Evaluation of fuel used in motorcycles circulating in Guayaquil according to ecuadorian homologation

Evaluación del combustible Usado en motocicletas que circulan en Guayaquil según la homologación ecuatoriana

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ABSTRACT

The objective of this article is to examine samples of Super fuel from selected gas stations in the province of Guayas. The purpose is to obtain a characterization of this fuel to determine which is the best for motorcycles, thus seeking to improve its performance. The methodology used is quantitative, based on the collection and analysis of numerical data to answer research questions, since three samples were collected from the selected gas stations: Gómez Rendon, Portete and via Durán Tambo. These samples were sent to certified laboratories for evaluation according to the study parameters. The results obtained showed that the Portete gas station provides the best fuel quality. However, it is necessary to evaluate the possibility of outliers that may affect the validity of the study. Therefore, it is decided to apply Dixon's theorem to rule out any outlier data. Before that, a check is performed to determine whether the data set follows a normal distribution using the Minitab program. The results of the analysis conclude that none of the values obtained can be considered outliers. In conclusion, this project focuses on the evaluation of Super fuel samples from different gas stations to determine which one offers the best quality. This study provides valuable information to improve the performance of the fuel.

Keywords: fuel; motorcycles; gas stations; outlier analysis; homologation

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RESUMEN

Este artículo tiene como objetivo examinar muestras de combustible Super de gasolineras seleccionadas en la provincia de Guayas. El propósito es obtener una caracterización de dicho combustible para determinar cuál es el mejor para motocicletas, buscando así mejorar su rendimiento. La metodología que se usa es la cuantitativa que se basa en la recopilación y análisis de datos numéricos para responder preguntas de investigación ya que se recolectaron tres muestras de las gasolineras seleccionadas: Gómez Rendón, Portete y vía Durán Tambo. Estas muestras fueron enviadas a laboratorios certificados para que realicen la evaluación de acuerdo con los parámetros del estudio. Los resultados obtenidos permitieron determinar que la gasolinera Portete provee la mejor calidad de combustible. Sin embargo, es necesario evaluar la posibilidad de que existan datos atípicos que puedan afectar la validez del estudio. Por lo tanto, se decide aplicar el teorema de Dixon para descartar cualquier dato atípico. Antes de eso, se realiza una verificación para determinar si el conjunto de datos sigue una distribución normal utilizando el programa Minitab. Los resultados del análisis concluyen que ninguno de los valores obtenidos puede ser considerado como dato atípico. En conclusión, este proyecto se enfoca en la evaluación de muestras de combustible Super de diferentes gasolineras para determinar cuál ofrece la mejor calidad. Este estudio proporciona información importante para mejorar el rendimiento de motocicletas al seleccionar el combustible adecuado.

Palabras claves: Combustible; motocicletas; gasolineras; análisis de valores atípicos; homologación

INTRODUCTION

In industrialized countries, the focus is on regulating the manufacturing processes of all vehicles, including motorcycles, to provide society and the planet with an environment of safety and care (Hasegawa & Kaneko, 2017; Moore, 2005; Nguyen Duy, 2021). In Ecuador, the NTE INEN 935 standard establishes the technical requirements that gasoline must meet for commercialization, regulating aspects such as quality, octane number, sulfur content, and other important parameters to ensure optimal engine performance and minimize environmental impact. The responsibility for ensuring that gasoline complies with these specifications falls on the Public Company Petroecuador (EPP), while service stations are responsible for its distribution (Noroña Merchan *et al.*, 2018). The search for more efficient and faster forms of transportation, along with caution regarding the use of mass transportation due to the pandemic, has led to a significant increase in the number of motorcycles in the country. It is important to note that home delivery services play a significant role in this increase.

According to data from the Ecuadorian Automotive Association, around 14.189 motorcycles were sold in Ecuador in 2021, indicating a growing trend in the presence of motorcycles in the country's vehicle fleet (AEADE, 2021). In addition, the public transport service has evolved, incorporating tricycles, according to the census of the Municipal Transit Authority (ATM), with 3.195 tricycles registered only in Guayaquil and regulated by regulations in the province of Guayas (Fuentes Maquilon & Lopez Suarez, 2018).

As for gasoline, it contains hydrocarbons with carbon and is marketed in two types: 85 octane (Extra), 87 octane Ecopaís and 95 octanes (Super Premium) according to the 2022 pilot plan of the Public Company Petroecuador (Lugmania Paillacho & Paillacho Aules, 2023). The quality of these gasolines is regulated by the NTE INEN 935 standard. Although it conforms to Ecuadorian standards, the quality of the gasoline generates uncertainty, since it only meets the Euro 1 quality standard or lower, being one of the lowest in the region and generating discrepancies with European regulations (Pazmiño-Viteri *et al.*, 2024; Toro *et al.*, 2023).

METHODOLOGY

a) Fuel sold in Ecuador

Fuel is any material capable of releasing energy when burned and then changing or transforming its chemical structure. The term fuel is limited to those substances that burn easily in air or oxygen by emitting substantial amounts of heat. It involves the release of an energy from its potential form into a usable form (because it is a chemical reaction, it is known as chemical energy) (Encalada & Ñauta, 2010). The gasoline sold in the city of Guayaquil comes from the La Libertad refinery (Montero Mosquera, 2020). This refinery around 45.000 barrels per day of derivatives with an average annual load of 14´850.000 barrels (Coral Guerrero & Encalada Rojas, 2017).

The commercialization of petroleum and its derivatives in Ecuador is carried out by EP Petroecuador through the National and International Marketing Departments, following internal processes to meet local demand, with optimal quality standards with social and environmental responsibility (Coral Guerrero & Encalada Rojas, 2017). The supply and marketing of fuels at the local level is summarized in Figure 1 below (Coral Guerrero & Encalada Rojas, 2017).

