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CHARACTERIZATION OF HYDROCARBON LIQUID BY-PRODUCT FROM POLYETHYLENE WAX PRODUCTION: GC–MS COMPOSITION AND FUEL PROPERTY EVALUATION

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Annotatsiya. Yuqori molekulyar og‘irlikdagi polietilenning termik parchalanishi orqali polietilen mumining ishlab chiqarilishining ortishi qo‘shimcha mahsulot sifatida suyuq uglevodorod fraksiyasini hosil qiladi, uning tarkibi va foydalanish potensiali yetarlicha o‘rganilmagan. Ushbu ishda ushbu suyuq fraksiyaning kimyoviy tarkibi va fizik-kimyoviy xususiyatlari uning sanoatda qo‘llanilishini baholash uchun har tomonlama o‘rganildi. Namuna polietilenni termik krekinglash jarayonida olingan va keyinchalik 220 °C gacha atmosfera bosimida haydash orqali fraksiyalangan. Molekulyar tarkib gaz xromatografiyasi-massa spektrometriyasi (GX-MS) yordamida aniqlangan, yonilg‘i bilan bog‘liq xususiyatlar esa tegishli ASTM usullariga muvofiq oktan soni, setan soni va past harorat xususiyatlarini o‘lchash orqali baholangan. GX-MS tahlili shuni ko‘rsatdiki, suyuq fraksiya asosan C_8-C_{26} uglerod soni oralig‘idagi parafinli uglevodorodlardan iborat bo‘lib, asosiy hissasi C_{10}-C_{16} birikmalaridan kelib chiqadi. Chiziqli alkanlar dominant komponentlar sifatida aniqlandi, ularga oz miqdordagi tarmoqlangan alkanlar va polietilen zanjirining uzilishi paytida hosil bo‘lgan oz miqdordagi olefinlar hamroh bo‘ldi. Olingan uglevodorod taqsimoti o‘rganilayotgan mahsulot odatda kerosin-dizel turidagi yonilg‘ilar bilan bog‘liq bo‘lgan o‘rta distillyat diapazoniga tegishli ekanligini ko‘rsatadi. Yonilg‘i xususiyatlarini tahlil qilish shuni ko‘rsatdiki, suyuqlik taxminan 42 setan sonini ko‘rsatadi, bu uning siqishli yonuv dvigatellari uchun qulay yonish xususiyatlarini tasdiqlaydi. Past haroratli o‘lchovlar −16 °C hiralanish haroratini va −27 °C qotish haroratlarini ko‘rsatdi, bu parafinga boy uglevodorod aralashmalari uchun odatiy holdir.

Natijalar shuni ko‘rsatadiki, o‘rganilgan suyuq fraksiyani to‘g‘ridan-to‘g‘ri standart tijorat yonilg‘isi sifatida tasniflash mumkin emas, lekin tegishli yangilash va tozalashdan so‘ng kerosin va dizel yonilg‘ilari uchun istiqbolli aralashtirish komponenti bo‘lib xizmat qilishi mumkin. Yonilg‘i qo‘llanilishidan tashqari, sanoat erituvchisi sifatida foydalanish, keyingi krekinglash yoki piroliz jarayonlari uchun xom ashyo, parafin ishlab chiqarish uchun xom ashyo, sirt faol moddalar va sintetik moylash materiallari uchun prekursor va sanoat reaktorlari uchun potentsial issiqlik uzatish suyuqligi kabi bir qancha muqobil foydalanish yo‘llari aniqlandi. Topilmalar polietilen krekingi suyuqliklarining qimmatli ikkilamchi uglevodorod resurslari sifatidagi salohiyatini ta’kidlaydi va polimerdan olingan uglevodorod oqimlari uchun yanada samarali va aylanma foydalanish strategiyalarini ishlab chiqishga hissa qo‘shadi.

Kalit so‘zlar: *Polietilen krekingi, GX-MS tahlili, uglevodorod tarkibi, yonilg‘i xususiyatlari, setan soni, past haroratli xususiyatlar, polimer chiqindilari utilizatsiyasi, neft-kimyo xom ashyosi*

Abstract. The increasing production of polyethylene wax through thermal degradation of high-molecular-weight polyethylene generates a liquid hydrocarbon fraction as a by-product, the composition and potential utilization of which remain insufficiently studied. In the present work, the chemical composition and physicochemical properties of this liquid fraction were comprehensively investigated in order to evaluate its potential industrial applications. The sample was obtained during the thermal cracking of polyethylene and subsequently fractionated by atmospheric distillation up to 220 °C. Molecular composition was determined using gas chromatography–mass spectrometry (GC–MS), while fuel-related properties were evaluated through measurements of octane number, cetane number, and low-temperature characteristics according to relevant ASTM methods. GC–MS analysis revealed that the liquid fraction is predominantly composed of paraffinic hydrocarbons in the carbon number range C_8–C_{26}, with the major contribution originating from C_{10}–C_{16} compounds. Linear alkanes were identified as the dominant components, accompanied by smaller amounts of branched alkanes and minor quantities of olefins formed during polyethylene chain scission. The obtained hydrocarbon distribution indicates that the investigated product belongs to the middle-distillate range typically associated with kerosene–diesel type fuels. Fuel property analysis showed that the liquid exhibits a cetane number of approximately 42, confirming its favorable ignition characteristics for compression ignition engines. Low-temperature measurements indicated a cloud point of −16 °C and a pour point of −27 °C, which are typical for paraffin-rich hydrocarbon mixtures.

