

Research Article

Comparative Studies of the Physicochemical Properties of Super Fuels Sold in the City of Brazzaville

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Abstract

The oil industry is divided into two sectors: the upstream sector, which involves exploration and production, and the downstream sector of the oil industry, comprising refining and distribution, plays a key role in converting crude oil into economically valuable products. Oil refining involves a range of processes that transform crude oil into fuels (LPG, gasoline, diesel), combustibles (fuel oils), and specialty products (waxes, paraffins), all of which must meet regularly updated standards. These operations are conducted in refineries, which are classified as either simple (few units) or complex (many units, allowing for more efficient and diverse output). The refining process produces various fractions, including combustible gases (C_1 - C_2), LPG, gasoline fractions (C_5 - C_{10}), kerosene (C_{10} - C_{13}), gas oils (C_{13} - C_{25}), and heavier products (C_{20} - C_{50}) that undergo cracking to yield lighter products. This study focuses on evaluating the physicochemical properties of premium gasoline sold in Brazzaville, Republic of Congo. The analysis of multiple samples showed that fuel sold by private vendors is of lower quality than that sold at official service stations. Key parameters assessed include density, specific gravity, viscosity, and pH.

Keywords

Physicochemical Properties, Super Fuel, Refining

1. Introduction

Refining encompasses all industrial processes used to transform crude oil into a variety of finished products. Among these are fuels (LPG, gasoline, and diesel), combustibles (fuel oils),

and specific products such as waxes and paraffins. Each product is manufactured according to strict technical specifications, which are regularly updated to keep pace with technological

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advancements, ensure optimal performance, and comply with current environmental standards [1]. Most petroleum products on the market are mixtures obtained through the physical separation of crude oil (distillation, fractionation, and cracking) and are characterized by a specific boiling point range. Premium gasoline, also known as high-octane petrol, is specially formulated to meet the requirements of spark-ignition engines. Its main advantage lies in its high octane rating, which ensures better resistance to engine knock and more efficient combustion [2]. This level of performance makes it a preferred choice for sports vehicles, high-performance engines, and modern vehicles requiring precise combustion control. In a context marked by increasingly stringent environmental regulations and the rapid evolution of engine technologies, premium fuels are now enriched with cleaning and protective additives. These components help maintain the cleanliness of fuel injectors and the fuel system, while meeting strict emission reduction standards. The main objective of this study is to carry out a comparative analysis of the physicochemical properties of premium gasoline sold in various locations in the city of Brazzaville, Republic of the Congo, and to compare the results with existing standards and specifications. The properties analyzed in this study include only: density, specific gravity, viscosity, and hydrogen potential (pH).

2. Materials and Methods

2.1. Materials

The study materials include all the equipment used for sampling, analysis, quality control, and safety. Their selection depends on the type of product studied and the objectives of the research. In this study, the following equipment was used: a balance for measuring mass, a test tube for measuring volume, a ball viscometer, and hydrogen potential (pH) paper.

2.2. Methodology

The determination of the physicochemical properties of the premium gasoline samples was carried out using basic laboratory instruments on a specific quantity of each product.

2.2.1. Density

Density was determined by collecting a quantity of each premium gasoline sample. Each sample was weighed to determine its mass, then its volume was measured. Density is the ratio of mass to volume. The density of liquids and solids depends on temperature [3]. It is calculated using the following formula [4]:

$$\rho = \frac{m}{V} \quad (1)$$

Where, m: mass of the sample (kg), V: volume of the sample (m^3), ρ : density of the sample (kg/m^3).

2.2.2. Specific Gravity (Relative Density)

The specific gravity of a solid or liquid substance at a given temperature is defined as the ratio of the density of that substance at the given temperature to the density of pure water at 4 °C. By definition, the density of water at 4 °C is equal to 1. Therefore, specific gravity was determined by dividing the density of the premium gasoline sample by the density of water at 4 °C ($1000 \text{ kg}/\text{m}^3$) [5].

$$d = \frac{\rho}{\rho_e} \quad (2)$$

Where, d: specific gravity of the sample (dimensionless), ρ : density of the sample (kg/m^3), ρ_e : density of water at 4 °C ($1000 \text{ kg}/\text{m}^3$).

