Articles

Consumption study using blends of additives and local fuels in combined cycles at 2800 meters above sea level.

Estudio de consumo usando mezclas de aditivos y combustibles locales en ciclos combinados a 2800 msnm

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ABSTRACT
The increase in the consumption of low octane fuel in Ecuador has meant a loss of performance in engines, to solve this problem a higher octane is needed due to new technologies, taking into account the increase in gasoline prices, it has been decided to use different additives, through this research the influence that additives have on the fuel consumption of vehicles was determined through an analysis in real conditions of the variations in fuel efficiency, using the fuel that is distributed locally and additives that are offered in the DMQ, The quantitative method was implemented with a vehicle of Korean origin with which several combined cycle route tests were carried out using two types of fuel and with the mixture of different additives, an external tank was placed in order to have an exact measurement taking into account the EPA FTP 75 regulations and what the manufacturer's manual says with the geography in which we are located, it was determined that

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gasoline 6 with additive 2 obtained a significant saving compared to the other tests carried out where a great variation was not obtained in order to determine a lower consumption both in positive slopes and in negative slopes.
Keywords: Consumption, Additives, Prices, Gasoline.

RESUMEN

El incremento en el consumo de combustible de bajo octanaje en el Ecuador ha significado una pérdida de rendimiento en los motores, para resolver este problema se necesita un mayor octanaje debido a las nuevas tecnologías, tomando en cuenta el aumento de precios en la gasolina se ha optado por utilizar diferentes aditivos, mediante la presente investigación se determinó la influencia que tienen los aditivos en el consumo de combustible de los vehículos a través de un análisis en condiciones reales de las variaciones en el rendimiento de combustible, utilizando el combustible que se distribuye a nivel local y aditivos que se ofertan en el DMQ, se implementó el método cuantitativo con un vehículo de procedencia coreana con el cual se efectuó diversas pruebas de ruta de ciclo combinado utilizando dos tipos de combustible y con la mezcla de diferentes aditivos, se colocó un tanque externo para así tener una medición exacta tomando en cuenta la normativa EPA FTP 75 y lo que dice el manual del fabricante con la geografía a la que nos encontramos, se determinó que la gasolina 6 con el aditivo 2 obtuvo un ahorro significativo a comparación de las demás pruebas realizadas donde no se obtuvo una gran variación para poder determinar un menor consumo tanto en pendientes positivas como en pendientes negativas.
Palabras clave: Consumo, Aditivos, Precios, Gasolina.

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INTRODUCTION

Nationally, there is a large increase in SUV vehicles which means an increase in fuel consumption, this type of vehicle brings with it new engine technologies, this implies that a higher octane fuel is needed to avoid damage to engine parts. In Ecuador, "in the first half of 2022, the demand for super gasoline fell 20%, this happened the same in the period of 2021. The increase in the price of this fuel drives drivers to migrate to other gasolines". (Serrano, 2022). The use of this type of low octane fuels has an impact on engine performance variation and also on an increase in environmental problems. Different alternatives have been tested in search of reducing the affectation to the engines due to the low octane rating of gasoline, one of them is the use of additives. In the present investigation it was analyzed if the additives improve combustion, reduce fuel consumption and contaminating emissions, without affecting the mechanical components, and determine which is the adequate percentage, so that they are functional, comparing with a fuel that is distributed at a local level.

This research determined the influence that additives have on the fuel consumption of vehicles, in order to establish through analysis under real conditions the variations in the fuel consumption of engines using the fuel that is distributed locally and the implementation of additives that are offered in the DMQ through a comparative study. In the first instance, the most sold vehicles at the local level were established in order to carry out the research. Subsequently, the different types of local additives were analyzed, with their technical data sheets and through field research to determine the most viable ones to improve engine performance. Once the vehicles and additives were selected, dynamic tests were carried out applying EPA FTP 75 regulations with different types of fuels without additives and with additive concentrations, establishing specific driving routes and under real conditions. Finally, a comparison was made of the variation in fuel consumption with the use of local fuels and with the implementation of additives marketed in the DMQ, to determine whether there is a variation in fuel consumption and pollutant emissions in laboratory and road tests.

