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Comparative Assessment of Head Deposition, Exhaust Gas Temperature and Sound Emission in CI Engine using Blend Fuel

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ABSTRACT

Energy has a significant role in the socio-economic growth for any country. The energy originates from fossil fuels, which are non-renewable and enact an undesirable impact on the environment. Waste cooking oil can be utilized in diesel engine directly. Preheating and trans-esterification process are expensive to convert waste cooking oil into biodiesel. This research aims to replace diesel with waste cooking oil as binary blend and compared with diesel fuel. Engine testing at the constant speed of 1300 rpm at constant load. This study revealed that, addition of waste cooking oil reduced exhaust gas temperature as compared to base line fuel. In case of noise emission, sound level for emulsion fuel DF95WCO5 was reduced compared to DF. In this study, a single-cylinder CI engine was run for 200 hours on two fuel samples: DF (diesel fuel) as the baseline fuel and DF95WCO5 (5% waste cooking oil and 95% DF). During the endurance test, the effects of DF95WCO5 on engine head deposits were studied. According to the investigation's findings, visual inspection of both fuel samples revealed some deposit buildup on injectors. SEM (scanning electron microscopy) and EDX (energy dispersive X-ray spectroscopy) analysis revealed that the engine running with DF95WCO5 formed more carbon deposits on and around the head. It can be concluded that binary emulsion can be used in compression ignition engine without any engine alterations. Consequently, WCO can be proficiently used to reduce detrimental effects and reduce fossil fuel dependency.

Keywords: Diesel engine; waste cooking oil; exhaust gas temperature; noise emission;; head deposit formation

INTRODUCTION

Diesel engines will continue to be used in the electrical power generation and heavy-duty transport industry Carbon monoxide (CO), unburned hydrocarbon (HC), and nitrogen oxides (NOx) released at the end of the diesel combustion process were determined as the main pollutants to be reduced (Caprotti et al. 2010; Macor et al. 2011). Especially in the case of generator engines running for long durations at a constant speed, it is necessary to control these emissions due to environmental and human health concerns. Two common approaches to reduce emissions in diesel engines are the use of after-treatment systems and reducing fuel based emissions that are a result of the fuel composition. Another driver toward the implementation of alternative fuels for application in diesel engines is the instability in oil prices and strict emission regulations (Birgel et al. 2008). In addition, it is inevitable to use alternative fuels in terms of sustainability at the point of protecting the environment (Sidibe, Blin et al. 2010). The higher amount of consumption of energy has caused the utilization of higher quantities of fuels (mostly fossil fuels) and generation of higher risk factors to the environment. Changing to renewable energy sources would mitigate these problems by reducing the consumption of fossil fuels. Further, inexhaustible energy sources have the potential to meet future energy demands. A study confirmed that waste cooking oil (WCO), from cooking or frying, is created in a considerable magnitude across the globe (Perrone, Algieri et al. 2021). This study reported that almost 23 million tons of waste vegetable oil are produced from the food processing section in India (Food and Agricultural Organization of the United Nations) (Bergthorson and Thomson 2015). Moreover, dumping of waste cooking oil (WCO) has increased ecological concerns, which call for reprocessing or consumption allied with a financial inducement (Salvi, Subramanian et al. 2013; Zöldy, Csete et al. 2022). The findings confirmed that WCO transesterified to give biodiesel and was, consequently, analyzed for engine performance (Yesilyurt 2018; Charpe and Rathod 2010). It was observed that there is inadequate literature related to the accessing of un-changed WCO as blend fuel with diesel for effluents classification and performance examination on its exploitation in a CI engine. The search for different cradlers of fuel for an IC engine was initiated first in the year 1893, when Rudolf Diesel assessed peanut oil as a fuel for engines (Majhi and Ray 2015). The research work for alternating fuel oil has launched at several sites and the need to investigate this issue was acknowledged in 1930 and 1940, where vegetable oil from several edible sources was powered in engines (Can 2014). On the basis of food-fuel certainty, second and third generation fuels replaced edible fuel sources in current eras (Murugesan, Umarani et al. 2009; Prabu, Asokan et al. 2017). Waste cooking oil (WCO) cannot be discharged into drains or sewers due to blockages and odour or vermin problems and may also pollute watercourse. It is also a prohibited substance and will cause problems if it is dumped in municipal solid waste landfill and municipal sewage treatment plants. Being cheap and easily available, waste cooking oil seems like a good substitute for diesel, but its high viscosity is a major drawback. To overcome this problem, a small percentage, like 5%, can be blended and tested for engine compatibility (Dey & Ray 2020). The temperature of the gaseous mixture leaving the combustion chamber is a chief factor for optimizing the efficiency and regulating the discharge of an internal combustion engine (Murugesan et al. 2009). This happens because the exhaust gas temperature (EGT) interacted with the ignition process within the cylinder and the "after combustion" activities inside the drain manifold (Ramadhas et al. 2004). In addition EGT can also be employed for engine analysis and organizing its maintenance for increased machine life (Kalam, Masjuki et al. 2011). For instance, EGT is afflicted by a polluted or constrictive air filter, a partially impassable air admission, weather circumstances (pressure, temperature, and humidity), and constrained airflow to or through the radiator (Agarwal et al. 2011). Furthermore, EGT can be utilized to construe the piston, cylinder head, and cylinder liner temperatures, which are significant for the advanced next generation of high-performance engines that operate near engine material limits (Abu-Qudais 1996). One of the slightest persistent techniques of analyzing engine efficiency involves measurement of exhaust gas temperature (EGT), which can be associated to the instantaneous torque through thermodynamic relationships. Practical execution of such a model requires major discussions of various determinants, such as selected points for temperature recognition along the emission streak, definite for each engine, kind of fitting for thermocouples, and thermal features of the interposed materials. These elements tend to significantly affect the torque-predictive capabilities (Parlak et al. 2006). This study was carried out within the scope of designing an alternative waste cooking oil mixture to be used in a diesel engine and was aimed at determining the optimum waste cooking oil and diesel binary mixture. Investigate the effect of waste cooking oil addition (5% in volume) WCO +DF (5% + 95% in vol.) with conventional diesel fuel, on exhaust gas temperature and noise of a DI diesel engine.

