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Ethanol–Gasoline Blends: A Comprehensive Review on Fuel Properties, Engine Performance, and Emission Characteristics

Ayush Tiwari, Pramod Chandra Tewari

Department of Mechanical Engineering, G. B. Pant University of Agriculture and Technology, Pantnagar, India

tiwari2001ayush@gmail.com, pct2628@gmail.com

ABSTRACT

The increasing global demand for energy, coupled with the depletion of petroleum reserves and environmental concerns, has necessitated the search for renewable and cleaner fuels. Ethanol, derived from biomass, has emerged as a promising alternative fuel or additive for spark-ignition (SI) engines. This review synthesises results from several experimental studies that investigated the effects of ethanol–gasoline blends on fuel properties, engine performance, and emission characteristics. Across the reviewed works, ethanol addition was found to improve octane rating, enhance combustion efficiency, and reduce carbon monoxide (CO) and hydrocarbon (HC) emissions. However, ethanol's lower heating value led to increased fuel consumption at higher blend ratios. The majority of studies indicated that moderate blends, particularly E20 (20% ethanol, 80% gasoline), provide an optimal balance of engine performance, thermal efficiency, and emission reduction. This review emphasises the potential of ethanol–gasoline blends as a transitional solution towards sustainable transport energy systems, while also highlighting challenges related to water miscibility, aldehyde emissions, and the need for engine modifications at high ethanol concentrations.

Keywords: *Ethanol gasoline blend, Spark ignition engine, Fuel properties, Engine performance, Emissions, Renewable fuels.*

1. Introduction

The transportation sector consumes over 60% of global petroleum, making it a major contributor to fossil fuel depletion and environmental pollution. Gasoline, the dominant fuel for spark ignition (SI) engines, releases large quantities of carbon monoxide (CO), unburned hydrocarbons (HC), nitrogen oxides (NOx), and greenhouse gases (GHGs) upon combustion. To mitigate these issues, researchers and policymakers have emphasised the partial substitution of gasoline with renewable fuels. Ethanol (C_2H_5OH), a simple alcohol derived from agricultural biomass and waste products, has gained worldwide attention as a gasoline substitute due to its renewable nature, oxygen content, high octane rating, and potential to reduce emissions. Its molecular structure contains oxygen, which promotes cleaner combustion. Countries like Brazil and the United States have already implemented large-scale ethanol–gasoline blending programs, with blends ranging from E10 (10% ethanol, 90% gasoline) to E85 (85% ethanol, 15% gasoline).

Despite these advantages, ethanol blending also poses challenges. Ethanol has lower energy density than gasoline, leading to increased fuel consumption. It is hygroscopic, which means it absorbs water and can cause phase separation in blends. It can also be corrosive to certain engine components. Understanding these trade-offs requires systematic evaluation.

This review integrates six research studies, each focusing on different aspects of ethanol–gasoline blends, to provide a comprehensive picture of their effect on fuel properties, engine performance, and exhaust emissions.

2. Research Methodology

This review paper adopts a systematic literature review methodology to analyze the impact of ethanol–gasoline blends on spark ignition (SI) engine performance, fuel properties, and emission characteristics. The methodology consisted of the following steps:

1. Selection of Literature
   - Five primary experimental studies and several supporting articles were selected, focusing on ethanol–gasoline blends ranging from low percentages (E5–E10) to higher ratios (E60 and above).
   - Sources included peer-reviewed journals such as *Renewable Energy*, *Energy Conversion and Management*, *Arabian Journal for Science and Engineering*, and institutional engineering journals.
2. Screening and Categorization
   - Studies were screened based on their relevance to three key domains:
     (i) Fuel properties (density, viscosity, calorific value, octane number, miscibility).
     (ii) Engine performance (brake power, torque, brake thermal efficiency, brake-specific fuel consumption).
     (iii) Emission characteristics (CO, CO_2, HC, NOx, aldehydes).
3. Comparative Analysis
   - Data from the selected studies were compared and synthesized to identify common trends and differences.
   - Special attention was given to identifying the optimal blend ratios (such as E20) that consistently provided the best balance of engine performance and emission reduction.
4. Interpretation of Findings
   - Each study's results were analyzed in context, highlighting how ethanol's oxygen content improves combustion but its lower heating value increases fuel consumption.
   - The analysis further explored engine modification requirements for higher blends and their implications for real-world applications.
5. Synthesis and Conclusion
   - Finally, the reviewed evidence was synthesized into broader conclusions about ethanol's viability as a renewable alternative to gasoline.
   - The methodology ensured objectivity by comparing results across multiple studies rather than relying on a single source.