The results suggest that the investigated liquid fraction cannot be directly classified as a standard commercial fuel but may serve as a promising blending component for kerosene and diesel fuels after appropriate upgrading and purification. In addition to fuel applications, several alternative utilization pathways were identified, including use as an industrial solvent, feedstock for further cracking or pyrolysis processes, raw material for paraffin production, precursor for surfactants and synthetic lubricants, and potential heat-transfer fluid for industrial reactors. The findings highlight the potential of polyethylene cracking liquids as valuable secondary hydrocarbon resources and contribute to the development of more efficient and circular utilization strategies for polymer-derived hydrocarbon streams.

Keywords: *Polyethylene cracking, GC–MS analysis, hydrocarbon composition, fuel properties, cetane number, low-temperature properties, polymer waste valorization, petrochemical feedstock*

Аннотация. Увеличение производства полиэтиленового воска путем термической деградации высокомолекулярного полиэтилена приводит к образованию жидкой углеводородной фракции в качестве побочного продукта, состав и потенциальное использование которой остаются недостаточно изученными. В данной работе был проведен всесторонний анализ химического состава и физико-химических свойств данной жидкой фракции с целью оценки ее потенциального промышленного применения. Образец был получен в процессе термического крекинга полиэтилена и впоследствии фракционирован атмосферной дистилляцией до 220 °C. Молекулярный состав определяли с помощью газовой хроматографии-масс-спектрометрии (ГХ-МС), а свойства, связанные с топливом, оценивали путем измерения октанового числа, цетанового числа и низкотемпературных характеристик в соответствии с соответствующими методами ASTM. Анализ ГХ-МС показал, что жидкая фракция преимущественно состоит из парафиновых углеводородов в диапазоне числа атомов углерода C_8–C_{26}, причем основной вклад вносят соединения C_{10}–C_{16}. В качестве доминирующих компонентов были идентифицированы линейные алканы, сопровождаемые меньшим количеством разветвленных алканов и незначительным количеством олефинов, образующихся в процессе разрыва полиэтиленовой цепи. Полученное распределение углеводородов указывает на то, что исследуемый продукт относится к диапазону средних дистиллятов, обычно ассоциируемых с керосиново-дизельным топливом. Анализ свойств топлива показал, что жидкость имеет цетановое число приблизительно 42, что подтверждает ее благоприятные характеристики воспламенения для двигателей внутреннего сгорания. Низкотемпературные измерения показали температуру помутнения −16 °C и температуру застывания −27 °C, что типично для смесей углеводородов, богатых парафинами.

Результаты показывают, что исследованная жидкая фракция не может быть напрямую классифицирована как стандартное коммерческое топливо, но может служить перспективным компонентом для смешивания керосина и дизельного топлива после соответствующей модернизации и очистки. В дополнение к применению в качестве топлива были выявлены несколько альтернативных путей использования, включая использование в качестве промышленного растворителя, сырья для дальнейших процессов крекинга или пиролиза, сырья для производства парафина, прекурсора для поверхностно-активных веществ и синтетических смазочных материалов, а также потенциального теплоносителя для промышленных реакторов. Полученные результаты подчеркивают потенциал жидкостей, образующихся при крекинге полиэтилена, как ценных вторичных углеводородных ресурсов и способствуют разработке более эффективных и циклических стратегий использования углеводородных потоков, полученных из полимеров.

Ключевые слова: *Крекинг полиэтилена, анализ ГХ-МС, состав углеводородов, свойства топлива, цетановое число, низкотемпературные свойства, утилизация полимерных отходов, нефтехимическое сырье.*

