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Physical Properties of Petroleum Products Marketed in Congo

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Abstract

The use of fuels and combustibles in internal combustion engines requires strict quality standards to ensure operational efficiency and to limit the environmental impact of emissions. This study focuses on the characterization of the physical properties of petroleum products marketed in Congo, with particular attention to parameters that are critical for proper engine functioning and environmental performance. To achieve this objective, a series of laboratory analyses was conducted on petroleum product samples to determine mass density, specific gravity, color, pH, and viscosity. These measurements were obtained using a controlled experimental setup that included a precision balance, test tube, stopwatch, and an aluminum-ball arrangement for viscosity determination. The characterization carried out provides a coherent description of the physical quality of the petroleum products examined and illustrates how essential fuel properties can be systematically monitored through relatively simple but rigorous testing procedures. The study concludes that careful control of these physical parameters is fundamental to ensuring that petroleum products meet the standards required for safe, efficient engine operation and for reducing the potential contribution of inadequate fuel quality to environmental pollution, thereby underscoring the importance of strengthening quality control practices in the fuel supply chain.

Keywords: Physical Properties; Petroleum Products; Fuel Quality; Internal Combustion Engines; Congo

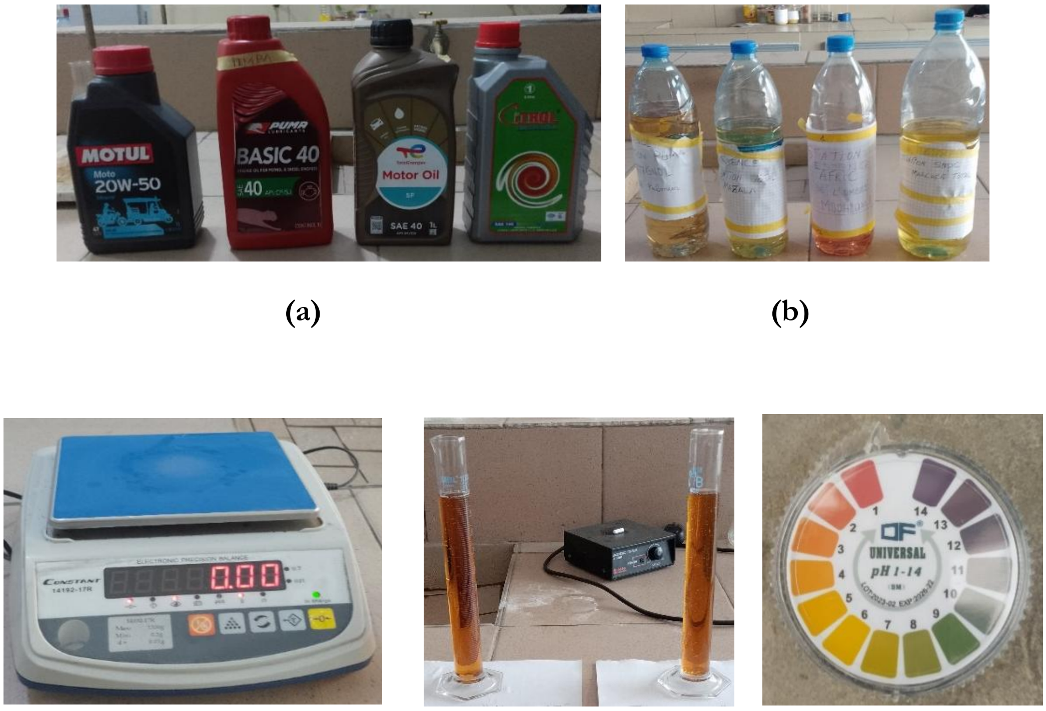
INTRODUCTION

The main objective of petroleum refining is the production of fuels and combustibles. These fuels, derived from crude oil, are essential for the proper functioning of thermal engines used in ships, automobiles, and industrial machinery. The physicochemical properties of fuels, such as density, viscosity, calorific value, octane number, and cetane number, are fundamental to their performance. These characteristics directly influence engine efficiency, pollutant emissions, and fuel storage safety. Therefore, a thorough understanding of these parameters is crucial for optimizing fuel use while minimizing environmental impact (Berry, U. et al, 2025).

