PERFORMANCE EVALUATION OF GASOLINE AND BIO-ETHANOL BLENDS ON SPARK IGNITION (SI) ENGINE

SEUN OYELAMI[1], EMMANUEL O. OLAFIMIHAN[2], OYETUNJI BABATUNDE OKEDERE[3] & ADEYI ABIOLA JOHN[4]
[1]Department of Mechanical Engineering, Osun State University, PMB 4494 Osogbo, Nigeria.
[2]Department of Mechanical Engineering,
Ladoke Akintola University of Technology, Ogbomoso, Nigeria
[3] Department of Chemical Engineering, Osun State University, Osogbo, Nigeria
[4] Research Coordinating Unit Forestry Research Institute of Nigeria
E-mail: eoolafimihan@lautech.edu.ng

Abstract
The experiment involves blending of pure gasoline with different compositions of bio-ethanol produced form corncobs. Different blends were used to run a spark ignition (SI) engine, with a view to evaluating their performance and emission characteristics at varying speed. The effects of various blends on engine performance parameters and emissions were evaluated and compared with those of pure gasoline. The results obtained showed that all blends performed better than pure gasoline. Among the blends tested, E7.0 produced the best engine torque and engine power of 12.3(±0.1) Nm and 950(±0.1) W respectively, as against 11.2(±0.1) Nm and 758(±0.1) W, for E0 at 2800 rpm. The CO and HC emissions reduced by 29.03(±0.1) % and 45.83(±0.1) %, respectively.

Keywords: waste, renewable, energy, bio-ethanol, blend, emission

Introduction
The rate of industrialization as well as motorization around the globe has brought about greater need for environmental pollution arising from water ways blockage by wastes, wastes burning and gasoline emissions. Cellulosic biomass wastes are not properly managed in developing countries such as Nigeria and therefore, a health and environmental risk. Increasing air pollution generated as a result of open burning of these waste fractions, as well as exhaust emissions from internal combustion engines are of greater challenge, meanwhile these waste fractions can be used by hydrolysis and fermentation to produce bio-ethanol as a source of renewable energy. This research work tends to remove the problem of disposal of these wastes fractions while also using the waste fractions in the positive direction (waste to energy). Investigations into the performance of bio-ethanol produced from locally generated cellulosic biomass waste fractions in internal combustion engines are limited. The increase in demand for energy alongside challenges of environmental pollution has promoted more findings into alternative and renewable energy fuels (Florida *et al.,* 2019). Organic fuels apart from being renewable are also characterized by reduced emissions of greenhouse gases and can represent a very cheap alternative to gasoline which can effectively ameliorate the growing concerns of energy shortage (Srithar *et al.,* 2014).

Locally domicile cellulosic wastes, differs from location to location. Reducing pollutant emissions arising from internal combustion engines, ethanol, natural gas etc, which are alternative fuels has can successfully replace the conventional fuels without major changes in the engines. (Mehmet *et al.,* 2019). Environmental protection issues have been the latest talk over the globe in recent years, therefore, the need to find clean and renewable fuel for spark ignition engines (Hsieh *et al.,* 2002). Nigeria has abundance of corn, been the highest producer of corn in Africa, with annual production of 8 million tons (IITA, 2012). Corn-cobs

from the processed corn can be used to produce the bio-ethanol, since the possible replacement fuel must be renewable as well as directly usable without major changes in the structure of the engine. Ethanol among the various alcohols is most suited fuel engines, having better anti-knock characteristics, that encourages its usage in higher compression ratio engines and also advantageous in reduction of CO, HC emissions (Wu *et al.,* 2004).
The reduction of CO emission is apparently caused by the wide amiability and oxygenated characteristic of ethanol. Therefore, it improves power output, efficiency and fuel economy. On the other hand, the auto-ignition temperature and ash point of ethanol are higher than those of gasoline, and the low Reid evaporation pressure which makes it safer for transportation and storage, and causing lower evaporative losses (Topgul *et al.,* 2006). Latent heat of vaporization for ethanol is 3–5 times higher than petrol, thus accounting for lower intake manifold temperature and better volumetric efficiency. Further storage and dispensing for ethanol are similar to petrol since both are liquid fuels. In addition, for most unleaded gasoline, methyl tertiary butyl ether (MTBE) is a problem as it will contaminate groundwater and harm human health (Koc *et al.,* 2009). Ethanol can be used to substitute MTBE in the future.

