oil and biofuel

D. Müllerová[1], M. Landis[2], I. Schiess[2], J. Jablonický[1], M. Prístavka[1]

[1]*Faculty of Engineering, Slovak University of Agriculture in Nitra, Nitra, Slovak Republic*
[2]*Agroscope Reckenholz-Tänikon Research Station ART, Tänikon, Ettenhausen, Switzerland*

Abstract

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This work is aimed at the evaluation of the operating parameters and emission of two tractors: Hürlimann H-488 DT and Hürlimann XB Max 100. The measurements were done on a test bench in the laboratory of the Agroscope Reckenholz-Tänikon Research Station ART, Ettenhausen, Switzerland during February 2010. The goal of this paper was to evaluate the operating parameters of the two models of tractors by using classical diesel oil and biofuel, as well as to evaluate the emission (greenhouse gases, dangerous exhaust gases and carcinogens), to make statistical analysis of the results and the conclusion about the samples used and the impact on engine parameters, environment and human health. From the results achieved, it is possible to state the following facts. In each way, the emissions of rape seed methylester (RME) and diesel are equivalent. The values of CO and HC and also particles are lower for RME. But NO_x values are lower for diesel oil. It is liquid that the newer engine of Hürlimann XB Max 100 decreases emission of CO, HC and NO_x significantly.

Keywords: environment; biofuels; tractors; parameters; greenhouse gases (GHG)

Presently, diesel oil and petroleum products belong to the most utilised fuels. Because of its uncoverability, the crude oil is often called 'the black gold'. Unfortunately, fossil fuels are not renewable or inexhaustible sources of energy. By the prognosis of Europe's energy portal, the real exhaustion of oil will be – 22^{nd} of October 2047. The supply of natural gas is estimated to last up to the year 2068 (Europe's energy portal 2008). The society really depends on the gas and oil supply and their depletion may cause total collapse.

In the European Union, strategy was made for the utilisation of the renewable sources of energy whose use should grow until the year 2010 by up to 12%. The expanded utilisation of biofuels in transportation is also included in the strategy and the aim is the substitution of 20% of fossil fuels by biofuels until the year 2020 (Anonymous 2007).

The aim of this paper is to perform the operating parameters and emission tests to achieve the results on the changes of these parameters by specific fuels including alternative fuel. A lot of work has been done on different fuel characteristics. Scientists found out which alternative fuel could be the most appropriate to replace diesel oil. Considering the character of agricultural production, the transport in agriculture significantly affects the economic effectiveness of the agricultural production (Korenko, Žitňák 2008; Žitňák, Korenko 2008). The most used fuels tested are crude vegetable oils made from rape seed, sunflower seed, soybeans, palm fruit and their esters. The power and torque of the engine performance are

Fig. 1. Tractor Hürlimann H-488 DT

Fig. 2. Tractor Hürlimann XB Max 100

about 3–6% lower for biodiesel. Fuel consumption is about 5–12% higher for biodiesel. Also, a great smoke reduction (50%) and lower CO and HC take place with biodiesel. If biodiesel is used, NO_x values are higher. Generally, vegetable oils and their esters have a strong potential to be used as an alternative fuel. Esters provided good results even if they were blended with diesel oil (Checchio-Grotta et al. 2008). Rape seed methylester (RME) can be also used as fuel for diesel engine without the addition of various components or additives (Walter, Schäfer 1990).

MATERIAL AND METHODS

To measure the operating parameters, two models of agricultural tractors were used: Hürlimann H-488 DT and Hürlimann XB Max 100.

Hürlimann H-488 DT (Fig. 1)

Producer:	Hürlimann/Same (I.)
Engine:	S. L. H 1000.4 WT
Number of cylinders:	4
Capacity of cylinders:	4,000 cm^3
Bore/stroke:	105 mm/115.5 mm
Rated revolution:	2,500 1/min
Rated power:	65 kW
Injector pump:	Bosch/Kolbenpumpe PFR
Year:	1994
Runtime:	3,273 h
Emission class:	Stage 0

Hürlimann XB Max 100 (Fig. 2)

Producer:	Same-Deutz Fahr
Engine:	Deutz 2012, TCD 2012 L04 2V
Number of cylinders:	4
Capacity of cylinders:	4,038 cm^3
Bore/stroke:	101 mm/126 mm
Rated revolution:	2,300 1/min
Rated power:	72.5 kW
Injector pump:	Bosch Steckpumpen
Year:	2009
Runtime:	200 h
Emission class:	Stage III.A

