

Research Article

Comparative Study of the Physicochemical Properties of Petroleum Products Sold in the Republic of Congo: The Case of Lubricants

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Abstract

Petroleum products play a vital role in global economic development and are fundamental to numerous industries as well as daily life. They are commonly used in transportation (as fuels) and in the petrochemical industry for the production of first- and second-generation synthesis intermediates. The most common petroleum products include gasoline, diesel fuels, liquefied petroleum gases (LPG), and lubricants. These products must meet sales standards and specifications to ensure optimal performance and environmental compliance. This study focuses exclusively on lubricants. Among the key properties required for petroleum products are: the octane number for gasoline, the cetane index for diesel, flash point, freezing point, density, vapor pressure, viscosity, and volatility. However, this study concentrates solely on the physicochemical properties of lubricants. Specifically, it investigates their density, relative density, viscosity, and pH which constitute the main objective of this research. The quantities analyzed were measured using standard laboratory equipment such as a precision balance, test tubes, pH paper, and a Hoppler-type viscometer (ball viscometer). All lubricant samples were collected from fuel stations and various informal vendors in Brazzaville, Republic of Congo. The results of the analyses indicate that lubricants sold at fuel stations are denser than those sold by informal vendors. Furthermore, station-sold lubricants are typically yellow in color, while those from informal sources range from light yellow to pink, and tend to exhibit slightly less stable viscosity levels.

Keywords

Properties, Petroleum Products, Lubricants

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1. Introduction

Friction, the force that opposes relative motion between two surfaces in contact, is an omnipresent phenomenon in both everyday life and industrial systems. Although widely observed, a detailed understanding of friction remains incomplete. Tribology, the science that studies friction, wear, and lubrication, faces both the complexity of the underlying physical phenomena and the technological challenges of developing appropriate measurement tools for experimental analysis. In industry, controlling friction is critical. It has driven the development of specialized lubricants designed to meet the specific requirements of various processes [1]. Lubrication aims to create a continuous fluid film between two moving surfaces, in order to reduce friction, limit heat generation, and prevent premature wear of the materials in contact. The effectiveness of this process depends on the lubricant's ability to maintain its properties under often severe conditions, such as high mechanical loads, variable speeds, temperature increases, surface irregularities, and abrasive effects. A high-quality lubricant must therefore offer optimal resistance to these stresses while ensuring the continuity of the protective film throughout the operational phase [2]. Today, oil companies and motor industry manufacturers face two major and simultaneous challenges. On the one hand, they must comply with increasingly stringent environmental regulations, imposed by governments to limit pollutant emissions, reduce carbon footprints, and protect public health. On the other hand, they must keep pace with the rapid rate of technological innovation, which demands constant adaptation of products, processes, and materials in order to remain competitive in a rapidly evolving market. These two dimensions, though sometimes contradictory, force industry stakeholders to deeply rethink their approaches to lubricant formulation, engine design, and sustainable industrial strategies [3]. A high-quality lubricating oil plays a crucial role throughout its life cycle by helping reduce energy losses and limiting the environmental impact of mechanical systems. In this study, we conducted a comparative analysis of the properties of the main lubricants sold in the Republic of Congo. The analyzed properties include mass density, relative density, kinematic viscosity, color, and pH. Mass density was determined by measuring the mass and volume of each sample; relative density was calculated by comparing each sample's mass density to that of water at 4 °C; viscosity was determined using the Hoppler's method (the falling ball viscometer method), and pH was measured using pH paper.

2. Materials and Methods

2.1. Materials

The raw materials used in this study are lubricants sold at fuel stations and those sold by individual vendors, all sourced from the city of Brazzaville in the Republic of Congo.

The equipment used includes: a precision balance, a graduated cylinder, an aluminum spherical ball, pH paper, and a stopwatch.



Figure 1. Lubricants from fuel stations and individual vendors.

2.2. Methodology

The determination of lubricant properties was carried out using laboratory instruments on a fixed quantity of each product.

2.2.1. Density (Mass Density)

Lubricant density, or specific mass, at a given temperature is defined as mass per unit volume and decreases slightly with rising temperature. At 15 °C, densities of internal combustion engine lubricants range from 0.85 to 0.92 kg/dm³ for mineral, semi-synthetic, and conventional synthetic oils, and are approximately 1 kg/dm³ for polyalkylene glycol-based synthetics [4]. The mass density of each lubricant was determined by

sampling a specific quantity of the product. Each sample was first weighed to determine its mass, and its volume was then measured. The mass density is calculated as the ratio of the mass to the volume of the substance:

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

Where: m is the mass of the sample (kg), V is the volume of the sample (m³), ρ is the mass density of the sample (kg/m³).