2.2.3. Viscosity

The viscosity of a liquid is its property resulting from the resistance exerted by its molecules against a force tending to move them by sliding past one another. Thus, the viscosity of a fluid is the resistance the fluid offers to its flow. It was determined using the Hoppler's method (falling ball viscometer), based on Stoke's law [6]. The method measures how long it takes a ball to fall a certain distance [7]. The ball is dropped into a cylindrical glass tube containing the liquid to be studied [8].

$$u_h = \frac{2}{9} \cdot \frac{(\rho_b - \rho_h) \cdot g \cdot r^2}{\eta} \quad (3)$$

The dynamic viscosity η of the sample was calculated using the following parameters, η : dynamic viscosity of the sample (Pa s) [9], ρ_b : density of the ball (kg/m^3), ρ_h : density of the sample (kg/m^3), g: acceleration due to gravity (m/s^2), r: radius of the ball (m), v: terminal falling velocity of the ball in the fluid (m/s). For this experiment, the ball used was spherical, made of aluminum, with a density of $2700 \text{ kg}/\text{m}^3$ and a radius of $2.6 \times 10^{-3} \text{ m}$.

2.2.4. pH

pH represents the concentration of hydrogen ions in a solution. This measurement is important because pH governs a large number of physicochemical equilibria. The pH was determined using pH paper [10]. The pH paper was dipped into a test tube containing the sample, and the color change of the paper was compared to the reference chart on the pH paper to determine the corresponding pH value.



Figure 1. Equipments used.

3. Results and Discussion

3.1. Results

The results of the analyses of all the samples examined in this study are summarized in the tables below.

Sample 1: Premium gasoline from the Puma station in the Batignolles district.

Table 1 shows the analysis results of the premium gasoline from the Puma station in the Batignolles district.

Table 1. Properties of super fuel from the Puma station in the Batignolles district.

Property	Value	Units
Mass	0.1849	kg
Volume	2.5×10^{-4}	m^3
Density	739.76	kg/m^3
Dynamic Viscosity	0.064	Pa s
Kinematic Viscosity	8.65×10^{-5}	m^2/s

Property	Value	Units
Specific Gravity	0.739	-
Density of Water (4 °C)	1000	kg/m^3
Color	Light Yellow	-
Temperature	20	°C
pH	5	-

Sample 2: super fuel from the TotalEnergies station in the Mazala district (Mfilou)

Table 2 presents the analysis results of the premium gasoline sample from the TotalEnergies station in the Mazala district (Mfilou).

Table 2. Properties of super fuel from the TotalEnergies station in the Mazala district (Mfilou).

Property	Value	Units
Mass	0.1847	kg
Volume	2.5×10^{-4}	m^3

Property	Value	Units
Density	738.96	kg/m ³
Dynamic Viscosity	0.070	Pa s
Kinematic Viscosity	9.47×10^{-5}	m ² /s
Specific Gravity	0.738	-
Density of Water (4 °C)	1000	kg/m ³
Color	Light Yellow	-
Temperature	20	°C
pH	5	-

Sample 3: Premium gasoline from the Afric station in the Mouhoumi district (L'Ombre).

Table 3 presents the analysis results of the premium gasoline sample from the Afric station in the Mouhoumi district (L'Ombre).

Table 3. Properties of super fuel from the Afric station in the Mouhoumi district (L'Ombre).

Property	Value	Units
Mass	0.185	kg
Volume	2.5×10^{-4}	m ³
Density	740.12	kg/m ³
Dynamic Viscosity	0.056	Pa s
Kinematic Viscosity	7.56×10^{-5}	m ² /s
Specific Gravity	0.740	-
Density of Water (4 °C)	1000	kg/m ³
Color	Light Red	-
Temperature	20	°C
pH	5	-

Sample 4: Premium gasoline from the SNPC station at Marché Total.

Table 4 presents the analysis results of the premium gasoline sample from the SNPC station at Marché Total.

Table 4. Properties of super fuel from the SNPC station at Marché Total.

Property	Value	Units
Mass	0.184	kg
Volume	2.5×10^{-4}	m ³

Property	Value	Units
Density	736.68	kg/m ³
Dynamic Viscosity	0.078	Pa s
Kinematic Viscosity	1.05×10^{-4}	m ² /s
Specific Gravity	0.736	-
Density of Water (4 °C)	1000	kg/m ³
Color	Dark Yellow	-
Temperature	20	°C
pH	5	-

Sample 5: Premium gasoline from the X-OIL service station at Patte d'Oie roundabout.

The **table 5** presents the analysis results of the premium gasoline sample from the X-OIL service station at Patte d'Oie roundabout.

