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ORIGINAL

Impact of Anhydrous Alcohol as a Complementary Fuel on Gasoline Engine Performance and Efficiency

Impacto del alcohol anhidro como combustible complementario en el rendimiento y la eficiencia de los motores de gasolina

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ABSTRACT

Introduction: the growing interest in preserving the environment has driven the search for cleaner energy sources, including biofuels such as anhydrous alcohol, which can reduce the environmental impact of fossil fuel use without affecting engine performance. This project aimed to analyze the behavior of a gasoline engine when using anhydrous alcohol as a fuel additive.
Objective: this study evaluates the effects of anhydrous alcohol-gasoline blends (E5, E10, E15, and E20) on the mechanical performance and pollutant emissions of a Chevrolet Aveo 1,6 L spark-ignition engine under different test conditions.
Method: the study was conducted on a Chevrolet Aveo vehicle equipped with an electronic injection system and a 1600 cc engine, evaluating its mechanical performance and emissions. Static tests, dynamic road tests, and laboratory analyses were carried out using conventional gasoline and blends containing 5 %, 10 %, 15 %, and 20 % anhydrous alcohol. Parameters such as power, torque, and emission levels were measured following the INEN 2204:2002 and 2203:99 standards.
Results: the results showed that the incorporation of anhydrous alcohol did not produce significant variations in power or torque but did reduce CO, HC, and CO_2 emissions, although with a slight increase in NOx, remaining within the established limits.
Conclusions: Anhydrous alcohol-gasoline blends up to 20 % (v/v) can be used in conventional engines without performance penalties, while contributing to reductions in CO, HC, and CO_2 emissions. The trade-off is a moderate increase in NOx, which must be considered in emission control strategies. These findings support the potential of alcohol as a transitional fuel in urban transport under Latin American regulatory frameworks.

Keywords: Engine Performance; Pollutant Gas Concentrations; Pollutant Emission Factors; Anhydrous Alcohol; Alternative Fuels.

RESUMEN

Introducción: el creciente interés por preservar el medio ambiente ha impulsado la búsqueda de fuentes de energía más limpias, entre ellas los biocombustibles como el alcohol anhidro, que pueden reducir el impacto ambiental del uso de combustibles fósiles sin afectar el rendimiento de los motores. Este proyecto tuvo como objetivo analizar el comportamiento de un motor a gasolina al emplear alcohol anhidro como aditivo del combustible.

Objetivo: este estudio evalúa los efectos de las mezclas de etanol y gasolina (E5, E10, E15 y E20) sobre el rendimiento mecánico y las emisiones contaminantes de un motor de encendido por chispa Chevrolet Aveo 1,6 L en diferentes condiciones de prueba.
Método: el estudio se realizó en un vehículo Chevrolet Aveo con sistema de inyección electrónica y motor de 1600 cc, evaluando su desempeño mecánico y las emisiones generadas. Para ello, se desarrollaron ensayos estáticos, pruebas dinámicas y análisis de laboratorio, utilizando gasolina convencional y mezclas con 5 %, 10 %, 15 % y 20 % de alcohol anhidro. Se midieron parámetros como potencia, torque y niveles de emisiones, siguiendo las normas INEN 2204:2002 y 2203:99.
Resultados: se mostraron que la incorporación de alcohol anhidro no produjo variaciones significativas en la potencia ni en el torque, pero sí redujo las emisiones de CO, HC y CO_2, aunque con un leve aumento en NOx, manteniéndose dentro de los límites establecidos.
Conclusiones: las mezclas de etanol y gasolina de hasta un 20 % (v/v) pueden utilizarse en motores convencionales sin penalizar el rendimiento, al tiempo que contribuyen a reducir las emisiones de CO, HC y CO_2. La contrapartida es un aumento moderado de los NOx, que debe tenerse en cuenta en las estrategias de control de emisiones. Estos resultados respaldan el potencial del etanol como combustible de transición en el transporte urbano en el marco normativo latinoamericano.