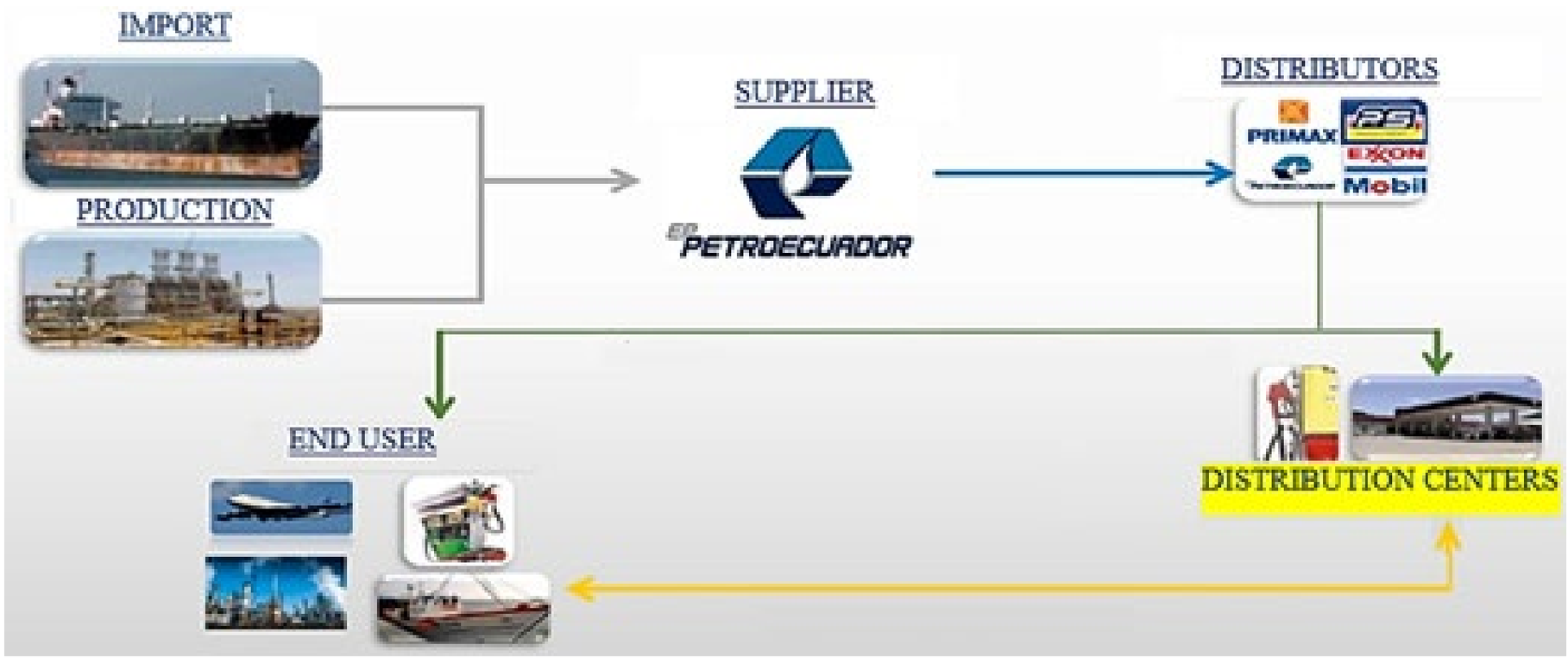

FIGURE 1
Supply & fuel chain
Source: Encalada Rojas, 2017

b) Gasoline sold in Ecuador

The most important parameter of our gasoline is the octane number. Three types of gasoline are used in the country: Super, Eco-País and Extra (Fernández Mora & Mideros Mora, 2023; Herrera-Franco *et al.*, 2022). The octane number of the engine correlates with the anti-knock performance of commercial internal combustion engines under severe operating conditions. This engine octane number is used by engine manufacturers, petroleum refiners and retailers, and in commerce as a related primary specification measurement for the pairing of fuels and engines (Instituto Ecuatoriano de Normalización, 2013a).

Eco-País gasoline, a biofuel composed of 5% bioethanol (from sugar cane) and 95% base gasoline (Terneus-Páez & Viteri-Salazar, 2023). Eco-País has the same octane rating (87 octane) and price of Extra gasoline. For the production of Extra gasoline with 87 octanes, it is necessary to mix 76% of high-octane naphtha (NAO), which is imported, with 24% of low-octane naphtha (NBO); while for the production of ECOPAÍS, with the same amount of octane, 62% of NAO, 33% of NBO and 5% of bioethanol are required (Castillo-Hernández *et al.*, 2012). Super gasoline is the highest quality fuel found in the city of Guayaquil for use in high-performance vehicles. It is used in engines that have a high compression ratio. Mainly the isoparaffinic and aromatic hydrocarbons (benzene chains that raise the octane index) found in super gasoline resist high pressures and temperatures (INSST, 2013).

c) Importation and sales of motorcycles in Ecuador

Figure 2 shows the number of motorcycles that were imported from 2019 to 2021 according to reports from the Association of Automotive Companies of Ecuador (AEADE, 2021).