Table 5. Properties of super fuel from the X-OIL service station at Patte d'Oie roundabout.

Property	Value	Units
Mass	0.18586	kg
Volume	2.5×10^{-4}	m ³
Density	743.44	kg/m ³
Dynamic Viscosity	0.074	Pa s
Kinematic Viscosity	9.95×10^{-5}	m ² /s
Specific Gravity	0.743	-
Density of Water (4 °C)	1000	kg/m ³
Color	Light Yellow	-
Temperature	20	°C
pH	5	-

Sample 6. Super fuels purchased from a private seller in the Mpila neighborhood near Chakona.

Table 6 provides the results of the analyses performed on the sample of superfuel purchased from a private seller in the Mpila neighborhood near Chakona.

Table 6. Properties of the super fuels purchased from a private seller in the Mpila neighborhood near Chakona.

Property	Value	Units
Mass	0.1899	kg

Property	Value	Units
Volume	2.5×10^{-4}	m ³
Density	759.96	kg/m ³
Dynamic Viscosity	0.071	Pa s
Kinematic Viscosity	9.34×10^{-5}	m ² /s
Specific Gravity	0.759	-
Density of Water (4 °C)	1000	kg/m ³
Color	Light Red	-
Temperature	20	°C
pH	5	-

Sample 7: Premium gasoline purchased from a private seller in Talangai near the Dragage area.

Table 7 presents the analysis results of the premium gasoline sample purchased from a private seller in Talangai near the Dragage area.

Table 7. Properties of the super fuel purchased from a private seller in Talangai near the Dragage area.

Property	Value	Units
Mass	0.18618	kg
Volume	2.5×10^{-4}	m ³
Density	744.72	kg/m ³
Dynamic Viscosity	0.067	Pa s
Kinematic Viscosity	8.99×10^{-5}	m ² /s
Specific Gravity	0.759	-

Property	Value	Units
Density of Water (4 °C)	1000	kg/m ³
Color	Light Yellow	-
Temperature	20	°C
pH	5	-

Sample 8: super fuel purchased from a private seller in Mouhoumi.

Table 8 presents the analysis results of the premium gasoline sample purchased from a private seller in Mouhoumi.

Table 8. Properties of super fuel purchased from a private seller in Mouhoumi.

Property	Value	Units
Mass	0.18509	kg
Volume	2.5×10^{-4}	m ³
Density	740.36	kg/m ³
Dynamic Viscosity	0.088	Pa s
Kinematic Viscosity	1.189×10^{-4}	m ² /s
Specific Gravity	0.759	-
Density of Water (4 °C)	1000	kg/m ³
Color	Light Yellow	-
Temperature	20	°C
pH	5	-

Table 9. Summary of the Results.

Sample Origin	Density (kg/m ³)	Specific Gravity	Kinematic Viscosity (m ² /s)	pH	Color
Puma station – Batignolles	739.76	0.73976	8.65×10^{-5}	5	Light Yellow
TotalEnergies station – Mazala (Mfilou)	738.96	0.73896	9.47×10^{-5}	5	Light Yellow
Afric station – Mouhoumi (L'Ombre)	740.12	0.74012	7.56×10^{-5}	5	Light Red
SNPC station – Marché Total	736.68	0.73668	1.05×10^{-4}	5	Dark Yellow
X-OIL station – Patte d'Oie	743.44	0.74344	9.95×10^{-5}	5	Light Yellow
Private seller – Mpila	759.96	0.75996	9.34×10^{-5}	5	Light Red
Private seller – Talangai (Dragage area)	744.72	0.75972	8.99×10^{-5}	5	Light Yellow
Private seller – Mouhoumi	740.36	0.75936	1.189×10^{-4}	5	Light Yellow

3.2. Discussion

Density and Specific Gravity

Figure 3 shows the specific gravities of the premium gasoline samples sold in the city of Brazzaville.