The work presented in this study focuses on the analysis of three key petroleum products: lubricating oil, diesel fuel, kerosene, and premium gasoline. These products were selected due to their widespread use and critical role in modern transportation and industry. Specific equipment was used for these analyses, including a precision balance, a test tube, a stopwatch, and an aluminum ball. These tools were essential for accurately measuring the quality parameters of each product. The primary parameters measured included mass density, specific gravity, pH, and viscosity. Each of these properties is integral to the behavior of fuels during circulation and combustion in internal combustion engines. Mass density is a critical parameter because it influences the energy content of the fuel. Fuels with higher densities generally have higher energy content, which can improve engine performance. Specific gravity, which is related to density, provides a comparative measure of the fuel's density relative to water. The pH of the fuel can affect its corrosive properties and its interaction with engine components, with excessively acidic or basic fuels potentially causing damage. Viscosity, on the other hand, plays a major role in fuel flow characteristics. High viscosity can result in poor fuel atomization and incomplete combustion, whereas low viscosity may lead to improper lubrication of engine components. The results of the analyses conducted at a temperature of 20°C were compared to the standard specifications for each of the fuels. The measurements for mass density, specific gravity, pH, and viscosity were found to be in accordance with the accepted norms for the analyzed products. This is significant because any deviation from these standards could lead to compromised fuel performance, increased engine wear, or heightened environmental pollution. For example, fuels with high viscosity can cause increased friction in the engine, leading to overheating and excessive wear. On the other hand, fuels with low viscosity may not provide adequate lubrication, potentially causing premature failure of engine components. The results demonstrate that adherence to these specifications is essential for optimal engine operation and for minimizing the environmental impact of fuels. Fuels that meet these quality standards help ensure efficient combustion, reduced emissions, and a longer engine lifespan. Furthermore, by using fuels that conform to these specifications, the risk of environmental contamination and pollution is minimized. The fuels analyzed in this study were found to be suitable for meeting the technical requirements of modern engines. They contribute to the efficient operation of these engines while simultaneously reducing their impact on the environment. In conclusion, the quality of petroleum products, specifically their density, viscosity, pH, and other key properties, is vital for the efficient and environmentally responsible use of fuels in internal combustion engines. Regular quality control measures, such as those employed in this study, are essential for ensuring that fuels meet the required specifications. This not only optimizes engine performance but also helps in the broader effort to reduce pollutant emissions and improve energy efficiency in transportation and industry.

MATERIALS AND METHODS

This study involved the use of several types of equipment to analyze various fuel samples, including premium gasoline, diesel fuel, kerosene, and lubricants. The precision balance was a key instrument for measuring the mass of each sample with high accuracy, ensuring reliable data for further analysis. A test tube was used to contain and handle the samples safely during experimentation. To measure viscosity, a falling-ball viscometer was employed, providing a straightforward method for assessing the fluid's resistance to flow. Additionally, pH paper was used to evaluate the acidity or basicity of the samples, which is crucial for understanding their chemical behavior and compatibility with engine systems. This combination of instruments was specifically chosen to ensure that each parameter could be measured under controlled and consistent conditions, allowing for accurate results. The carefully selected apparatus provided the necessary tools to conduct reliable tests and obtain precise measurements of the key properties of the fuels and lubricants. By using these tools, the study was able to gather critical data that helps to evaluate the quality and performance of the fuels and lubricants, ensuring that they meet the required standards for optimal engine operation and efficiency. In total, twelve samples were analyzed, including three from each product. The samples were collected from service stations and from private sellers in the city of Brazzaville between May and June 2025. The number of repetitions for the analyses was three in order to obtain the average value.



