FT-IR Spectral Characterization of Aromatic Compounds in Pyrolytic Oil from Waste Tires: Implications for Alternative Fuel Applications

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***Abstract*— This study investigates the chemical properties and potential fuel applications of oil derived from waste tire pyrolysis, analyzed through Fourier Transform Infrared (FT-IR) spectroscopy. Pyrolysis was conducted at 500°C under controlled conditions, followed by small-scale atmospheric distillation to enhance the oil's fuel characteristics. The FT-IR analysis identified key functional groups, indicating the presence of aromatic hydrocarbons such as octadecane, and styrene/isoprene, along with long-chain alkanes. A comparative spectral assessment with diesel revealed similarities in hydrocarbon structures, suggesting that pyrolytic oil could serve as an alternative fuel.**

To further analyze its composition, FT-IR spectral library matching was performed. The raw pyrolytic oil exhibited a 95.59% similarity to octadecane ($C_{18}H_{38}$), confirming a significant presence of long-chain hydrocarbons commonly found in conventional fuels. Meanwhile, the distilled fraction demonstrated an 83.83% match with styrene-isoprene, indicating the presence of polymeric compounds that may influence combustion behavior. While these findings highlight the fuel potential of pyrolytic oil, the presence of oxygenated compounds suggests that additional refinement may be necessary to improve stability and performance.

The findings underscore the potential of waste tire pyrolytic oil as a renewable energy source. However, the presence of oxygenated compounds necessitates further refinement to optimize its fuel properties. This research lays the groundwork for future studies aimed at improving the pyrolysis process and assessing the environmental implications of using pyrolytic oil on a larger scale. By exploring the opportunities for utilizing waste materials in energy production, this study contributes to the ongoing efforts to develop sustainable fuel alternatives.

Keywords—pyrolytic oil, FT-IR spectroscopy, waste tires, alternative fuel, hydrocarbons, spectral analysis, FT-IR library matching

I. INTRODUCTION

The increasing global focus on sustainable energy has intensified efforts to find renewable fuel sources that can mitigate the environmental impact of waste materials. Waste tires represent a significant environmental concern due to their non-biodegradability and large-scale accumulation. Each year, millions of tires are discarded worldwide, posing disposal challenges and potential hazards such as fires and toxic leaching. Converting waste tires into pyrolytic oil through pyrolysis offers a promising solution to this issue, transforming a problematic waste stream into a resource that could contribute to the energy sector. This approach not only addresses tire waste but also aligns with the growing demand for alternative fuels that reduce dependence on fossil resources [1].

Pyrolysis, a thermochemical process conducted in the absence of oxygen, decomposes organic materials into smaller molecules, resulting in products such as gases, char, and oil. Pyrolytic oil has drawn attention due to its resemblance to conventional liquid fuels. However, the composition of pyrolytic oil varies depending on the feedstock and process conditions, making it essential to characterize its chemical components before it can be considered a viable fuel. Studies have shown that pyrolytic oil derived from waste tires contains a mixture of aromatic and aliphatic hydrocarbons, which are significant for fuel properties, as they impact the oil's energy content, viscosity, and combustion behavior [2-3].

Fourier Transform Infrared (FT-IR) spectroscopy is a well-established technique for identifying the chemical makeup of substances through their unique absorption patterns. By detecting functional groups such as C-H, C=C, and C=O bonds, FT-IR provides insights into the molecular structure of hydrocarbons in pyrolytic oil. Previous studies have utilized FT-IR spectroscopy to characterize tire-derived oil, identifying prominent aromatic compounds like benzene and toluene that contribute to the fuel's energy density [4]. These aromatic hydrocarbons are of particular interest as they are associated with high energy content, which is advantageous for fuel applications [5].

Despite the promise of pyrolytic oil as an alternative fuel, there is a need for detailed analysis to quantify its components and assess how it compares to conventional fuels like diesel. In this study, we employ FT-IR spectroscopy to analyze pyrolytic oil obtained from waste tires, focusing on the identification and quantification of aromatic and aliphatic compounds. To provide a comprehensive understanding of the oil's fuel properties, a statistical analysis of the FT-IR spectral data will be conducted, examining the mean peak areas of key compounds and exploring their correlation with calorific values. This analysis aims to clarify the potential of

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pyrolytic oil as a renewable energy source and to lay the groundwork for optimizing the pyrolysis process to enhance fuel quality and yield.

By addressing the chemical composition and fuel characteristics of pyrolytic oil, this research contributes to the broader field of sustainable energy and waste management. It underscores the feasibility of transforming waste tires into valuable fuel sources, advancing the shift toward greener, more sustainable fuel options.

II. Related Literature

A. *Pyrolytic Oil from Waste Tires as an Alternative Fuel*

As environmental concerns continue to grow, the need for sustainable waste management solutions has become increasingly urgent. Waste tires, due to their non-biodegradability and sheer volume, pose a significant disposal challenge worldwide. Each year, millions of tires are discarded, often ending up in landfills where they can leach toxic chemicals into the soil or, worse, catch fire and release harmful pollutants. Pyrolysis provides a promising avenue for converting this waste into valuable resources, particularly in the form of pyrolytic oil. This process involves thermally decomposing tires at high temperatures in an oxygen-free environment, resulting in a liquid oil that can potentially be utilized as a fuel source [6].