2.2.2. Density (Relative Density)

The density of a fluid shows how “heavy” it is compared to a reference fluid (often water). Since it is a ratio, it has no unit [5]. The relative density was determined as the ratio between the mass density of the sample and the mass density of water at 4 °C (1000kg/m³):

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

Where: d is the relative density of the sample, ρ is the mass density of the sample (kg/m³), ρ_e is the mass density of water at 4 °C (1000kg/m³).

2.2.3. Viscosity

The viscosity of a liquid is the property of that liquid resulting from the resistance its molecules offer to a force attempting to move them by sliding within it. Thus, the viscosity of a fluid is the resistance the fluid opposes to being set in motion [6]. The viscosity of a fluid is also its ability to resist shear forces that tend to cause the fluid layers to slide over one another [7]. The viscosity of a fluid generally depends on temperature. Temperature affects the cohesive forces between molecules, which determine viscosity. As a result, viscosity usually decreases when the temperature increases [8]. The viscosity was determined using the Hoppler’s method (falling ball viscometer) based on Stoke’s law:

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

Where: μ_h is the dynamic viscosity of the sample (Pa s), ρ_b and ρ_h are the mass densities of the ball and the sample, respectively (kg/m³), g is the acceleration due to gravity (m/s²), r is the radius of the ball (m), v is the velocity of the falling particle (m/s).

2.2.4. pH

The pH (potential of hydrogen) was determined using pH paper. The pH paper was dipped into a test tube containing the sample, and the resulting color change on the paper was compared to the reference color chart provided with the pH paper to determine the corresponding pH value. Any color

change affects both the indicator and the color scale in the same way, ensuring reliable readings even for colored solutions. This allows the user to obtain accurate and dependable pH measurements [9].

3. Results and Discussion

3.1. Results

The results of the analyses are summarized in the tables below.

3.1.1. Lubricants Sold by Gas Stations

(i). Citrol Lubricants

Table 1 presents the results of the analyses performed on the oil named Citrol Lubricants.

Table 1. Properties of Citrol Lubricants.

Properties	Sample (Citrol Lubricants SAE 40)	
	Value	Units
Mass	0,211	kg
Volume	2,5.10 ⁻⁴	m ³
Mass Density	844,080	Kg /m ³
Drop Height	0,250	m
Drop Time	7,800	s
Falling Velocity	0.032	m/s
Dynamic Viscosity	0.85	Pa. s
Kinematic Viscosity	10-3	m ² /s
Particle Radius	2,6.10 ⁻³	m
Liquid Density	0,844	-
Ball Density (or Mass Density of the Ball)	2700	Kg /m ³
Water Density (4 °C)	1000	Kg /m ³
Color	Yellow	-
Temperature	20	°C
pH		-

(ii). Motor Oil (Total Énergies)

Table 2 presents the results of the analyses performed on the oil named Motor Oil.

Table 2. Properties of Motor Oil.

Properties	Sample (Motor oil)	
	Value	Units
Mass	0,215	kg
Volume	2,5.10 ⁻⁴	m ³
Mass Density	860,760	Kg /m ³
Drop Height	0,250	m
Drop Time	6,680	s
Falling Velocity	0,037	m/s
Dynamic Viscosity	0,73	Pa. s
Kinematic Viscosity	8,51.10 ⁻⁴	m ² /s
Particle Radius	2,6.10 ⁻³	m
Liquid Density	0,860	-
Ball Density (or Mass Density of the Ball)	2700	Kg /m ³
Water Density (4 °C)	1000	Kg /m ³
Color	Light yellow	-
Temperature	20	°C
pH	6	-

(iii). Puma Lubricants

Table 3 presents the results of the analyses performed on the oil named Puma Lubricants.

Table 3. Properties of Puma Lubricants.

Properties	Sample (Puma Lubricants)	
	Valeur	Unit é
Mass	0,211	kg
Volume	2,5.10 ⁻⁴	m ³
Mass Density	845,720	Kg /m ³
Drop Height	0,250	m
Drop Time	6,190	s
Falling Velocity	0,040	m/s
Dynamic Viscosity	0,68	Pa. s
Kinematic Viscosity	8,07.10 ⁻⁴	m ² /s
Particle Radius	2,6.10 ⁻³	m
Liquid Density	0,845	-
Ball Density (or Mass Density of the Ball)	2700	Kg /m ³
Water Density (4 °C)	1000	Kg /m ³
Color	Dark yellow	-

Properties	Sample (<i>Puma Lubricants</i>)	
	Valeur	Unit é
Temperature	20	°C
pH	5	-

(iv). Motul Moto

Table 4 presents the results of the analyses performed on the oil named Motul Moto.