Palabras clave: Rendimiento del Motor; Concentraciones de Gases Contaminantes; Factores de Emisión de Contaminantes; Alcohol Anhidro; Combustibles Alternativos.

INTRODUCTION

The transportation sector is one of the largest contributors to greenhouse gas (GHG) emissions and local air pollutants worldwide. Internal combustion engines (ICEs), which account for more than 99 % of road vehicles, are still the dominant propulsion system.[1] Gasoline-powered spark-ignition (SI) engines emit carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), carbon dioxide (CO_2), and particulate matter (PM), all of which negatively affect both climate and human health.[2,3]

Ethanol has emerged as one of the most promising renewable fuels to partially substitute gasoline. Anhydrous ethanol possesses a high-octane number and oxygen content, enabling more complete combustion and potential reductions in toxic emissions.[4] Brazil and the United States have successfully implemented large-scale ethanol programs, demonstrating its technical feasibility in conventional SI engines.[5,6] Recent experimental studies confirm that ethanol–gasoline blends generally decrease CO and HC emissions, although they may lead to higher NOx formation due to higher in-cylinder temperatures and excess oxygen availability.[7,8,9,10]

In Latin America, the urban environment of Quito, Ecuador, represents a relevant case study. The city's high altitude (2 850 m above sea level) and complex topography reduce atmospheric dispersion of pollutants, resulting in persistent exceedances of air quality standards for CO, NOx, and PM.[11,12] Mobile sources are responsible for the majority of these emissions, highlighting the need for transitional fuels that can reduce their environmental impact while remaining compatible with the existing vehicle fleet.[13]

Although global literature on ethanol–gasoline blends is extensive, few studies have experimentally evaluated their effects on vehicles operating under Ecuadorian driving conditions and regulatory frameworks. Previous works in the region often focus on policy analysis or combustion modeling rather than real-world testing.[14,15] This creates a research gap in the practical assessment of ethanol as a complementary fuel for SI engines in South American cities.

Therefore, the objective of this study is to evaluate the impact of ethanol–gasoline blends (E5, E10, E15, and E20) on the performance and emissions of a Chevrolet Aveo 1.6 L SI engine. The study integrates on-road tests, static idle evaluations, and chassis dynamometer analyses to determine whether ethanol blends can improve emission profiles while maintaining acceptable performance levels under Ecuadorian emission standards.[16,17]

METHOD

Experimental vehicle and engine

The experimental tests were conducted on a Chevrolet Aveo Family (General Motors, model year 2009), equipped with a 1,6 L spark-ignition (SI) engine, four cylinders in line, multi-point electronic fuel injection, compression ratio 9,5:1, and maximum power output of 92 hp at 6 000 rpm. The vehicle had no engine modifications and was representative of the most common passenger fleet in Quito, Ecuador.

Fuels and blending procedure

Commercial extra gasoline (87 octane, sulfur content 358 ppm, density 0,740 g/cm^3) was used as the baseline fuel. The additional fuel was anhydrous alcohol (99,5 % purity, 100° Gay-Lussac, supplied by OVALCOHOL

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S.A.). anhydrous alcohol-gasoline blends were prepared by volumetric splash blending in closed containers at ambient temperature, ensuring homogeneity by mechanical agitation. The tested blends were E5, E10, E15, and E20 (v/v). Fuel properties were characterized following ASTM standards (D-4294 for sulfur content, D-287 for specific gravity).

Test conditions

Three categories of tests were conducted:

- *Static idle test:* exhaust emissions were measured at idle conditions to compare pollutant concentrations with Ecuadorian INEN standards.
- *On-road test:* fuel consumption and exhaust emissions were measured during controlled driving cycles under urban conditions at constant speeds (40–60 km/h).
- *Chassis dynamometer test (ASM cycles):* tests were performed on a MAHA LPS 3000 dynamometer, applying ASM 2525 and ASM 5015 cycles to simulate real driving conditions under load.

All tests were performed at an altitude of 2,850 m (Quito), under average ambient conditions of 18–22 °C and 65–75 % relative humidity.