Research indicates that pyrolytic oil from waste tires is rich in hydrocarbons, particularly aromatic compounds, which are valuable for their high energy density and favorable combustion characteristics. According to Cunliffe and Williams [2], pyrolytic oil derived from tires contains a complex mixture of hydrocarbons, including a significant proportion of aromatic and aliphatic compounds. Aromatics, such as benzene and toluene, are particularly important for fuel applications due to their ability to produce high calorific values, making pyrolytic oil an attractive alternative to conventional fossil fuels [7]. Additionally, the energy yield of pyrolytic oil can be comparable to that of traditional fuels like diesel, especially when aromatic compounds are present in significant quantities. Studies have shown that optimizing the pyrolysis process can increase the yield of these compounds, further enhancing the fuel quality of pyrolytic oil [1].

Moreover, the specific conditions under which pyrolysis is conducted—such as temperature, heating rate, and reactor type—play a critical role in determining the composition and quality of the resulting oil. Onay and Kusefoglu [8] found that higher pyrolysis temperatures tend to increase the concentration of aromatic compounds, thereby improving the oil's fuel properties. This demonstrates that, with the right process optimizations, pyrolytic oil from waste tires can serve as a viable alternative fuel source, contributing to both waste reduction and renewable energy generation.

B. *Characterization of Pyrolytic Oil using FT-IR Spectroscopy*

Accurate characterization of pyrolytic oil is essential for evaluating its potential as a fuel. Fourier Transform Infrared (FT-IR) spectroscopy has emerged as a powerful tool for analyzing the chemical composition of pyrolytic oil due to its ability to identify functional groups within complex mixtures. FT-IR spectroscopy works by passing infrared light through a sample and measuring the absorption at different wavelengths, which corresponds to specific molecular vibrations. This method allows researchers to distinguish between various hydrocarbons, providing detailed insights into the oil's makeup [4].

Several studies have employed FT-IR spectroscopy to investigate the composition of pyrolytic oil from waste tires, with a particular focus on the identification of aromatic and aliphatic hydrocarbons. Laresgoiti et al. [9] conducted a detailed FT-IR analysis of tire pyrolysis oil and discovered prominent absorption peaks associated with aromatic compounds, including benzene, toluene, and xylene. These compounds contribute to the oil's high energy density, underscoring its suitability as a fuel. Additionally, FT-IR spectroscopy can detect oxygenated compounds, which are byproducts of pyrolysis and can affect the oil's combustion properties. The presence of oxygenated compounds often requires further refining to improve fuel quality and ensure compatibility with existing fuel infrastructure [5].

FT-IR analysis not only provides a snapshot of the chemical composition but also offers insights into the consistency and repeatability of the pyrolysis process. By comparing FT-IR spectra from different batches, researchers can assess the stability of the process and adjust optimized fuel properties. For instance, Williams and Brindle [6] found that catalytic pyrolysis could selectively enhance the production of desired hydrocarbons, particularly aromatics, thus improving the quality of the pyrolytic oil. As a result, FT-IR spectroscopy has become a valuable tool in refining pyrolytic oil production techniques, enabling a better understanding of the chemical interactions involved and supporting the development of alternative fuels.

FTIR spectroscopy involves transmitting infrared light through a sample of the diesel to be analyzed. As the light passes through the sample, the molecules present in the fuel absorb light at specific wavelengths depending on their chemical structure. The spectral data of waste tire pyrolysis oil characterizes diesel-fuel as properties in which the spectral data of diesel serves as reference.

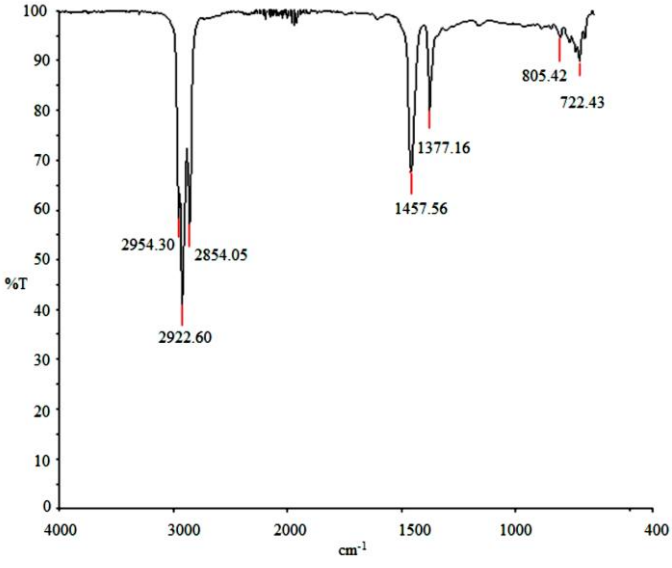

Fig. 1. FT-IR spectrum of a Diesel

The infrared spectrum of diesel does not have carbonyl groups (shown in Figure 1), and no absorption is presented in the fingerprint region, indicating an absence of C-O bonds. This explains the decrease of the peak intensity around 1740 cm−1 as the concentration of diesel in the mixture increases. Therefore, the peak intensity generated by the carbonyl group can be used for the determination of the concentration of biodiesel in these mixtures.