Table 4. Properties of Motul Moto.

Properties	Sample (<i>Motul Moto</i>)	
	Value	Units
Mass	0,212	kg
Volume	2,5.10 ⁻⁴	m ³
Mass Density	849	Kg /m ³
Drop Height	0,250	m
Drop Time	6,210	s
Falling Velocity	0,040	m/s
Dynamic Viscosity	0,68	Pa. s
Kinematic Viscosity	8,03.10 ⁻⁴	m ² /s
Particle Radius	2,6.10 ⁻³	m
Liquid Density	0,849	-
Ball Density (or Mass Density of the Ball)	2700	Kg /m ³
Water Density (4 °C)	1000	Kg /m ³
Color	Deep yellow	-
Temperature	20	°C
pH	6	-

(v). Rubia (Total Energies)

Table 5 presents the results of the analyses performed on the oil named Rubia.

Table 5. Properties of Rubia.

Properties	Sample (<i>Rubia</i>)	
	Value	Units
Mass	0,084	kg
Volume	10 ⁻⁴	m ³
Mass Density	840	Kg /m ³
Drop Height	0,183	m

Properties	Sample (Rubia)	
	Value	Units
Drop Time	11,600	s
Falling Velocity	0,015	m/s
Dynamic Viscosity	1,68	Pa. s
Kinematic Viscosity	0,002	m ² /s
Particle Radius	2,5.10 ⁻³	m
Liquid Density	0,840	-
Ball Density (or Mass Density of the Ball)	2700	Kg /m ³
Water Density (4 °C)	1000	Kg /m ³
Color	Dark yellow	-
Temperature	20	°C
pH	6	-

(vi). Quartz (Total Energies)

Table 6 presents the results of the analyses performed on the oil named Quartz.

Table 6. Properties of Quartz.

Properties	Sample (Quartz)	
	Value	Units
Mass	0,085	kg
Volume	10-4	m ³
Mass Density	850	Kg /m ³
Drop Height	0,183	m
Drop Time	7,730	s
Falling Velocity	0,023	m/s
Dynamic Viscosity	1,09	Pa. s
Kinematic Viscosity	0,001	m ² /s
Particle Radius	2,5.10 ⁻³	m
Liquid Density	0,850	-
Ball Density (or Mass Density of the Ball)	2700	Kg /m ³
Water Density (4 °C)	1000	Kg /m ³
Color	Dark yellow	-
Temperature	20	°C

Properties	Sample (Quartz)	
	Value	Units
pH	5	-

3.1.2. Lubricants Sold by Individual Vendors

In this section, we present the properties of lubricants sold by individual vendors in various neighborhoods of Brazzaville.

(i). Oil Purchased from an Individual Vendor in the La Base Neighborhood (Saint-Michel Area)

Table 7 presents the results of the analyses performed on the oil purchased from an individual vendor in La Base near the Saint-Michel Parish.

Table 7. Properties of the oil purchased from an individual vendor in La Base near the Saint-Michel Parish.

Properties	Sample (La base)	
	Value	Units
Mass	0,210	kg
Volume	2,5.10 ⁻⁴	m ³
Mass Density	841,56	Kg /m ³
Drop Height	0,183	m
Drop Time	6,6	s

Properties	Sample (La base)	
	Value	Units
Falling Velocity	0,037	m/s
Dynamic Viscosity	0,740	Pa. s
Kinematic Viscosity	8,79.10 ⁻⁴	m ² /s
Particle Radius	2,6.10 ⁻³	m
Liquid Density	0,840	-
Ball Density (or Mass Density of the Ball)	2700	Kg /m ³
Water Density (4 °C)	1000	Kg /m ³
Color	Light yellow	-
Temperature	20	°C
pH	5	-

(ii). Oil Purchased from an Individual Vendor in the Mpila Neighborhood (Chakona Area)

Table 8 presents the results of the analyses performed on the oil purchased from an individual vendor in Mpila near Chakona.

Table 8. Properties of the oil purchased from an individual vendor in the Mpila neighborhood near Chakona.