Measurement equipment

Gas analyzers: MAHA MGT 5 and Nextech equipment were used to measure concentrations of CO (%), CO_2 (%), HC (ppm), NOx (ppm), and O_2 (%). Calibration was performed before each test following manufacturer specifications.

Performance measurements: torque and power were obtained from the chassis dynamometer. Fuel consumption was determined by mass flow measurement using a calibrated flowmeter.

Auxiliary equipment: diagnostic scanner, GPS, and digital sensors were used to monitor engine operating parameters.

Data analysis

Performance indicators included torque (Nm), brake power (kW), brake-specific fuel consumption (BSFC, g/kWh), and brake thermal efficiency (BTE, %). Pollutant emissions were reported as average concentrations for each fuel blend and condition. Emission factors (g/km) were calculated using stoichiometric combustion models adapted to anhydrous alcohol-gasoline mixtures. All results were statistically averaged over at least three repeated measurements per condition.

Regulatory framework

Emission results were evaluated against the Ecuadorian regulations: INEN 2204:2002 (limits for gasoline-powered motor vehicles under dynamic tests) and INEN 2203:99 (exhaust gas concentration limits under static idle conditions). These standards define permissible thresholds for CO, HC, CO_2, and NOx emissions, which were used as reference benchmarks for compliance analysis.

RESULTS

Fuel properties

Table 1 summarizes the main physicochemical properties of the test fuels. Increasing anhydrous alcohol content raised the octane number and slightly increased density, while sulfur concentration decreased.

Table 1. Properties of gasoline and anhydrous alcohol-gasoline blends

Fuel	Octane rating	Sulfur (ppm)	Density (g/cm³)
Standard applied	**INEN 2699**	**ASTM D-4294**	**ASTM D-287**
Extra gasoline (E0)	87	358	0,740
E5	89	320	0,742
E10	92	293	0,744
E15	95	223	0,745
E20	97	195	0,748

On-road tests

Average pollutant concentrations measured during on-road tests are presented in table 2. Compared to baseline gasoline, alcohol blends reduced CO and HC emissions by up to 10 % and 25 % respectively, and decreased CO_2 slightly. However, NOx emissions increased progressively with higher alcohol content, reaching +38 % in the E20 case.

Table 2. Average on-road pollutant emissions

Fuel	CO [%]	HC [ppm]	CO_2 [%]	O_2 [%]	NO_x [ppm]
Extra (E0)	0,372	26,301	13,392	0,923	269,507
E5	0,362	22,195	12,521	2,917	287,353
E10	0,349	22,1	12,643	2,626	323,985
E15	0,348	19,748	12,433	3,254	309,007
E20	0,364	20,796	12,504	3,172	373,621

Trend analysis

CO remained relatively stable, with small reductions across E5–E15.

HC decreased steadily up to E20, indicating more complete combustion.

CO_2 concentrations fell slightly, consistent with alcohol's lower carbon-to-hydrogen ratio.

O_2 levels in exhaust increased with alcohol content, confirming oxygen enrichment.

NOx increased, with the maximum observed at E20 (+38 % compared to baseline).

Static idle test

Under idle conditions, all blends complied with INEN 2203:99 emission limits. CO and HC concentrations decreased with alcohol addition, while NOx showed a minor increase.

Chassis dynamometer tests (ASM cycles)

The ASM 2525 and ASM 5015 cycles confirmed the on-road trends. Figure 1 illustrates the variation in pollutant emissions with increasing alcohol content.

CO and HC: consistent reductions up to 20 % alcohol.

CO_2: moderate decrease compared to E0.

NOx: significant increase, especially in ASM 5015, where E20 exceeded 370 ppm.