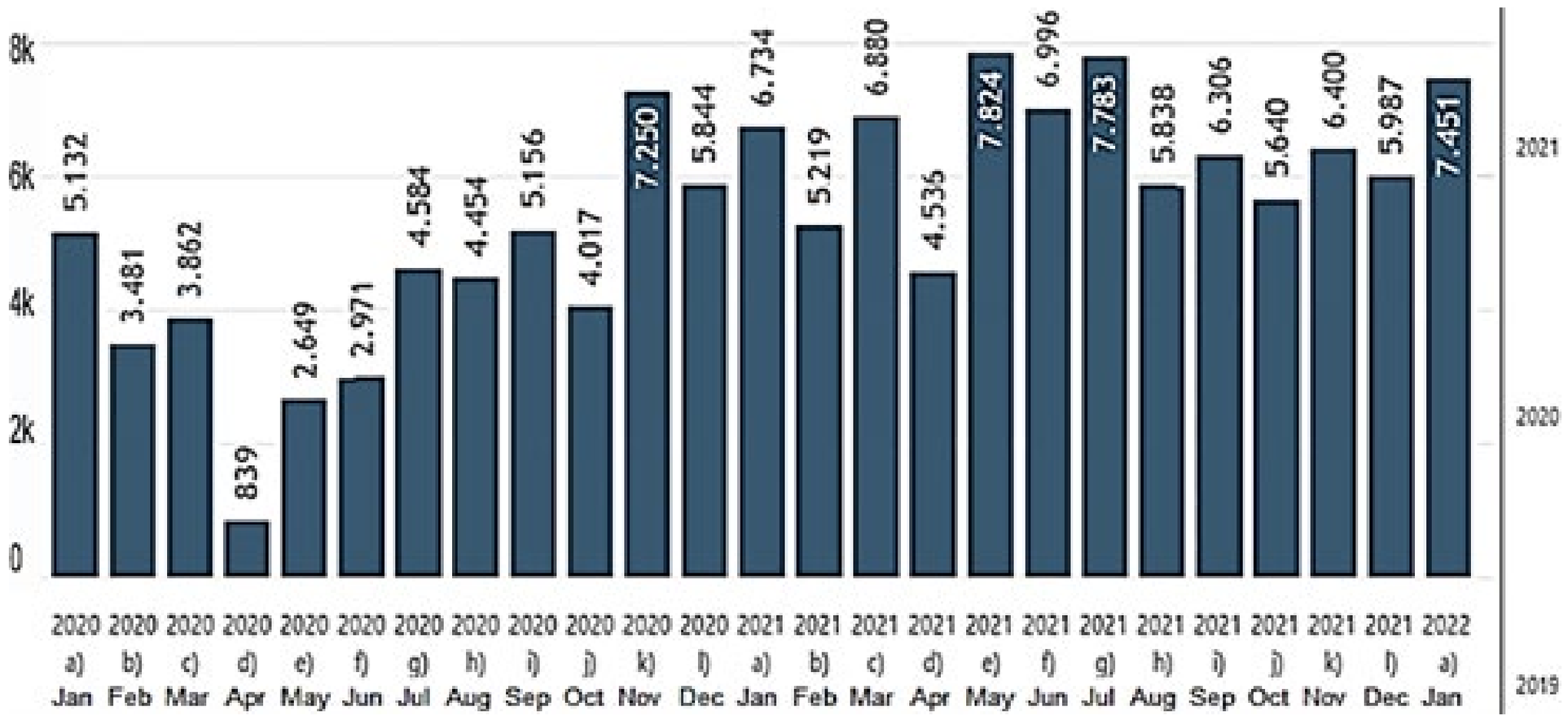

FIGURE 2
Importing motorcycles in Ecuador
Source: AEADE, 2021

d) Regulations for indicating the technical characteristics of fuel

In Ecuador there is the NTE INEN 935 Standard (Instituto Ecuatoriano de Normalización, 2021) (Diario Oficial de las Comunidades Europeas, 1998), which is responsible for establishing what value according to parameter the gasoline that is being sold must meet, in Table 1 below you can see these mandatory characteristics (Freepik, 2022; Tribologik, 2013; Motorgiga, 2000).

TABLE 1
Ecuadorian Regulations NTE INEN 935

Requirements	Unit	Minimum	Maximum	Test Method [a]
Octane Number Research (RON)	--	92,0	--	NTE INEN 2102 ASTM D2699
Distillation Temperature: 10%	°C	-	70	ASTM D86
20%	°C	77	121	
90%	°c	--	190	
End Boiling Point	°c	--	220	
Distillation residue	%[c]	--	2,0	
Temperature for vapor/liquid ratio equal to 20	°c	56,0	--	ASTM D5188
Vapor Pressure	kPa	--	60,0	ASTM D323 ASTM D4953 ASTM D5191
Corrosion of copper foil (3 h at 50 °C)	--	--	No, 1	ASTM D130
Rubber content	mg/100 mL	--	4,0	ASTM D381
Sulphur content	% rt	-	0,0450	ASTM D2622 ASTM D4294 ASTM D5453
Aromatic content	%c	-	35,0	ASTM D1319 ASTM D6730 ASTM D6733
Benzene content	%c	-	2,00	ASTM D3606 ASTM D5580 ASTM D6277 ASTM D6730
Olefin content	%c	-	25,0	ASTM D1319 ASTM D6730 ASTM D6733
Oxidation stability	min	240	-	ASTM D525 ASTM D7525
Lead content	mg/L	-	1,0	ASTM D3237 ASTM D5059 ASTM D5185
Manganese content	mg/L	--	1,0	ASTM D3831 ASTM D5185
Iron content	mg/L	-	1,0	ASTM D5185

Source: Instituto Ecuatoriano de Normalización, 2021

RESULTS AND DISCUSSION

a) Selection of petrol stations

We proceed to investigate which selected gas stations are operational in the province of Guayas, which includes Guayaquil, Samborondón and Durán, to place them in a list as shown in Table 2, after this we have the purpose of choosing fuel samples for their respective analysis.

TABLE 2
List of selected gas stations in Guayas

Sector	Address
Guayaquil	Portete De Tarqui/ Juan Pío Montúfar y Guaranda
Guayaquil	Capitán Nájera/ Entre Rumichaca y Noguchi
Guayaquil	Gómez Rendon/ Entre Carchi y Tungurahua
Guayaquil	Av. 25 de Julio in the South
Durán	Av. Nicolás Lapenti y Durán 092409
Durán	El Recreo
Durán	Before toll Durán Tambo

A market analysis is carried out at these gas stations and the method used was the counting of motorcycles (Motorecambios VFerrer, 2020; Toledo Montaleza, 2016) at each service station in such a way that it can be achieved to have an idea of the influx, this is detailed in Table 3.