A more detailed description of the peaks observed in this region is shown in Table 1 below [10].

TABLE I. FOURIER TRANSFORM INFRARED (FT-IR) PEAKS DESCRIPTION

Wavenumber (cm^{-1})	Functional Groups
2924	Asymmetric stretch of CH, CH_2, CH_3
2854	Symmetric stretch of CH, CH_2, CH_3
1742	Stretch of the carbonyl group bond C=O
1457 and 1435	Asymmetric deformation of the bonds CH, CH_2, CH_3

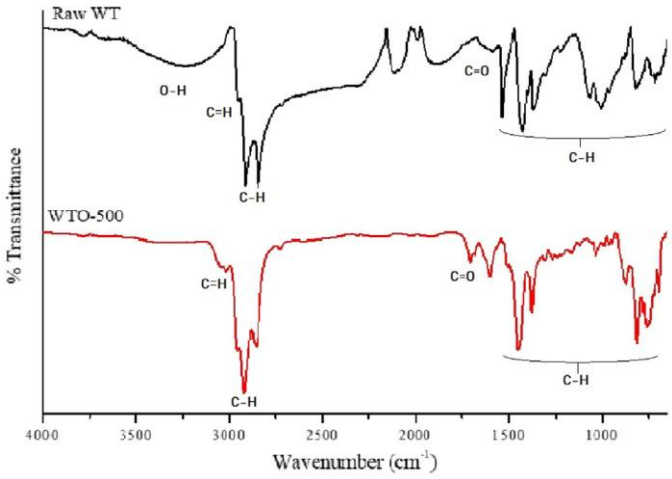

Fig. 2. FT-IR spectra on waste tire pyrolysis oil (WTO-500) and waste tire crumb (raw WT)

Figure 2 shows the FT-IR spectra of waste tire pyrolysis oil obtained at the optimum operating conditions of pyrolysis. In this study, waste tire pyrolysis oil contained mainly aliphatic and aromatic compounds. The FT-IR spectrum of the waste tire pyrolysis oil at 500 degrees Celsius was almost like the raw waste tire crumb. The weak absorption between 3500 and 3200 cm-1 is assigned to O-H stretching, which indicates the presence of waste and hydroxyl groups such as alcohols, phenols and carboxylic acids, according to the findings by other researchers. The band 3018 cm-1 the presences of C=H stretching, while 3100 to 2700 cm-1 are due to C-H stretch, this absorption represents the peaks around 1750-1675 cm-1 corresponded to C=O stretch attributed to aldehydes or ketones mainly from the additives inside waste tire. From the overall result, it shows that waste tire pyrolysis oil mainly consists of aromatic contents. This is comparable to the findings by other researchers [11].

Identification of Key Functional Groups

Several key functional groups were identified from the FT-IR analysis of the diesel sample:

- **Aromatic C-H Stretching**: Peaks between 3100 and 3000 cm^{-1} indicate the presence of aromatic C-H stretching, which is a hallmark of aromatic hydrocarbons in the diesel sample. These aromatic compounds are crucial for understanding the potential of pyrolytic oil derived from waste tires, as they are known to enhance the calorific value and stability of the fuel.
- **Aliphatic C-H Stretching**: Absorption bands around 2850-2950 cm^{-1} correspond to aliphatic C-H stretching vibrations. This is typical of both straight-chain and branched alkanes, which are also present in conventional fuels. The presence of both aromatic and aliphatic hydrocarbons confirms that the pyrolytic oil has a complex mixture of compounds, like traditional fossil fuels.
- **C=O Stretching**: A peak around 1700 cm^{-1} suggests the presence of carbonyl compounds (C=O), which may originate from oxygenated species formed during pyrolysis. These oxygenated compounds can affect the combustion behavior and need to be minimized in refining processes to improve fuel quality.

Overview of FTIR Spectrum and Functional Groups

The FTIR spectrum for the Diesel sample shows key absorption bands. Each of these bands represents functional groups that are commonly present in hydrocarbons and oils. This sample's absorption bands suggest the presence of compounds characteristic of diesel fuel and possibly lubricating components, indicating a complex blend suitable for engine use. The observed peaks and their corresponding functional groups in the diesel sample are summarized in Table 2 below.