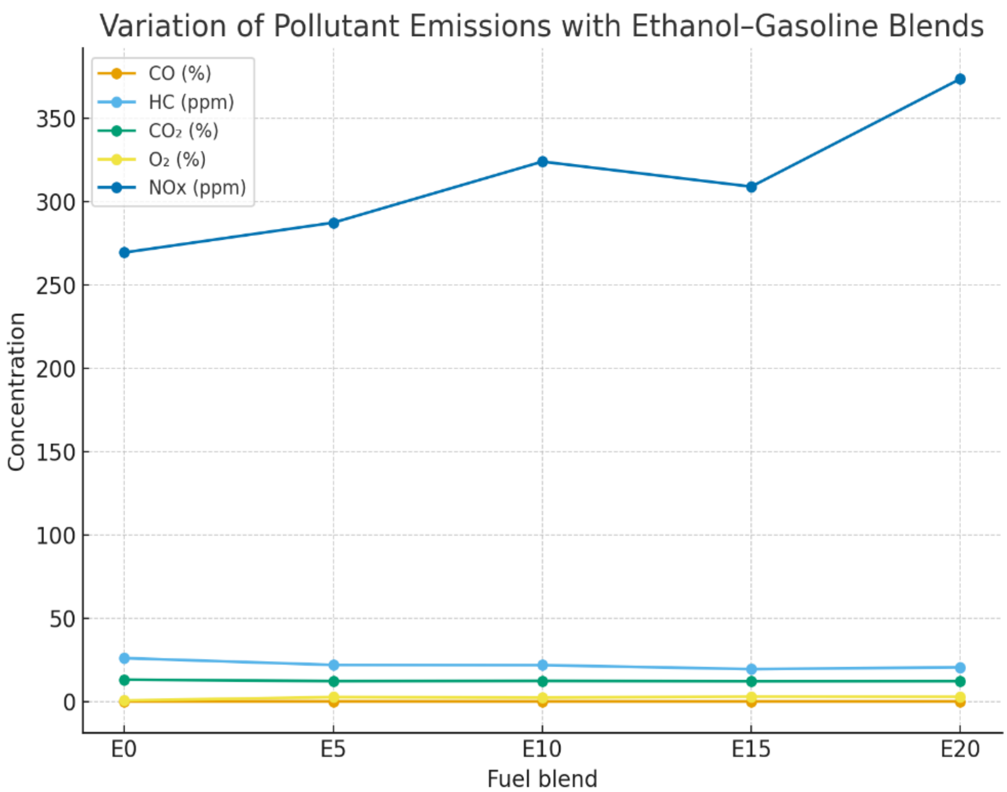

Figure 1. Variation of Pollutant Emissions with Alcohol-Gasoline Blends

Performance results

Torque and power curves obtained from the chassis dynamometer (figure 2,3) revealed no statistically significant differences between gasoline and alcohol blends up to 20 %. Maximum torque remained around 135 Nm at 4,000 rpm, while maximum power was stable at 92 ± 1 hp at 6,000 rpm.

