Performance Evaluation of Ethanol-Blended Petrol on a Two-Wheeler Spark-Ignition Engine

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Abstract

Depletion of fossil fuels, volatile petrol prices and vehicular pollution have increased interest in renewable fuels for spark-ignition (SI) engines. Ethanol, a renewable oxygenated fuel with a high octane rating, can be blended with petrol, but its lower calorific value and material compatibility issues complicate its use. This paper experimentally evaluates ethanol–petrol blends from E0 (pure petrol) to E100 in a four-stroke, single-cylinder, air-cooled two-wheeler engine (Hero Honda Passion Plus). Blends were prepared in 50 mL volumes in 10% increments. Mileage, fuel consumption, starting behaviour, throttle response and smoothness were recorded, and CO, HC, CO_2 and O_2 were measured with an exhaust gas analyser. Mileage fell steadily with ethanol content, from 30.5 km/L (E0) to 29.8 km/L (E10), 29.0 km/L (E20) and 21.1 km/L (E100), a 30.8% reduction at E100. CO fell from 0.16% to 0.03% (about 81%). HC fell from 196.5 ppm to a minimum of 112 ppm at E80 before rising at E90 and E100. CO_2 and O_2 rose modestly.

Starting and running quality degraded above E30 and became poor above E70. E10–E20 gave the best balance, with under 5% mileage loss, a 25–40% CO reduction and no drivability penalty. Because the tests were short, single-run and carried out on an unmodified engine, the findings are indicative and should be confirmed by repeated, dynamometer-based and durability testing.

Keywords: ethanol–petrol blends, two-wheeler, spark-ignition engine, mileage, exhaust emissions, E20

1. Introduction

Two-wheelers are a dominant form of daily transport, especially in developing countries, so their fuel economy and exhaust emissions have a large cumulative effect on energy demand and air quality. Petrol combustion releases carbon monoxide (CO), unburnt hydrocarbons (HC) and carbon dioxide (CO_2), which contribute to air pollution and climate change. Reducing dependence on petroleum without major changes to existing vehicles has therefore become a research priority.

Ethanol can be produced by fermenting sugar- and starch-rich feedstocks such as sugarcane and corn, or from other biomass. It has a high octane rating, which improves knock resistance, and contains oxygen, which can promote more complete oxidation of fuel. Blends are denoted Ex, where x is the ethanol percentage by volume. However, ethanol has a lower volumetric energy content than petrol, so more fuel is needed for the same energy, and its high latent heat of vaporisation and affinity for water can hurt cold starting and attack some elastomers, plastics and metals.

These competing effects make the best blend engine-specific, and published work often relies on dynamometer tests or particular vehicle configurations that may not represent commercial two-wheelers. This study compares blends from E0 to E100 in a common motorcycle engine under consistent conditions, and assesses fuel economy, emissions and engine behaviour together.

Objectives

1. Evaluate the performance of a two-wheeler SI engine on E0–E100 blends.
2. Measure and compare fuel consumption and mileage for each blend.
3. Analyse CO, HC, CO_2 and O_2 in the exhaust.
4. Observe starting behaviour, throttle response, smoothness and stability.
5. Compare all blends against conventional petrol and identify a suitable blend.

2. Literature Review

Previous studies show that ethanol blending generally lowers CO and HC emissions in SI engines. Lee et al. (2022) tested E0, E30, E50, E85 and E100 in a motorcycle engine and reported that brake power rose with ethanol content, with CO, HC and NOx falling relative to gasoline. Di Gaetano et al. (2023) used calibrated 1D and 3D CFD simulation of a single-cylinder motorcycle engine and found E85 needed higher fuel flow and optimised spark timing to match E5 performance, while improving combustion efficiency and reducing CO and HC but slightly raising NO. Dinh et al. (2020) reported performance gains and emission reductions in used carburettor motorcycles on flex-fuel gasoline–ethanol blends, and Kaya (2022) examined ethanol–gasoline blends in a two-stroke uniflow engine. Work on alcohol blends in carburetted motorcycles (Lutanto and Wijaya, 2024, using methanol) likewise found lower HC and CO.