TABLE II. SUMMARY OF OBSERVABLE PEAKS AND THEIR FUNCTIONAL GROUPS

Wave number (cm^{-1})	Intensity	Functional Group	Type of Vibration	Likely Compound
3000–2850	Strong	C-H (Alkane)	Stretching (sp^3 C-H)	Saturated hydrocarbons
1740	Moderate	C=O (Carbonyl)	Stretching	Possible esters
1600	Weak	C=C (Alkene)	Stretching	Unsaturated hydrocarbons
1465	Medium	CH_2/CH_3 (Alkane)	Bending	Methylene/methyl groups
1375	Medium	CH_3	Bending	Branched alkanes
720	Strong	CH_2 (Long-chain alkanes)	Bending (rocking)	Diesel, lubricants

Table 2 presents a summary of the discussion of observable peaks and their functional groups. The presence of strong C-H stretching bands around 3000–2850 cm^{-1} and CH_2/CH_3 bending modes at 1465 and 1375 cm^{-1} are characteristic of alkanes, which dominate hydrocarbon-based diesel fuels and lubricants. On the other hand, Table 3 shows the interpretation of key peaks for FT-IR spectrum of commercial diesel sample. The peak at 720 cm^{-1}, indicative of long-chain hydrocarbons, is common in diesel and lubricant oils, suggesting the sample has substantial paraffinic content.

TABLE III. INTERPRETATION OF KEY PEAKS FOR FT-IR SPECTRUM OF DIESEL

Wavenumber & Vibrations	Interpretation
3000–2850 cm^{-1} (Alkane C-H Stretching)	This broad, strong band can be suggested as saturated hydrocarbons, confirming the presence of alkanes, the primary components in diesel fuel and lubricants.
1740 cm^{-1} (Carbonyl C=O Stretching)	This moderate peak suggests the presence of carbonyl groups, which could indicate ester compounds. Esters may be added to enhance lubrication properties or could originate from base oil additives.
1600 cm^{-1} (Alkene C=C Stretching)	The weak C=C stretch indicates minor unsaturated hydrocarbons, possibly present as small quantities of aromatic or unsaturated compounds within the diesel blend.
1465 cm^{-1} and 1375 cm^{-1} (CH_2 and CH_3 Bending)	These medium-intensity bending vibrations are associated with methylene and methyl groups, reinforcing the presence of branched and straight-chain hydrocarbons.
720 cm^{-1} (Long-chain Alkane Rocking)	This strong band suggests long-chain alkanes, which are typical in diesel oils and indicate a stable, viscous fuel suitable for engines.

Library Match Results and Interpretation

TABLE IV. LIBRARY MATCHING RESULTS OF DIESEL SAMPLE

Quality	Library	Name
0.98897	ART Demo Library (13)	Base Oil 75 Standard
0.98613	Poly_D (54)	Ethylene/Propylene/ Diene (High MWZ)
0.98370	Poly_D (43)	Ethylene/Propylene/ Butadiene (Med MW)
0.97465	ART Demo Library (32)	Kerosene

The FTIR library matching results shown in Table 4 provides further insight into the possible components present in the diesel sample. Each match is associated with compounds commonly found in diesel and engine oils:

- The Diesel sample FTIR spectra library matched with *Base Oil 75 Standard* at *98.897 %*. This match indicates the presence of base oil, a primary component in diesel engine oils. Base oils provide the foundational hydrocarbon structure that enhances stability, viscosity, and lubrication in engine applications.
- The Diesel sample FTIR spectra library matched with *Ethylene/Propylene/ Diene* at 98.613 *%*. The presence of ethylene/propylene diene polymers, known for their high molecular weight, suggests this sample may include synthetic additives. These polymers are often used to improve the oil's durability, stability, and viscosity, making it suitable for high-temperature engine conditions.
- The Diesel sample FTIR spectra library matched with *Ethylene/Propylene/ Butadiene* at 98.370 *%*. This match points to a medium-weight hydrocarbon component that contributes to the fuel's overall stability and may help optimize viscosity. These compounds are often used to enhance performance, particularly in demanding diesel engine applications.
- The Diesel sample FTIR spectra library matched with *Kerosene* at 97.465 *%*. Kerosene is a lighter hydrocarbon distillate often blended with diesel to improve cold-weather performance. This match suggests the diesel sample might contain a kerosene-like component, which would increase volatility and improve combustion efficiency in lower temperatures.

III. METHODOLOGY

The pyrolytic oil used in this study was derived from waste tires collected from a local disposal facility. The tires were cleaned and shredded to ensure uniform feedstock size, facilitating consistent pyrolysis. The pyrolysis process was conducted in a fixed-bed reactor under atmospheric conditions and distilled in the modified small-scale atmospheric distillation. The reactor was heated to a final temperature of 500°C, with a heating rate of 10°C per minute. This temperature range was selected based on previous studies, which indicated that higher temperatures yield a greater concentration of aromatic hydrocarbons [8]. The pyrolysis process lasted for approximately two hours, ensuring complete thermal decomposition of the tire material. The resulting pyrolytic oil was then collected, filtered to remove any solid residues, and stored in sealed containers for subsequent analysis.

Sample Preparation and Pyrolysis Process

Waste tire pyrolytic oil (WTPO) will be obtained through a controlled pyrolysis process. Waste tires will be collected from a local disposal facility, cleaned, and shredded to ensure uniform feedstock size. The pyrolysis will be conducted in a fixed-bed reactor at an optimized temperature of 500°C with a heating rate of 10°C per minute under atmospheric conditions. The process will last approximately two hours to ensure complete thermal decomposition of the tire material. The resulting pyrolytic oil will then be collected, filtered to remove solid residues, and stored in sealed containers for analysis.