Presently, ethanol is used in spark-ignition engines with gasoline at low concentrations without any modification (Mehmet *et al.,* 2019); (Yosecu *et al.,* 2006). Pure ethanol can be used in spark-ignition engines but necessitates some modifications to the engine. To avoid modifying engine design, using ethanol–gasoline blended fuel was suggested and so, cold start and anti-knock performance will be improved (Stephen & David, 2018); (Yosecu *et al.,* 2007). Ethanol is the main focus of the whole work for bringing it out into usage in a more beneficial way.

Materials and Method

The materials used in this work were sourced within the vicinity, Procurement of materials were specifically limited to Osun and Oyo State. Soft wood sawdust a waste from kapok tree, was collected from Bodija saw mill in Ibadan, Oyo state. While the hard wood sawdust a waste from Albizia tree, was collected from Alekunwodo saw mill in Osogbo, Osun state. The corncobs were collected from Adeoti maize mill in Isale Osun, Osogbo in Osun State. The choice of the locations was due to proximity as well as the dominance of the type of waste needed. Acetic acid (Sigma aldrich, 1.05 g / cm^3) and 98 percent sulphuric acid (Sigma aldrich, 1 mmhg, density: 1.840g/ ml, 25 °C) and distilled water are used as reagent.
The Major equipment used for this test includes

(i) A heating element (J.P. Selecta S.A, 3003145, S/N 0548400, 230V, 50/60 Hz, Spain)
(ii) Muffle Furnace (J.P. Selecta, S.A, 582543 S/N, 230 VAC, 00-C/2000367, 50/60 Hz, 3500W, Spain)
(iii) Precision balance (RADWAG electronics, 2013, Poland, Precisions: 0.001 grams)
(iv) An Electro-magnetic sieve shaker (BA 200N, 01006, 230 V, 50/60 Hz, 450 VA, Spain).

Corn cobs were smashed, grounded and sieved to (≤0.58mm), to enlarge the surface area, thus increasing the accessibility of acid into the feedstock. The gasoline was procured from Bovas filling station at Oke-fia in Osogbo, Osun state.

The cellulose ethanol production method of separate hydrolysis and fermentation (SHF) was adopted in this work for the experimental production of ethanol from 100 g sample, this is as shown in Figure 2.1

Reagents for the Experiment
The reagents for the experiment are presented below:

i. ($_P$H 7.0) Distilled water
ii. Water ($_P$H 9.7)
iii. 18M H_2SO_4
iv. 0.4m H_2SO_4
v. 8.5m NaOH
vi. Saccharomyces cerevisiae
vii. Corn-cobs
viii. Tween 80
ix. 0.01m Ca $(OH)_2$

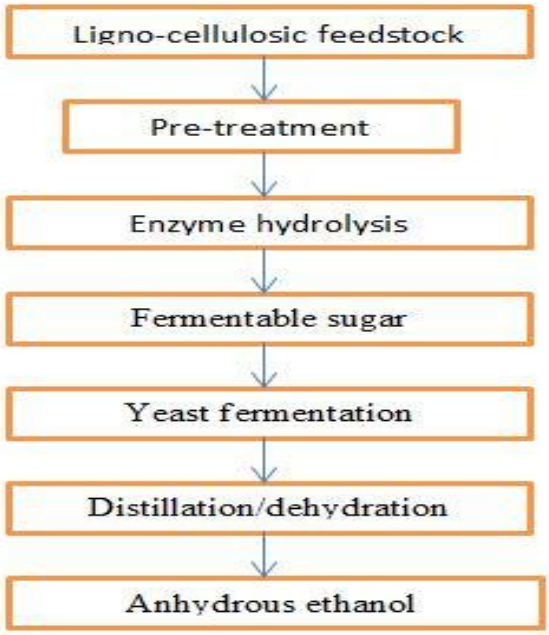

Figure 2.1: Schematic diagram of bio-ethanol production process of lingo cellulosic feedstock

Preparation of blend samples
Bio-ethanol from the samples was prepared and purified to 99.90% and gasoline was used as the base line fuel. Gasoline and ethanol were mixed thoroughly in a container to produced blend preparations. The mixtures/blends were obtained by mixing 3.5%, 7.0%, 10.5% and 14% of bio-ethanol in gasoline as E3.5, E7.0, E10.5 and E14.0 respectively, and used without any engine modifications.