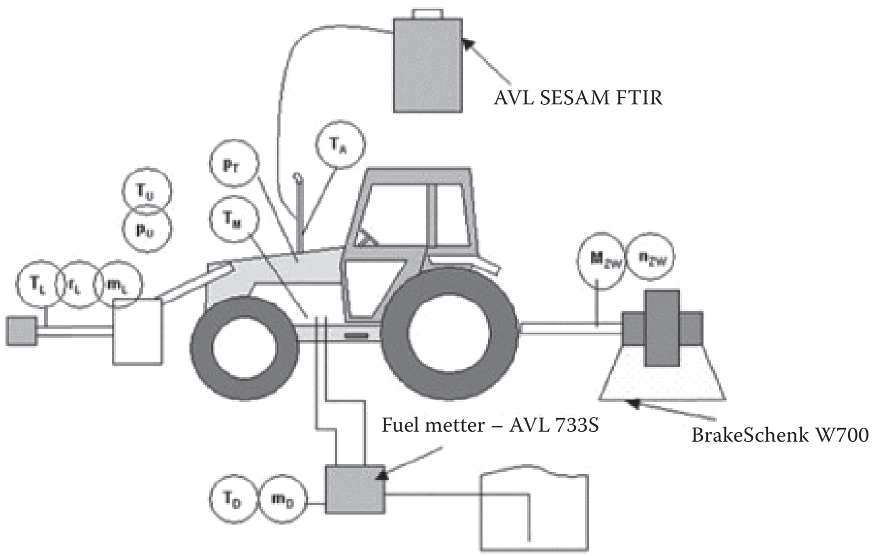

Fig. 3. Sight of the test bench

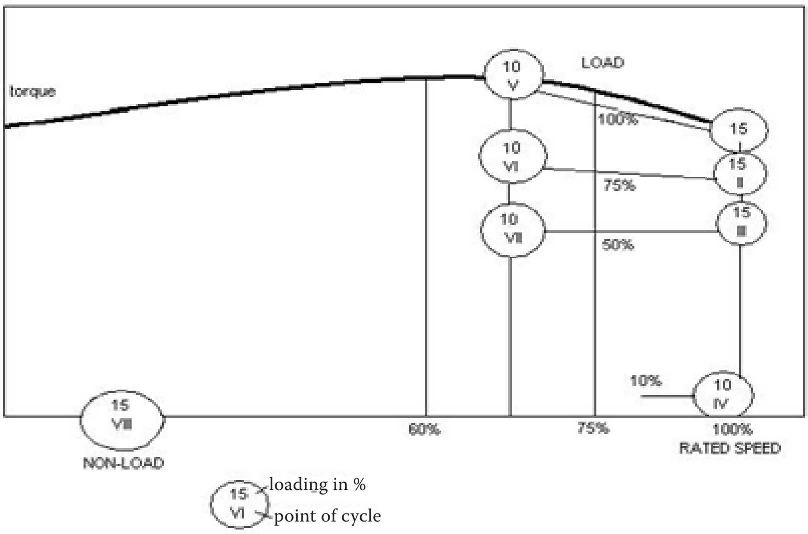

Fig. 4. Characteristics of 8-points cycle by ISO 8178-4 (2007), C_1

Specific: 100% biodiesel

The measurements were done on a test bench in Agroscope Reckenholz-Tänikon Research Station ART, Ettenhausen, Switzerland. The following measurement devices were used:

- Brake Schenck W700 (Schenck RoTec GmbH, Darmstadt, Germany) – measured torque and power, through output shaft;
- Filtermethod BOSCH (Bosch Rexroth Schweiz AG, Büttikon, Switzerland) – measured smoke, utilisation of filter layer with photo-element adapter, information in SZ Bosch (number/smoke places), smoke sonde on exhaust pipe;
- AVL 733S (AVL Graz, Graz, Austria) – measured fuel consumption, regulation (kg/h);
- Matter Engineering NanoMet C with particle counter CPC 3010D from TSI (Matter Aerosol AG, Wohlen, Switzerland) – measured particles in number/cm^3 in diluted exhaust gases, then calculated values (number/kWh);
- AVL SESAM FTIR 4 Fourier Transform Infra-Red gaseous analyser emission test system (AVL Graz, Graz, Austria) – measuring of limited and unlimited emission, values (ppm), calculated to g/kWh.