Properties	Sample (Mpila/Chakona)	
	Value	Units
Mass	0,206	kg
Volume	2,5.10 ⁻⁴	m ³
Mass Density	824	Kg /m ³
Drop Height	0,250	m
Drop Time	6,21	s
Falling Velocity	0,040	m/s
Dynamic Viscosity	0,69	Pa. s
Kinematic Viscosity	8,38.10 ⁻⁴	m ² /s
Particle Radius	2,6.10 ⁻³	m
Liquid Density	0,820	-
Ball Density (or Mass Density of the Ball)	2700	Kg /m ³
Water Density (4 °C)	1000	Kg /m ³
Color	Orange	-

Properties	Sample (Mpila/Chakona)	
	Value	Units
Temperature	20	°C
pH	6	-

(iii). Oil Purchased from an Individual Vendor at the Mougali Roundabout

Table 9 presents the results of the analyses performed on the oil purchased from an individual vendor at the Mougali roundabout.

Table 9. Properties of the oil purchased from an individual vendor at the Mougali roundabout.

Properties	Sample (Rond-Point Mougali)	
	Value	Units
Mass	0,204	kg
Volume	2,5.10 ⁻⁴	m ³
Mass Density	819.96	Kg /m ³
Drop Height	0,250	m
Drop Time	7.67	s
Falling Velocity	0,032	m/s
Dynamic Viscosity	0,86	Pa. s
Kinematic Viscosity	1,05.10 ⁻³	m ² /s
Particle Radius	2,6.10 ⁻³	m
Liquid Density	0,81	-
Ball Density (or Mass Density of the Ball)	2700	Kg /m ³
Water Density (4 °C)	1000	Kg /m ³
Color	Orange	-
Temperature	20	°C
pH	5	-

(iv). Oil Purchased from an Individual Vendor on Trois Martyrs Avenue

Table 10 presents the results of the analyses performed on the oil purchased from an individual vendor on Trois Martyrs Avenue.

Table 10. Properties of the oil purchased from an individual vendor on Trois Martyrs Avenue.

Properties	Sample (Av des 3 Martyrs)	
	Value	Units
Mass	0,207	kg
Volume	2,5.10 ⁻⁴	m ³
Mass Density	828,68	Kg /m ³
Drop Height	0,250	m
Drop Time	6,88	s
Falling Velocity	0,036	m/s
Dynamic Viscosity	0,766	Pa. s
Kinematic Viscosity	9,24..10 ⁻⁴	m ² /s
Particle Radius	2,6.10 ⁻³	m
Liquid Density	0,828	-
Ball Density (or Mass Density of the Ball)	2700	Kg /m ³
Water Density (4 °C)	1000	Kg /m ³
Color	Orange	-
Temperature	20	°C
Properties	5	-

3.2. Discussion

3.2.1. Mass Density

The following figures respectively show the viscosities of lubricants sold at fuel stations and those sold by individual vendors.

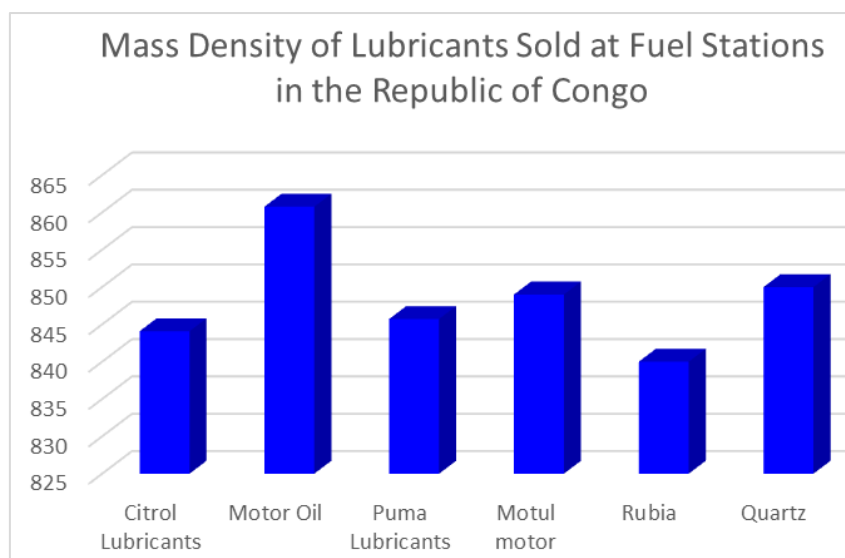
**Figure 2.** Mass densities of lubricants sold at fuel stations.