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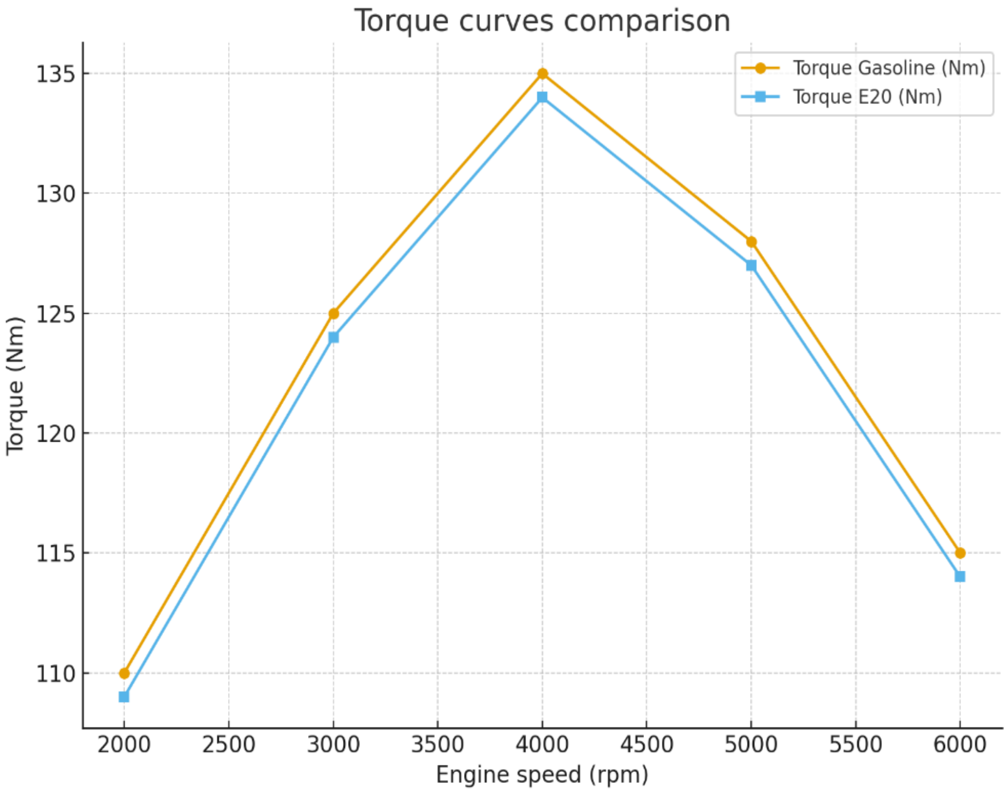

Figure 2. Torque comparison

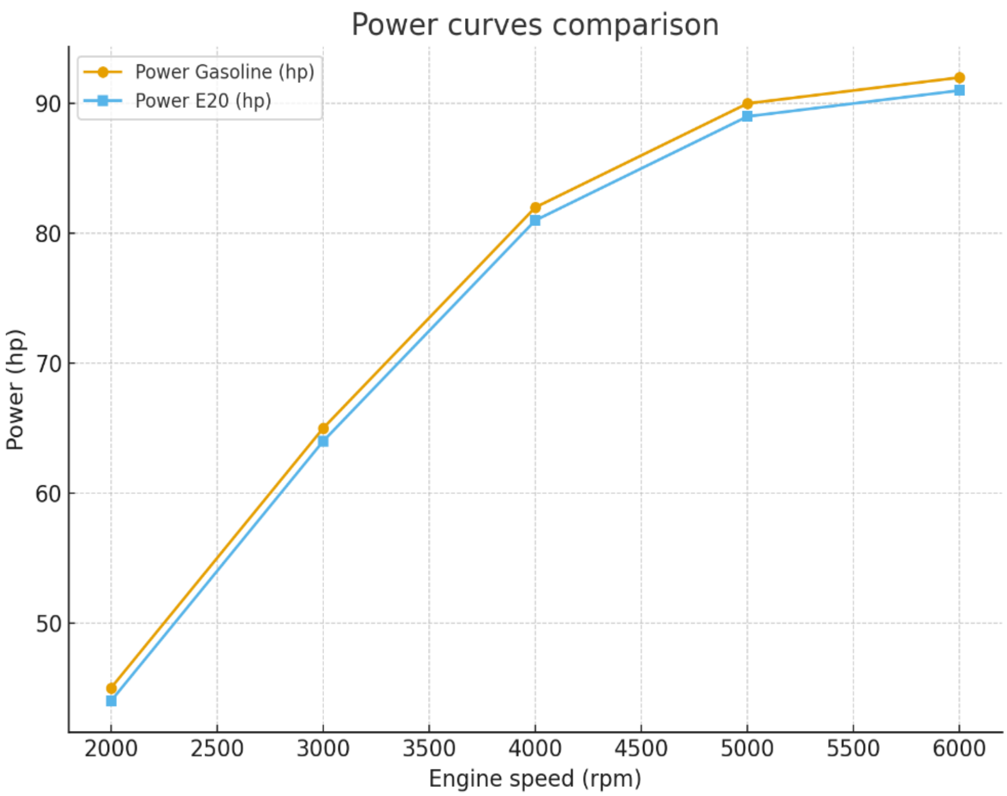

Figure 3. Power curves comparison

Fuel consumption, however, increased progressively with alcohol concentration (figure 4). At E20, consumption rose by approximately 7 % compared to gasoline, consistent with alcohol's lower heating value.