Small-Scale Atmospheric Distillation of Pyrolytic Oil

To evaluate the fuel characteristics of pyrolytic oil, a small-scale atmospheric distillation system will be used for

fractionation. The system will be modified to enhance temperature and pressure control, incorporating a heat exchanger and a band-type heating element. The distillation will be conducted in stages, separating lighter fractions from heavier residues. The distilled WTPO will then be collected and compared with raw WTPO to determine its improved fuel properties.

Fourier Transform Infrared (FT-IR) Spectroscopic Analysis

FT-IR spectroscopy will be employed to characterize the chemical composition of WTPO and its distilled fractions. The FT-IR spectra will be recorded in transmittance mode over a wavenumber range of 4000 to 500 cm^{-1}, with a resolution of 4 cm^{-1}. Each sample will be scanned three times to obtain an average spectrum. The identified peaks will be analyzed for key functional groups, including aromatic C-H stretching (3100-3000 cm^{-1}), aliphatic C-H stretching (2950-2850 cm^{-1}), and carbonyl C=O stretching (1700-1750 cm^{-1}). The spectral data will be compared against a diesel reference sample to determine similarities in molecular composition.

*A. **FT-IR Library Matching for Compound Identification***

To confirm compound composition, FT-IR spectral data will be matched against a reference spectral library. The library matching will provide quality indices for each identified compound, with a focus on hydrocarbons such as octadecane ($C_{18}H_{38}$) and polymeric additives like styrene-isoprene blends.

*B. **Comparative FT-IR Analysis of Diesel, WTPO, and Distilled WTPO***

Overlayed FT-IR spectra will be analyzed to compare the molecular structures of diesel, WTPO, and distilled WTPO. Functional group similarities and deviations will be documented, with particular emphasis on aromatic-to-aliphatic hydrocarbon ratios. The analysis aims to assess the potential of WTPO and its distilled fractions as alternative fuels with properties comparable to conventional diesel.

IV. Results and Discussion

FT-IR Spectroscopic Analytical Method using Library Matched Results

- **Diesel Sample FT-IR Spectra in Transmittance**

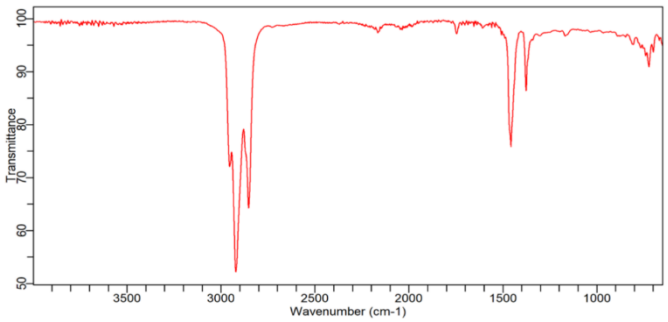

Fig. 3. FT-IR spectrum of Pyrolytic Oil compared to Diesel, highlighting aromatic and aliphatic regions

The FTIR spectrum for the Diesel sample shown in Figure 3 presents key absorption bands. Each of these bands represents functional groups that are commonly present in hydrocarbons and oils. This sample's absorption bands suggest the presence of compounds characteristic of diesel fuel and possibly lubricating components, indicating a complex blend suitable for engine use.

Diesel FT-IR Peaks Library Match Results and Interpretation

The identified peaks and library matches indicate that this diesel sample is not a pure diesel fuel but instead contains additional components that are often found in diesel engine oils. The spectrum and library matches suggest a blend with a high paraffinic base, possibly mixed with additives to enhance performance, durability, and cold-weather functionality.

The FTIR analysis of the Diesel sample confirms that it contains compounds typical of diesel engine oils. The primary components include:

- Base oils and alkanes for stable, sustained combustion.
- Ethylene/propylene copolymers for improved durability and wear resistance.
- Kerosene-like compounds for enhanced volatility and performance in cold conditions.

- **WTPO FT-IR Spectra in Transmittance**

The FTIR spectrum of the WTPO (Waste Tire Pyrolysis Oil) sample shown in Figure 4 reveals characteristic peaks of hydrocarbon-based functional groups, indicating that the sample primarily consists of alkanes. The summary of observable peaks and their functional groups is interpreted in Table 5. The peaks are particularly indicative of long-chain hydrocarbons, a feature commonly associated with oils, lubricants, or fuel additives. The presence of compounds such as octadecane suggests that the sample has a significant concentration of saturated hydrocarbons, which are typical in paraffinic oils or mineral-based lubricants.