Figure 2 illustrates the variations in mass density observed among lubricants sold at fuel stations in the Republic of

Congo. These variations reflect a degree of disparity between products, likely attributable to specific formulations designed to meet varying requirements such as engine type, operating conditions, or temperature ranges. Among all the evaluated products, *Motor Oil*, marketed by *Total Energies*, exhibits the *highest mass density*. This characteristic may result from a denser formulation, possibly enriched with functional additives. In contrast, *Rubia* stands out with the *lowest mass density*, which may indicate a lighter composition or a lower concentration of heavy components. The other lubricants analyzed: *Citrol Lubricants*, *Puma Lubricants*, *Motul Moto*, and *Quartz*, show values ranging from 845 to 851 kg/m³, suggesting similar physicochemical formulations and potentially equivalent technical applications. According to [10], the mass density of hydraulic oils should range from 800 kg/m³ to

1900 kg/m³ at 40 °C.

Figure 3 illustrates the differences in mass density among lubricants sold by individual vendors in the Republic of Congo. These variations reflect a certain degree of heterogeneity, likely due to formulations tailored to specific uses. The lubricant purchased in La Base near the Saint-Michel Parish stands out with the highest mass density, possibly indicating a more concentrated composition. In contrast, the lubricant sold at the Mounjali roundabout shows the lowest mass density, which could suggest a lighter formulation. The lubricant purchased on Trois Martyrs Avenue has a density of 828.68 kg/m³, while the one from Mpila near Chakona shows a density of 824 kg/m³. Overall, the mass densities of lubricants sold by individual vendors are lower than those sold at fuel stations.

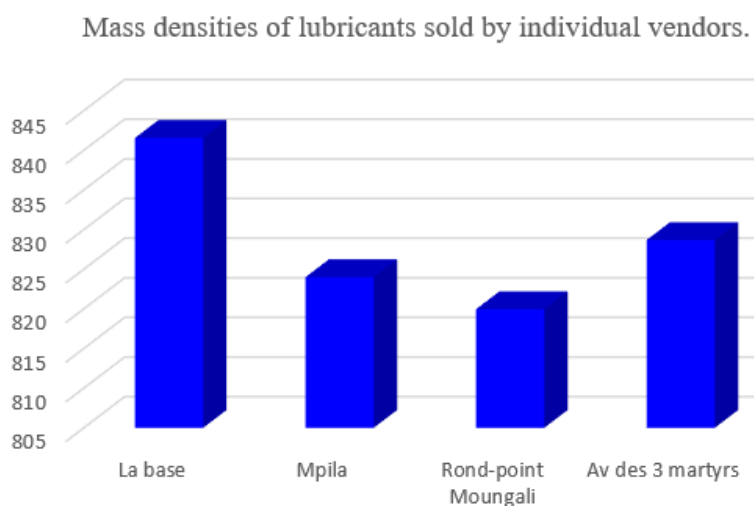


Figure 3. Mass densities of lubricants sold by individual vendors.

3.2.2. Density

Figures 4 and 5 show the viscosities of lubricants sold at service stations and those sold by private individuals, respectively.

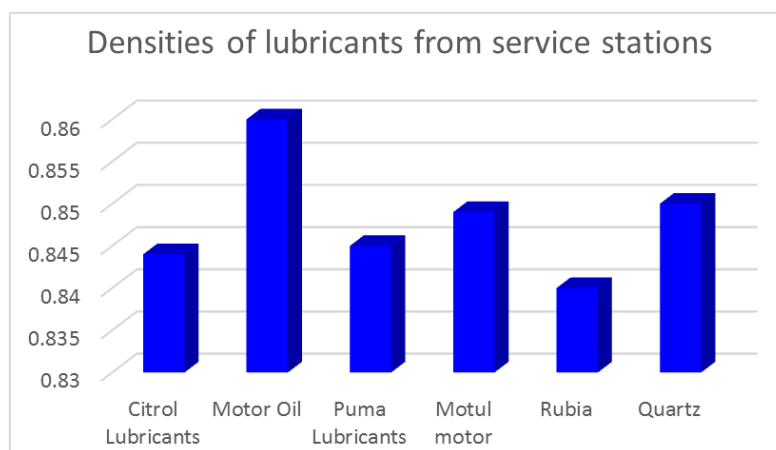


Figure 4. Densities of lubricants sold in service stations.