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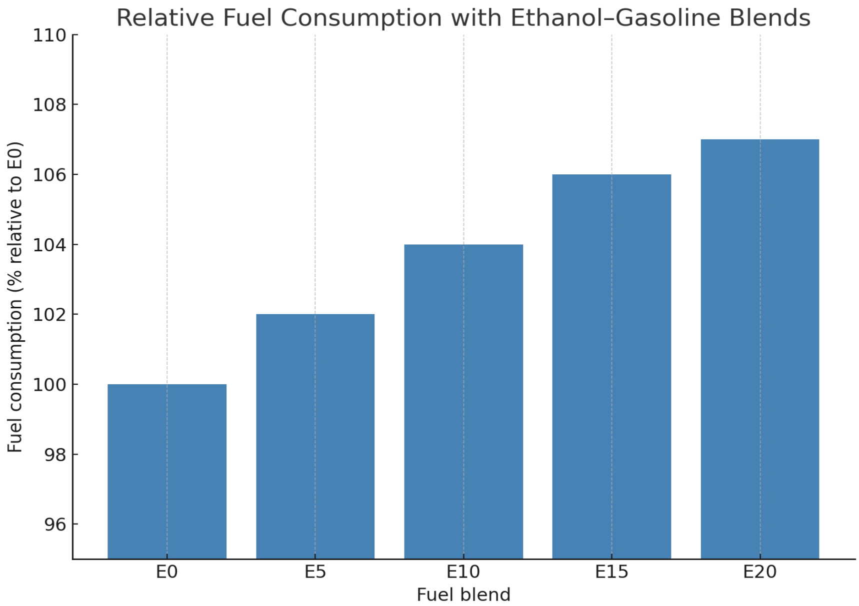

Figure 4. Relative Fuel Consumption with Alcohol-Gasoline Blends

DISCUSSION

The results obtained in this study confirm that alcohol-gasoline blends up to 20 % (v/v) can be used in conventional spark-ignition engines without detrimental effects on torque or power output. This aligns with previous investigations showing that alcohol's high-octane rating compensates for its lower heating value, preventing power losses at moderate blending levels.[9,18]

Emission behavior

The most consistent benefits observed were reductions in CO and HC emissions, in agreement with findings from recent experimental studies in Europe, Brazil, and Asia.[19,20,21] These reductions are attributed to alcohol's oxygen content, which promotes more complete combustion and reduces the presence of unburned hydrocarbons.

CO_2 emissions also decreased slightly, which can be explained by the lower carbon-to-hydrogen ratio of alcohol compared to gasoline. However, the magnitude of this reduction was modest, reflecting the limited substitution level (maximum 20 %).

By contrast, NOx emissions increased progressively with alcohol content, particularly at E20. This outcome has been widely reported in the literature[22,23] and is associated with higher in-cylinder temperatures and the enhanced availability of oxygen, which favor thermal NOx formation. Mitigation of this trade-off requires either improved ignition timing strategies or catalytic aftertreatment optimization.

Fuel consumption and efficiency

Fuel consumption increased by approximately 7 % at E20 compared to pure gasoline, consistent with alcohol's lower lower heating value. Similar trends have been documented by Dhande et al.[24] and Rimkus et al.[25], who also reported higher brake-specific fuel consumption with alcohol blends above 10 %. Although efficiency losses were moderate, they highlight the importance of balancing environmental gains with energy consumption.

Regulatory framework and local relevance

From a regulatory perspective, all blends tested complied with Ecuadorian emission standards INEN 2204:2002 and INEN 2203:99, both under static idle and dynamic ASM tests. This indicates that alcohol can be integrated into the fuel matrix without requiring major modifications to the current vehicle fleet. Nevertheless, the observed increase in NOx emissions suggests that further regulatory adjustments may be needed if higher alcohol blends are introduced in the future.