MATERIAL AND METHODS

The present study is conducted on an engine installed in the thermodynamics laboratory of Mechanical Engineering Department at QUEST University Nawabshah. The essential fuel properties are given in the Table 1. The experimental setup is shown in Fig. 1. A one-

cylinder, four-stroke diesel engine is selected and is mounted on a test-bed. Its major specifications are shown in Table 2. Two fuel tanks, one for DF and another for blend fuels were used for supplying the fuels to the test engine. The engine is coupled to an eddy current dynamometer. The engine was first fuelled with DF to determine the baseline parameters and then, it was fuelled with blend fuels. In order to calculate mean values, each test was repeated three times.

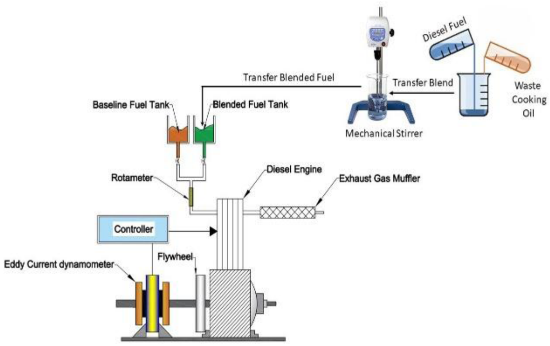

FIGURE.1. Schematic diagram

TABLE 1. Properties of Tested Fuels

Properties	D100	D95WC05
Calorific Valve MJ/Kg	42.5	39
Viscosity Cst at 40c	2.28	2.338571
Density g/ml	0.835	0.836281
Flash Point ^{o}C	78	85
Cetane Number	50	53

TABLE 2. Engine Specification

Model	Single-Cylinder, Horizontal, water cooled four stroke pre-combustion chamber
Bore	75mm
Stroke	80mm
Output (12 hours rating)	4.4kW/2600r/min
Displacement	0.353L
Compression Ration	21-23
Means effective pressure	576 kPa
Piston mean speed	6.93 m/s
Specific fuel consumption	278.8 m/kW h
Specific oil consumption	4.08 g/kW h
Cooling water consumption	1360 m/kW h
Injection Pressure	14.2 + 0.5 MPa
Valves clearance	Inlet valve 0.15-0.25mm
At cooled condition	Exhaust valve 0.25-0.35mm