The measuring devices used were connected on the test bench. Fig. 3 is showing specific connection of the measuring devices with the parameters denoted.

Two different fuel samples were used for the measurement: diesel oil (SN 181160-1 2009) and RME (STN EN 14214 2009) – from EcoEnergie Etoy, produced in Switzerland. In Table 1, the analysis is given of the samples used. Obviously, there were just small differences between both samples. Oxidation stability of RME could be min 6 h but its value 5.2 h was good and should not have caused

Table 1. Analysis of used samples

Analysis	Abunit	Limit	Diesel oil[1]	Rape seed methylester (RME)[2]
Density by 15°C	kg/m^3	845.0	831.3	880.0
Carbon	mass. %	×	86.2	76.6
Hydrogen	mass. %	×	14.3	12.2
CFPP	°C	–20	–30	–17
Flamepoint	°C	×	67.0	×
Coldpoint	°C	–10	–10	×
Sulphur contain	mg/kg	10	7.4	×
Oxidability	h	min 6	×	5.2
Acid value	MgKOH/g sample	0.5	×	0.19
Water contain	ppm	500	×	256
Glycerol contain	%	0.02	×	0.0035

[1]Analysis by Intertek Caleb Brett, Switzerland (No. 109026/02); [2]Analysis by CleanPal, Ltd., Slovak Republic (No. 180110/D007)

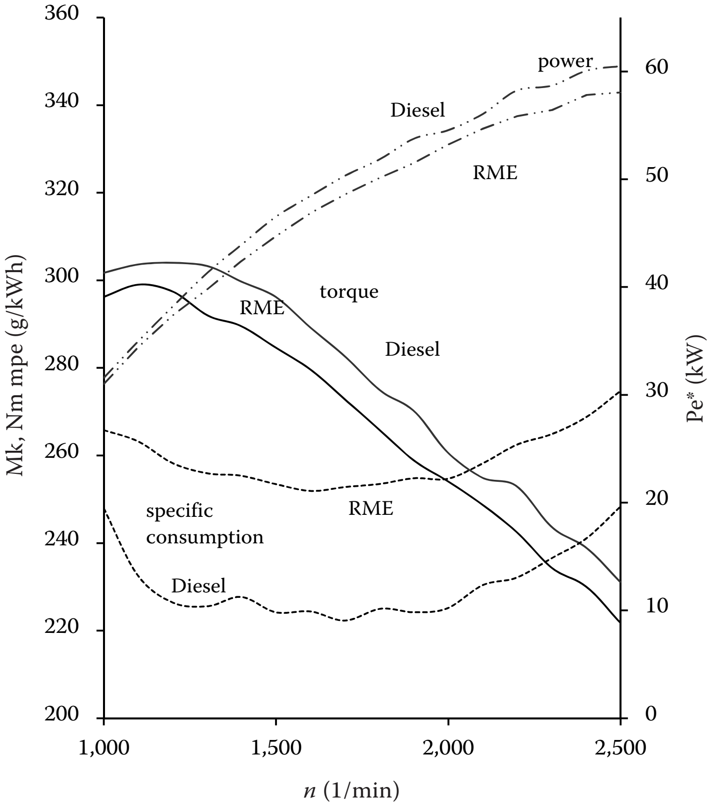

Fig. 5. External revolution curve for Hürlimann H-488 DT (for abbreviations see Fig. 6)

any problems. Also, the water and glycerol contents of RME were in the limits. They met the norm and both products could be used as engine fuel.

As the measuring method, the norm (EN ISO 8178-4 2007) was used. This norm is an international standard which is used for non-road engines. By the International Organization for Standardization (ISO), this norm specifies the test cycles for the measurement and the evaluation of gaseous and particulate exhaust emissions from reciprocating internal combustion engines, and is applicable to engines for mobile, transportable and stationary uses (Fig. 4).