The case of Quito is particularly relevant due to its high altitude and limited pollutant dispersion capacity.[11,12] Introducing alcohol blends could contribute to reductions in CO and HC concentrations, which are pollutants of major concern in the metropolitan area. However, given the increase in NOx, complementary policies such as fleet modernization and catalytic converter inspections remain essential.

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Broader implications

These findings reinforce the role of alcohol as a transitional fuel in the Latin American context, bridging the gap between fossil fuel dependence and full electrification of the vehicle fleet. While bioethanol adoption in countries like Brazil has proven successful, smaller economies such as Ecuador must balance fuel costs, agricultural supply chains, and regulatory adaptations. Integrating ethanol at low to moderate levels (≤20 %) appears technically feasible and environmentally beneficial, but further studies should explore lifecycle emissions, economic viability, and compatibility with advanced emission control systems.

CONCLUSIONS

This study assessed the impact of anhydrous alcohol-gasoline blends (E5, E10, E15, and E20) on the performance and emissions of a Chevrolet Aveo 1.6 L spark-ignition engine under idle, on-road, and chassis dynamometer conditions. The following conclusions can be drawn:

Engine performance (torque and power) was not significantly affected by alcohol blends up to 20 %, confirming their technical feasibility in conventional SI engines without modifications.

Pollutant emissions showed consistent reductions in CO, HC, and CO_2 concentrations, demonstrating the environmental benefits of alcohol's oxygenated nature.

NOx emissions increased with higher alcohol content, particularly at E20, highlighting the need for complementary control strategies.

Fuel consumption rose moderately (≈7 % at E20) due to alcohol's lower heating value, although this trade-off remains acceptable within the tested range.

All blends complied with Ecuadorian emission standards (INEN 2204:2002; INEN 2203:99), supporting their potential introduction into the national fuel matrix.

Overall, alcohol-gasoline blends up to 20 % can serve as a transitional strategy to reduce pollutant emissions from the urban vehicle fleet in Ecuador, with tangible air quality benefits and minimal performance penalties. Future research should explore long-term durability effects, lifecycle GHG emissions, and optimization of NOx mitigation technologies.

REFERENCES

1. Sinigaglia T, Santos Martins ME, Cezar Mairesse Siluk J. Technological evolution of internal combustion engine vehicle: a patent data analysis. Appl Energy. 2022;306:118003.

2. Huang Y, Unger N, Harper K, Heyes C. Global climate and human health effects of the gasoline and diesel vehicle fleets. GeoHealth. 2020;4(3):e2019GH000240.

3. Cengel YA, Boles MA. Termodinámica. 8ª ed. México: McGraw-Hill Education.

4. Ribeiro CB, Martins KG, Gueri MVD, Pavanello GP, Schirmer WN. Effect of anhydrous ethanol/gasoline blends on performance and exhaust emissions of spark-ignited non-road engines. Environ Sci Pollut Res. 2018;25(24):24192–200.

5. Feijo EAV, Fujisawa R. Emission control evolution of the 2.0 L gasohol/ethanol engines in Brasil. São Paulo; 1992. p. 921493. https://saemobilus.sae.org/papers/emission-control-evolution-20-l-gasohol-ethanol-engines-brasil-921493

6. Goldemberg J. The Brazilian biofuels industry. Biotechnol Biofuels. 2008;1(1):6.

7. Kumar TS, Ashok B. Critical review on combustion phenomena of low carbon alcohols in SI engine with its challenges and future directions. Renew Sustain Energy Rev. 2021;152:111702.

8. Tsai JH, Ko YL, Huang CM, Chiang HL. Effects of blending ethanol with gasoline on the performance of motorcycle catalysts and airborne pollutant emissions. Aerosol Air Qual Res. 2019;9(12):2781–92.

9. Gajewski M, Wyrąbkiewicz S, Kaszkowiak J. Effects of ethanol-gasoline blends on the performance and emissions of a vehicle spark-ignition engine. Energies. 2025;18(13):3466.