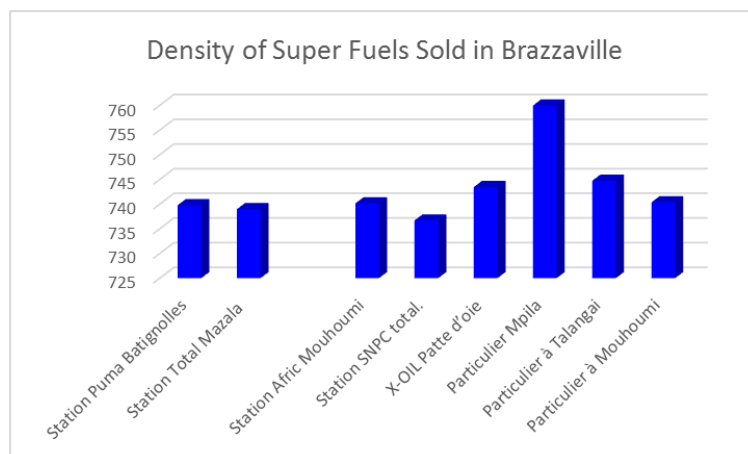


Figure 2. Density of Super Fuels samples sold in the city of Brazzaville.

Figure 2 illustrates the density of premium gasoline samples sold in the city of Brazzaville. The density of premium gasoline sold at service stations in Brazzaville generally ranges around 740 kg/m^3 , except for the X-OIL station at Patte d'Oie, which stands out with a slightly higher density of 743.44 kg/m^3 . In contrast, the premium gasoline sold by private individuals in various neighborhoods shows higher density values, all exceeding 740 kg/m^3 . The highest recorded value is 759.96 kg/m^3 , attributed to the sample purchased from a private seller in the Mpila district near Chakona. These results show that gasoline sold by private vendors tends to have a higher density than that sold in official service stations. Since specific gravity is directly related to density, the same trend is observed: samples from service

stations have specific gravities close to 0.740, with the highest being 0.743 (X-OIL station at Patte d'Oie), while samples from private sellers exceed 0.740, with a maximum value of 0.759, again from the Mpila (Chakona) sample. This indicates that premium gasoline from informal sources has a significantly higher density and specific gravity compared to that of regulated service stations. According to François-Xavier Merlin [11], the density of premium gasoline should range between 720 and 775 kg/m^3 at 15°C . Similarly, Christine Boust et al [12] confirm that the standard density range for premium gasoline lies between 720 and 775 kg/m^3 .

pH

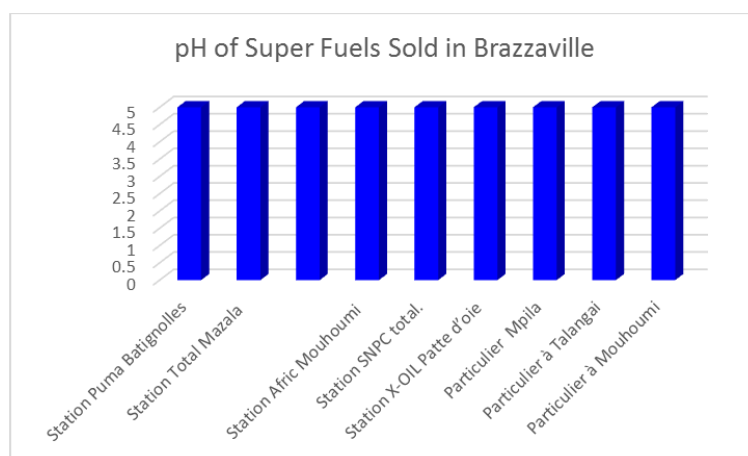


Figure 3. pH values of super fuels samples sold in the city of Brazzaville.

As shown in Figure 3, all premium gasoline samples sold in Brazzaville have a pH equal to 5.

Color

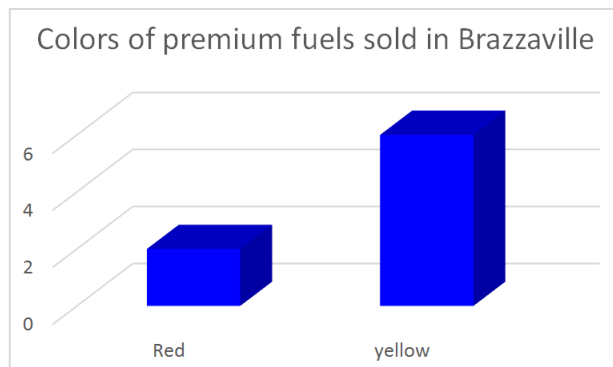


Figure 4. Shows the colors of super fuels samples sold in the city of Brazzaville.

Figure 4 shows the colors of the premium gasoline samples sold in the city of Brazzaville. The results shown in this figure indicate that the majority of premium gasoline samples sold in Brazzaville have a yellow color. The color of all premium gasoline sold at gas stations in Brazzaville ranges from light yellow to dark yellow, except for the sample from the Afric station in the Mouhouni district (l'ombre), which has a light red color. For the premium gasoline sold by private individuals, most also have a light yellow color, with only one exhibiting a light red color. Therefore, it can be noted that the premium gasoline sold in Brazzaville presents two main colors: red and yellow.