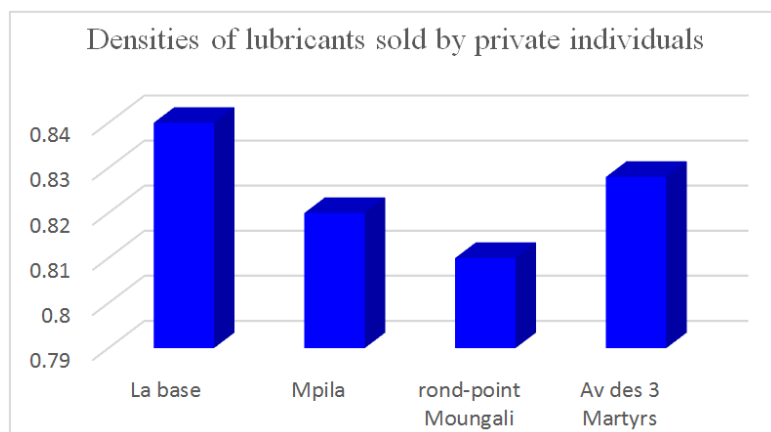


Figure 5. Densities of lubricants sold by private individuals.

Figures 4 and 5 show that the lubricants sold in service stations are denser than those sold by private individuals, as their densities are above 0.84. In contrast, those sold by private individuals have densities below 0.84. The density of lubricants generally ranges between 0.7 and 0.95 [11]. Therefore, the lubricants sold by private individuals meet the required specifications.

3.2.3. Kinematic Viscosity

Viscosity is an essential characteristic for evaluating oils or combustible liquids such as fuel oil. It defines the temperature range within which the fluid can be used effectively, thereby ensuring optimal operation of thermal or hydraulic equipment. In the case of oils, viscosity influences energy transmission within hydraulic systems, guarantees smooth circulation to all moving parts of the engine, and plays an important role in resistance to impacts and mechanical stresses between contacting components [1]. Figure 6 illustrates the viscosity variations observed among lubricants sold at service stations

in the Republic of Congo. These variations reflect some disparity between products, probably attributable to specific formulations designed to meet different requirements such as engine type, operating conditions, or temperature ranges. Among the evaluated lubricants, the Rubia lubricant marketed by Total Energies shows the highest viscosity. This characteristic could result from a denser formulation, possibly enriched with functional additives. Conversely, the Motor Oil lubricant stands out with the lowest density, which may indicate a lighter composition or a lower concentration of heavy components. Citrol Lubricants and Quartz lubricants both present the same viscosity of 10^{-3} m²/s, suggesting they likely have similar compositions. The other lubricants have kinematic viscosities at 20 °C ranging between $0.803 \cdot 10^{-3}$ and $0.851 \cdot 10^{-3}$ m²/s, indicating that their compositions are very close. According to international standards [12], lubricants for open gears must have a viscosity between 4140 and 5060 mm²/s at 40 °C. Moreover, the viscosity of lubricants should range between 95 and 140 mm²/s [13].

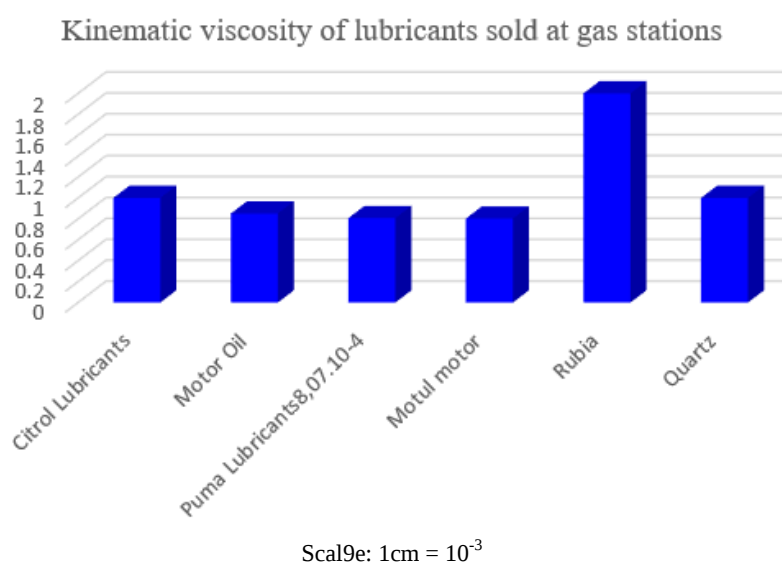


Figure 6. Kinematic viscosities of lubricants sold in service stations.