"Tracking the difference in fuel consumption between official or manual and real-world measurements is a topic of great interest to policy makers and researchers worldwide" (Ktistakis et al., 2022). In addition, "concerns about the environmental and energy crisis worldwide have drawn attention to the reduction of fuel consumption of internal combustion engines" (Karnaukhov et al., 2022). To measure or determine fuel consumption, indirect tests exist, mainly the carbon balance method, however, performing this type of test presents requirements that are difficult to follow (Fu et al., 2021). Most of the fuel and lubricants are imported from other countries. The issue of fuel economy is relevant (Troyanovskaya, 2022). Fuel consumption of the transport sector accounts for about 30% of total greenhouse gas emissions (Alshayeb et al., 2021). Vehicles with new technologies are those that require better quality fuel to guarantee the useful life of the engines. Currently, in the Ecuadorian market, super gasoline is the highest quality with 92 octane (Serrano, 2022). The research was carried out by performing fuel consumption tests with different percentages of additives and fuels marketed nationally, which are, consumption tests with Super and Extra gasoline, the tests were conducted in two modes, one of them consumption tests on the road in ideal driving conditions, for which a driving model was applied both in urban and highway or extra-urban route applying the EPA FTP 75 regulations to establish fuel consumption.

Gasolines are a mixture of hydrocarbons obtained by fractional distillation of crude oil, whose properties of volatility, flammability and octane rating provide the vehicle's engine with easy cold starting and maximum power during acceleration.

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"In 1990, Super gasoline was introduced in the national market, a gasoline that according to Ecuadorian regulations has 92 octane, as part of a requirement for new internal combustion engine technologies that have a high compression ratio. Also, as a contribution to the protection of the environment, since it does not contain tetraethyl lead as an antiknock agent, a substance that causes severe damage to health." (Alexandra Aguilar, 2016)

Octane rating

The octane number is the anti-knock characteristic of gasoline, i.e. how easy the fuel is to ignite. The anti-knock index is the sum of the octane number obtained by the Research method and the octane number obtained by the Motor method. (Plaza, 2020)

Eq. [1]

$$IAD = \frac{MON + RON}{2}$$

Where (IAD) is the anti-knock index, (MON) motor octane number, (RON) is the Research octane number.

Fuel characteristics

The physical characteristics of a fuel are those that affect its ability to form a gaseous mixture of fuel and air suitable for the type of engine in which it is to be used; they also influence its storage, transportation and sales criteria. The chemical characteristics, on the other hand, affect its capacity and behavior during combustion and also its safety during storage. (Flores, 2004)

Table 1. *Physicochemical characteristics of fuels*

Feature	Unit	Extra	Super
Octane number	RON	87	92
Specific gravity	Kg/ cm³	0,73	0,76
Calorific value	KJ/Kg	47901,51	46201,779
Density	Kg/m³	680	725
Distillation 10% Distillation	°C	70	70
Distillation 50% Distillation	°C	121	121
Distillation 90%	°C	189	190
Final point	°C	215	220
Distillation residue	%	2	2
Vapor pressure	kPa	56	60
Gum content	mg/100 cm³	3	4
Sulfur content, Ws	%	0,075	0,1
Oxidation stability	min.	240	240
Oxygen content	%	2,7	2,7

Note: Authors based **on** (INEC, 2002)

Additives

Additives, octane boosters are both solid and non-solid elements elaborated with physicochemical characteristics specific to each manufacturer with the purpose of improving the performance and benefits of fuels, such as cleaning, power increase and mainly fuel consumption, which was defined with greater certainty through the research.

Table 2. *Physical and chemical characteristics of the additives*

Feature	Value
Aggregation state	Liquid
ASTM Color	0,5
Kinematic Viscosity	1.633mm2/s
Flash point	67 degrees Celsius
Density	0.8192kg/l

Note: Authors based on (Juan Rocha, 2015)

Fuel consumption

To determine the consumption with different fuels that are marketed locally, the following formula must be taken into consideration. where (*L*) is the consumption in lt/km, (*V*) average speed in km/h and *(a, b, c and d*) are the vehicle parameters indicated by the manufacturer.