Experimental Set Up
The experimental set-up consists of a single, four-stroke SI engine combined with a dynamometer of the hydraulic type to control the load. The instrumentation unit [air consumption cell, a viscous fluctuation meter, a inclined manometer, the temperature metered thermocouple and the Versatile Data Acquisition System (VDAS)] was placed next to the motor to monitor the engine performance as shown in Figure 2.2. The performance parameters [torque, motor speed, airflow, fuel mass flux rate, exhaust temperature, volumetric efficiency, thermal efficiency, and brake mean effective pressure] were obtained from the VDAS connected to a computer. Values for all performance parameters were obtained at the two minutes run at varying engine speed for each experiment and the

corresponding performance parameters were recorded. The compositions of the blends are as shown in table 2.1

Table 2.1: Composition of fuel blends

S/N	Gasoline (%)	Bio-ethanol (%)	Blend
1	100	0	E0
2	96.5	3.5	E3.5
3	93	7	E7.0
4	89.6	10.5	E10.5
5	86	14.0	E14.0

Similarly, the CO, HC and CO_2 emission results were noted through the gas analyser connected to the exhaust as shown in plate 2

Figure 2.2: Experimental setup (the engine, dynamometer and VDAS instrumentation unit)

Figure 2.2: The gas emission analyser [A: Gas analyzer ;B: Exhaust of the TD200 test set engine]

Specifications

The Spark Ignition (SI) engine used for this experiment has the following specifications as shown in Table 2.2

Table 2.2: TD200 Four Stroke Engine Specification

Engine type	**4-stroke, single-cylinder**
Net power	4.8 kW at 3600 rpm 2.2 kW at 1800rpm
Maximum torque	1.35 kg-m/2500 rpm
Bore/Stroke	70.00 mm/54.00 mm
Displacement vol.	196 cc
Compression ratio	8:5:1
Engine cooling	air cooled
Fuel	Gasoline Ethanol mixed of 85% unleaded Gasoline and 15% Ethyl Alcohol
Ignition system	Electric

The test engine refers to the 4-stroke single cylinder SI engine. The dynamometer is of water brake type. The control panel consists of the cylinder cut-off system, rotameter, pressure guage, orifice meter. The exhaust gas analyser is of general type capable of analysing CO, HC emissions, this was done by placing the analyzer's probe directly at the exhaust of the engine. This was in a bit to ascertain the quantity, in percentage of constituents of the emission.

Results and Discussions

The corncobs sample used to produce bio-ethanol was characterized to ascertain the its content and the results is as shown in table 3.1.

Table 3.1: Result of Characterization of corncobs

Characteristics	Corn cobs
	Proximate analysis (%)
Moisture	10.35
Volatile matters	77
Fixed carbon	11.07
Ash	1.85
Protein	2.87
Fibre	37.85
Carbohydrate	42.76
	Ultimate analysis (%)
Carbon	46.61
Hydrogen	5.89
Oxygen	45.48
Sulphur	0.007
Nitrogen	0.459
Calorific Value (Kcal/Kg)	4505
pH	6.98

The higher the ash content, the higher the quality. A solid fuel's ash content is important to its combustion properties. Ash is the result of slackening. E.g. slackening in boiler tubes of electricity plants during combustion. The lesser ash content can be attributed to the slightly higher calorific value of the three samples. Ash has a major impact on heat transfer on a fuel's surface and oxygen diffusion to the fuel surface during the combustion of the cargo. (Kim *et al*. 2001). Ash and moisture content had a significant effect on the heat value; ash is an incombustible material and decreases the heat value of solid fuels. This is closely consistent with reported values (Akowuah *et al.,* 2012).

The characterization results on corncobs showed that the corn cobs sample contains low sulphur and nitrogen content, 0.007%, and 0.459% respectively. Burning of potential pollutants of nitrogen and sulphur in solid fuels can pollute the environment and affect human health. Thus, the very low content of sulphur is an advantage; it can be combined with other solid fuel to decrease the aggregate content. The fuel's carbon content reflects its potential for CO_2 release. Below is the comparative analysis of the characterization of gasoline used and the produced bio-ethanol from corncobs. The result of the characterization was in line with previous works (Mourad & mahmoud, 2019). The produced bio-ethanol and gasoline were blended in the proportion stated in the earlier chapter and the results were plotted in the graphs shown in figures 3.1 to 3.5 below

Characterization of Produced Bio-Ethanol

The characterization of the ethanol produced was carried out, to determine the fuel properties in the production. The result is as shown in Table 3.2

Table 3.2: Result of Analysis for Characterization of the produced Bio-ethanol compared to Gasoline