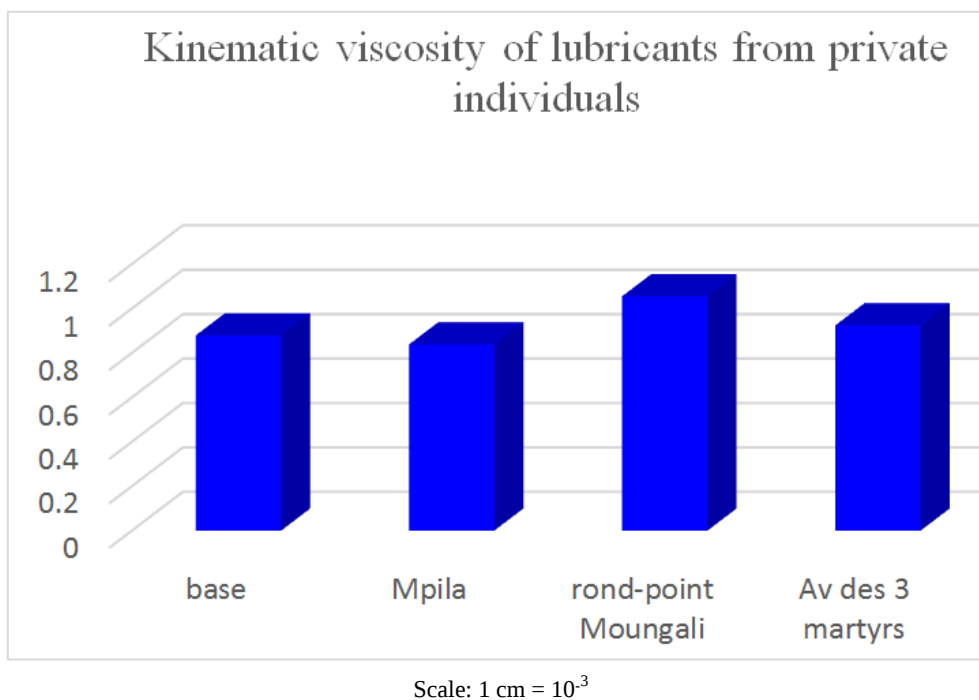


Figure 7. The kinematic viscosities of lubricants sold by individuals.

3.2.4. pH

Weekly monitoring of the pH of the cooling lubricant is essential to ensure its chemical stability during use. Any deviation from the recommended pH range serves as an early

indicator of fluid degradation, requiring immediate corrective action [14]. The pH of lubricants is around 8.9 [15]. Figures 8 and 9 show the pH values of lubricants sold by gas stations and individuals.

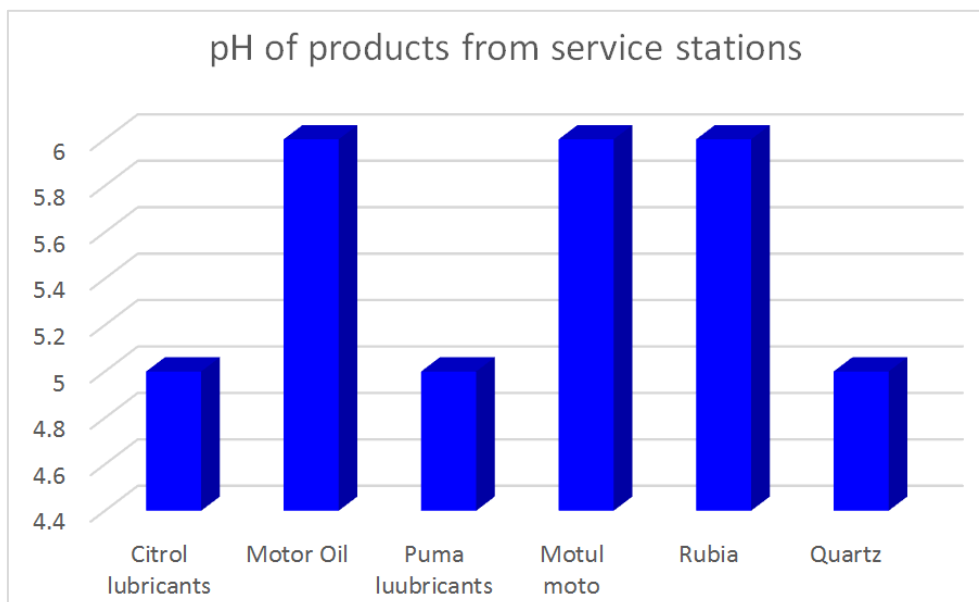


Figure 8. pH of lubricants sold by gas stations.