TABLE 3
Influx of motorcycles at gas stations

Gas stations	Number of motorcycles
Portete de Tarqui/ Juan Pío Montufar y Guaranda	50
Capitán Nájera/ Entre Rumichaca y Noguchi	190
Gómez Rendon/ Entre Carchi y Tungurahua	619
Av. 25 de Julio in the South	515
Av. Nicolás Lapenti y Durán 092409	435
El Recreo	510
Before toll Durán Tambo	300

Considering that the Dixon statistical analysis (Statologos, 2022), it lets us know if there is an outlier in a dataset that should be discarded. That said, we relied on this criterion to be able to select the number of gas stations that are going to be chosen to sample, it was determined that it had to be a minimum of 3 gas stations since, to apply Dixon to the results obtained. It determines that the number of samples to apply this theory is from a minimum of 3 to 30 samples maximum (Rorabacher, 1991), as shown in Table 4.

This selection of 3 gas stations is due to the excessive cost of the laboratories to analyze the fuel of approximately $2,500 for each sample. The gas stations selected are Gómez Rendón, Portete and vía Durán Tambo according to Dixon's analysis.

TABLE 4
Snippet of the amount of data Dixon analyzes

	Confidence level					
Nᵇ	**80% (∝ = 0,20)**	**90% (∝ = 0,10)**	**95% (∝ = 0,05)**	**96% (∝ = 0,04)**	**98% (∝ = 0,02)**	**99% (∝ = 0,01)**
3	0,886	0,941	0,970	0,976	0,988	0,994
4	0,679	0,765	0,829	0,846	0,889	0,926
5	0,557	0,642	0,710	0,729	0,780	0,821
6	0,482	0,560	0,625	0,644	0,698	0,740
7	0,434	0,507	0,568	0,586	0,637	0,680
8	0,399	0,468	0,526	0,543	0,590	0,634

Note: In the table you can see 3 samples, but there are 30 samples

Source: Statologos, 2022.

b) Selection of laboratories

For the selection of laboratories, the difficulty in Ecuador is to find a laboratory where all the necessary tests are carried out.

Below is the list of laboratories that carry out these tests, however, for this project we only worked with 2, which are the laboratory of the Department of Petroleum, Energy and Pollution of the Central University and the laboratory of Fuels, Biofuels and Lubricating Oils of the National Polytechnic School. Table 5 shows the list of laboratories that were investigated to make the respective quotation.

TABLE 5
Researched laboratories for samples

Laboratory Name	City
Instrumental Chemical Analysis Laboratory (ESPOL)	Guayaquil
Department of Petroleum, Energy and Pollution (Central University)	Quito
Laboratory of Fuels, Biofuels and Lubricating Oils (National Polytechnic School)	Quito
PetroEcuador Laboratories	Guayas

Each laboratory has its fundamental requirements for the correct collection and transport of samples. The fuel is stored in an amber glass jar and moved to a temperature of no more than 30 degrees.

Another requirement is to place a label on the bottle indicating where they come from, the date of the sample and the type of gasoline, in this way we can avoid confusion at the time of analysis.

Figure 3 shows 4 amber containers, 2 of 250 milliliters, which are the smallest, these were delivered to the laboratory of the Central University of Ecuador, and the other two of 1 liter were delivered to the National Polytechnic School.

FIGURE 3
Storing Samples in Amber Bottle

The results of the selected laboratories are placed in Table 6 to visualize the difference in the values obtained according to the ASTM D86 standard (Laboratorios DPEC y LACBAL, 2022; Universidad Internacional del Ecuador, 2021).

TABLE 6
Laboratory test results

Parameters	Unit	Gómez Rendon	Portete	Via Durán Tambo
Octane Count, RON	N/A	92,4	95,1	91,1
10%	°C	54	71,2	35
50%	°C	102,5	116,3	54,9
90%	°C	168,6	172,9	165,4
End Boiling Point	°C	215,6	210,7	201,6
Distillation Residue	%	1	1	1
Steam Pressure	kPa	53	54	55,5
Corrosion Of Copper Foil (3h At 50°C)	N/A	1ª	1a	N/A
Rubber Content	mg/100mL	0,6	0,8	1
Sulphur Content	%	0,00279	0,00232	0,00208
Lead Content	mg/L	0	0	N/A
Manganese Content	mg/L	0	0	N/A
Iron Content	mg/L	0	0,017	N/A

As shown in the results, there are variations in each of the parameters, so the Minitab application is used to know the normality criterion, which is a determining detail to apply the Dixon method and thus establish the gas station that provides the best parameters.

c) Application of Dixon's theory in parameter vehicles

Minitab software is used (Vila, 2012), to know the criterion of normality and then apply Dixon's theory in each parameter of the results obtained in the laboratory of Super gasoline, to determine the feasibility of each of the 3 gas stations established and thus validate the results. To be able to apply Dixon to the values obtained by the laboratories, it is essential to know that the data set follows a normal distribution. The Minitab program was used to find out if it effectively complies with the analysis of knowing how much the distribution of the data obtained differs based on the expected data.

Placing Data in Minitab Sheet

The values obtained are placed on the worksheet (Figure 4), it is necessary to include a title to keep a correct order.

1		Octane Rating	
2		92.4	
3		95.1	
4		91.1	
5			
6			

Worksheet

FIGURE 4
Worksheet in Minitab

Normalcy Test Selection in Minitab

You look for the stats tab (Figure 5), where you select basic stats, then normality test (Rodó, 2006).
d en Minitab