RESULT AND DISCUSIONS

ENGINE HEAD DEPOSIT VISUAL INSPECTION

During 200-h endurance test on DF and DF95WCO5 blend, engine head were photographed as shown in figure 2 and figure 3. Visual inspection after different hours of operation revealed some deposit accumulations on their head surfaces for both fuel samples. However, the engine head running on DF95WCO5 was dirtier than the engine head running on DF. To some extent, Similar results have been reported. In another study according to Birgel et al. 2021, waste

FIGURE.1 Experimental test bed setup. cooking oil was observed to lead to greater deposit formation in the engine head. Moreover, deposits on engine head run with DF were observed to be oily/ greasy, whereas dry deposits were observed on engine head run with the DF95WCO5 blend.

FIGURE.2 Macroscopic view of engine head deposit operated with DF

FIGURE.3 Macroscopic view of engine head deposit operated with DF95WCO5.

SEM (SCANNING ELECTRON MICROSCOPY) AND EDX (ENERGY DISPERSIVE X-RAY SPECTROSCOPY) ANALYSIS

Upon completion of the long-term 200 h endurance test on DF and the DF95WCO5 blend, the engine was partly disassembled and deposit formation on each engine head was studied. Advanced diesel injection systems are characterized by higher temperatures in the area of the head depositions that can lead to particularly stubborn deposits (Kalghatgi 2018) (Bietresato, Selmo et al. 2021). Figure 4 shows the SEM micrographs at 43_ magnifications of deposits on engine head fueled with DF and DF95WCO5 respectively. It can be clearly seen that deposits with DF are substantially reduced compared to DF95WCO5 blend. Figure 4 shows the SEM of deposits on an engine head fueled with DF (diesel fuel) at 43_ magnification and Fig. 5 shows the elemental analysis by EDX on deposited surfaces. Whereas figure 6 and figure 7 shows SEM and EDX of DF95WCO5 operated fuel respectively.