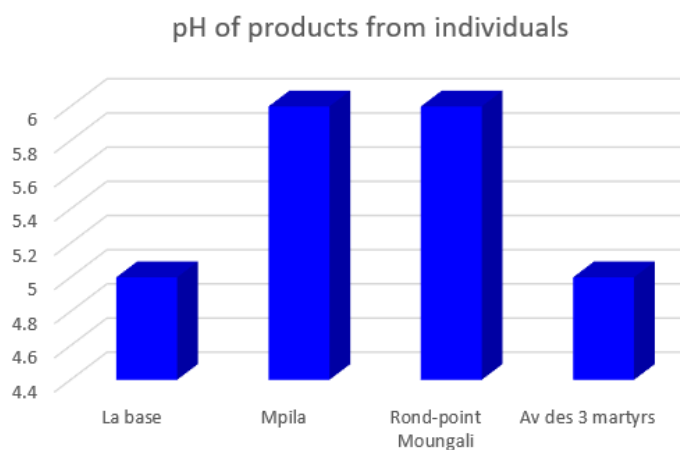


Figure 9. pH of lubricants sold by individuals.

3.2.5. Color

a) Lubricants from service stations

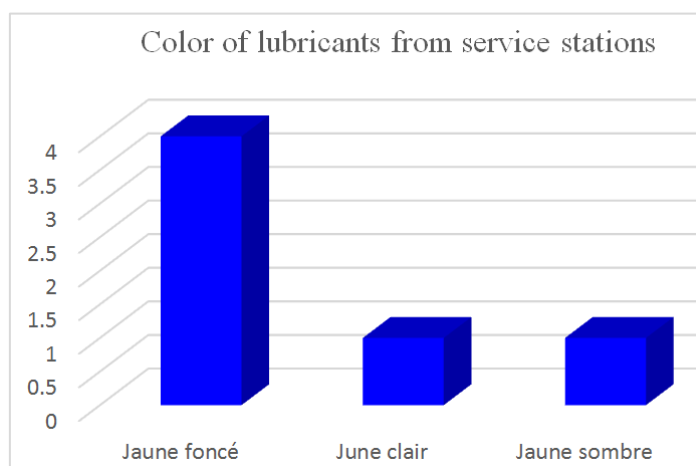


Figure 10. Color of lubricants from service stations.

b) Lubricants from individuals

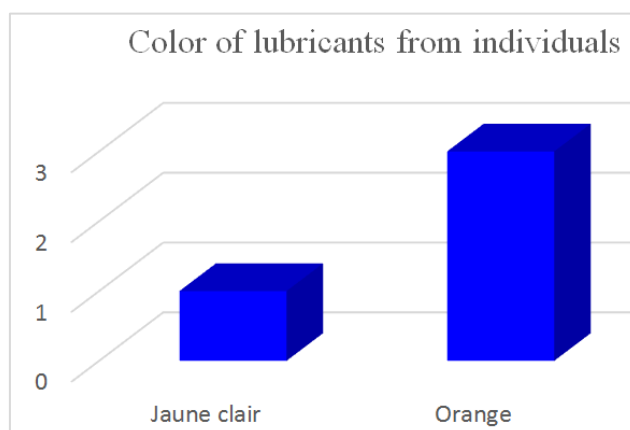


Figure 11. Color of lubricants from individuals.

The color of lubricants sold at service stations is yellow, ranging from light yellow to dark yellow. The predominant color is dark yellow. In contrast, the color of lubricants sold by individuals varies from light yellow to orange, with orange being the predominant color for individual sellers' lubricants.

4. Conclusion

This study focused on the properties of lubricants sold in the city of Brazzaville, Republic of Congo. The results of tests performed on these lubricants allowed the following conclusions to be drawn:

- 1) The density of lubricants sold at service stations ranges from 825 to 860 kg m⁻³, whereas that of lubricants sold by individuals ranges from 800 to 840 kg m⁻³. Lubricants sold by individuals have a lower density than those sold at service stations.
- 2) Lubricants sold at service stations are denser than those sold by individuals.
- 3) The viscosity of lubricants sold by individuals is slightly more stable than that of lubricants sold at service stations.
- 4) Lubricants sold in the Republic of Congo have a pH ranging between 5 and 6.
- 5) The color of lubricants sold at service stations varies from light yellow to dark yellow, while those sold by individuals vary from light yellow to orange.

Abbreviations

pH Potential of Hydrogen
SAE Society of Automotive Engineer

Author Contributions

Ulrich Berry: Conceptualization, Formal Analysis, Project administration

Westinevy Benarez Ndzessou: Methodology, Resources, Supervision

Laurette Brigelia Nkeketela: Software, Supervision, Writing – review & editing

René Evrard Josué Samba: Funding acquisition, Visualization, Writing – review & editing

Ermelan Makaya Poaty: Funding acquisition, Methodology, Validation, Writing – original draft

Conflicts of Interest

The authors declare no conflicts of interest.

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