Conversely, Rosdi and Erdiwansyah (2025) found that ethanol and fuel-oil blends reduced brake power and thermal efficiency and increased brake-specific fuel consumption despite lowering NOx, CO and HC. Reviews of the Indian E20 programme highlight reduced crude imports and lower greenhouse gas emissions, but also calibration and material compatibility problems in older vehicles, particularly degradation of non-metallic components. Wan et al. (2020) and related corrosion studies show ethanol can affect stainless steel and fuel-pump surfaces under some conditions.

Research gap. Results depend strongly on blend ratio, compression ratio, air–fuel ratio, ignition timing and fuel-system design, so conclusions from one engine cannot be transferred directly to another. There are few simple, reproducible comparisons covering the full E0–E100 range in a widely used commuter motorcycle, reporting mileage, emissions and drivability together. This work addresses that gap.

3. Methodology

3.1 Test engine

The test vehicle was a Hero Honda Passion Plus motorcycle with a four-stroke, single-cylinder, air-cooled spark-ignition engine. The same engine was used for every fuel, and its ignition system, spark plug, fuel supply, air filter and exhaust were inspected before testing. Petrol was run first to confirm normal starting, stable idle and throttle response and to establish baseline values.

3.2 Fuel preparation

Blends were prepared by volume using a graduated measuring vessel, in a fixed total of 50 mL per sample (Table 1). Samples were labelled and stored in sealed, compatible containers to limit evaporation and cross-contamination. The fuel line was purged between blends.

Table 1. Composition of 50 mL test samples

Blend	Ethanol (mL)	Petrol (mL)
E0	0	50
E10	5	45
E20	10	40
E30	15	35
E40	20	30
E50	25	25
E60	30	20
E70	35	15
E80	40	10
E90	45	5
E100	50	0

3.3 Instrumentation

A measuring tape or distance meter recorded distance travelled, a stopwatch recorded run time, a digital tachometer was available for engine speed, and an exhaust gas analyser (PUC-type) measured CO, HC, CO
2
and O . Safety equipment (goggles, chemical-resistant gloves, lab coat) and a fire extinguisher were kept at
2
hand, and all work was done in a ventilated area away from ignition sources.

The experimental arrangement is shown in Fig. 1. Ethanol (500 mL bottle) was measured out with a 100 mL graduated beaker and mixed with petrol to the required ratio. Each 50 mL sample was held in an inverted bottle fitted with a filler pipe, which supplied fuel directly to the engine in place of the standard tank feed during the test run.