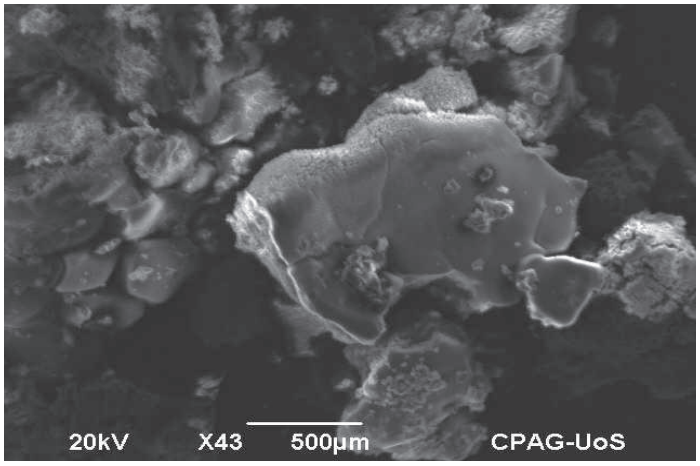

FIGURE. 4 SEM running 200h on diesel fuel DF

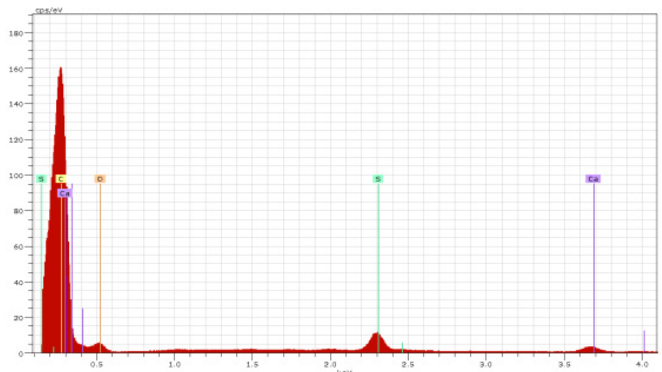

FIGURE. 5 EDX running 200h on diesel fuel

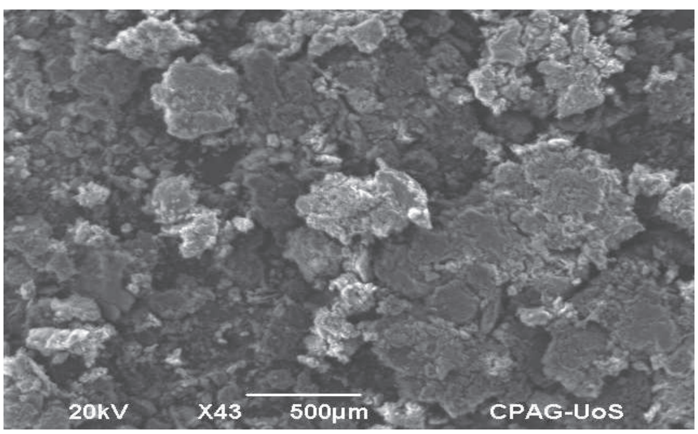

FIGURE. 6. SEM running 200h on DF95WCO5

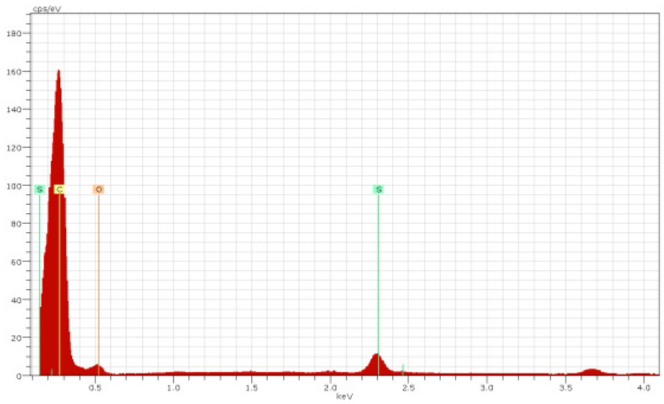

FIGURE. 7. EDX running 200h on DF95WCO5

NOISE EMISSIONS

Figure 8 and 9 shows the sound level at directions (top and right) of the engine test bed along with average of both directions when engine was fueled with diesel fuel (DF) both blend fuel such as, DF100 and binary blend DF95WC05.

Although, the best results regarding noise emissions are achieved by diesel fuel, when DF95WCO5 blend fuel was used, it provided increased deviation in comparison to that of diesel fuel. This could be due to the engine injection strategy (load shifts injection timing, ignition delay and therefore, decreases in-cylinder pressure). Moreover, might be regarded due to some debris available in the blend which caused increase in noise emissions as shown in figures 8 and 9 respectively.

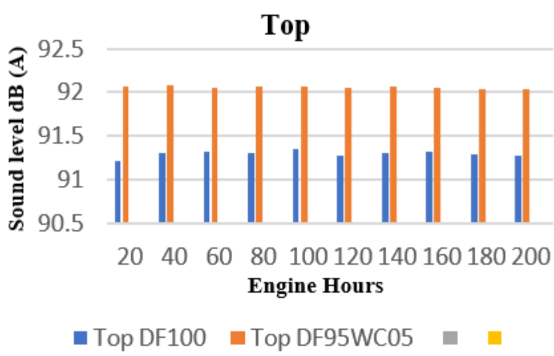

FIGURE. 8. Sound pressure level top position varus engine running hours.

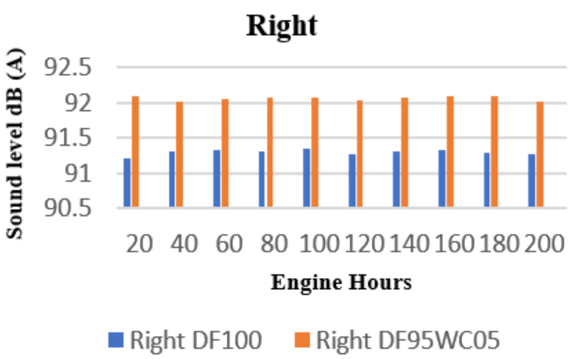

FIGURE. 9. Sound pressure level right position varus engine running hours.