TABLE V. WTPO Summary of Observable Peaks and their Functional Groups

Wave number (cm^{-1})	Intensity	Functional Group	Type of Vibration	Likely Compound
2950–2850	Strong	C-H (Alkane)	Stretching (sp^3 C-H)	Long-chain hydrocarbons (e.g., octadecane)
1470	Medium	CH_2 (Methylene)	Bending	Alkane chains
1375	Medium	CH_3 (Methyl)	Bending	Branched hydrocarbon
720	Moderate	C-H (Long-chain alkane)	Rocking	Straight-chain alkanes (indicative of a waxy or oily structure)

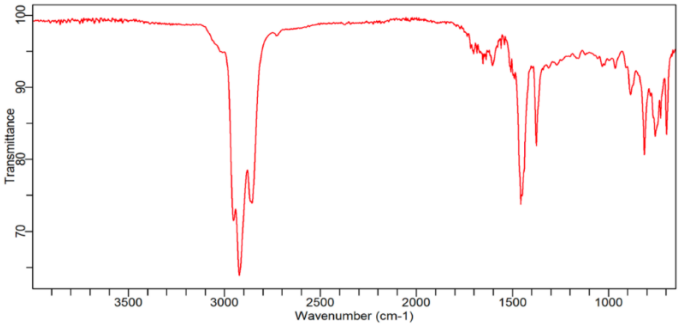

Fig. 4. WTPO Sample FT-IR Spectra

WTPO FT-IR Peaks Library Match Results and Interpretation

TABLE VI. LIBRARY MATCHING RESULTS OF WTPO SAMPLE

Quality	Library	Name
0.96521	Pharma_D (0)	TEM Tetramethyl ethylene
0.96243	Pharma_D (1)	Trenimon
0.95588	BioRad_Demo (2)	Octadecane
0.95222	Intro_D (43)	Octadecane

The library matching shown in Table 6 of the FTIR spectrum provided a high-quality match with octadecane, a straight-chain hydrocarbon. This match offers insight into the possible primary components of the WTPO sample:

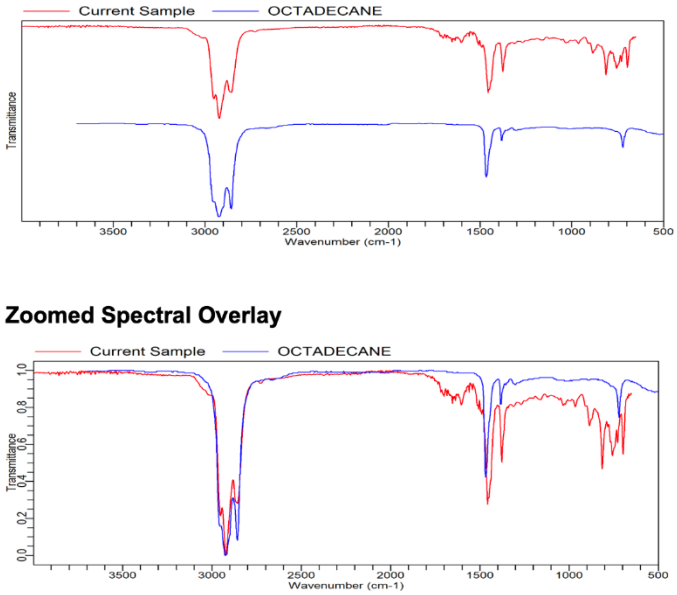

Fig. 5. WTPO Sample FT-IR Spectra Library Matched Octadecane

The WTPO sample FTIR spectra library matched with Octadecane at 95.588% and 95.222% (see Figure 5). Octadecane ($C_{18}H_{38}$) is a long-chain alkane commonly found in paraffinic oils and waxes. Its high-quality match with the WTPO sample indicates that the sample likely contains a significant number of straight-chain alkanes, typical of mineral-based oils or lubricants. These compounds are valued in oils for their stability, viscosity, and ability to reduce friction.

- **Distilled WTPO FT-IR Spectra in Transmittance**

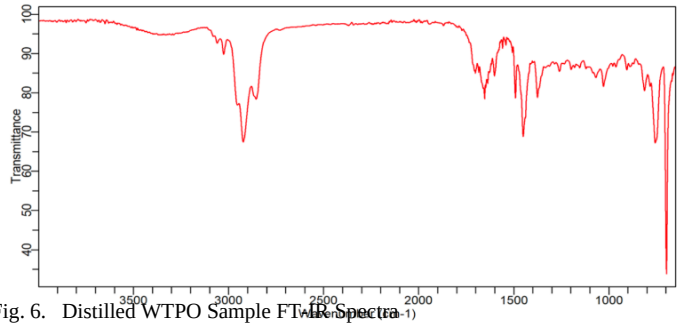

Fig. 6. Distilled WTPO Sample FT-IR Spectra

Distilled WTPO FT-IR Peaks Library Match Results and Interpretation

The FTIR spectrum for the Distilled WTPO (Waste Tire Pyrolysis Oil) sample shown in Figure 6 provides insight into the types of chemical bonds present, corresponding to various functional groups typically seen in hydrocarbon-based oils. This spectrum reveals distinctive absorption bands that suggest the presence of both aliphatic and aromatic hydrocarbons, as well as polymeric materials. These characteristics point to a possible synthetic or semi-synthetic oil that includes polymer additives, which are often incorporated to enhance the oil's performance properties.