INTRODUCTION

The global growth of polymer production has significantly increased the volume of polymer waste and industrial by-products generated during manufacturing processes. Among synthetic polymers, polyethylene (PE) represents the most widely produced thermoplastic due to its low cost, chemical resistance, and versatility in industrial and consumer applications [1]. However, the high chemical stability of polyethylene makes it resistant to natural degradation, creating environmental challenges associated with both post-consumer plastic waste and process-related by-products [2,16]. Thermochemical conversion technologies such as pyrolysis and thermal cracking have emerged as promising routes for the valorization of polyolefin materials. During these processes, long polymer chains undergo random chain scission and β-scission reactions that generate lower molecular weight hydrocarbons including n-alkanes, iso-alkanes, and α-olefins [3,4]. These reactions transform polymeric feedstocks into liquid hydrocarbon fractions that can resemble petroleum-derived fuels and petrochemical intermediates [5]. As a result, thermal conversion of polyethylene has gained increasing attention as a pathway for producing alternative hydrocarbon resources and circular carbon feedstocks [20]. In industrial practice, controlled thermal degradation of polyethylene is widely used in the production of polyethylene waxes. This process involves the reduction of polymer molecular weight through thermal cracking, producing wax fractions with defined chain length distributions. During this process, a liquid hydrocarbon fraction is formed as a secondary product [6]. Previous studies have shown that such liquids often contain hydrocarbons in the range of C8–C30, primarily composed of linear paraffins and olefins formed through random chain cleavage reactions [8,15]. The composition of these products strongly depends on the cracking conditions such as temperature, residence time, and reactor configuration [14,18]. Compared with conventional plastic pyrolysis oils obtained from mixed polymer wastes, by-product liquids generated during controlled polyethylene processing may exhibit a more uniform composition and lower contamination by heteroatom-containing compounds. This makes them potentially attractive as feedstocks for fuel production or petrochemical applications [7]. Several studies have reported that polyolefin pyrolysis oils can contain significant fractions of linear paraffins and α-olefins that resemble components present in petroleum-derived fuels such as kerosene or diesel [10]. The physicochemical properties of these hydrocarbon mixtures play a critical role in determining their possible industrial utilization. In particular, parameters such as octane number, cetane number, boiling range, and cold-flow properties are essential indicators for evaluating fuel performance [11]. Paraffinic hydrocarbons generally exhibit high cetane numbers but relatively poor low-temperature properties due to the crystallization of long-chain n-alkanes [10]. As the temperature decreases, wax crystals can form in the fuel, leading to turbidity and eventually loss of fluidity. These phenomena are typically characterized by parameters such as cloud point and pour point, which are widely used to evaluate the cold-flow behavior of hydrocarbon fuels [17].

Modern analytical techniques provide powerful tools for investigating the composition and properties of complex hydrocarbon mixtures. Gas chromatography coupled with mass spectrometry (GC–MS) is one of the most widely used analytical techniques for detailed molecular characterization of petroleum fractions and pyrolysis oils [9,12,13]. GC–MS analysis enables identification of individual hydrocarbon compounds and determination of carbon number distribution, which is crucial for understanding fuel properties and potential processing routes. Despite the growing body of research on plastic pyrolysis oils, relatively limited attention has been paid to the characterization of liquid hydrocarbon fractions produced as by-products during polyethylene wax production. Such materials represent a potentially valuable hydrocarbon resource that could be utilized as blending components for fuels or as feedstocks for further catalytic upgrading. In addition, pyrolysis-derived hydrocarbon mixtures may contain unsaturated compounds and light hydrocarbons that influence odor, volatility, and combustion characteristics [19]. Therefore, comprehensive characterization of these by-product liquids is required in order to evaluate their chemical composition and fuel-related properties. In this context, combined analytical approaches integrating chromatographic composition analysis and physicochemical testing are particularly important for assessing their potential industrial applications.

The aim of the present study is to investigate the chemical composition and physicochemical properties of a liquid hydrocarbon fraction obtained as a by-product during polyethylene wax production through thermal cracking of high-molecular-weight polyethylene. The research combines GC–MS analysis with measurements of octane number, cetane number, and low-temperature fuel properties according to ASTM methods. The results provide new insights into the molecular composition and potential applications of polyethylene cracking liquids as alternative hydrocarbon resources. The present study provides a comprehensive characterization of a liquid hydrocarbon fraction formed as a by-product during polyethylene wax production through thermal cracking of high-molecular-weight polyethylene. While most previous studies have focused on pyrolysis oils obtained from mixed plastic waste streams, limited information is available regarding the composition and fuel-related properties of liquid fractions generated under controlled industrial polyethylene degradation processes.

The novelty of this work lies in the integrated analysis of the molecular composition and physicochemical properties of this by-product liquid using gas

chromatography–mass spectrometry (GC–MS) combined with fuel property evaluation, including octane number, cetane number, and low-temperature characteristics determined according to ASTM standards. The obtained results reveal the predominance of C_8–C_{26} paraffinic hydrocarbons and demonstrate that the investigated liquid fraction exhibits physicochemical properties comparable to kerosene–diesel range hydrocarbon mixtures. Furthermore, the study provides new insights into the potential utilization pathways of polyethylene cracking liquids as alternative hydrocarbon resources for fuel blending or petrochemical feedstock applications.

