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CONTRIBUTION TO THE PRODUCTION AND PHYSICOCHEMICAL CHARACTERIZATION OF PYROLYTIC OIL FROM USED INNER TUBES FOR THE PRODUCTION OF CONVENTIONAL FUELS IN CONGO REPUBLIC (RC).

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ABSTRACT

Nowadays, plastic materials have become omnipresent in our daily lives due to their light weight, strength, and low cost. They are used in a wide range of applications such as packaging, clothing, electronic equipment, furniture, and more. However, their widespread use comes with a serious environmental downside, as a large portion of plastic waste ends up in nature or landfills, contributing to land and marine pollution. Recycling plastic waste has therefore become a necessary solution to reduce its ecological impact. The aim of this study is to characterize the pyrolytic oil produced from used plastics (specifically inner tubes). The method used to produce this oil is slow pyrolysis. After extraction, the oil was characterized based on parameters such as color, density, viscosity, and pH.

INTRODUCTION

Used inner tubes and end-of-life tires are among the most common hazardous solid wastes worldwide, with an estimated global annual production of around 17 million tons [1]. These materials have been identified as a major environmental concern. Due to their non-biodegradable nature, these bulky wastes pose significant health and environmental risks, such as landscape degradation, the proliferation of harmful insects, and fire hazards, including the emission of black smoke that is harmful to human health. The growing global demand for raw materials to meet the needs of industrial growth is one of the main causes of today's environmental problems. In this context, the treatment of end-of-life inner tubes has become an important environmental issue. The depletion of oil reserves and the consequences of global dependence on fossil resources which, according to some experts, could run out in the coming years have prompted deep reflection and awareness. Nearly all modes of transportation and many industries rely on fossil energy resources. Our idea was to recover and recycle this tire waste to give it a second life, with the aim of conserving natural resources in the Republic of Congo and addressing the frequent fuel shortages (gasoline and diesel) that occur monthly in the country. The main goal of this work is to develop an energy recovery pathway to reduce the volume of waste generated by the tire industry (inner tubes). In this context, pyrolysis and distillation are potential solutions, though only pyrolysis is considered in our case. Indeed, pyrolysis is carried out at lower temperatures compared to incineration and gasification, significantly reducing the risk of metal evaporation or sublimation.

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MATERIALS AND METHODS

Materials Used

The organic material used in this study consisted of end-of-life inner tubes, which were collected from the streets of Bacongo, a district in the city of Brazzaville, the capital of the Republic of Congo (Fig. 1).

Fig. 1. Inner tube waste.

Production of Pyrolytic Oil

The process is based on parameters including reactor type, temperature, residence time, pressure, and reactor volume. In the case of waste treatment from the tire industry, various types of reactors and operating conditions have been tested and described by different authors. Notably, Williams [2] and Martinez et al. [3] have published comprehensive reviews on the subject.

The production of pyrolytic oil in this study was carried out in five steps.

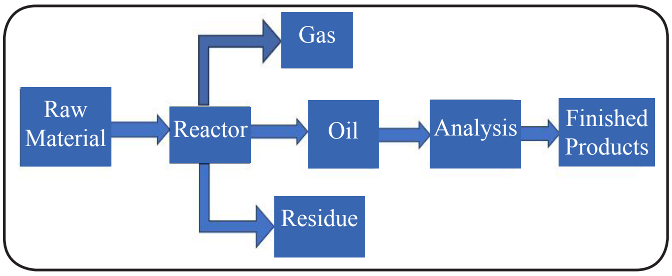

Fig. 2. The different stages of pyrolytic oil production

The first step consisted of selecting the inner tubes, cutting them into pieces, and weighing them. A mass of 2 kg of inner tubes was used.

The second step involved placing the inner tube pieces into a cylindrical tank used as a reactor, and then heating the system to a temperature of 800°C for 37 minutes.

The third step was the collection of pyrolytic oil. During heating, the vapor generated in the reactor was transported through a pipeline and cooled using a water condenser (at room temperature). A portion of the vapor condensed and was collected in a storage container, while the remainder consisted of non-condensable gases.

After pyrolysis, three products were obtained: pyrolytic oil, carbon black (char), and non-condensable gas.

Fig. 3. (a) Pyrolysis setup, (d) Pyrolytic oil,(c) Carbon black (char).

Pyrolytic Oil Yield

The yield (η) of the pyrolytic oil was calculated using Equation (1):

$$\eta = \frac{m_h}{m_c} x100 \quad ....(1)$$

Where: m_h: mass of the oil produced (in grams), mc: mass of the inner tubes used (in grams)

Physicochemical Characterization of the Pyrolytic Oil

To evaluate the physicochemical properties of the produced oil, several tests were carried out on the pyrolytic oil sample:

- ***Decantation***

Decantation is the separation process, under the effect of gravity, of several immiscible phases, at least one of which is liquid or gaseous. In this study, we performed a separation of the two phases in order to isolate the relevant part of the sample.

- ***Filtration***

Filtration is a separation technique involving a continuous phase (liquid or gas) and a dispersed phase (solid or liquid), using a filter medium. The selected portion of pyrolytic oil was filtered accordingly.

- ***Density Measurement***

Density is the ratio between the mass per unit volume of a substance and that of a reference material. The density of the pyrolytic oil was determined by measuring both the mass and the volume of a given quantity of oil. Water at the same temperature was used as the reference liquid [4].

$$\rho_h = \frac{m_h}{v_h} \quad ....(2)$$

Where:ρ_h: density of the oil (g/cm³), m_h: mass of the oil sample (g), v_h: volume of the pyrolytic oil measured (cm³).

$$d = \frac{\rho_h}{\rho_e} \quad \text{.............(3)}$$

Where:d: relative density of the pyrolytic oil, ρ_e: density of water (g/cm³), equal to 1 g/cm³.