Eq. [2]

$$\boxed{L = a + b * V + c * V^2 + d * V^3}$$

Where

(L) is the consumption in lt/km,

(V) average speed in km/h and

(a, b, c and d) are the vehicle parameters and are given by the manufacturer.

Another way to calculate fuel consumption is by the following formula:

Eq. [3]

$$\boxed{Fc = a_0 + \frac{a_1}{V} + a_2V^2 + a_3R + a_4F + a_5IRI}$$

Where (Fc) is fuel consumption lt/100km, (V) is vehicle speed km/h, (R) average road uphill m/km, (F) average road downhill m/km, (IRI) international regularity index and (a_I) model parameters.

Poor and rich mix

Rich blend has a higher volume of gasoline than air and a lower ratio of 14.7:1 with higher fuel consumption and more pollutant gases produced.

Lean mixtures have a higher air volume and a higher ratio of 14.7:1 and are required under the following conditions.

Table 3. *Type of mixtures and their characteristics*

Rich mix	Poor Blend
Starting the engine	Motor in stable speed
Accelerating	Saves fuel
More engine power	May have rattling

Note: Authors

Polluting gases

Exhaust gases are produced by the combustion of fuel. It includes a wide range of pollutants such as: carbon monoxide and dioxide, hydrocarbons, nitrogen oxides and particulates. The amount of tailpipe emissions depends on the characteristics of the car, technology and emission control system; heavier cars.

A gasoline vehicle generally consumes approximately 6 liters per 100 kilometers in order to calculate the CO2 generated per kilometer by multiplying 2392 grams (coefficient) by the 6 liters and dividing by 100 km.

Table 4. *Pollutant emissions generated by gasoline-powered vehicles*

Type of emissions	Pollutants emitted
Exhaust pipe	Hydrocarbons, carbon monoxide, nitrogen oxide, carbon dioxide, sulfur dioxide, lead
Evaporatives	Hydrocarbons

Note: Authors based on (Camacho, 2009)

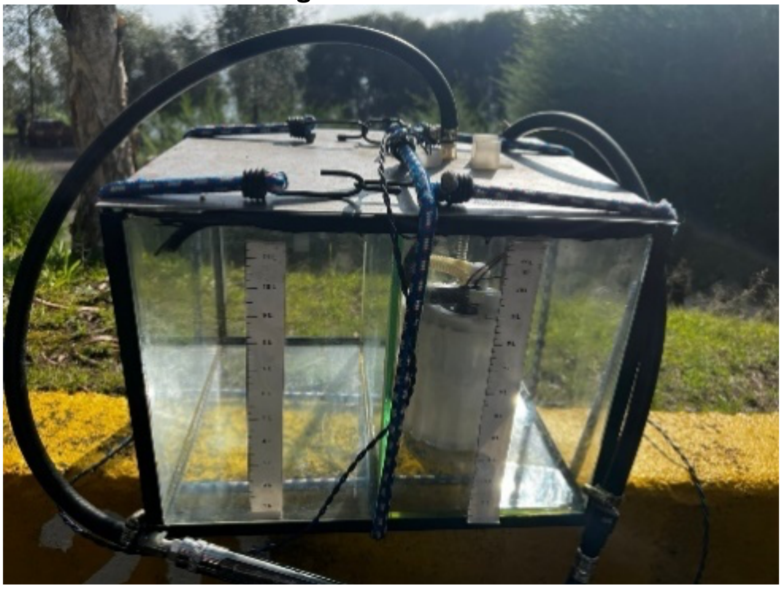
MATERIALS AND METHODS

The method applied in the research was the quantitative experimental method, because through this method numerical data are obtained to prove or disprove a thesis, this was the purpose of the research, within the main variables, the altitude at which the tests were conducted was determined, in this case they were carried out in the city of Quito with an altitude of 2800 meters above sea level, the vehicle used was a car of Korean origin, it is a medium range vehicle in Ecuador according to the 2021 yearbook of the AEADE. Another variable determined was the gasoline to be used, in this case gasoline marketed locally was used (Extra and Super gasoline). The additives used were determined according to their popularity in the local environment (national, European and American respectively).