METHODS

The investigated liquid hydrocarbon fraction was obtained as a by-product during the industrial production of polyethylene wax. In this process, high-molecular-weight polyethylene undergoes controlled thermal degradation, resulting in the cleavage of polymer chains and formation of lower molecular weight hydrocarbons. The resulting liquid product represents a complex mixture of paraffinic hydrocarbons formed during the cracking process. Prior to analysis, the liquid product was subjected to atmospheric distillation, and the fraction boiling below 220 °C was collected and used for further physicochemical and compositional analysis. The obtained fraction was a transparent, colorless liquid with a characteristic hydrocarbon odor. The chemical composition of the liquid fraction was determined using gas chromatography coupled with mass spectrometry (GC–MS). The analysis was performed on an Agilent gas chromatograph equipped with a mass selective detector and an automatic injection system. Separation of the components was carried out on a capillary column coated with a non-polar stationary phase (5% phenyl–95% dimethylpolysiloxane). Helium was used as the carrier gas. The injection was performed in split mode, and the sample volume was 1 μL. The oven temperature program was designed to ensure effective separation of hydrocarbons over a wide boiling range. The temperature was initially held at a low value and then gradually increased to allow elution of heavier components. Mass spectra were recorded in electron ionization (EI) mode. Identification of individual compounds was performed by comparing the obtained mass spectra with reference spectra from the NIST mass spectral library. Only compounds with high similarity indices were considered for qualitative identification.

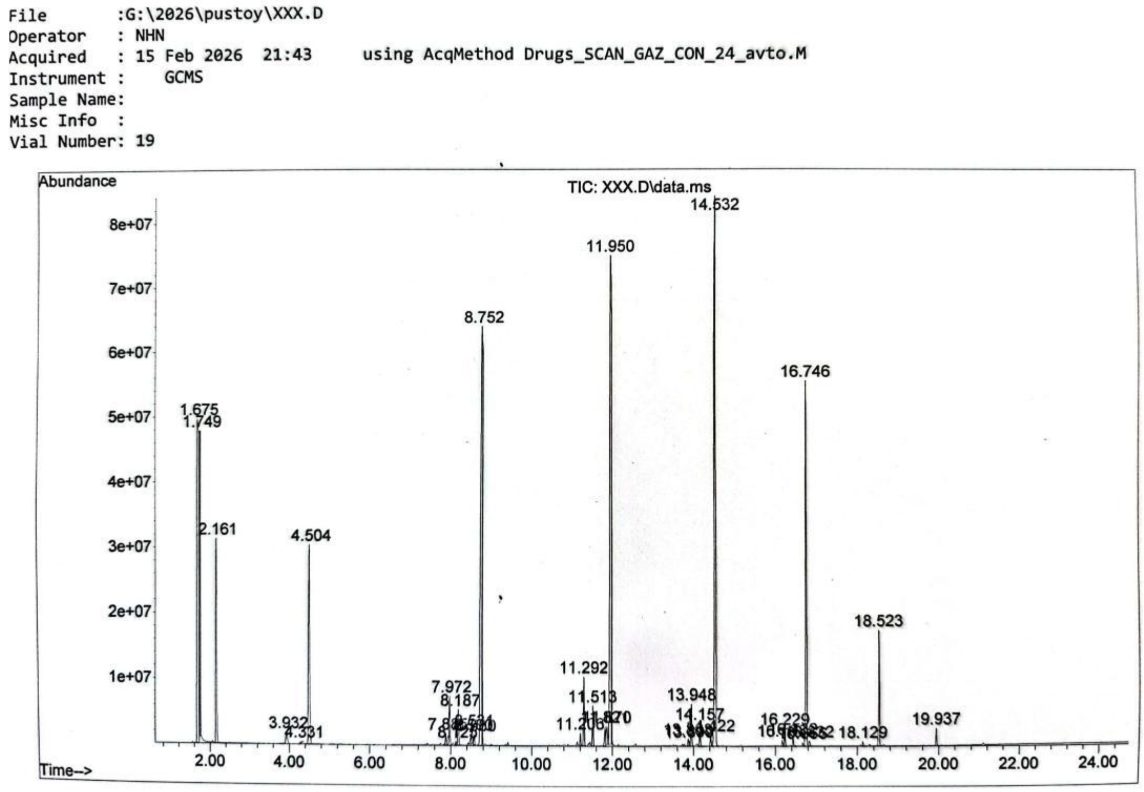
The octane number of the investigated liquid fraction was measured using a portable fuel analyzer Shatox SX-300. This instrument determines octane number based on the measurement of dielectric properties of the fuel and comparison with calibration models developed for hydrocarbon fuels. Measurements were performed using several operational modes of the analyzer, including Octane, Octane1, and Oct+Oct modes. The instrument provides calculated values of Research Octane Number (RON), Motor Octane Number (MON), and Anti-Knock Index (AKI). Each measurement was repeated several times to ensure reproducibility, and the average values were reported. The cetane number of the liquid fraction was evaluated using the same Shatox SX-300 analyzer operating in Cetane mode. The instrument estimates the cetane number (CN) of diesel-type fuels based on dielectric properties and internal calibration algorithms. The measurements were performed at ambient laboratory conditions. The instrument also provides additional parameters such as estimated flash point and fuel type classification.

Low-temperature fuel properties were determined using the TPZ-LAB-12 automated analyzer, which is designed for evaluating cold-flow characteristics of petroleum fuels. The cloud point and pour point of the investigated liquid fraction were determined according to the standardized test methods: ASTM D6749 – Standard test method for determination of cloud point of petroleum products using automatic optical detection; ASTM D7683 – Standard test method for determination of pour point using automated instruments. During the experiment, the sample was gradually cooled under controlled conditions. The cloud point was determined as the temperature at which the first wax crystals became visible, causing turbidity in the sample. The pour point was defined as the lowest temperature at which the liquid remained capable of flowing under the test conditions. All measurements were performed in accordance with the operational procedures of the instrument and the requirements of the respective ASTM standards.