- ***pH Measurement***

The pH measurement was carried out using pH paper. A sample volume of pyrolytic oil was placed in contact with pH paper in a beaker, causing the paper to change color. The pH value was then determined by comparing the color of the pH paper (after contact with the oil sample) to the color chart provided on the pH paper packaging. The pH value corresponds to the color that most closely matches that of the paper after exposure to the oil.

- **Viscosity**

Viscosity is the ability of a fluid to resist flow. It was determined using the falling ball method, which is based on measuring the terminal velocity of a spherical ball of radius *a* and density (ρ_{ball}) as it falls through a liquid of known density. This experiment is based on Stokes law, as developed by Stokes [5].

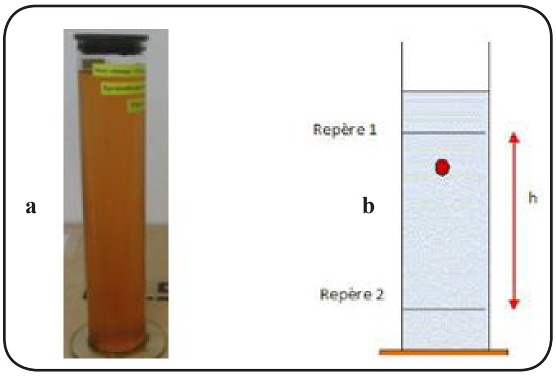

Fig. 5: (a) Ball viscometer [6], (b) Principle [7].

The dynamic viscosity is calculated using the following equation:

$$u_h = \frac{2}{9} \cdot \frac{(\rho_b - \rho_h).g.a^2}{v} \quad \text{..............(4)}$$

Where:μ_h: dynamic viscosity of the oil (Pa·s), ρ_h: density of the oil (g/cm³), ρ_b: density of the ball (g/cm³), g: gravitational acceleration (9.81 m/s²), a: radius of the spherical particle (m), : terminal falling velocity of the ball (m/s).

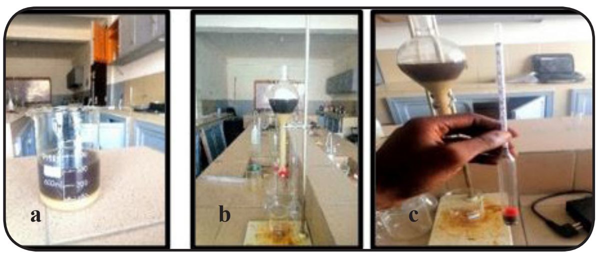

Fig. 6. (a) Raw pyrolytic oil, (b) Decantation, (c)Densimeter.

RESULTS AND DISCUSSION

The physicochemical characteristics of the pyrolytic oil intended for fuel production are presented in Table I. The studied parameters include: color, density (mass per volume), relative density at 25°C, viscosity at 28°C, acidity, and pH of the obtained pyrolytic oil. These characteristics are compared with those of pyrolytic oil produced from used vehicle tires, as reported by Ndrianome T.C.A [7] and Marwa Ourak [8].

Table I: Physicochemical characteristics of the extracted pyrolytic oil compared with those reported in the literature (Ndrianome T.C.A and Marwa Ourak).

Characteristic	Unit	Pyrolytic Oil Produced (This Work)	Oil Produced by Ndrianome T.C.A
Color	–	Dark yellow	Dark yellow
Density (mass per volume)	kg/m³	818.05	868.50
Relative Density	–	0.81805	0.876
Kinematic Viscosity	cSt	2.4	2.03
pH	–	3	2.6

The analyses performed on the obtained pyrolytic oil revealed a dark yellow color and a density of 0.818 at 25°C. This density value is lower than that reported in the literature for oil produced from used tires. This difference is attributed to the varying compositions of tires and inner tubes. Pyrolytic oil produced from inner tubes is therefore more suitable for the production of higher-quality fuels (diesel) and can be directly blended with conventional diesel [9].

The pyrolytic oil obtained exhibited an acidic pH (pH = 3). Diesel fuel production typically requires a minimum pH of 5.50. However, this pH can be increased by adding certain additives to approach neutrality (pH = 7) [10], in accordance with ASTM D6751–2024 standards.

The pyrolytic oil produced in this work has a kinematic viscosity of 2.4 mm²/s, which is significantly lower than the viscosity of standard diesel fuel, generally around 6 mm²/s at 40°C. However, oils intended for diesel production are expected to have low viscosity, in accordance with ASTM D6751–2024. This value therefore complies with both ASTM D6751 and EN 14214 standards [11].

CONCLUSION

The pyrolysis of used inner tubes has proven to be a viable and promising method for producing pyrolytic oil with characteristics suitable for fuel applications. The oil obtained exhibited a dark yellow color, a relatively low density (0.818 g/cm³ at 25°C), and a kinematic viscosity of 2.4 mm²/s, making it compatible with the requirements for diesel blending, in line with ASTM D6751 and EN 14214 standards. However, the oil presented an acidic pH of 3, which remains below the required threshold for direct fuel application. This limitation can be addressed through additive treatments to neutralize the acidity and improve its chemical stability.Compared to pyrolytic oil obtained from used tires, the oil produced from inner tubes offers favorable characteristics, highlighting the importance of feedstock selection in waste-to-fuel conversion processes. Overall, this study contributes to waste recovery strategies and energy sustainability efforts in the Republic of Congo by proposing an alternative way for managing rubber-based waste and mitigating recurring fuel shortages.

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