External storage tank

The fuel tank was made with glass materials and glue resistant to different fuels to avoid fuel leaks during the tests, the tank had a maximum capacity of 24 liters divided into 2 sections for the established routes. An original fuel pump of the vehicle was used to have the same fuel pressure and not vary the fuel performance, the pump was connected directly to the piping of the fuel supply system.

Figure 1: Fuel tank



Test vehicle

The vehicle to perform the tests is a car of Korean origin, this is a mid-range suv vehicle at national level according to the AEADE, taking into account the correct operation of the engine and preventive maintenance to obtain a good performance of the same during the tests, also the vehicle meets the emission standards established by the INEN 2204 regulations.

Figure 2: Test vehicle

The main technical specifications of the test vehicle were detailed in the following table.

Table 5. *Technical specifications of the test vehicle*

Technical specifications	
Engine	1.999L
Torque(ps/rpm)	154/6200
Power(hp/rpm)	114/5200
Compression ratio	10.3: 1
Transmission	5-speed manual

Note: Hyundai Ecuador

Fuels

There are 3 fuels offered at the national level, one of the most sold at the national level is Extra because it is more desirable due to its price, but vehicles with new technologies need Super fuel. In the present investigation, Super and Extra fuels were used, including additives.

Table 6. *Fuel characteristics*

Feature	Extra	Super
Octane rating	87	92
Price	$2,40	$5,20

Note: Authors

Additives

Through a field investigation, the most commercialized additives at the local level were established. The octane boosters are imported and distributed by different companies in the country, whose characteristics and ideal proportions according to the technical data sheets provided by the manufacturers are detailed in Table 7.

Table 7. *Technical specifications of additives*

Specifications	United States	Germany	Ecuador
Engine	Gasoline	Gasoline	Gasoline
Volume	148 ml	500 ml	125 ml
Octane rating increase	3	3	3
Recommended use	1 additive per tank up to 16 gallons	1 additive per tank up to 13 gallons	1 additive per tank up to 16 gallons

Note: Authors based on (Bardahl, n.d.), (Mannol, n.d.), (Qualco, n.d.)

Measuring equipment

The tests were carried out in a millimeter tank, built with a capacity of 6 gallons or 24 liters of fuel and therefore installed at the rear of the vehicle to monitor consumption and data collection.

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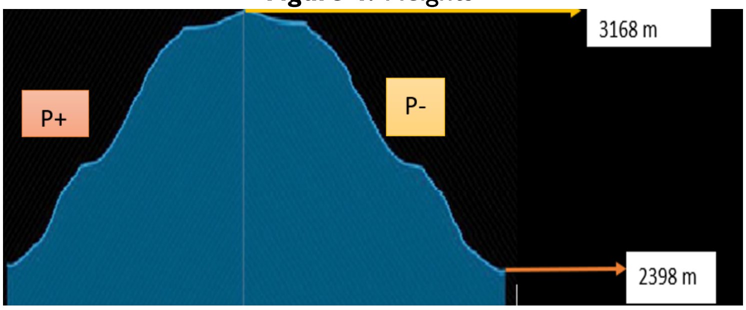
Figure 3: Fuel Tank

Altitude during tests

To measure the heights during the tests, the altimeter application altimeter was used, which is available in the Apple app store, where it was observed that the maximum height during the tests was 3169 meters above sea level, while the minimum height of the route was 2396 meters above sea level, with a difference of 773 meters in height.