S/N	Parameters	Gasoline	Bio-ethanol
1.	Colour		Colourless
2.	Density (g/cm^3)	0.69-0.79	0.8158(±0.001)
3.	Purity (%)	100	95.68(±0.1)
4.	Flash point(^{o}c)	22	17
5.	Pour point (^{o}c)	32 to -57	-5
6.	Fire point (^{o}c)	43	44
7.	Vapour Pressure (kPa)	7-9	5.32(±0.1)
8.	Octane Number	88-100	108.6
9.	Hydrogen (%)	12-15	8.0(±0.1)
10	Carbon (%)	85-88	75.3(±0.1)
11.	Oxygen (%)	0	5.85(±0.1)
12.	Sulphur (%) mass	0.56	0.005(±0.001)
13.	Latent Heat (MJ/kg)	34.5	22.1

The effect of bio-ethanol-gasoline blends on the engine torque at varying speed for the various blend ratios is shown in Figure 3.1. Though, it shows a similar trend at different speeds used but, in all cases, it was better off using blends than pure gasoline. The engine power, specific fuel consumption (SFC), and thermal efficiency at varying speed for the various blend ratios show a gradual increase as shown in Figures 3.2 to 3.4. It was however noticed that for the volumetric efficiency and brake mean effective pressure (BMEP) the increase was not significant, though better off to those of pure gasoline. This was as a result of the low energy level of bio-ethanol, which it's oxygenate characteristics tries to balance. The effect of bio-ethanol/gasoline blends on the emission of CO shows an average emission reduction of 29.03% for E7.0 as seen in Figure 3.7. also, HC observed in Figure 3.8 was reduced to the tune of 45.83%. Mourad and mahmoud (2019) reported similar trend of 13.7% CO reduction and 25.2% HC reduction.

Conclusion

This work showed that blending bio-ethanol with gasoline yielded a good engine performance in respect of engine parameters like power, torque and with reduced hazardous exhaust emissions. The experiment went further to reveal that E7.0 blend ratio gives the best engine performance. The CO_2 emissions results shown in Figure 3.9 were expected to be close since the high content of oxygen in bio-ethanol is expected to aid more combustion to reduce the HC and invariably increase the CO_2.