RESULTS AND DISCUSSION

The molecular composition of the liquid hydrocarbon fraction obtained during polyethylene wax production was investigated using gas chromatography–mass spectrometry (GC–MS). The chromatographic profile revealed a complex mixture of hydrocarbons dominated by linear and slightly branched alkanes within the carbon number range C_8–C_{26}, accompanied by minor quantities of unsaturated hydrocarbons Figure 1.

The chromatogram exhibits a characteristic distribution pattern typical for products generated during thermal degradation of polyolefins. The identified compounds include a homologous series of n-alkanes such as octane (C_8), nonane (C_9), decane (C_{10}), undecane (C_{11}), dodecane (C_{12}), tridecane (C_{13}), tetradecane (C_{14}), pentadecane (C_{15}), and higher paraffins extending up to C_{26} Table 1. In addition to the linear hydrocarbons, several branched alkanes and olefinic compounds were detected in smaller quantities, including methyl-substituted alkanes and α-olefins such as 1-decene and 1-dodecene. The presence of this homologous distribution



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Instrument :    GCMS
Sample Name:
Misc Info  :
Vial Number: 19
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Fig. 1. The molecular composition of the liquid hydrocarbon fraction obtained during polyethylene wax production using gas chromatography–mass spectrometry (GC–MS)

of n-alkanes is consistent with the well-established mechanism of polyethylene thermal cracking. During thermal degradation, polymer chains undergo random scission followed by β-scission reactions, generating shorter hydrocarbon fragments that subsequently stabilize to form saturated and unsaturated hydrocarbons. The predominance of n-alkanes indicates that hydrogen transfer reactions play an important role in the stabilization of primary radical fragments formed during the cracking process. The carbon number distribution observed in the chromatogram suggests that the main fraction of the liquid product is concentrated in the C_{10}–C_{16} region, which corresponds to the boiling range typical of kerosene and diesel fuels. This distribution explains the relatively moderate boiling range observed during distillation of the liquid fraction. The presence of heavier hydrocarbons up to C_{20}–C_{26} indicates that partial secondary reactions and incomplete chain scission occur during the degradation process, resulting in the formation of heavier paraffinic species. Another notable feature of the chromatographic profile is the relatively low abundance of aromatic hydrocarbons and oxygen-containing compounds. The absence of significant aromatic fractions can be attributed to the chemical structure of polyethylene, which consists exclusively of saturated carbon chains. As a result, thermal degradation primarily produces aliphatic hydrocarbons rather than aromatic species. This observation distinguishes polyethylene-derived liquids from pyrolysis oils obtained from mixed plastic wastes, where aromatic hydrocarbons are often present in higher concentrations. The detected olefinic compounds, including several α-olefins, are typical intermediates formed during polyolefin degradation. These compounds originate from β-scission reactions of polymer radicals and can subsequently undergo hydrogenation, isomerization, or secondary cracking reactions. Although their concentration in the investigated liquid fraction is relatively low, the presence of olefins contributes to the characteristic odor of the product and may influence its chemical reactivity during further processing.

The overall chromatographic pattern indicates that the investigated liquid fraction can be classified as a paraffin-rich hydrocarbon mixture, predominantly composed of linear alkanes. Such compositions are commonly observed in hydrocarbon liquids obtained from the pyrolysis or thermal cracking of polyethylene. Compared with conventional petroleum fractions, polyethylene-derived liquids often contain a higher proportion of straight-chain hydrocarbons due to the linear structure of the original polymer. From the perspective of potential applications, the observed composition is particularly favorable for processes where paraffinic hydrocarbons are desired. The predominance of linear alkanes may contribute to relatively high cetane numbers and favorable ignition characteristics if the material is used as a diesel blending component. At the same time, the presence of α-olefins may provide opportunities for further catalytic upgrading or petrochemical processing.

Overall, the GC–MS analysis demonstrates that the liquid fraction generated during polyethylene wax production consists primarily of middle-range paraffinic hydrocarbons with a broad carbon number distribution and limited contamination by

Table 1. Relative peak area distribution of hydrocarbons in the sample according to GC–MS analysis

Hydrocarbon class	Relative content (peak area, %)
n-alkanes C_8–C_{12}	25–30%
n-alkanes C_{13}–C_{18}	40–45%
Heavy hydrocarbons C_{20+}	10–15%
Branched alkanes	15–20%
Oxygen-containing compounds	<2%

heteroatomic compounds. These characteristics highlight the potential value of this by-product as a hydrocarbon resource for fuel or petrochemical applications.