(a) (b)

(c) (d) (e)

Figure 1: a) Lubricant samples (Berry, U. et al, 2025) b) Gasoline samples [2]
c) Precision balance d) Diesel fuel samples e) pH paper

Mass Density (or Density)

It is imperative to know the mass densities of both the ball and the fluid for this experiment. Mass density is defined as the ratio of the mass of a substance to its corresponding volume, measured at the same temperature. According to Boudjemaa and Abdelkrim [3], this fundamental property is essential for understanding the behavior of materials in various fluid dynamics experiments. Accurate measurement of mass density allows for reliable calculations and analysis of fluid viscosity, ensuring that experimental results are precise. Thus, knowing the densities of both the ball and the fluid is crucial for obtaining valid data.

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

Where m: mass (kg) of petroleum product, V: volume (m^3) of petroleum product. The same process is also used to calculate the mass density of the ball.

Specific Gravity (or Relative Density)

The specific gravity of a substance is defined as the ratio of its mass density to that of a reference body. For liquid and solid phases, water is commonly used as the reference substance, while for gases, air serves as the standard reference. This ratio allows for the comparison of densities between different substances without the need for units, making it a dimensionless quantity. According to Boudjemaa and Abdelkrim (2015), understanding specific gravity is crucial for various applications, including fluid dynamics and material characterization, as it directly influences the behavior of substances in different environments.

$$d = \frac{\varrho}{\varrho e} \quad (2)$$

Where ρ: the mass density of the substance, ρe : the mass density of water, and d : the specific gravity (or relative density) of the substance.

Viscosity

Viscosity is a fluid's resistance to flow. The viscosity measurement was performed using the falling-ball method, which is based on measuring the terminal velocity of a ball with a radius r and mass density (ρ_{ball}) in a liquid with known mass density. This method allows for the determination of viscosity by observing the rate at which the ball moves through the fluid. This approach is widely used due to its simplicity and reliability in measuring the viscosity of liquids in various contexts. The dynamic viscosity is calculated using the following relationship :

$$u_h = \frac{2}{9} \cdot \frac{(\varrho_b - \varrho_h).g.r^2}{v} \quad (3)$$

Where ρ_h : mass density of the oil (g/cm^3); ρ_b : mass density of the ball (g/m^3); g: acceleration due to gravity, which is 9.81 m/s^2; a : radius of the spherical particle (m), v: falling velocity of the ball (m/s), u_h : viscosity of the oil ($Pa{\cdot}s$).

The kinematic viscosity (η) was determined by the ratio between the dynamic viscosity and the density of each sample.

$$\eta = \frac{u_h}{\varrho} \quad (4)$$

Fig 2: Principle of viscosity measurement (Boudjemaa, B. and Abdelkrim, D., 2015)

RESULTS

The results obtained from the various experiments conducted throughout this study are clearly organized and presented in the tables below, providing a concise and structured summary of the findings.

Diesel Fuel from Service Stations and Private Sellers.

Table 1: Average physical properties of diesel fuel [2]

Parameter	Symbol	Value	Units
Mass density	ρ	743	$Kg{\cdot}m^{-3}$
Specific gravity	d	0,74725	-
Kinematic viscosity	η	$1{,}042\times10^{-4}$	$m^2{\cdot}s^{-1}$
Falling height	h	0,250	m
Particle radius	r	$2{,}6\times10^{-3}$	m
Falling velocity	v		$m{\cdot}s^{-1}$
pH	pH	5	-
Temperature	T	20	°C

Premium Gasoline (Supercarburant)

Table 2 : Characteristics of premium gasoline (Berry, U. et al)