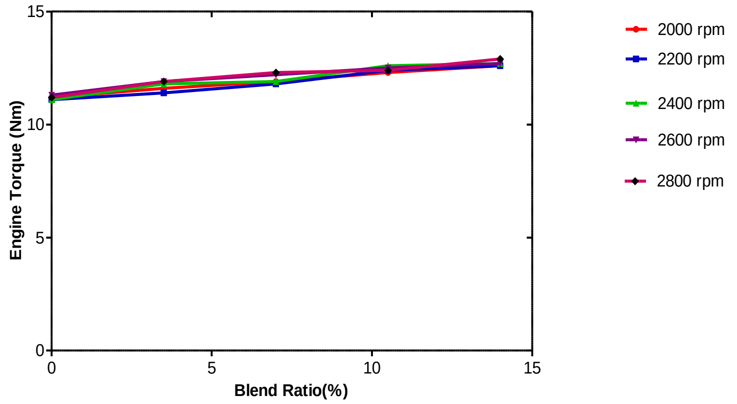

Figure 3.1: Graph of engine torque against gasoline/ethanol blend

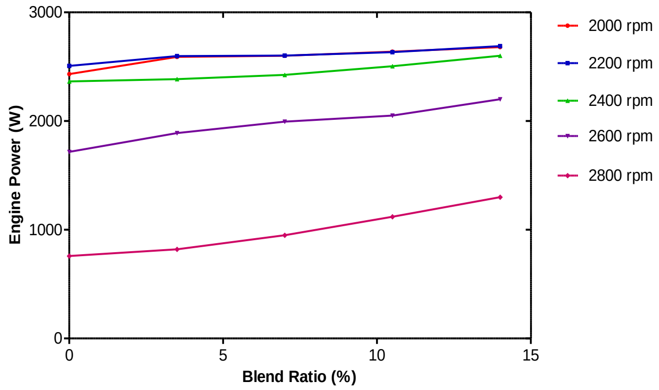

Figure 3.2: Graph of engine power against gasoline/ethanol blend

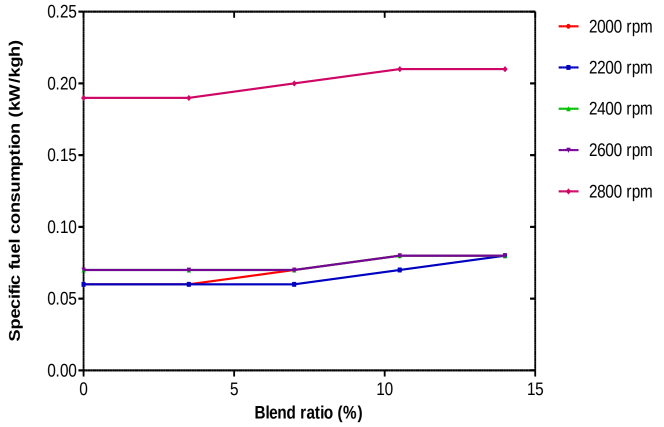

Figure 3.3: Graph of specific fuel consumption against gasoline/ethanol blend

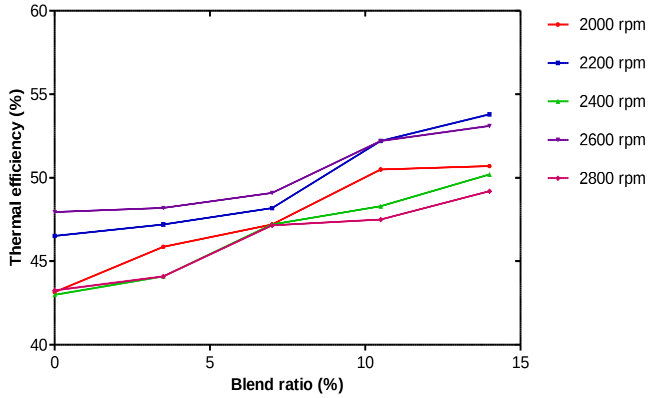

Figure 3.4: Graph of thermal efficiency against gasoline/ethanol blend

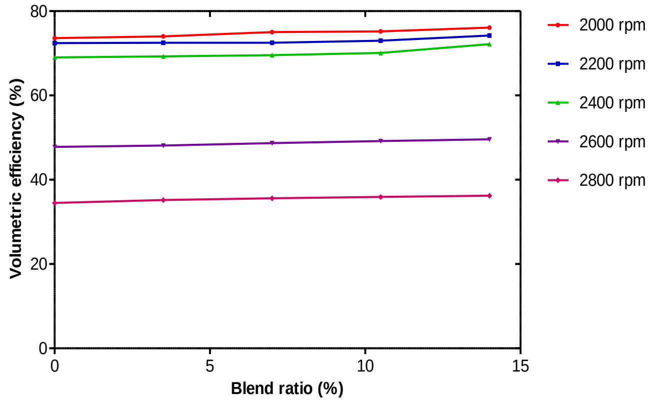

Figure 3.5: Graph of volumetric efficiency against gasoline/ethanol blend

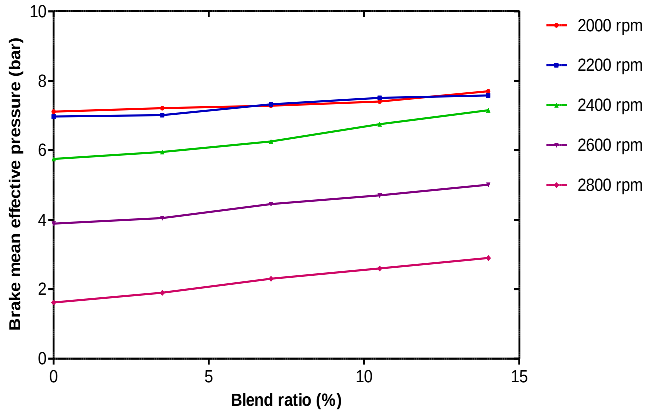

Figure 3.6: Graph of brake mean effective pressure against gasoline/ethanol blend