Prior to analytical characterization, the liquid product was subjected to atmospheric distillation and the fraction boiling below 220 °C was collected for analysis Table 2. This boiling range corresponds approximately to hydrocarbons from C_8 to C_{12}–C_{13}, which is consistent with the compounds detected by GC–MS. The relatively narrow boiling range indicates that the obtained liquid fraction represents a middle distillate-type hydrocarbon mixture rather than heavy wax fractions. Similar boiling ranges have been reported for hydrocarbon fractions obtained during plastic pyrolysis and polyethylene cracking processes [5]. The transparency and low color of the obtained liquid further indicate the absence of heavy aromatic compounds and polymeric residues, which are commonly found in pyrolysis oils derived from mixed plastic wastes. This observation suggests that the controlled degradation of polyethylene during wax production results in a relatively clean paraffinic hydrocarbon fraction.

Estimated distillation curve of the hydrocarbon liquid fraction obtained during polyethylene wax production Figure 2. The curve was constructed based on GC–MS carbon number distribution of hydrocarbons (C_8–C_{26}) and corresponding boiling point correlations for n-alkanes.

The estimated distillation curve of the investigated hydrocarbon liquid fraction is presented in Figure 2. The curve was constructed based on the carbon number distribution obtained from GC–MS analysis and the corresponding boiling points of n-alkanes. The results indicate that the majority of the fraction is concentrated within the 150–210 °C boiling range, which corresponds to hydrocarbons in the C_{10}–C_{13} region. Approximately 50 % of the distilled volume boils at around 180 °C, confirming that the investigated liquid fraction belongs to the middle distillate range typical for kerosene–diesel type hydrocarbon mixtures. The relatively smooth distillation profile suggests a homogeneous hydrocarbon distribution and the absence of heavy aromatic or polymeric residues. Such distillation characteristics are typical for paraffinic liquids obtained from thermal degradation of polyethylene and indicate potential applicability of this fraction as a blending component in middle distillate fuels.

Table 2. Estimated distillation characteristics

Distilled volume (%)	Temperature (°C)	Main hydrocarbons
IBP	125	C_8-C_9
10%	140	C_9-C_{10}
20%	150	C_{10}
30%	160	C_{10}-C_{11}
40%	170	C_{11}
50%	180	C_{11}-C_{12}
60%	190	C_{12}
70%	200	C_{12}-C_{13}
80%	210	C_{13}
90%	215	C_{13}-C_{14}
FBP	220	C_{14+}

The anti-knock characteristics of the obtained liquid fraction were evaluated using a portable fuel analyzer. Measurements performed in different operational modes produced varying results, with the Research Octane Number (RON) ranging

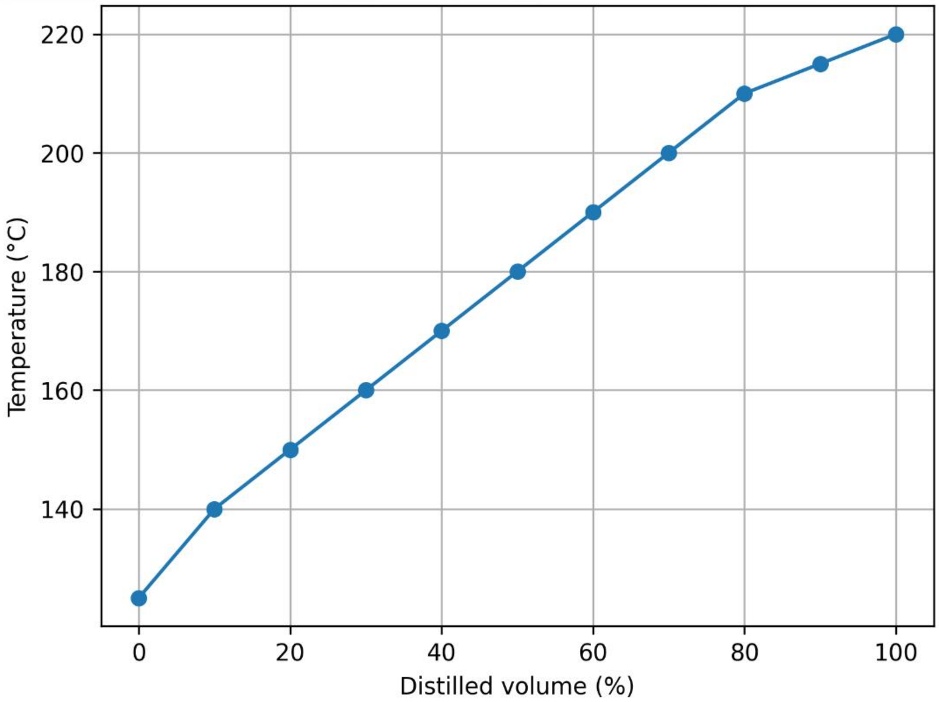
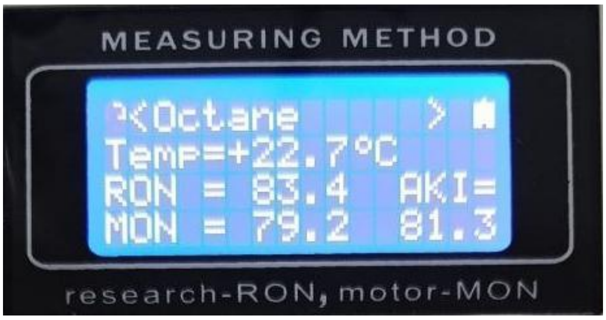