Figure 4: Heights

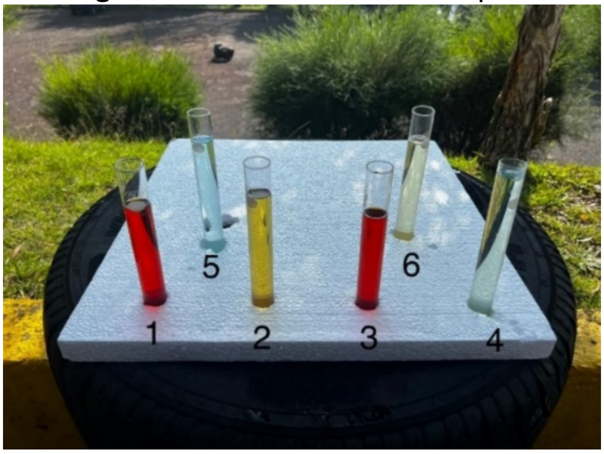


Fuel and additive samples

Figure 5 shows the additive samples, which are shown in the first three test tubes, as well as the fuels used for the study, whose color characteristics are detailed below. It should be noted that all the fuels were purchased at the same service station to avoid variations in the results.

1. Domestic additive
2. European additive
3. American additive
4. Super-Extra Blend
5. Extra Gasoline
6. Super Gasoline

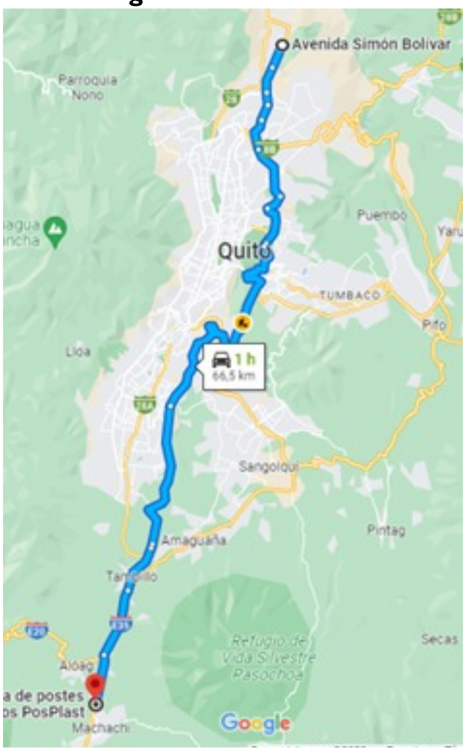
Figure 5: Fuels and Additives Samples



Test site

The tests were conducted with a route of 66.4 kilometers, which begins halfway around the world on Simon Bolivar Avenue and ends in the city of Machachi, which is a route where it can be maintained at a constant speed and without traffic with significant consumption, this route was determined, based on a field investigation, where it was found that Simon Bolivar Avenue, was one of the busiest on trips to the highlands of the country.

Figure 6: Test route



Note: Google Maps

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Regulations
EPA FTP 75
The EPA Urban Driving Schedule (UDDS) is commonly referred to as "LA4" or "the city test" and represents city driving conditions. It is used for light vehicle testing. UN/ECE Regulation 53 refers to the EPA UDDS as the "Test equivalent to the Type I test (emissions verification after a cold start)." (Us Epa, O, n.d.)

RESULTS

Input data

The route for the tests was established as described in the materials and methods, through the application of the regulations that indicate the percentage of acceleration, thus generating consumption without significant variations between each of the tests carried out, in addition all the tests were performed with the same vehicle driver, so the accelerations, speed and test time were similar in all the case studies.

Table 9. *Test variables*

Variable	P1	P2	
Earrings	3168	2398	msnm
Length	66,3	66,3	Km
Temperature	8	8	°C
Fuel	S/E	S/E	
Additives	A1, A2, A3	A1, A2, A3	
Regulations	FTP-75	FTP-75	
Schedule	11	11	p.m.
Relative humidity	81	81	%
Average speed	60	60	km/h
% of additive mix	10	10	%