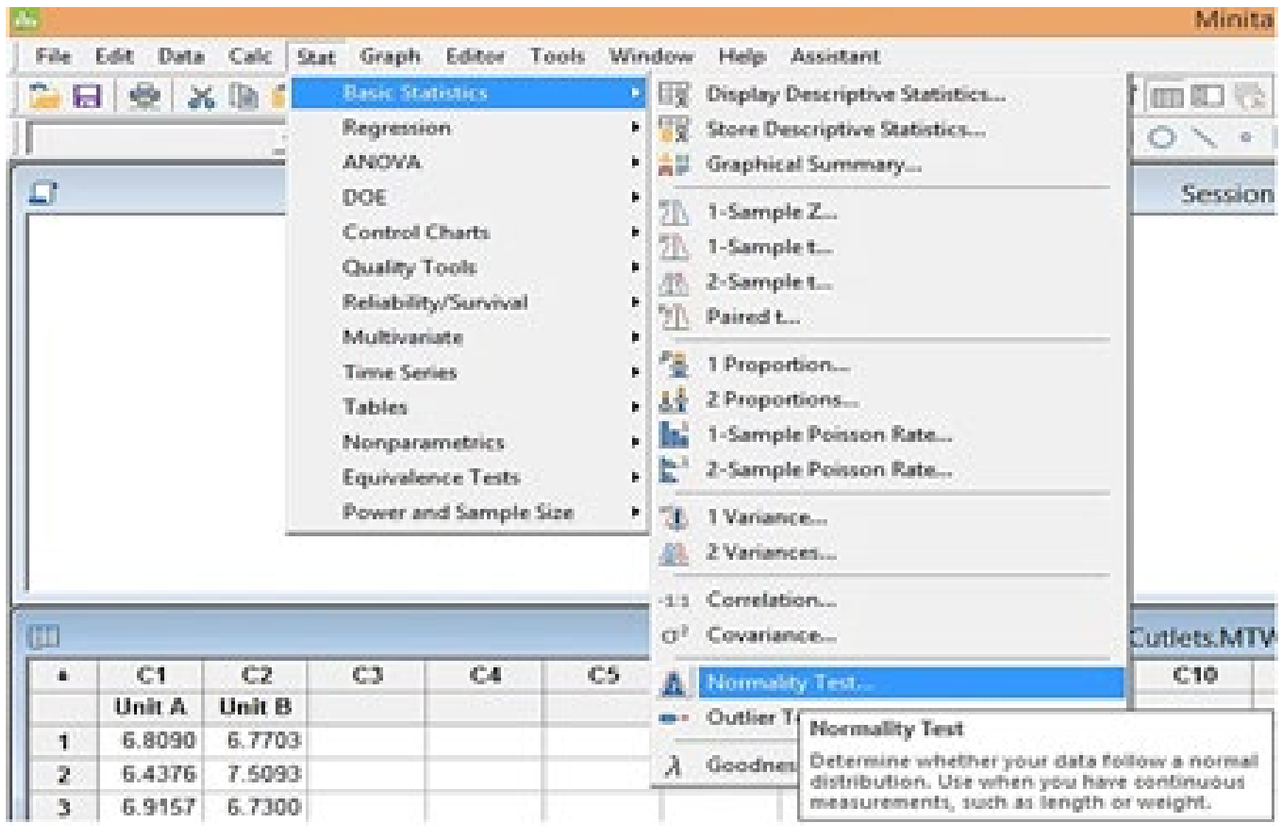

FIGURE 5
Normality test in Minitab

Anderson-Darling Test Selection

A screen is displayed with the different tests that can be performed to check normality, in this case Anderson-Darling was selected (Flores Tapia & Flores Cevallos, 2021). Select the dataset that belongs to C1 on the left and click OK (Figure 6).

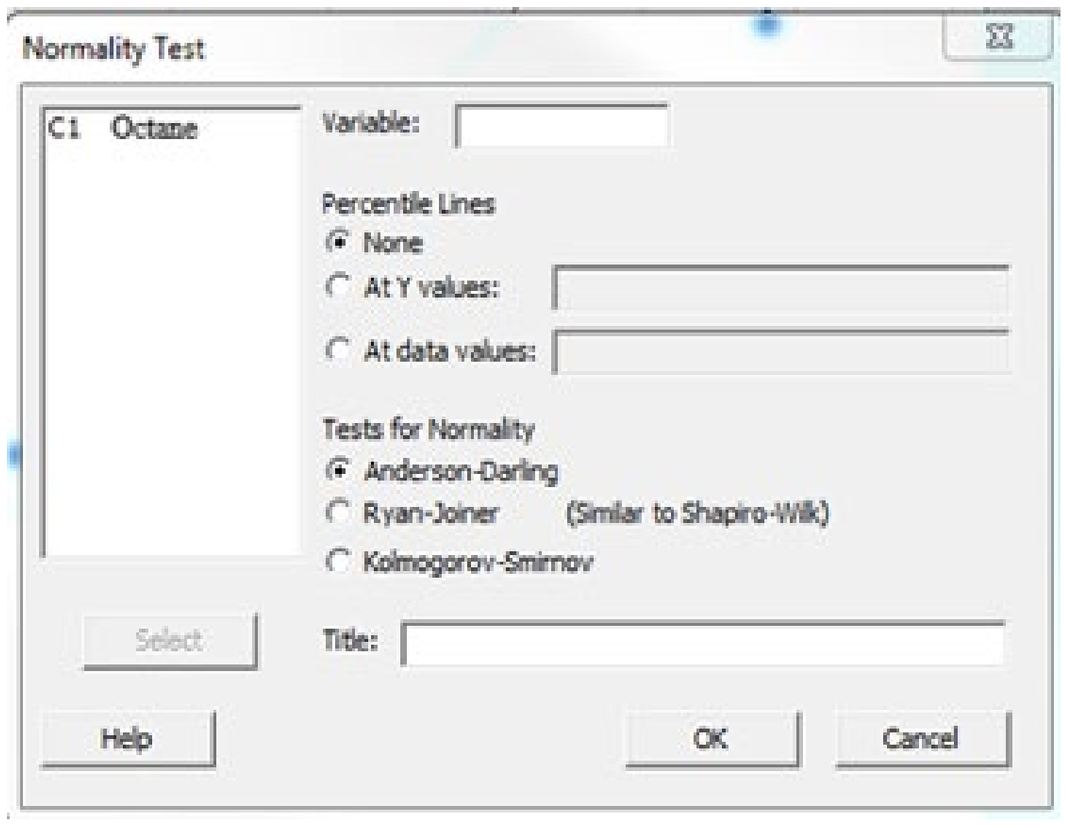

FIGURE 6
Normality tests available

Obtaining a graph of the Normality Criterion

As can be seen in Figure 7, a p-value is obtained, which serves as a criterion to determine whether the set of results for Super gasoline follows a normal distribution.