Parameter	Symbol	Value	Units
Mass density	ρ	770	$Kg{\cdot}m^{-3}$
Specific gravity	d	0,77	-
Kinematic viscosity	η	0,00006	$m^2{\cdot}s^{-1}$
Falling height	h	0,183	m
Particle radius	r	0,0015	m
Falling velocity	v	0,192	$m{\cdot}s^{-1}$
pH	pH	5	-
Temperature	T	20	°C

Jet Fuel (Kerosene)

Table 3: Characteristics of jet fuel(Berry, U. et al)

Parameter	Symbol	Value	Units
Mass density	ρ	783,5	$Kg{\cdot}m^{-3}$
Specific gravity	d	0,7835	-
Kinematic viscosity	η	$1{,}46x10^{-3}$	$m^2{\cdot}s^{-1}$
Dynamic viscosity	u	$6{,}38x10^{-3}$	Pa.s
Falling height	h	0. 183	m
Particle radius	r	0,0015	m
Falling velocity	v	0,148	$m{\cdot}s^{-1}$
pH	pH	5	-
Temperature	T	20	°C

Lubricants

Table 4 : Average physical properties of lubricants [2].

Parameter	Symbol	Value	Units
Mass density	ρ	842,64	$Kg{\cdot}m^{-3}$
Specific gravity	d	0,84264	-
Kinematic viscosity	η	$1{,}3x10^{-3}$	$m^2{\cdot}s^{-1}$
Drop Height	h	0,250	m

Parameter	Symbol	Value	Units
Falling Velocity	v	0,037	m/s
Particle radius	r	2,6x10^{-3}	m
pH	pH	5	-
Temperature	T	20	°C

DISCUSSION

Mass Density

Figure 3 presents the mass density values for the petroleum products marketed in Congo.

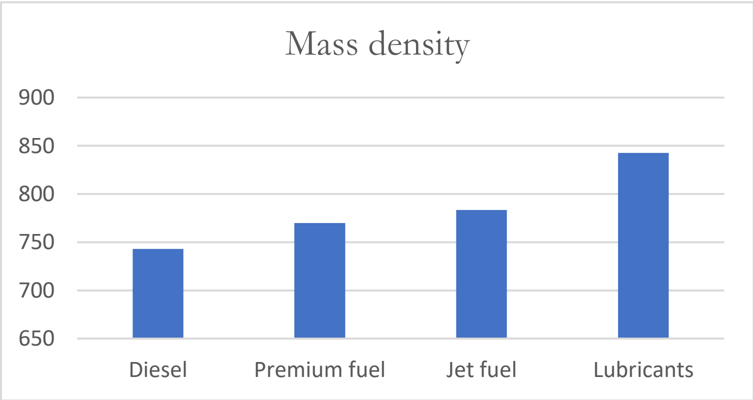


Figure 3: Mass densities of petroleum products

Figure 3 illustrates that the mass density of diesel fuel is lower than that of premium gasoline. This difference is likely due to the fact that diesel fuels marketed by private sellers tend to have significantly lower mass densities compared to those sold at service stations. The variability in diesel fuel density can be attributed to the lack of uniformity in its sourcing and quality control measures in certain markets. On the other hand, premium gasoline and jet fuels were found to comply with the expected standards, which is reassuring for ensuring proper engine operation and fuel performance. Furthermore, it is important to note that these measurements are framed by strict regulatory guidelines. For instance, according to (Le Coin Formation d'In Situ, 2025), hydraulic oils must have a mass density between 800 and 1900 kg/m³ at 40°C, ensuring consistency and optimal performance in industrial applications. In contrast, (François-Xavier Merlin, 2008) and (Christine Boust et al, 2019) set the standard mass density range for premium gasoline between 720 and 775 kg/m³ at 15°C. These regulatory frameworks ensure that fuels meet quality standards and contribute to the reliable operation of engines, while also minimizing harmful emissions. The observed density differences underline the importance of adhering to these regulatory standards, especially in the context of environmental impact and engine performance. Inaccurate or substandard fuel densities could lead to engine malfunctions, increased fuel consumption, or even pollution. Therefore, maintaining consistent and reliable fuel characteristics is vital, not only for optimizing engine efficiency but also for meeting environmental and safety regulations. This highlights the role of strict quality control and regulation in ensuring the performance and sustainability of fuel products in the market.