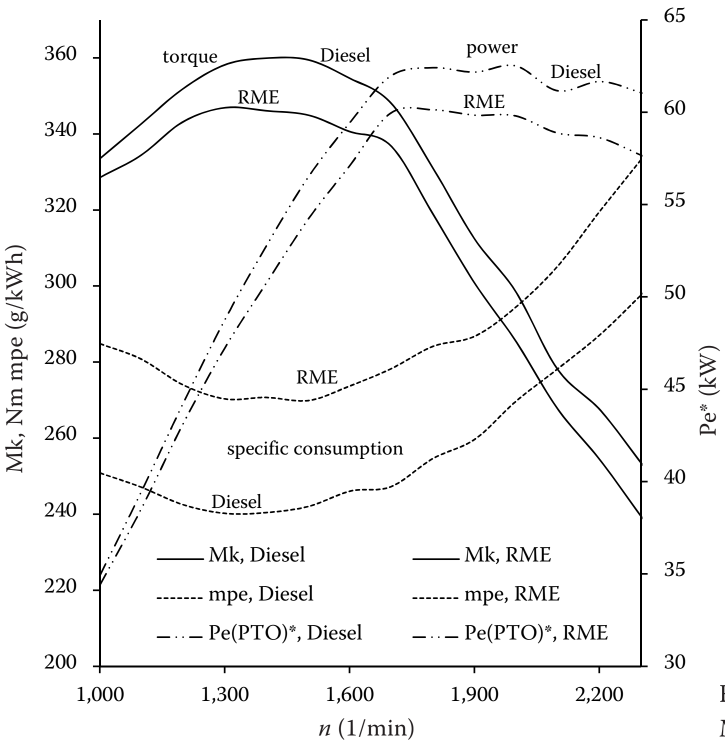

Fig. 6. External revolution curve for Hürlimann XB Max 100

Table 2. Values of limited emission

	Particle	CO	NO_x	HC
	number/kWh	g/kWh		
Hürlimann H-488 DT				
Diesel	3.93E+14	1.8	11.13	0.77
RME	3.33E+14	1.61	12.42	0.6
Hürlimann XB Max 100				
Diesel	4.31E+14	1.05	5.09	0.19
RME	2.66E+14	0.91	5.92	0.13

*average value, based on PTO (power take-off) power; RME – rape seed methylester

RESULTS AND DISCUSION

In Fig. 5 is presented the external revolution curve for Hürlimann H-488 DT, while the results obtained for Hürlimann XB Max 100 are presented in Fig. 6. Generally, there was no significant difference in the external revolution curve between both tractors but there were slight differences between diesel oil and RME characteristics:

- power and torque were lower with RME compared to diesel by about 5% at the rated power,
- fuel consumption was higher with RME by about 10% compared to diesel.

This was caused by the lower thermal capacity of methylester (37.3 MJ/kg) in comparison with the thermal capacity of diesel oil (42.5 MJ/kg). It was lower for RME by about 12%.

However, the fuel density should be also referred to, being with methylester (0.88 g/cm^3) and with diesel oil (0.82 g/cm^3), thus methylester density being higher by about 7%. This is also the reason for increasing fuel consumption and decreasing the power, and all this has to be taken into account if the individual results are compared. Based on these facts, the fuel tested may be marked as convenient for the motor engines.

Measurement of limited emission

Measurements were done with both tractors for limited emission which comprised – CO, HC, NO_x and particle by EN ISO 8178-4 (2007). In Table 2, the average values are given for each fuel based on

Table 3. Values of unlimited emission (in ppm)

Hürlimann H-488 DT	carbon dioxide	nitric oxide	nitrogen dioxide	nitrous oxide	ammonia	methane
Diesel	55,867	845	40	0.5	0.13	0.52
RME	56,769	890	43	0.66	0.21	1.27
	1.3-butadiene	hydrogen cyanide	aromatics HC	sulphur dioxide	formaldehyde	acetaldehyde
Diesel	0.97	0.57	2.1	4.6	8.1	2.7
RME	1.98	0.57	1.19	1.40	9.95	0.57
Hürlimann XB Max 100	carbon dioxide	nitric oxide	nitrogen dioxide	nitrous oxide	ammonia	methane
Diesel	64,426	378	16.9	0.43	0.12	0.1
RME	66,040	431	16.8	0.57	0.13	0.1
	1.3-butadiene	hydrogen cyanide	aromatics HC	sulphur dioxide	formaldehyde	acetaldehyde
Diesel	0.44	0.59	0.77	5.0	2.23	0.49
RME	0.90	0.45	1.19	2.9	2.08	0.73