3. Theory and Calculation

The theoretical basis for evaluating ethanol–gasoline blends lies in the fundamental thermodynamic and combustion properties of ethanol compared with gasoline. Ethanol (C_2H_5OH) is an oxygenated fuel with a high octane number, lower heating value, and high latent heat of vaporisation, all of which influence combustion processes and engine performance.

3.1 Effect of Ethanol on Fuel Properties

3.1.1 Density and Viscosity: Ethanol addition increases the density and kinematic viscosity of blends. For example, blends containing up to 30% ethanol showed a steady increase in viscosity, which affects spray atomization during injection. Although higher viscosity can slightly affect vaporisation, the ethanol's oxygen content compensates by enhancing combustion.

3.1.2 Heating Value and Calorific Content: The lower heating value (LHV) of ethanol (26.8 MJ/kg) is significantly lower than that of gasoline (42–44 MJ/kg). As a result, increasing the ethanol proportion reduces the blend's overall energy density. This is the primary reason why higher blends (E30–E40) often increase specific fuel consumption.

3.1.3 Octane Rating: One of the most significant benefits of ethanol is its high octane number (106–108). Research consistently reports a linear increase in Research Octane Number (RON) with ethanol addition. For instance, E10 can improve RON by nearly 3–4 units, while E20 can raise it by over 6 units. This allows engines to operate at higher compression ratios, improving efficiency.

3.1.4 Flash Point, Vapour Pressure, and Miscibility: Ethanol raises the flash and fire points of blends, making them safer for storage and handling. However, miscibility with water is a challenge. Ethanol's hydrophilic nature can cause phase separation if water contamination occurs, especially at low temperatures. Some studies suggest using stabilisers or redesigning carburettors to overcome this problem.

3.2 Engine Performance with Ethanol–Gasoline Blends

3.2.1 Torque and Brake Power: The impact of ethanol on torque and brake power varies across studies.

- Jekayinfa et al. (2018) observed that torque decreased with higher ethanol content due to reduced energy density.
- Conversely, Al-Hasan (2003) and Rao et al. (2020) found that blends like E20 improved torque and brake power, particularly at mid-speed ranges.

These differences highlight that performance outcomes depend on blend ratio, engine type, and operating conditions.

3.2.2 Brake Thermal Efficiency (BTE): Almost all reviewed studies reported an increase in brake thermal efficiency with ethanol addition. The oxygen in ethanol promotes better combustion, and its high latent heat of vaporisation lowers intake charge temperature, improving volumetric efficiency.

3.2.3 Specific Fuel Consumption (SFC): Ethanol blends generally increase volumetric fuel consumption because of the lower heating value. However, brake-specific fuel consumption (BSFC) often decreases at moderate blends (E15–E25) due to improved combustion efficiency.

3.2.4 Engine Modifications: Low-level blends (≤E20) can typically be used in existing SI engines without modification. High blends (≥E40) may require adjustments such as advancing ignition timing, reinforcing fuel system materials, or redesigning carburetors.

3.3 Emission Characteristics

3.3.1 Carbon Monoxide (CO): Ethanol significantly reduces CO emissions due to its oxygen content, which supports more complete oxidation of carbon. Reductions of up to 40–50% have been reported with E20.

3.3.2 Hydrocarbons (HC): Unburned hydrocarbons decrease with ethanol blends because of enhanced flame propagation. This improves air quality and reduces smog-forming compounds.

3.3.3 Carbon Dioxide (CO_2): Studies consistently report a slight increase in CO_2 with ethanol addition. This reflects more complete combustion rather than increased greenhouse gas impact, as ethanol is renewable and part of the carbon cycle.

3.3.4 Nitrogen Oxides (NOx): The effect on NOx is inconsistent. Some studies reported negligible change, while others found slight increases due to higher in-cylinder temperatures.

3.3.5 Aldehydes: Yüksel & Yüksel (2004) noted increased emissions of acetaldehyde and formaldehyde with ethanol blends. However, these are less environmentally harmful than the polyaromatic hydrocarbons emitted by gasoline.