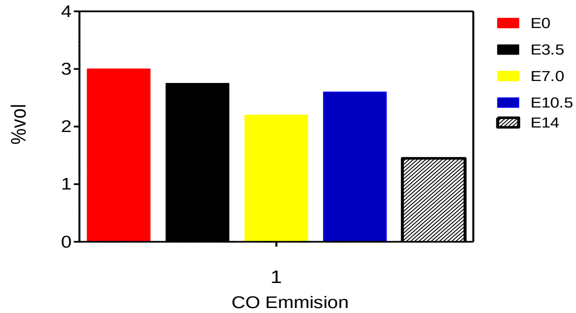

Figure 3.7: CO emission result for blends of the samples

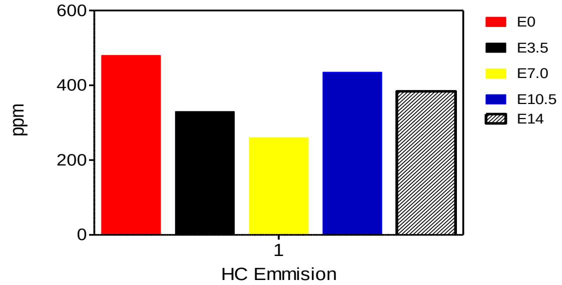

Figure 3.8: HC emission result for blends of the samples

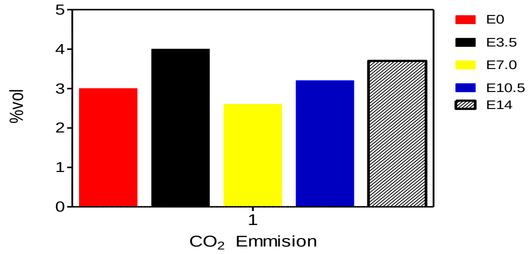

Figure 3.9: CO_2emission result for blends of the samples

Declaration of Conflict of Interest

The authors wish to declare that there is no conflict of interest has regards this manuscript.

References

Akowuah, J., Kemausuor, F., & Mitchual, S. (2012). Physico-chemical characteristics and market potential of sawdust charcoal briquette. *International Journal of Energy and Environmental Engineering,* 3, 20.

Florinda, M., Carlos, F., Miroslava, S., & Nídia, C. (2019). Analysis of fossil fuel energy consumption and environmental impacts in European Countries. *Energies*, 12, 964.

Hsieh, W., Chen, R., Wu, T., & Lin, T. (2002). Engine performance and pollutant emission of an SI engine using ethanol–gasoline blended fuels. *Atmospheric Environment,* 3, 403–410.

International Institute of Tropical Agriculture (IITA) (2012). Hybrid-Maize-Farming-In-Nigeria-Time-to-Start-Your-Planting-For-The-Season. http://www.naijafinder.com/threads/4870

Kim, H., Lu, G., Naruse, I., Yuan, J., & Ohtake, K. (2001). Modeling combustion characteristics of bio-coal briquettes. *J. Energy Resour. Technol*. 123, 27–31.

Koç, M., Sekmen, Y., & Tolga, T. (2009). The effects of ethanol–unleaded gasoline blends on engine performance andexhaust emissions in a spark-ignition engine. *Renewable Energy*, 34, 2101–2106.

Mehmet, I. I., Selim, T., Selahaddin, O. A., & Nafiz, K. (2019). Alternative fuels for internal combustion engines. *Intechopen, 85446, DOI: 10.5772.*

Mourad, M., & Mahmoud, K. (2019). Investigation into SI engine performance characteristics and emissions fuelled with ethanol/butanol-gasoline blends. *Renewable Energy*, 143, 762–771. https://doi.org/10.1016/j.renene.2019.05.064

Srithar, K., Balasubramanianb, K. A., Pavendana, V., & Kumar, B. A. (2014). Experimental investigations on mixing of two biodiesels blended with diesel as alternative fuel for diesel engines. *Journal of King Saud University – Engineering Sciences*.

Stephen, S., & David, R. (2018). Impact of ethanol blending on particulate emissions from a spark-ignition direct-injection engine. *Fuel* https://doi.org/10.1016/j

Topgul, T., Yucesu, H. S., & Cinar, C. (2006). The effects of ethanol–unleaded gasoline blends and ignition timing on engine performance and exhaust emissions. *Renewable Energy*, 31, 2534–2542.

Wu, C. W., Chen, R. H., & Pu, J. Y. (2004). The Influence of air–fuel ratio on engine performance and pollutant emission of an SI engine using ethanol–gasoline-blended fuels. *Atmospheric Environment*, 38, 7093–100.

Yucesu, H. S., Tolga, T., & Cinar, C. (2006). Effect of ethanol–gasoline blends on engine performance and exhaust emissions in different compression ratios. *Applied Thermal Engineering.*; 26: 2272–2278.

Yucesu, H. S., Sozen, A., & Tolga, T. (2007). Comparative study of mathematical and experimental analysis of spark ignition engine performance used ethanol–gasoline blend fuel. *Applied Thermal Engineering*, 27, 358–368.