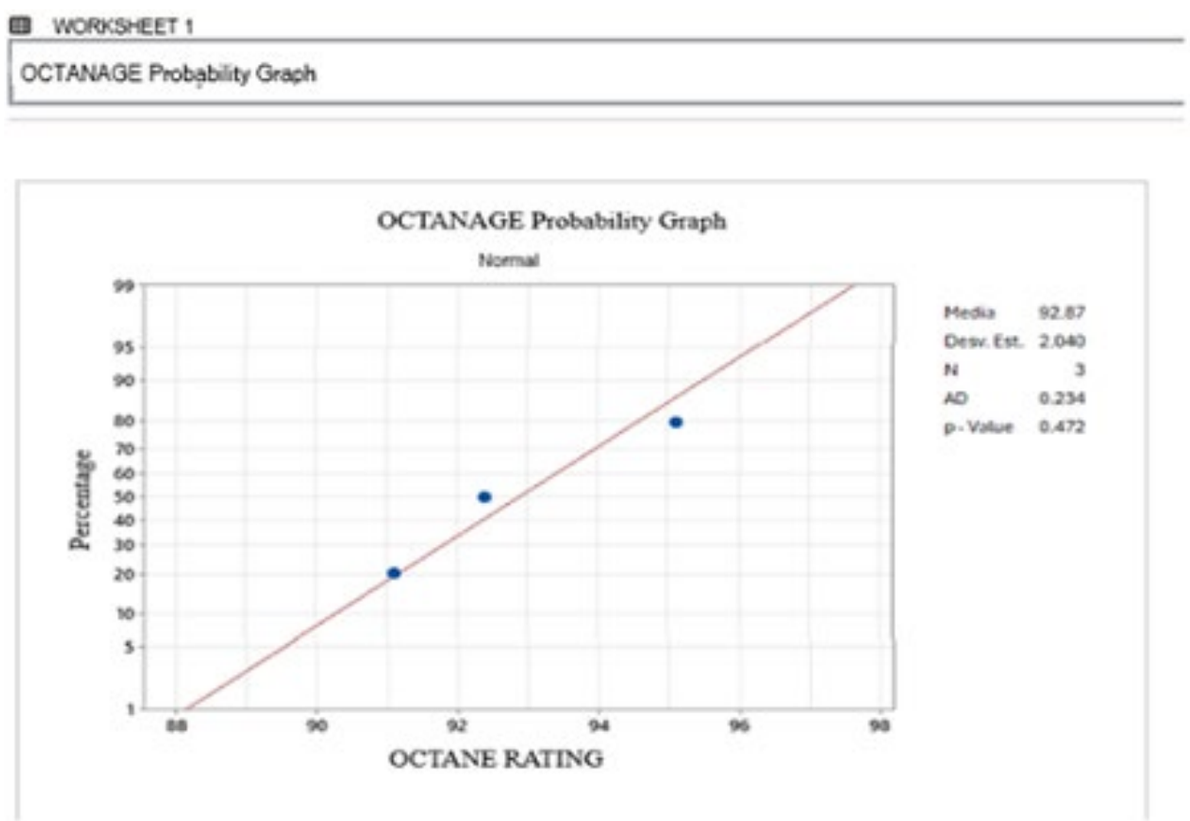

FIGURE 7
Chart to check Normality

d) Normality test results applying Anderson-Darling in Minitab

Below is a breakdown of normality testing by applying Anderson-Darling in Minitab software (Closas et al., 2010), of each of the parameters investigated, i.e. octane number, distillation temperature at 10%, 50%, 90%, boiling endpoint, vapour pressure, gum content and sulphur content.

Octane Normality Test

Analyzing the octane parameters in Minitab shows that the obtained value of P = 0,472 > 0,05 (Figure 8). Since the p - value is greater than the significance value of 0,05, the probability that the data obtained at the three gas stations follows a normal distribution cannot be rejected. In the case of this parameter, the highest-octane parameter, which is the Portete gas station, will be taken as a base.