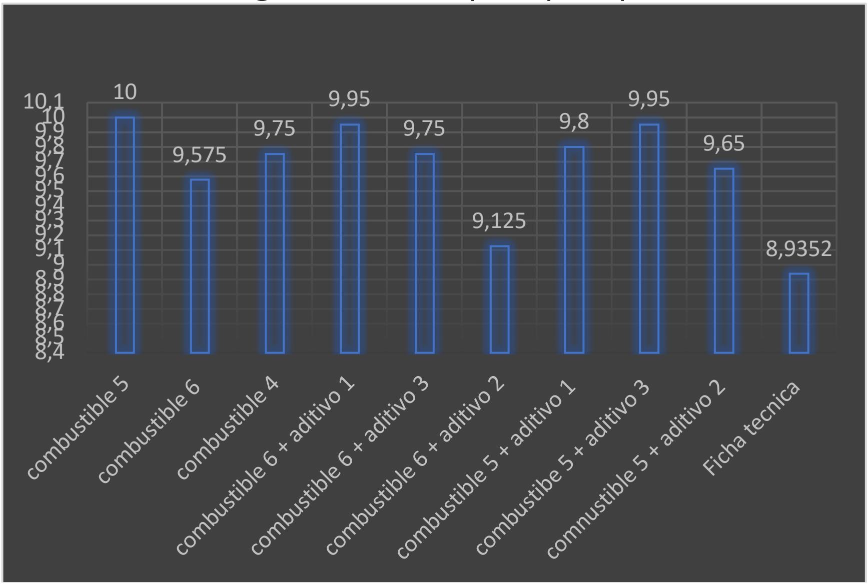
Note: Authors

The variable data established in Table 9 were taken during the tests, whose values were standardized for all the tests performed.

Individual results

The results are based on the use of the three additives, in a percentage of 10% for every 8 liters of fuel. Once the tests were carried out, it was determined that the data were similar in the negative slope condition as well as in the positive slope condition.

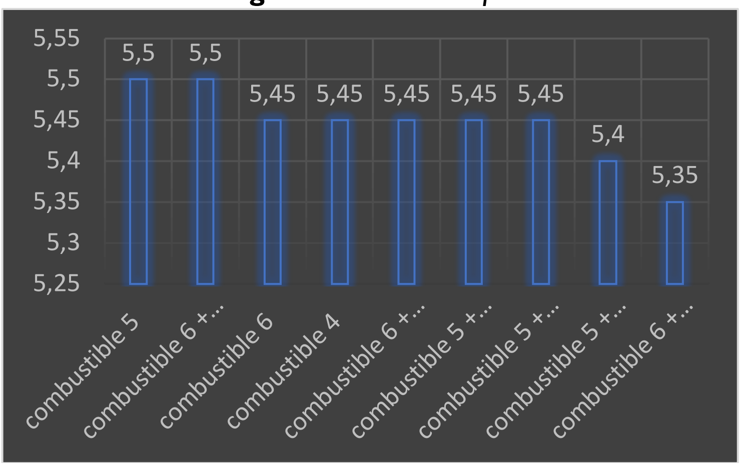
Figure 7: Consumption per lap



Comparison of results

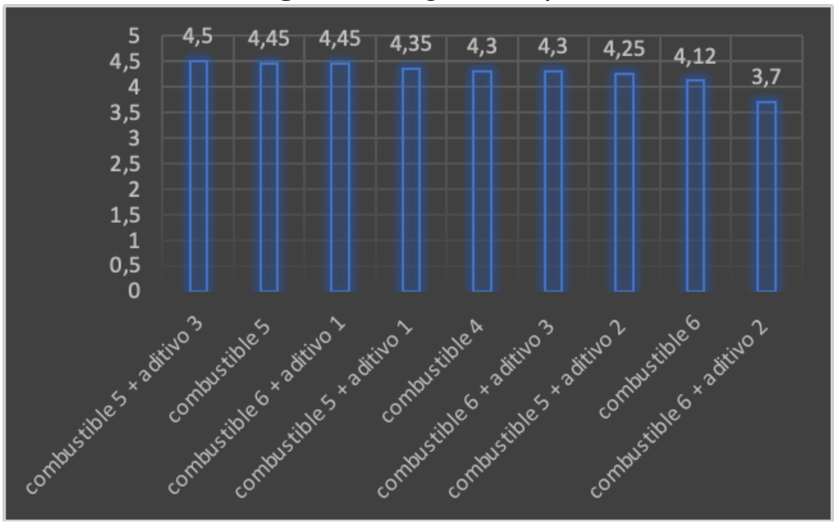
In the results of consumption per lap it was observed that with gasoline 5 the highest consumption was obtained with a result of 10 liters, where the lowest consumption was obtained is gasoline 6 plus additive 2 with a consumption of 9.125 liters, with a significant difference with respect to the former.