Fig. 2. Estimated distillation curve of the hydrocarbon liquid fraction obtained during polyethylene wax production

between approximately 83 and 105 depending on the selected calibration model Figure 3. The variation in the measured values can be explained by the composition of the investigated liquid. Portable octane analyzers estimate octane number based on dielectric properties of fuels and calibration models developed primarily for conventional gasoline blends. However, the investigated liquid fraction contains a high concentration of linear paraffins, which typically exhibit low octane numbers but high cetane numbers. Therefore, the obtained octane values should be interpreted cautiously, as the measurement technique is optimized for gasoline-type fuels rather than paraffinic hydrocarbon mixtures.

The results nevertheless indicate that the investigated liquid does not possess the chemical characteristics of conventional gasoline.

The ignition quality of the investigated liquid fraction was evaluated through determination of the cetane number (CN). The obtained value of approximately 42 indicates that the investigated hydrocarbon mixture exhibits ignition characteristics similar to those of conventional diesel fuels Table 3. The relatively high cetane number can be attributed to the dominance of linear paraffins in the hydrocarbon composition. It is well known that n-alkanes exhibit high cetane numbers because they ignite readily under compression conditions. In contrast, aromatic



```
?<Octane        >
Temp=+22.7°C
RON = 83.4  AKI=
MON = 79.2  81.3
```

Fig. 3. The octane number of the investigated liquid fraction was measured using a portable fuel analyzer Shatox SX-300

Table 3. Fuel quality parameters of the polyethylene cracking liquid measured using the Shatox SX-300 analyzer

Measurement mode	RON	MON	AKI	Additional parameters
Octane	83.4	79.2	81.3	–
Octane1	91.5	82.7	87.1	–
Oct+Oct	104.9	105.4	105.1	–
Oct+Bd.time	–	–	–	A80 / Normal; Tbd = 162.9 °C
Cetane	–	–	–	Cetane number = 42.0; Fuel type = A; Estimated flash point (Tfl) = −45.5 °C

hydrocarbons and branched compounds generally exhibit lower cetane values [10]. The measured cetane number suggests that the liquid fraction obtained from polyethylene cracking could potentially be used as a blending component in diesel fuels or as a feedstock for further upgrading processes.

The low-temperature behavior of the investigated liquid fraction was evaluated by determining the cloud point and pour point using an automated cold-flow analyzer according to ASTM standards Table 4. The measured cloud point was −16 °C, while the pour point was −27 °C. These values indicate that the fuel begins to form wax crystals at approximately −16 °C, and the flow properties become significantly restricted at lower temperatures Figure 4.

These results are consistent with the paraffinic composition revealed by GC–MS analysis. Linear paraffins tend to crystallize at relatively high temperatures compared to aromatic hydrocarbons or branched compounds. The formation of wax crystals leads to turbidity in the liquid, followed by progressive loss of fluidity as the crystal network develops. The difference between the cloud point and pour point (approximately 11 °C) is typical for paraffin-rich hydrocarbon mixtures. Similar cold-flow characteristics have been reported for paraffinic diesel fuels and synthetic fuels derived from Fischer–Tropsch processes.

The combined results of compositional and physicochemical analyses suggest that the investigated liquid fraction obtained during polyethylene wax production represents a paraffinic hydrocarbon mixture with properties comparable to middle

ТП: -16.0°C

ТПТ:-27°C

01:32:54 27.02.2026 11:53:16

-28.3°C

-38.9°C

-1°C/мин

Поиск Ттекучести/Тзастывания

```
-25    -->    5 мм.в.ст.
-26    -->    5 мм.в.ст.
-27    -->    1 мм.в.ст.
-28    -->    30 мм.в.ст.
```

Поиск Тпомутнения

```
-15.8    <=>    1173
-15.9    <=>    1172
-16.0    <=>    1171
-16.1    <=>    1167
```

Fig. 4. Low-temperature fuel properties were determined using the TPZ-LAB-12

Table 4. Comparison with typical diesel fuels

Fuel	Cloud Point	Pour Point
Summer diesel	–5…–10 °C	–15…–20 °C
Winter diesel	–15…–20 °C	–25…–35 °C
Arctic diesel	–30…–40 °C	–45…–60 °C

distillate fuels. The dominance of C_{10}–C_{16} hydrocarbons, relatively high cetane number, and moderate cold-flow properties indicate that this liquid could potentially be utilized as: a blending component for diesel fuels; a feedstock for hydroprocessing or catalytic upgrading; a raw material for petrochemical applications involving paraffinic hydrocarbons. Compared with conventional plastic pyrolysis oils, the investigated product appears to have a relatively clean hydrocarbon composition with limited contamination by heteroatom-containing compounds. This characteristic may facilitate its integration into existing refining and fuel production processes. Further research should focus on detailed distillation analysis, determination of density and viscosity, and evaluation of catalytic upgrading pathways to improve the fuel quality and broaden the potential applications of this material.