RME – rape seed methylester

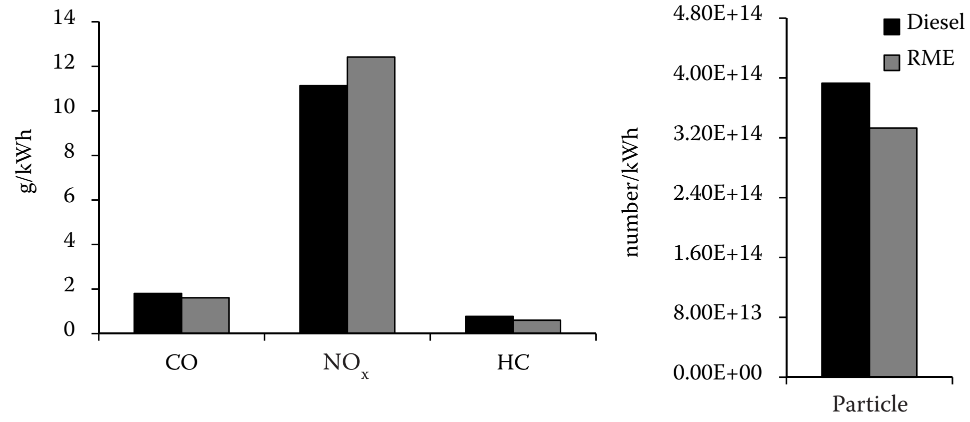

Fig. 7. Limited emission values for Hürlimann H-488 DT

power take-off (PTO) power. The graphic description for Hürlimann H-488 DT is in Fig. 7 and for Hürlimann XB Max 100 in Fig. 8.

Also, statistical analysis was carried out of limited emission using software Statistics (StatSoft, Tulsa, USA). Based on the results achieved, the method of regulatory diagram was chosen for average and standard deviations. This diagram works with the data measured on the output of the process. Standard deviation is a more effective indicator of the process variability, especially for larger subgroups. But it is more difficult for the calculation and less sensitive in the detection of determinable causes of instability introduced by the individual unusual values in the subgroups (Hrubec 2001).

Measurement of unlimited emission

Measurements were also done of unlimited emission which can be measured by AVL SESAM FTIR 4: CO_2, NO, NO_2, N_2O, NH_3, CH_4, C_4H_6, HCN, AHC, SO_2, HCHO and MECHO. In Table 3, the average values are shown for each fuel based on PTO power.

Measurement of smoke

The values of smoke in the exhaust gases are usually considerably lower with RME than with diesel oil. For the older tractor Hürlimann H-488 DT, the value of smoke was by more than 50% lower with RME than with diesel oil. From Fig. 9, it is evident that the newer tractor Hürlimann XB Max 100 had about 90% lower value of smoke than the tractor Hürlimann H-488 DT at maximal torque (MaxD). These values approached zero by using RME or diesel oil. The value of the emitted smoke was also determined at 95% and 70% of the rated revolution.

As for the operating parameters of the engine run on vegetable oils methylester as given by Walter and Schäfer (1990), the consumption and power are similar to the conventional fuel and there is not needed for the engine modification. Methylester can be used as fuel without using additives. Also according to Krahl et al. (1992), there is no need for the engine modification. Based on our results, we can confirm these theories and our results can be integrated into the existing information system. We have identical attitude to the emitted smoke measurements. As given by Sahoo et al. (2009), by us-