TABLE VII. LIBRARY MATCHING RESULTS OF DISTILLED WTPO SAMPLE

Quality	Library	Name
0.83834	Poly_D(5)	Styrene/Isoprene (Styrene 14%)
0.80199	Poly_D (1)	Poly (Isoprene), trans

The FTIR library matching results shown in Table 7 provides clues about the possible synthetic polymers and hydrocarbons present in the Distilled WTPO spectrum.

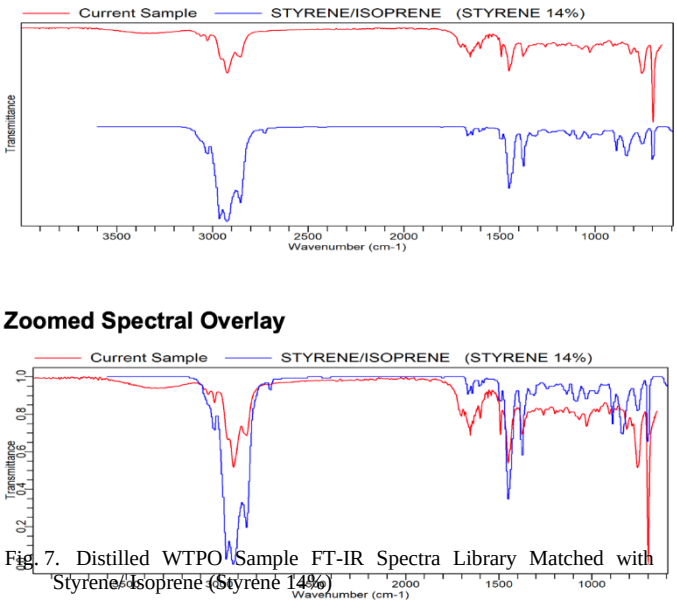

Fig. 7. Distilled WTPO Sample FT-IR Spectra Library Matched with Styrene/Isoprene (Styrene 14%)

The Distilled WTPO sample FTIR spectra library shown in Figure 7 matched with Styrene/Isoprene (Styrene 14%) at 83.834 %. This match points to a copolymer blend of styrene and isoprene, which indicates the presence of synthetic additives. Styrene adds oxidation resistance and stability, while isoprene contributes elasticity, making this blend suitable for high-performance oils used in industrial and automotive applications.

- **FT-IR Spectra Overlay of Diesel, WTPO, and Distilled WTPO Samples**

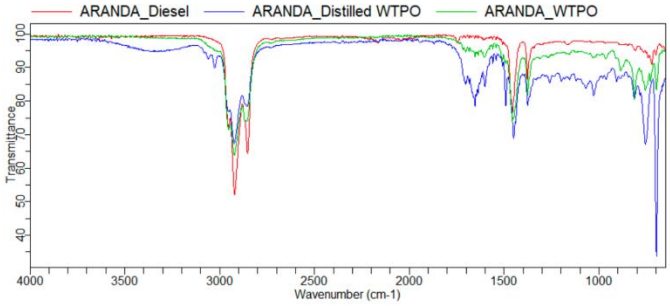

Fig. 8. FT-IR Spectra of three samples

The FTIR spectra presented in Figure 8 show overlayed peaks for three samples: “Diesel” (red), “Distilled WTPO” (blue), and “WTPO” (green). By analyzing the characteristic peaks and comparing the similarities and differences in their bond bending and stretching vibrations, insights into the molecular composition of each sample are obtained. This analysis enables an understanding of the functional groups present and their potential implications for the chemical composition of each sample, specifically to establish the similarity between the WTPO (Waste Tire Pyrolysis Oil) and diesel fuel.

TABLE VIII. WAVENUMBER OF REGIONS AND FUNCTIONAL GROUPS OF THE THREE SAMPLES

Wavenumber (cm^{-1})	Type of Vibration	Bond Type	Possible Compound
2800-3000	C–H Stretch	Alkane C–H	Aliphatic hydrocarbons (alkanes)
1700-1750	C=O Stretch	Carbonyl (C=O)	Ketones, esters, carboxylic acids
1460	C–H Bend	Alkane C–H bending	Aliphatic hydrocarbons
1375-1450	CH_2 and CH_3 Bend	Methylene and Methyl groups	Hydrocarbons, possibly branched
1000-1300	C–O Stretch	Alcohol or ester C–O stretching	Oxygenated compounds (esters, alcohols)
720-750	C–H Rock	Long-chain alkanes	Aliphatic hydrocarbons (waxes, oils)

Table 8 summarizes the key wavenumber regions observed in the spectra, their corresponding vibrations, bond types, and the possible compounds each peak may represent.