4. Results and Discussion

- **Comparative Analysis Across Studies**
- **Low blends (E5–E10)**: Perform almost identically to pure gasoline, suitable for unmodified engines.
- **Moderate blends (E15–E25)**: Provide optimal performance, higher thermal efficiency, reduced CO/HC, and manageable fuel consumption. E20 was consistently identified as the best performing blend.
- **High blends (E30–E60)**: Can further reduce emissions but require engine modifications and suffer from reduced energy density, as displayed in Table 1 below.

Table 1: Summary of Experimental Investigations on Ethanol–Gasoline Blends

Author (Year)	Engine Used	Fuel Blends Tested	Key Experimental Parameters	Main Findings
Jekayinfa et al. (2018)	4-stroke SI test rig (TQ Education)	E0, E5, E10, E15, E20, E100	Torque, Brake Power, Brake Thermal Efficiency, Fuel Properties	Torque & brake power decreased with ethanol %; efficiency increased; E20 identified as feasible with modifications.
Yüksel & Yüksel (2004)	Opel Record L, 4-cyl SI engine	60% ethanol + 40% gasoline	Power, Fuel Consumption, CO, CO_2, HC, Aldehydes	New carburetor solved miscibility issue; ethanol blends reduced CO & HC, but increased aldehydes; stable

				operation at high ethanol ratio.
Al-Hasan (2003)	Toyota Tercel-3A, 4-cyl SI engine	E0–E25 (2.5% increments)	Brake Power, Torque, BTE, BSFC, CO, CO_2, HC	Brake power, torque & efficiency improved with ethanol; BSFC decreased at E20; CO & HC reduced, CO_2 increased.
Kheiralla et al. (2011)	4-cyl, 4-stroke SI engine (Blue Nile Univ.)	E0–E35 (5% increments)	Fuel Properties (density, viscosity, flash point, calorific value, RON)	Density & viscosity ↑; calorific value ↓; Octane number ↑ with ethanol; blends up to 30% stable and usable.
Rao et al. (2020).	Honda GX200, 1-cyl, 4-stroke engine	E0, E10, E20, E30, E40	Thermal Efficiency, Mechanical Efficiency, Volumetric Efficiency, Power	E10 close to gasoline; E20 best balance of efficiency & power; E40 better at low speed but needs optimization.
Additional Review Sources	(Literature cited within studies)	Up to E85 (85% ethanol) in other contexts	Emissions, durability, miscibility issues	Low blends (<E20) widely acceptable without modification; higher blends require system adjustments.

5. Conclusions

Ethanol–gasoline blends offer a promising pathway for reducing petroleum dependency and improving combustion quality in SI engines. The reviewed studies demonstrate that ethanol improves octane rating, reduces CO and HC emissions, and enhances brake thermal efficiency. The trade-off lies in increased fuel consumption due to lower heating value and potential issues with water miscibility and aldehyde emissions.

Among the blends studied, E20 consistently emerges as the most favorable, striking a balance between fuel economy, emissions, and performance without requiring significant engine modifications. Ethanol gasoline blends can therefore be regarded as a viable transitional fuel towards sustainable transport energy systems.

Future work should focus on optimizing engine calibration for ethanol blends, addressing long-term material compatibility, and integrating ethanol fuels within broader biofuel policies.

References

[1] Al-Hasan, M. (2003). Effect of ethanol–unleaded gasoline blends on engine performance and exhaust emission. *Energy conversion and management*, *44*(9), 1547-1561.

[2] Jekayinfa, S. O., Olorunmaiye, J. A., Ogunsola, A. D., Soji-Adekunle, A. R., & Ilori Olutosin, O. (2018). Evaluation of petrol and ethanol mixture as a fuel for gasoline engines. *Adeleke University Journal of Engineering and Technology*, *1*(1), 139-148.

[3] Kheiralla, A. F., El-Awad, M., Hassan, M. Y., Hussen, M. A., & Osman, H. I. (2011). Effect of ethanol− gasoline blends on fuel properties characteristics of spark ignition engines. *University Of Khartoum Engineering Journal*, *1*(2).

[4] Rao, R. N., Silitonga, A. S., Shamsuddin, A. H., Milano, J., Riayatsyah, T. M. I., Sebayang, A. H., ... & Sembiring, R. W. (2020). Effect of ethanol and gasoline blending on the performance of a stationary small single cylinder engine. *Arabian Journal for Science and Engineering*, *45*(7), 5793-5802.

[5] Yüksel, F., & Yüksel, B. (2004). The use of ethanol–gasoline blend as a fuel in an SI engine. *Renewable energy*, *29*(7), 1181-1191.