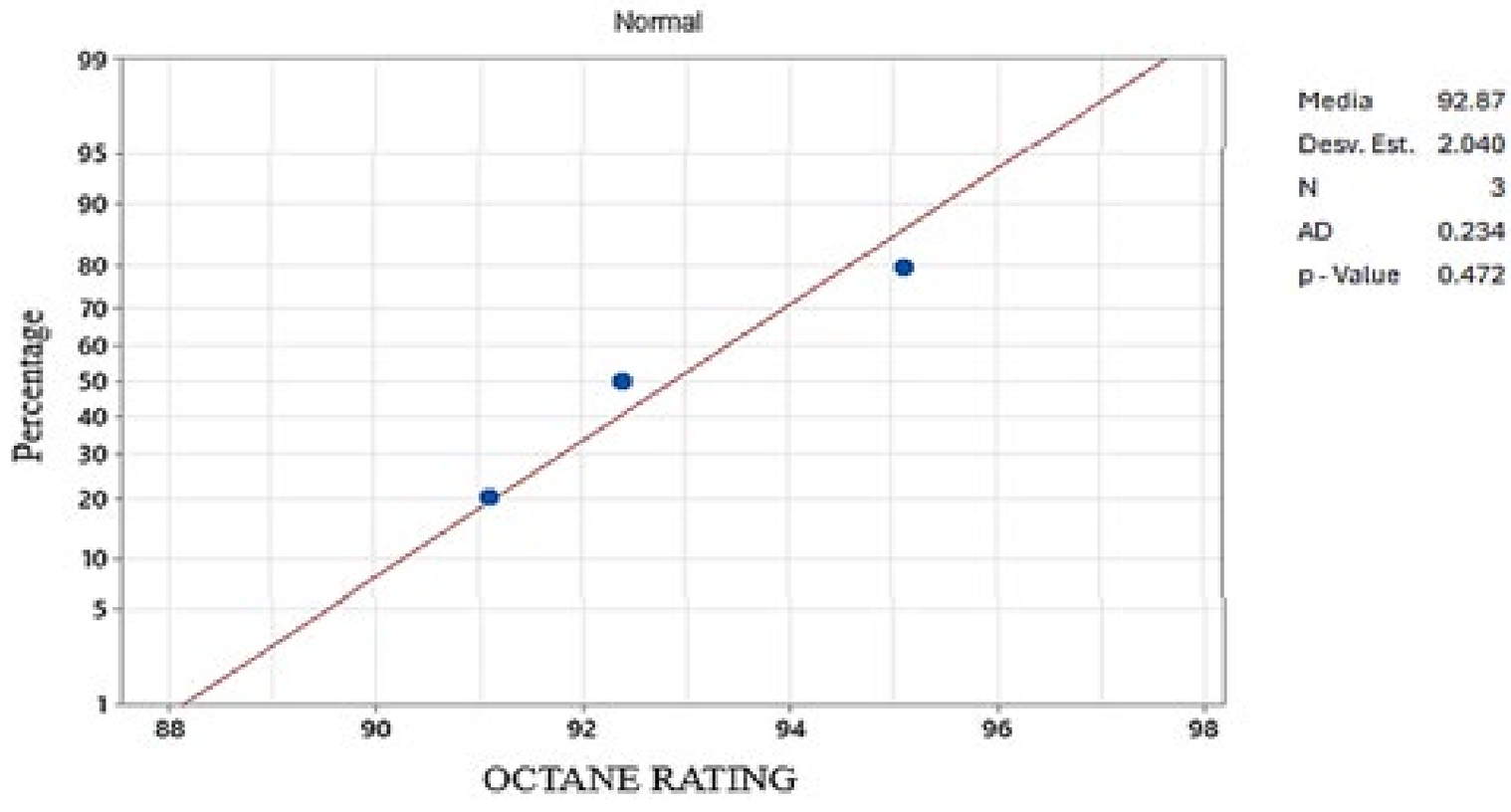

FIGURE 8
Octane probability graph

Figure 9 shows the histogram of how this dataset follows a normal distribution.

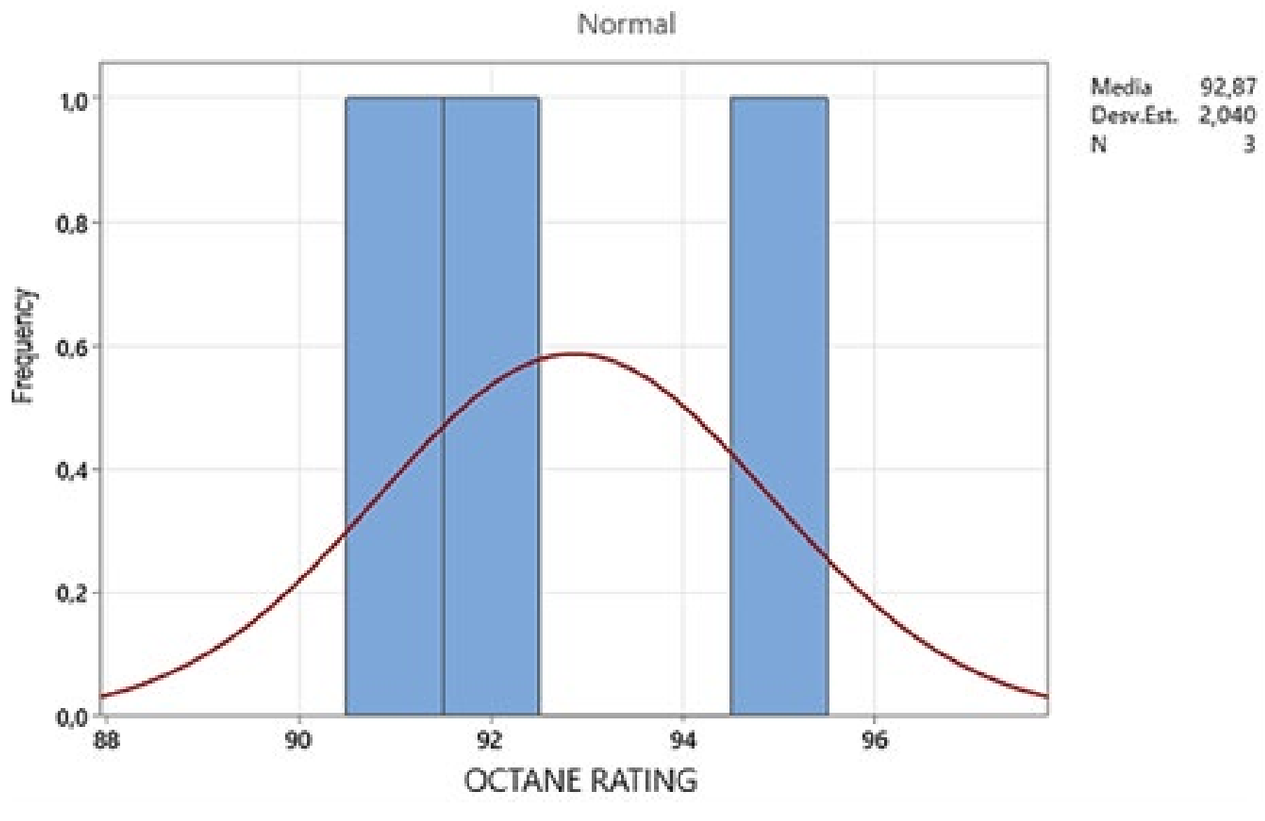

FIGURE 9
Octane histogram

Results obtained by applying Dixon by choosing maximum and minimum values of each parameter, results for all parameters applying Dixon

This test is performed to find out if one of the parameter values has an outlier and this is given according to the criterion formula called Q. Here is indicated how this criterion is obtained, based on the octane parameter, and the same steps must be replicated to all the other parameters.