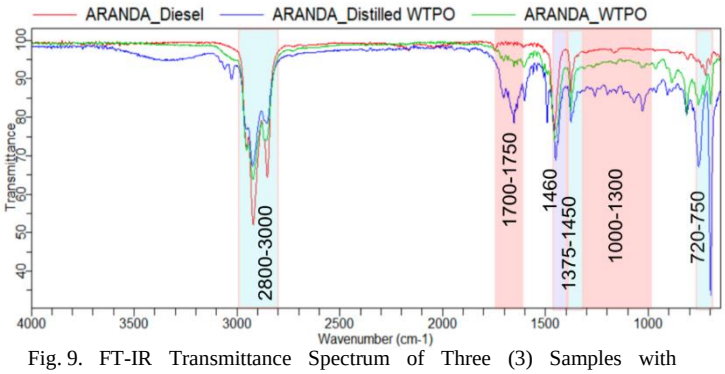

Fig. 9. FT-IR Transmittance Spectrum of Three (3) Samples with Equivalent Wavenumber Peaks

The FTIR spectra analysis of three samples as shown in Figure 9 demonstrates that Diesel and WTPO share a high degree of similarity in terms of their functional groups and molecular structure. Both spectra exhibit similar peaks in regions associated with aliphatic hydrocarbons (C–H stretches and bends), carbonyl groups (C=O stretches), and oxygenated compounds (C–O stretches). The presence of similar functional groups and bond types in both samples suggests that WTPO may be a feasible alternative to diesel, as it possesses similar molecular characteristics necessary for fuel performance.

The slight differences observed in the Distilled WTPO spectrum indicate that distillation modifies the sample, possibly by removing some volatile or lighter components, resulting in a marginally different composition. However, the main structural similarities between Diesel and WTPO remain, indicating that distilled WTPO could retain much of the beneficial properties of raw WTPO and still mimic diesel properties.

The FTIR analysis confirms that WTPO exhibits functional groups and bond structures closely aligned with those of Diesel, including aliphatic hydrocarbons, carbonyl compounds, and oxygenated groups. These similarities strongly suggest that WTPO is chemically compatible with diesel fuel applications, offering a renewable, alternative source of energy.

The FTIR spectral analysis suggests that WTPO (Waste Tire Pyrolysis Oil) and distilled WTPO resemble the composition of conventional diesel fuel. They contain significant aliphatic hydrocarbons, carbonyl groups, and oxygenated compounds, indicating that they are a mix of hydrocarbon chains with minor oxygenated compounds. The similarity of these FTIR peaks to those in diesel supports the classification of WTPO as a diesel-like synthetic fuel derived from tire pyrolysis.

The distilled WTPO shows similar peaks to raw WTPO, with minor modifications likely due to the removal of lighter or more volatile compounds during distillation. This purification process likely improves the stability and homogeneity of the fuel, making distilled WTPO even more similar in composition to refined diesel.

WTPO and distilled WTPO can be considered diesel-like synthetic fuels with the potential for use as alternative or supplementary fuels in diesel engines, subject to further testing on combustion properties and emissions.

V. Conclusion and Future Works

This study has investigated the chemical composition of This study thoroughly examines the potential of waste tire pyrolytic oil (WTPO) as an alternative fuel by analyzing its chemical composition through Fourier Transform Infrared (FT-IR) spectroscopy. The findings confirm that WTPO contains substantial aromatic and aliphatic hydrocarbon content, essential for fuel-like properties. The spectral similarities between WTPO and conventional diesel suggest that with proper refinement, WTPO could serve as a viable supplementary fuel. However, variations in spectral profiles and the presence of oxygenated compounds indicate that additional processing is necessary to enhance fuel quality and combustion efficiency.

The comparative evaluation of WTPO, distilled WTPO, and diesel provided valuable insights into their molecular structures. The distillation process improved WTPO's fuel properties by reducing oxygenated compounds and refining hydrocarbon composition. FT-IR spectral analysis verified the presence of key hydrocarbon functional groups consistent with those in conventional fuels. Library matching results revealed that WTPO showed a 95.59% match with octadecane ($C_{18}H_{38}$), signifying a composition similar to long-chain hydrocarbons found in mineral-based fuels. Additionally, the distilled WTPO exhibited an 83.83% match with styrene-isoprene, suggesting the presence of synthetic polymer additives that may impact fuel stability. These findings reinforce the potential of WTPO as a diesel-like synthetic fuel while emphasizing the need for further refinement to optimize its application.

Future Works

Future research should aim to refine the pyrolysis and distillation processes to maximize the yield of beneficial hydrocarbons while minimizing impurities. The use of catalysts during pyrolysis should be explored to enhance the selectivity for aromatic hydrocarbons, improving overall fuel quality.

Additionally, combustion testing should be conducted to assess the engine performance, emissions profile, and efficiency of WTPO in comparison to standard diesel. Understanding how WTPO performs under different operating conditions will be critical for its practical applications.

Environmental impact assessments will also be necessary to determine the sustainability of WTPO as a fuel alternative. These studies should include lifecycle analyses to evaluate greenhouse gas emissions, energy consumption, and overall environmental footprint.

Collaboration with industry stakeholders can facilitate large-scale testing and potential commercialization of WTPO. Conducting pilot studies in industrial or transportation sectors will be instrumental in determining its viability as a sustainable fuel source. By addressing these key areas, this study contributes to the advancement of alternative fuels derived from waste materials, supporting a more circular and sustainable energy economy.

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