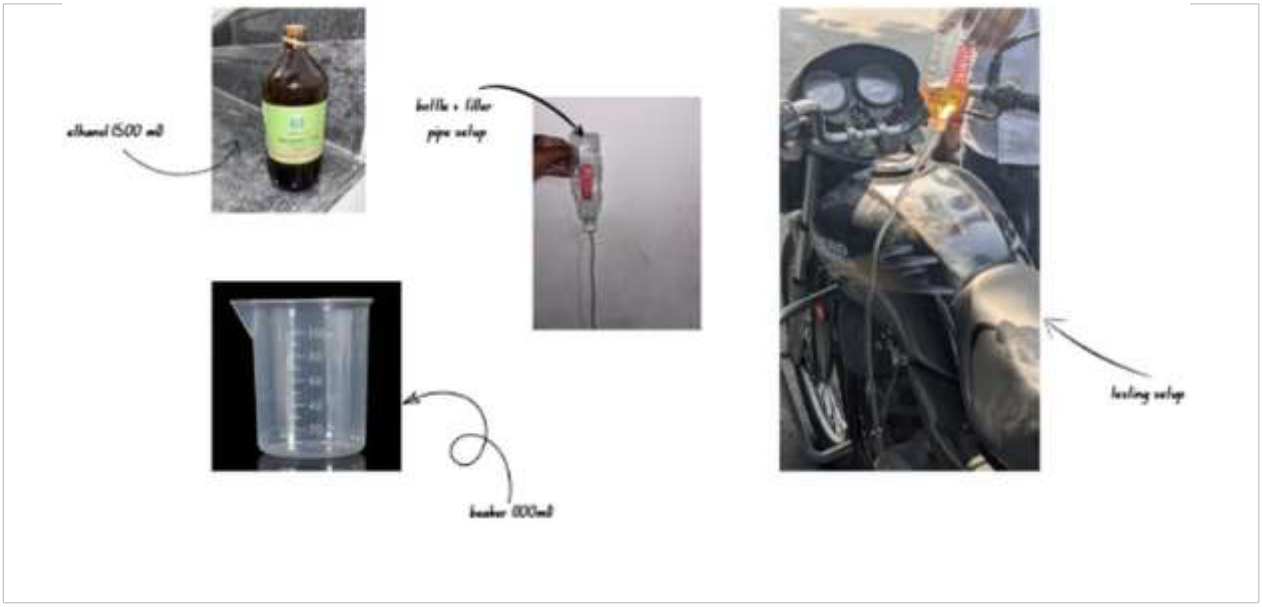


Fig. 1. Experimental setup: ethanol (500 mL) used for blending, 100 mL measuring beaker, bottle and filler-pipe arrangement for supplying the 50 mL fuel sample, and the complete testing setup on the Hero Honda Passion Plus motorcycle.

3.4 Test procedure

The engine was warmed to a stable temperature before each run. For each blend, the 50 mL sample was supplied to the engine, and the distance travelled on that quantity was recorded. Mileage was calculated as:

Mileage (km/L) = Distance travelled (km) ÷ Fuel consumed (L)

For example, for petrol, 1.525 km on 0.050 L gives 30.5 km/L. Fuel consumption in L/100 km is 100 ÷ mileage, and the percentage change relative to petrol is (blend value − E0 value) ÷ E0 value × 100. Exhaust gas readings were taken after the engine and analyser stabilised. Starting, throttle response and smoothness were rated qualitatively on a consistent scale (e.g. easy to very hard; excellent to very poor; very smooth to very rough). Results were tabulated and plotted against ethanol percentage with petrol as the baseline.

4. Results

Table 2 summarises engine behaviour, exhaust emissions and mileage for every blend. Fig. 2 shows the on-road test and the exhaust measurement from which these values were obtained.

Table 2. Engine behaviour, emissions and mileage for E0–E100

Blend	Starting	Response	Smoothness	CO (%)	HC (ppm)	CO_2	O_2	Mileage (km/L)	Fuel cons. (L/100 km)	Fuel per 1.5 km (mL)
E0	Easy	Excellent	Very smooth	0.16	196.5	11.0	2.0	30.5	3.28	49
E10	Easy	Excellent	Very smooth	0.14	183	11.1	2.2	29.8	3.36	50
E20	Easy	Very good	Smooth	0.12	170	11.2	2.3	29.0	3.45	52
E30	Slightly	Very good	Smooth	0.10	158	11.3	2.5	28.2	3.55	53
E40	Slightly delayed	Good	Smooth	0.09	144	11.4	2.6	27.2	3.68	55
E50	Delayed	Good	Slightly rough	0.08	130	11.5	2.8	26.3	3.80	57
E60	Delayed	Fair	Slightly rough	0.07	122	11.6	3.0	25.4	3.94	59
E70	Hard	Fair	Rough	0.06	115	11.6	3.3	24.4	4.10	62
E80	Hard	Poor	Rough	0.05	112	11.5	3.6	23.4	4.27	64
E90	Very hard	Poor	Very rough	0.04	118	11.4	4.0	22.3	4.48	67
E100	Very hard	Very poor	Very rough	0.03	128	11.3	4.4	21.1	4.74	71

delayed



Fig. 2. Performance testing: (a) road test of the motorcycle on the test fuel, (b) instrument cluster used to read the distance covered, and (c) exhaust gas measurement at a PUC (pollution-under-control) station.

4.1 Mileage and fuel consumption

Mileage decreased monotonically with ethanol content (Table 2). Relative to petrol (30.5 km/L), E10 gave 29.8 km/L (−2.3%) and E20 29.0 km/L (−4.9%). The loss grew to −13.1% at E50 (26.3 km/L), −23.3% at E80 (23.4 km/L) and −30.8% at E100 (21.1 km/L). Fuel consumption rose correspondingly from 3.28 to 4.74 L/100 km, and fuel needed to cover 1.5 km rose from 49 mL to 71 mL. This trend matches the lower volumetric energy content of ethanol.