To perform this analysis, you must determine the critical value Q (Rorabacher, 1991), that in this research a confidence level of 95% and a sample number N° 3 are taken, since our population covers only 3 data points which are gas stations. In conclusion, the critical Q is 0,97 as can be seen in Table 7, so any value obtained in the Dixon tests below must be less than 0,97 in order not to be considered rejected because it is an outlier.

TABLE 7
Dixon test critical values

	Confidence Level					
Nᵇ	**80% (∝ = 0.20)**	**90% (∝ = 0.10)**	**95% (∝ = 0.05)**	**96% (∝ = 0.04)**	**98% (∝ = 0.02)**	**99% (∝ = 0.01)**
3	0,886	0,941	0,970	0,976	0,988	0,994
4	0,679	0,765	0,829	0,846	0,889	0,926
5	0,557	0,642	0,710	0,729	0,780	0,821
6	0,482	0,560	0,625	0,644	0,698	0,740
7	0,434	0,507	0,568	0,586	0,637	0,680
8	0,399	0,468	0,526	0,543	0,590	0,634
9	0,370	0,437	0,493	0,510	0,555	0,598
10	0,349	0,412	0,466	0,483	0,527	0,568
11	0,332	0,392	0,444	0,460	0,502	0,542
12	0,318	0,376	0,426	0,441	0,482	0,522
13	0,305	0,361	0,410	0,425	0,465	0,503
14	0,294	0,349	0,396	0,411	0,450	0,488
15	0,285	0,338	0,384	0,399	0,438	0,475
16	0,277	0,329	0,374	0,388	0,426	0,463
17	0,269	0,320	0,365	0,379	0,416	0,452
18	0,263	0,312	0,356	0,370	0,407	0,442
19	0,258	0,306	0,349	0,363	0,398	0,433
20	0,252	0,300	0,342	0,356	0,391	0,425
21	0,247	0,295	0,337	0,350	0,384	0,418
22	0,242	0,290	0,331	0,344	0,378	0,411
23	0,238	0,285	0,326	0,338	0,372	0,404
24	0,234	0,281	0,321	0,333	0,367	0,399
25	0,230	0,277	0,317	0,329	0,362	0,393
26	0,227	0,273	0,312	0,324	0,357	0,388
27	0,224	0,269	0,308	0,320	0,353	0,384
28	0,220	0,266	0,305	0,316	0,349	0,380
29	0,218	0,263	0,301	0,312	0,345	0,376
30	0,215	0,260	0,298	0,309	0,341	0,372

Table 8 details the values to be used for the Dixon analysis.

TABLE 8
Octane result values

Parameters	Unit	Gómez Rendon	Portete	Via Durán Tambo
Octane Count, RON	N/A	92,4	95,1	91,1

e) Results for all parameters applying Dixon

As can be seen in Table 9, Dixon is applied for each parameter (number of octanes, distillation temperature at 10%, 50%, 90%, boiling endpoint, vapor pressure, gum content and sulfur content) for each parameter there is a population of 3 samples, for the calculation of the outlier value was considered for both the maximum and the minimum value of the data set.

After applying the respective formula, the values detailed in the calculated Q column were collected, because all the values shown in Table 7 do not exceed the critical Q (0,97), it is determined that there are no outliers (Chorro, 2010), that said, it is concluded that all values within this population can be selected for analysis.

As shown in Table 9, the gas station that complies the most is La Portete, therefore it is verified with the INEN 935 standard (Instituto Ecuatoriano de Normalización, 2013b).

TABLE 9
Q Results calculated for Dixon tests

Parameters	Unit	Portete	Gómez Rendón	Vía Durán Tambo	Q Calculated	
					Greater Value	Lover Value
Octane Number, RON	N/A	95,1	92,4	91,1	0,675	0,325
Distillation Temperature 10%	°C	71,2	54	35,0	0,47513812	0,52486188
Distillation Temperature 50%	°C	116,3	102,5	54,9	0,2247557	0,7752443
Distillation Temperature 90%	°C	172,9	168,6	165,4	0,5733333	0,4266667
End Boiling Point	°C	210,7	215,6	201,6	0,35	0,65
Distillation Residue	%	1,0	1,0	1,0	N/A	N/A
Vapor Pressure	kPa	54	53	55,5	0,6	0,4
Rubber Content	mg/100mL	0,800	0,600	1,0	0,5	0,5
Sulphur Content	%	0,00252	0,00279	0,00208	0,66197183	0,33802817

CONCLUSIONS

Although no outliers were found in the analyzed parameters, the differences in the octane number between the stations suggest variations in fuel quality, with the gasoline from the Portete station being of the highest quality, with an octane rating of 95,1 RON, exceeding the minimum requirements established by the INEN 935 standard.

The differences in the distillation curves at 50% and 90%, as well as the final boiling point, indicate that the analyzed gasoline samples show significant variations in their composition, suggesting on-site blending at service stations. These variations in parameters can directly affect fuel quality and, consequently, engine performance. It is recommended to include the color parameter in future studies, as it can provide a clear visual indication of fuel blending. Continuous supervision and validation by the relevant authorities are essential to ensure that these parameters comply with the INEN 935 standard and to guarantee consistency in the final product quality.

Although the Hydrocarbon Regulation and Control Agency (ARCH) already monitors the fuel sold in Ecuador, it is concluded that strengthening quality control at all service stations is crucial to ensure that the fuel consistently meets the INEN 935 standard. This will help improve the quality of fuel available in the market and mitigate possible variations that could affect engine performance. Furthermore, it is concluded that this monitoring should include more frequent and detailed evaluations, enabling the timely identification and correction of any deviations in quality parameters.

Fuel distributors must ensure proper transportation from the point of origin to delivery, implementing constant inspections of the containers. The sharing of periodic test results at service stations is also key to building consumer trust, which can be achieved through communication of the results via social media or directly at the stations. The proper implementation of these processes promotes transparency, continuous improvement, and regulatory compliance, contributing to increased consumer confidence in the fuel industry.

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