The comparative analysis indicates that the investigated liquid hydrocarbon fraction obtained during polyethylene wax production exhibits physicochemical properties close to those of middle distillate petroleum fractions Table 4. The boiling range and hydrocarbon distribution correspond to kerosene–diesel type hydrocarbons, while the measured cetane number (42) approaches the lower limit of conventional diesel fuels. The cold-flow properties of the investigated liquid (cloud point −16 °C and pour point −27 °C) fall within the range typical for winter-grade diesel fuels but do not meet the stricter requirements of aviation kerosene. Therefore, the obtained hydrocarbon fraction cannot be directly classified as a standard commercial fuel but may be considered a potential blending component for diesel fuels or a petrochemical feedstock after further upgrading.

CONCLUSION

This study investigated the chemical composition and physicochemical properties of a liquid hydrocarbon fraction obtained as a by-product during polyethylene wax

Table 4. Comparison of physicochemical properties of polyethylene cracking liquid with standard specifications for kerosene and diesel fuels

Parameter	Polyethylene cracking liquid	Kerosene (GOST 10227-2013)	Diesel fuel (GOST 32511-2013 / GOST 305-2013)
Hydrocarbon range	C_8–C_{26}	C_8–C_{16}	C_{10}–C_{22}
Boiling range (°C)	up to 220	150–300	180–360
Research octane number (RON)	83	not regulated	not regulated
Cetane number	42	not regulated	≥ 45–51
Cloud point (°C)	−16	≤ −50 (aviation fuels)	−5 to −35 (depending on grade)
Pour point (°C)	−27	≤ −60	−10 to −35
Appearance	transparent	transparent	transparent

production via thermal cracking of high-molecular-weight polyethylene. The combined analytical approach, including GC–MS analysis, fuel property measurements, and low-temperature characterization, provided comprehensive insight into the nature and potential applications of the investigated liquid fraction. GC–MS analysis revealed that the liquid product consists predominantly of paraffinic hydrocarbons within the carbon number range C_8–C_{26}, with the main fraction concentrated in the C_{10}–C_{16} region. Linear alkanes were identified as the dominant components, accompanied by smaller amounts of branched alkanes and minor quantities of olefinic compounds. This hydrocarbon distribution is typical for polyethylene thermal degradation and reflects the random chain scission mechanism characteristic of polyolefin cracking processes. Distillation characteristics indicated that the majority of the liquid fraction falls within the middle distillate boiling range, corresponding to kerosene–diesel type hydrocarbons. The transparency and relatively uniform composition of the product suggest the absence of significant aromatic compounds and heavy polymeric impurities, which distinguishes this material from conventional mixed plastic pyrolysis oils. Fuel property measurements demonstrated that the investigated liquid exhibits a cetane number of approximately 42, indicating ignition characteristics comparable to conventional diesel fuels. At the same time, the measured cloud point (−16 °C) and pour point (−27 °C) confirm the paraffinic nature of the mixture and indicate moderate low-temperature flow properties typical of paraffin-rich middle distillates. Based on the obtained results, the investigated liquid fraction may be considered a potential blending component for petroleum fuels after appropriate upgrading and detailed characterization. In particular, the lighter fraction could potentially be used as an additive to kerosene-type fuels, while the heavier fraction may be suitable as a blending component for diesel fuels. However, before practical application, comprehensive physicochemical and environmental analyses are required, including evaluation of combustion properties, stability, and removal of the characteristic hydrocarbon odor associated with the presence of light olefinic compounds.

In addition to fuel applications, several alternative utilization pathways can be considered. Due to its hydrocarbon composition, the liquid fraction may potentially be used as an industrial solvent, particularly in processes where slow evaporation is acceptable. Another promising direction is its use as a feedstock for further thermal or catalytic cracking and pyrolysis processes, enabling the production of lighter hydrocarbons and petrochemical intermediates. The heavier fractions of the product may also serve as a raw material for paraffin production, which is widely used in chemical, cosmetic, and industrial applications. Furthermore, the presence of linear hydrocarbons suggests potential applicability as a feedstock for the synthesis of surfactants and surface-active compounds, which are important components of detergents and industrial formulations. Due to the relatively high viscosity and paraffinic nature of the heavier fraction, it may also be considered as a candidate for the production of lubricating oils or synthetic base oils, including precursors for polyalphaolefins (PAO). In addition, the liquid fraction may potentially be utilized as a heat-transfer fluid in reactor jackets and industrial heating systems, where stable hydrocarbon heat carriers are required.

Overall, the results of this study demonstrate that the liquid by-product formed during polyethylene wax production represents a promising secondary hydrocarbon resource with multiple potential industrial applications. Further research will focus on more detailed compositional analysis, fractional separation, catalytic upgrading, and evaluation of its applicability in the fuel, petrochemical, solvent, lubricant, and heat-transfer fluid sectors.

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