10. Boretti A. Towards 40% efficiency with BMEP exceeding 30 bar in directly injected, turbocharged, spark ignition ethanol engines. Energy Convers Manag. 2012;57:154–66.

11. Alexandrino K, Zalakeviciute R, Viteri F. Seasonal variation of the criteria air pollutants concentration in an urban area of a high-altitude city. Int J Environ Sci Technol. 2021;18(5):1167–80.

12. World Health Organization. Health and climate change urban profile: Quito. Geneva: WHO; 2019.

13. Vega D, Ocaña L, Parra Narváez R. Inventario de emisiones atmosféricas del tráfico vehicular en el Distrito Metropolitano de Quito. Año base 2012. Av Cienc Ing (Quito). 2015;7(2). https://revistas.usfq.edu.ec/index.php/avances/article/view/270

14. Escobar F. Evaluación de un motor Otto experimental de baja cilindrada. [Trabajo técnico].

15. Llanes Cedeño EA, Rocha-Hoyos JC, Peralta Zurita DB, Leguísamo Milla JC. Evaluación de emisiones de gases en un vehículo liviano a gasolina en condiciones de altura: caso de estudio Quito, Ecuador. Enfoque UTE. 2018;9(2):149–58.

16. Instituto Ecuatoriano de Normalización (INEN). NTE INEN 2203: 2000. Gestión ambiental. Aire. Vehículos. Quito: INEN; 2000.

17. Instituto Ecuatoriano de Normalización (INEN). NTE INEN 2204: 2002. Gestión ambiental. Aire. Vehículos. Quito: INEN; 2002.

18. Mohammed MK, Balla HH, Al-Dulaimi ZMH, Kareem ZS, Al-Zuhairy MS. Effect of ethanol-gasoline blends on SI engine performance and emissions. Case Stud Therm Eng. 2021;25:100891.

19. Zacarías A, Grijalva MR, Rubio JDJ, Romage G, Mena VY, Hernández R, et al. Improvement efficiency and emission reduction in used cars for developing regions using gasoline–bioethanol blends. Energies. 2025;18(3):638.

20. Yang HH, Liu TC, Chang CF, Lee E. Effects of ethanol-blended gasoline on emissions of regulated air pollutants and carbonyls from motorcycles. Appl Energy. 2012;89(1):281–6.

21. European Commission, ICF Consulting Ltd, CE Delft, ENSYS Energy, Vivid Economics. Impact of higher levels of bio components in transport fuels in the context of Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998: final report. Luxembourg: Publications Office of the EU; 2017. https://data.europa.eu/doi/10.2834/153655

22. Dinh Xuan T, Vu Minh D, Hoa BP, Duc KN, Nguyen Duy V. Influence of ethanol-gasoline blended fuel on performance and emission characteristics of the test motorcycle engine. J Air Waste Manag Assoc. 2022;72(8):895–904.

23. Tutunea D, Dumitru I. Experimental study on the effect of adding bioethanol in spark ignition engine. BUP J Auto. 2017;27(1). https://automotive.upit.ro/index_files/2017/2017_11_.pdf

24. Dhande DY, Sinaga N, Dahe KB. Study on combustion, performance and exhaust emissions of bioethanol-gasoline blended spark ignition engine. Heliyon. 2021;7(3):e06380.

25. Rimkus A, Pukalskas S, Mejeras G, Nagurnas S. Impact of bioethanol concentration in gasoline on SI engine sustainability. Sustainability. 2024;16(6):2397.

26. Instituto Ecuatoriano de Normalización (INEN). Norma Técnica INEN 2203:1999. Vehículos automotores. Control de gases de escape en condiciones de marcha mínima. Quito: INEN; 1999. https://www.normalizacion.gob.ec

27. Instituto Ecuatoriano de Normalización (INEN). Reglamento Técnico Ecuatoriano RTE INEN 089. Combustibles líquidos derivados de petróleo. Gasolina automotriz. Quito: INEN; 2008. https://www.normalizacion.gob.ec

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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