Specific Gravity (or Density)

According to Figure 4, lubricants have a higher specific gravity (or density) than fuels. This difference is due to the presence of heavier molecules in lubricants compared to those found in fuels. The higher density of lubricants is a result of their chemical composition, which typically includes larger hydrocarbons that provide greater viscosity and lubricating properties. The mass density of lubricants should fall within the range of 0.7 to 0.95, as indicated by the standards. These values are essential for ensuring optimal lubrication and effective engine performance, as well as reducing wear and tear during operation [3].

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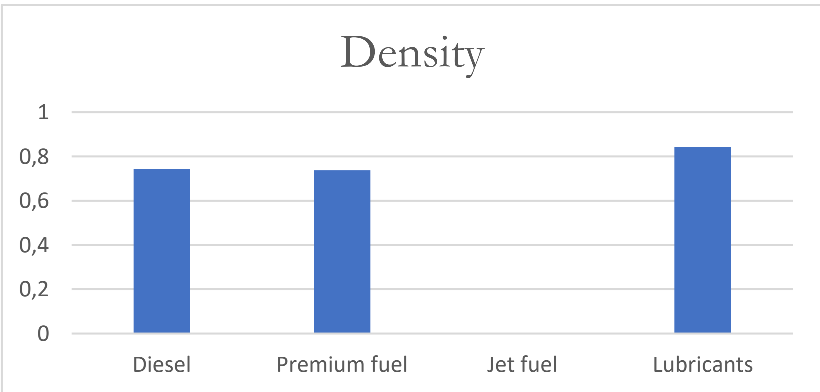

Figure 4: Specific gravities of petroleum products.

Viscosity

Figure 5 presents the kinematic viscosity of the petroleum products marketed in Congo. Viscosity is a critical property that affects the fluidity, flow behavior, and overall performance of fuels and lubricants in engines. Proper viscosity ensures optimal fuel combustion and efficient lubrication, preventing engine wear and maintaining performance.

It is essential for meeting industry standards and ensuring the reliable operation of internal combustion engines..