Figure 8: *Positive slope*



The following results were obtained on the positive slopes, i.e., the one-way trip, in which the lowest consumption is seen in the case of the fuel mixture 6 plus additive 2, with a consumption of 5.35 liters, in the case of the highest consumption it was determined that it is fuel number 5 with a consumption of 5.5 liters.

Figure 9: Negative slope

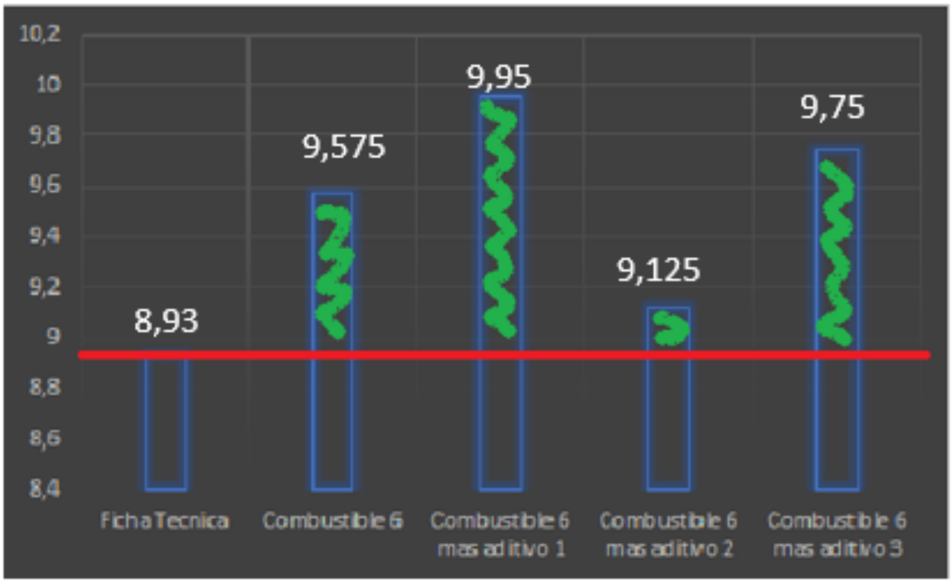


The negative slopes, i.e. when the route is downhill, a similar consumption was obtained in most of the cases, in which it can be observed in the same way that fuel 6 plus additive 2 is the mixture that generates a greater fuel saving than the others with a consumption of 3.7 liters, while the mixture condition that established the lowest fuel saving is fuel 5 plus additive 3 with a consumption of 4.5 liters.

Comparison

Figure 10 shows that fuel 6 had the lowest difference with respect to the other fuels, with a difference of 12% more consumption with respect to that established by the vehicle's technical data sheet, while the lowest consumption in additive and fuel mixtures established that fuel 6 plus additive 2 had the lowest consumption with respect to the technical data sheet with a difference of 2% more consumption, This means that the differences with respect to the technical data sheet are mainly due to the conditions under which the consumption tests are performed by the manufacturer, which are carried out under ideal conditions, while the tests in this study are performed under local conditions.

Figure 10: Comparison with data sheet



CONCLUSIONS

The additive that generated the greatest fuel savings was additive 2, with a 2% difference in consumption when mixed with fuel 6, compared to the data obtained from the technical data sheet, which indicates significant fuel savings. In relation to using only gasoline in vehicles, especially if we make long-term projections.

In conditions of positive slopes, more fuel was consumed compared to the negative slope condition, the variation is given due to the force that the engine has to perform to overcome such positive slopes and taking into account the altitude at which we are at the end of the outbound route that has an altitude of 3168 meters above sea level.

In the comparison with the technical data sheet, it was established that with the best fuel sold in the country (6), we have a 7% higher consumption than what is stated in the technical data sheet, which is generated mainly because the tests carried out for the preparation of the technical data sheet are performed in ideal geographical and climatic conditions and with a fuel with a better octane rating.

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