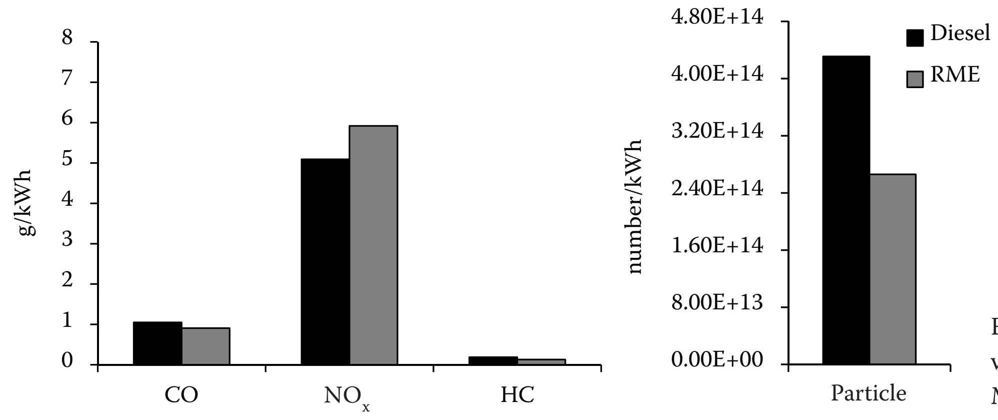

Fig. 8. Limited emission values for Hürlimann XB Max 100

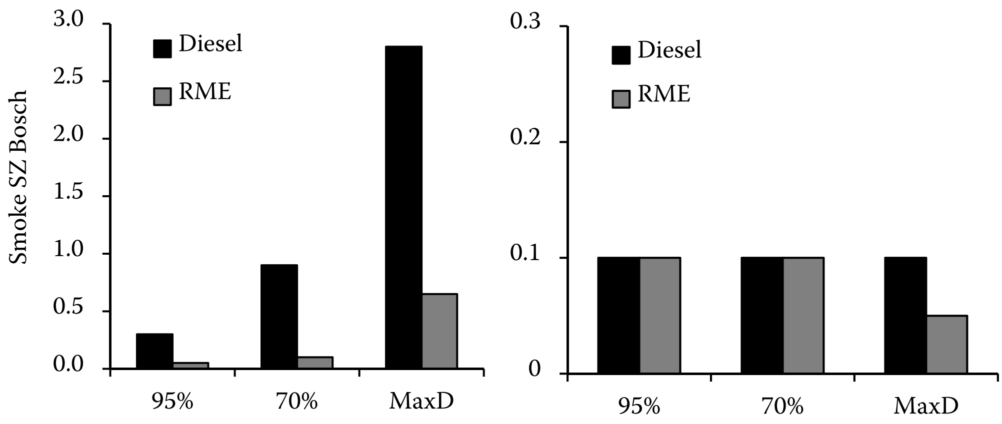

Fig. 9. Measurement of smoke (MaxD – maximal torque)

ing biofuel and full blends containing it, a significant emitted smoke reduction is reached. In our case, the reduction was up to 50%. By the biofuel utilisation, we also achieved limited emission reduction (CO, HC and particles), but also an increase of NO_x emission, similarly as presented by Thuneke and Emberger (2007), Thuneke et al. (2009). This evaluation can be affirmed by our results published. The significant unlimited emissions reduction can be monitored in the sphere of aromatic hydrocarbons, formaldehyde, sulphur dioxide, and hydrocyanic acid by using biofuel. These results agree with the publication by Wörgetter and Wurst (1990).

CONCLUSION

The measured values are based on PTO power, thus they can not be evaluated by the Emission Standards for Off-Road Vehicles. If these measurements had been done on the engines, both tractors would have met the emission norm for CO and HC of RME and diesel. The values of NO_x were higher by about 21% for both fuels with Hürlimann H-488 DT, and by about 25% with Hürlimann XB Max 100 than the determined emission limit.

The values of unlimited emission for both fuels are equivalent. The tractor which used RME revealed not only higher values of NO_x (NO, NO_2 and N_2O) but also by almost 50% higher values of ammonia, methane, and 1.3-butadiene which are considered dangerous substances. With the newer tractor Hürlimann XB Max 100, higher values of NO_x, 1,3-butadiene, and acetaldehyde were obtained with RME use but the difference was not too great. On the other side, lower values were observed with RME for sulphur dioxide and acetaldehyde with Hürlimann H-488 DT, and for sulphur dioxide, hydrogen cyanide, and formaldehyde with Hürlimann XB Max 100. Nevertheless, the values of unlimited emission are negligible, except carbon dioxide where higher values could be seen for RME with both tractors. Statistical analysis shows the standard deviation from the determined value by the norm for emission – CO, HC and NO_x. From the graphs, it is evident that a higher value of the standard deviation occurred in the 4th point. That means at maximal revolution without loading.

The purpose of this work was to evaluate the operating parameters of two models of tractors by using classic diesel oil and biofuel. It is possible to state that the differences between these two tractors are inherent in their engines construction, the year of production, and specification (Hürlimann XB Max 100 is specified as 100% biodiesel). On the evaluation of the emission [greenhouse gases (GHG), dangerous exhaust gases and carcinogens] it can be declared that it is very important to study not just the limited but also unlimited emissions which can be very dangerous, although it was discovered in this work that the values of unlimited emission did not exceed the lethal limit.

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Corresponding author:

Ing. Daniela Müllerová, Slovak University of Agriculture in Nitra, Faculty of Engineering,
Department of Transport and Handling, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic
phone: + 421 907 562 864, e-mail: mullerova.daniela@gmail.com