EXHAUST GAS TEMPERATURE

The exhaust gas temperature (EGT) pointed out the conception of the burning operation or else known as the in-cylinder temperature by identifying the temperature of the combusted gas after it leave the engine (Yaman and Yesilyurt 2021) (Ansari, Memon et al. 2023). The EGT values for diesel and waste cooking oil blend. Diesel fuel DF100 at 160 hour the highest was recorded to be as 275^{0}C, 279^{0}C and 288^{0}C respectively

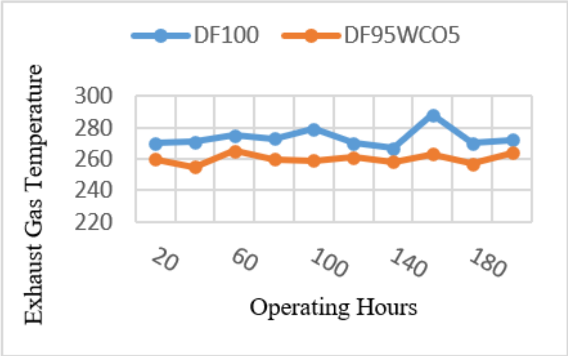

FIGURE.8 operating hours varus Exhaust Gas Temperature.

While in case of DF95WCO5 on same engine operating hours were recorded as 265^{0}C, 259^{0}C and 263^{0}C at same engine operating hours. It can be summarized that the mixture of WCO into the neat diesel fuel has caused to go down in the EGT values because of the intensification of the burning reaction and considerable with the growing in the concentration of WCO as a binary blend.

CONCLUSION

In this work, engine head deposition, exhaust gas temperature and noise emissions were investigated and compared with diesel fuel:

Based on visual inspection, engine head running on either fuel (DF and DF95WCO5) showed some deposit accumulation. However, engine operated on DF95WCO5 was found dirtier than the engine operated with DF. At the end of the endurance test, SEM and EDX analysis showed that engine head deposits when the engine was run with DF were substantially less than when it was run with the DF95WCO5 blend. The investigation revealed that the deposition didn't present a uniformly thick layer of carbon. Moreover, deposits on and around the engine head didn't interfere significantly with the engine head.

Exhaust gas temperature reduced when using DF95WCO5 was found for WCO5 when compared to DF at engine operating conditions. In comparison with diesel fuel, blend fuel produced lower sound levels due to different factors including increased in oxygen content, reduction in the ignition delay, higher viscosity, lubricity etc. However, blend fuel WCO5 produced the lowest level of sound.

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DECLARATION OF COMPETING INTEREST

None

REFERENCES

Abu-Qudais, M. 1996. Exhaust gas temperature for knock detection and control in spark ignition engine. Energy Conversion and Management 37(9): 1383-1392.

Agarwal, D., S. Singh and A. Agarwal 2011. Effect of Exhaust Gas Recirculation (EGR) on performance, emissions, deposits and durability of a constant speed compression ignition engine. Applied Energy 88: 2900-2907.

Ansari, A. M., L. A. Memon, M. T. Ghannam and M. Y. E. Selim 2023. Impact of biodiesel blended fuel with nanoparticles on performance and noise emission in compression ignition engine. International Journal of Thermofluids 19: 100390.

Bergthorson, J. and M. Thomson 2015. A review of the combustion and emissions properties of advanced transportation biofuels and their impact on existing and future engines. *Renewable and Sustainable Energy Reviews* 42: 1393-1417.

Bietresato, M., F. Selmo, M. Renzi and F. Mazzetto 2021. Torque Prediction Model of a CI Engine for Agricultural Purposes Based on Exhaust Gas Temperatures and CFD-FVM Methodologies Validated with Experimental Tests. *Applied Sciences* 11: 3892.

Birgel, A., N. Ladommatos, P. Aleiferis, S. Zülch, N. Milovanovic, V. Lafon, A. Orlovic, P. Lacey and P. Richards 2008. Deposit Formation in the Holes of Diesel Injector Nozzles: A Critical Review. SAE Technical Papers.

Can, Ö. 2014. Combustion characteristics, performance and exhaust emissions of a diesel engine fueled with a waste cooking oil biodiesel mixture. *Energy Conversion and Management* 87: 676-686.

Caprotti, R., N. Bhatti and G. Balfour 2010.Deposit Control in Modern Diesel Fuel Injection Systems. *SAE International Journal of Fuels and Lubricants* 3: 901-915.

Charpe, T. and V. Rathod 2010. Biodiesel production using waste frying oil. *Waste management* (New York, N.Y.) 31: 85-90.