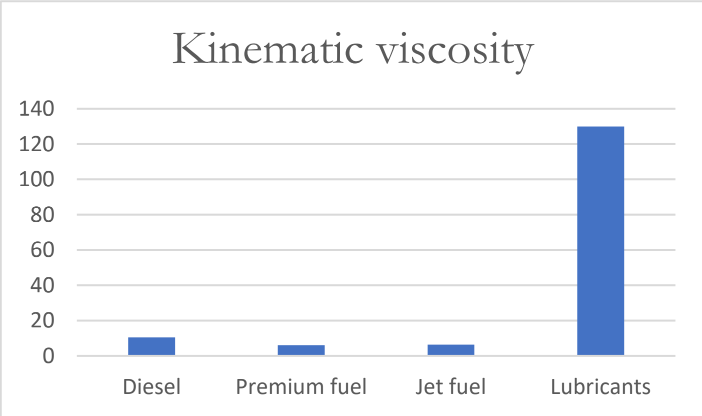

Figure 5 : Kinematic viscosities of petroleum products

Fuels such as diesel, premium gasoline, and lubricants vary significantly in terms of viscosity, which influences their performance in engines and mechanical systems. Diesel fuel has a higher viscosity than premium gasoline and jet fuel, while lubricants have an especially high viscosity. Jean-Claude GUIBET (1997) notes that premium gasoline should have a kinematic viscosity between 0.5 and 0.6 $mm^2.s^{-1}$. In contrast, the kinematic viscosity of diesel fuel should not exceed 9.5×10^{-5} $m^2.s^{-1}$(Guibet, J.-C., 1997). Lubricants, particularly those used for open gears, must meet stringent viscosity requirements. According to international standards (Agence Française de Normalisation), lubricants for open gears should have a viscosity ranging from 4140 to 5060 mm^2/s at 40°C. Additionally, lubricants should have a viscosity between 95 and 140 mm^2/s (WinGD) to ensure adequate lubrication of moving components. These viscosity values are crucial for the proper functioning of engines and mechanical systems. Inadequate viscosity can lead to malfunctions, premature component wear, or a loss of energy efficiency. Therefore, it is essential to adhere to the viscosity standards set for each type of product in order to ensure optimal equipment performance and prolong its lifespan. Viscosity standards help prevent breakdowns and improve operational efficiency in industries using these fluids.

pH

The evaluation of the pH of petroleum products is a key indicator of their chemical stability and compatibility with engine systems. Although pH is traditionally defined for aqueous solutions, adapted techniques allow the measurement of an apparent pH in fuels and lubricants, providing information on their relative acidity. Fuels, with an average pH of approximately 5, contain weak acids dissolved or in emulsion, resulting from hydrocarbon oxidation or contaminants such as carboxylic acids formed during storage, particularly in the presence of moisture, which can promote corrosion and reduce fuel stability. In contrast, lubricants, with a slightly higher pH, contain basic or neutral additives, such as detergents and neutralizing agents, which neutralize acids generated by oxidation or combustion, thereby protecting metal surfaces and maintaining fluid stability. These differences reflect the distinct chemical characteristics of these products and highlight the importance of monitoring them to ensure engine performance and longevity.

Color

Gasolines and diesel fuels display a wide range of colors, varying from light yellow to deep red, reflecting differences in composition and refining processes. Lubricants, on the other hand, consistently present a yellow appearance, indicating a more uniform formulation compared to these more variable fuel products.

CONCLUSION

This study characterized the physical properties of petroleum products marketed in Congo, with a focus on fuels and lubricants. The findings show that the mass density of diesel fuels, particularly those sold by private vendors, is lower than that of premium gasoline, indicating potential differences in energy content and efficiency. The pH of fuels is approximately 5, whereas lubricants have a pH of around 6, reflecting a slightly more neutral character for lubricants and a more acidic nature for fuels, with possible implications for storage conditions and long-term effects on engine components. The color of fuels was found to be highly variable and sometimes misleading, making visual identification unreliable and increasing the risk of misclassification and improper use. In terms of flow properties, the average kinematic viscosity of premium gasoline is 6×10^{-5} m^2/s, compared with 1.3×10^{-3} m^2/s for lubricants and 1.042×10^{-4} m^2/s for diesel fuels, underscoring substantial differences in their functional roles in combustion and mechanical protection.

These results provide an empirical baseline on the quality-related physical characteristics of fuels and lubricants available on the Congolese market. Scientifically, the study contributes to the characterization of petroleum products in a context that remains underrepresented in the literature, by jointly examining mass density, pH, color, and kinematic viscosity as interrelated indicators of product performance and suitability for engine use. Practically, the evidence reinforces the critical importance of systematic quality control and regular testing, since variations in these properties can directly affect engine performance, fuel efficiency, and the durability of mechanical components. The conclusions support the need for stricter monitoring and standardization in supply chains, especially where products are distributed by private vendors.

Future research should extend this work by incorporating larger and more diverse samples of fuels and lubricants, including products from different regions, suppliers, and seasons, to better capture variability in market quality. Subsequent studies are also encouraged to combine physical measurements with chemical analyses and controlled engine performance tests to more precisely link specific property profiles to operational outcomes and component degradation. In addition, longitudinal investigations on storage conditions and aging effects would help clarify how parameters such as pH, color, and viscosity evolve over time and how these changes influence the reliability and safety of engines and machinery.

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