4.2 Exhaust emissions

CO fell continuously from 0.16% (E0) to 0.03% (E100), a maximum reduction of about 81%. E10 and E20 gave reductions of about 12.5% and 25% respectively. HC fell from 196.5 ppm to a minimum of 112 ppm at E80 (about 43% lower) and then rose to 118 ppm at E90 and 128 ppm at E100, although every blend remained below petrol. CO_2 rose slightly from 11.0% to a peak of 11.6% at E60–E70 and eased to 11.3% at E100. O_2 increased steadily from 2.0%

to 4.4%.

4.3 Engine behaviour

Up to E20 the engine started easily and ran smoothly, with response rated excellent to very good. From E30 starting became slightly delayed and from E50 delayed with slight roughness. From E70 starting was hard and running rough, and E90–E100 were very hard to start with very rough running and very poor response.

4.4 Material compatibility

The test design included exposure of metal, rubber and plastic specimens to the blends, with inspection for discolouration, swelling, softening, cracking and corrosion and measurement of mass and dimensional change. Short-term specimen exposure gives only preliminary evidence and cannot establish long-term fuel-system durability.

5. Discussion

Fuel economy. The steady mileage decline is explained by ethanol's lower calorific value: a larger fuel volume is needed for the same energy. The falling mileage together with rising fuel-per-distance is consistent with the literature, and the 30.8% penalty at E100 shows that neat ethanol is uneconomic in an unmodified commuter engine.

Emissions. The strong CO reduction is consistent with ethanol's oxygen content, which leans the effective mixture and promotes more complete oxidation. The HC minimum at E80 followed by an increase at E90–E100 coincides with the onset of very poor starting and rough running, suggesting that misfire or incomplete combustion under an uncalibrated carburettor offsets the oxygen benefit at very high ethanol fractions. The rising O_2 readings support the view that the blends leaned the mixture, since ethanol requires less air per unit fuel and the carburettor was not retuned. The modest CO2changes should not be read as a change in net greenhouse-gas impact, because the renewable origin and production pathway of ethanol determine life-cycle emissions. NOx was not measured; it is a significant omission because leaner combustion can raise NOx.

Drivability. Deterioration in starting and smoothness from E30 upward reflects ethanol's higher latent heat and lower volatility, which hamper mixture preparation, together with leaning in a carburetted engine. This is consistent with reports that fuel injection systems cope with ethanol better than uncalibrated carburettors.

Choice of blend. The lowest value of one pollutant does not identify the best fuel. E80 gave the lowest HC but had a 23% mileage loss, hard starting and rough running. E10 and E20 gave a CO reduction of 12.5–25%, an HC reduction of 7–13%, mileage loss under 5% and no drivability penalty, and are therefore the most practical candidates. This agrees with the national direction towards E20 and with studies recommending low-level blends for existing vehicles.

Limitations. (i) Mileage was derived from distance covered on a 50 mL sample (about 1.5 km), so small errors in fuel measurement, warm-up or riding conditions are magnified; the sample volume should be confirmed as consumed. (ii) Results appear to be from single runs, with no repeated trials or uncertainty analysis. (iii) Qualitative ratings are subjective. (iv) The engine was not modified or recalibrated, and engine power and torque were not measured on a dynamometer. (v) Water content and purity of the ethanol were not characterised. (vi) Operation on E50–E100 in a standard engine and fuel system risks seal, hose and corrosion damage and should only be performed with compatible equipment and appropriate safety precautions. The results apply to the tested engine and conditions.

6. Conclusion

Increasing ethanol content in petrol lowered CO by up to about 81% and reduced HC in all blends (minimum at E80), but reduced mileage from 30.5 km/L to 21.1 km/L at E100 and progressively impaired starting and smoothness in an unmodified two-wheeler engine. Low blends of E10–E20 offered the best compromise, with under 5% mileage loss, meaningful CO and HC reduction and normal operation. High blends require engine recalibration and ethanol-compatible materials. Future work should include repeated mileage trials with accurate fuel-consumption measurement, dynamometer-based power and torque tests, NOx measurement, engine optimisation (air–fuel ratio, ignition timing, fuel injection), long-term durability and material compatibility studies, and real-world road trials.

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