Dey, P. and D. Ray 2020. Comparative analysis ofwaste vegetable oil versus transesterified waste vegetable oil in diesel blend as alternative fuels for compression ignition engine. *Clean Technologies and Environmental Policy* 22: 1-14.

Kalam, M. A., H. H. Masjuki, M. H. Jayed and A. M. Liaquat 2011. Emission and performance characteristics of an indirect ignition diesel engine fuelled with waste cooking oil. *Energy* 36(1): 397-402.

Kalghatgi, G. 2018. Is it really the end of internal combustion engines and petroleum in transport *Applied Energy* 225.

Li, J., Y. Wenbin and W. M. Yang 2021. Evaluating performance and emissions of a CI engine fueled with n-octanol/diesel and n-butanol/diesel blends under different injection strategies. *Fuel* 284: 119085.

Li, W., Y. Ren and H. Miao 2008. Combustion characteristics of a compression ignition engine fuelled with diesel–ethanol blends. Proceedings of The Institution of Mechanical Engineers Part D-journal of Automobile Engineering - *PROC INST MECH ENG D-J AUTO* 222: 265-274.

Li, X., C. Guan, K. Yang, C. s. Cheung and Z. Huang 2019. Impact of lower and higher alcohol additions to diesel on the combustion and emissions of a direct-injection diesel engine. *Environmental Science and Pollution Research* 26.

Macor, A., F. Avella and D. Faedo 2011. Effects of 30% v/v biodiesel/diesel fuel blend on regulated and unregulated pollutant emissions from diesel engines. *Applied Energy* 88(12): 4989-5001.

Majhi, S. and D. Ray 2015. A study on production of biodiesel using a novel solid oxide catalyst derived from waste. Environmental science and pollution research international 23.

Murugesan, A., C. Umarani, T. R. Chinnusamy, M. Krishnan, R. Subramanian and N. Neduzchezhain 2009. Production and analysis of bio-diesel from non-edible oils—A review. *Renewable and Sustainable Energy Reviews* 13(4): 825-834.

Murugesan, A., C. Umarani, R. Subramanian and N. Natarajan 2009. Bio-diesel as an alternative fuel for diesel engines-A review. *Renewable and Sustainable Energy Reviews* 13: 653-662.

Parlak, A., Y. Islamoglu, H. Yasar and A. Egrisogut 2006. Application of artificial neural network to predict specific fuel consumption and exhaust temperature for a Diesel engine. *Applied Thermal Engineering* 26(8): 824-828.

Perrone, D., A. Algieri, P. Morrone and T. Castiglione 2021. Energy and Economic Investigation of a Biodiesel-Fired Engine for Micro-Scale Cogeneration. *Energies* 14: 496.

Prabu, S., M. A. Asokan, R. Roy, S. Francis and M.K. Sreelekh 2017. Performance, Combustion and Emission Characteristics of Diesel Engine fuelled with Waste Cooking Oil Bio-diesel /diesel b lends with Additives. *Energy* 122.

Ramadhas, A. S., S. Jayaraj and C. Muraleedharan 2004. Use of vegetable oils as I.C. engine fuels—A review. *Renewable Energy* 29(5): 727-742.

Salvi, D. B. L., K. Subramanian and N. L. Panwar 2013. Alternative fuels for transportation vehicles: A technical review. *Renewable and Sustainable Energy Reviews* 25: 404–419.

Shu, G., L. Dong and X. Liang 2012. A review of experimental studies on deposits in the combustion chambers of internal combustion engines. *International Journal of Engine Research* 13: 357-369.

Sidibe, S., J. Blin, G. Vaitilingom and Y. Azoumah 2010. Use of crude filtered vegetable oil as a fuel in diesel engines state of the art: Literature review. *Renewable and Sustainable Energy Reviews* 14: 2748-2759.

Yaman, H. and M. Yesilyurt 2021. The influence of n-pentanol blending with gasoline on performance, combustion, and emission behaviors of an SI engine. *Engineering Science and Technology, an International Journal* 24.

Yesilyurt, M. 2018. The effects of the fuel injectionpressure on the performance and emission characteristics of a diesel engine fuelled with waste cooking oil biodiesel-diesel blends. *Renewable Energy* 132.

Zöldy, M., M. Csete, P. Kolozsi, P. Bordás and A. Torok. 2022. Cognitive Sustainability. *1 Arch.* 1: 1–5.