Kinematic Viscosity

Figure 5 shows the kinematic viscosities of the premium gasoline samples sold in the city of Brazzaville.

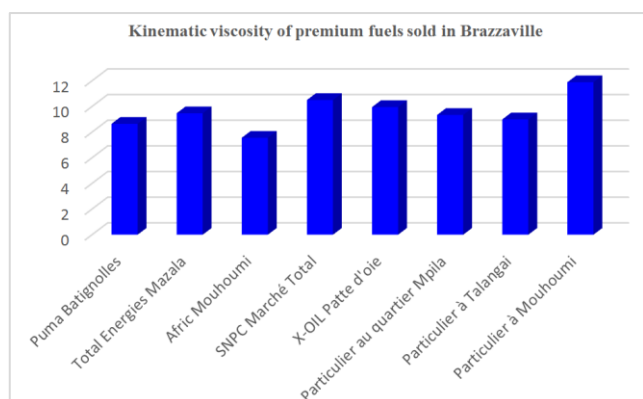


Figure 5. Kinematic viscosities of super fuels sold in Brazzaville.

Figure 5 shows that the kinematic viscosity of premium

gasoline sold in Brazzaville varies depending on the point of sale. The viscosity of premium gasoline sold at gas stations ranges from $7.56 \times 10^{-5} \text{ m}^2/\text{s}$ to $10.05 \times 10^{-5} \text{ m}^2/\text{s}$. The lowest value is attributed to the Afric gas station in the Mouhouni district (l'ombre), while the highest value is from the SNPC (Société Nationale des Pétroles du Congo) station at Marché Total. The viscosity of premium gasoline sold by private individuals ranges from $8.99 \times 10^{-5} \text{ m}^2/\text{s}$ to $11.89 \times 10^{-5} \text{ m}^2/\text{s}$. The lowest value is for premium gasoline purchased from a private seller in the Talangai district near the dragage area, while the highest value is for that sold by a private seller in the Mouhouni district. This shows that the viscosity of premium gasoline sold by private individuals is higher than that of premium gasoline sold at gas stations. According to François-Xavier MERLIN [12], the viscosity of premium gasoline typically ranges between 0.5 and 0.75 mm²/s. Relationship between the applied shear stress and the shear rate of a liquid, sometimes also called the dynamic viscosity or simply viscosity; dynamic viscosity is a measure of a liquid's resistance to flow or deformation [13, 14] and he is so important for petroleum products [15].

4. Conclusion

At the end of this study, the following conclusions were drawn:

- 1) The density and specific gravity of premium gasoline sold in Brazzaville vary depending on whether they are sold at gas stations or by private individuals. It was observed that the density and specific gravity of premium gasoline sold by private individuals are higher than those sold at gas stations.
- 2) The color of premium gasoline sold in Brazzaville ranges from light yellow to light red. The majority of premium gasoline, whether sold at gas stations or by private sellers, is yellow in color, while a small minority exhibits a red color.
- 3) All premium gasoline sold in Brazzaville has a hydrogen potential (pH) equal to 5.
- 4) The kinematic viscosity of premium gasoline sold at gas stations ranges from 7.56×10^{-5} to $10.5 \times 10^{-5} \text{ m}^2/\text{s}$. The lowest value is attributed to the gasoline from the Afric station in the Mouhouni neighborhood, while the highest is from the SNPC station at Marché Total. For gasoline sold by private individuals, the viscosity ranges from 8.99×10^{-5} to $11.89 \times 10^{-5} \text{ m}^2/\text{s}$. Therefore, the kinematic viscosity of gasoline sold by private individuals is higher than that of gasoline sold at gas stations.

Abbreviations

pH Hydrogen Potential

Author Contributions

Ulrich Berry: Conceptualization, Formal Analysis, Methodology, Validation

Smael Magloire Elombo Motoula: Project administration, Software, Visualization, Writing – review & editing

Rene Evrard Josue Samba: Formal Analysis, Funding acquisition, Investigation

Laurette Brigelia Nkeletela: Methodology, Project administration, Validation, Visualization

Ermelan Makaya Poaty: Investigation, Software, Supervision, Validation

Conflicts of Interest

The authors declare no conflicts of interest.

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