GC-MS PROFILING OF FATTY ACID METHYL ESTERS FROM FRESH AND WASTE COOKING OIL-BASED BIODIESEL

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Abstract

The production of sustainable biodiesel is contingent upon the utilization of high-quality feedstocks to guarantee an optimal composition of fatty acid methyl esters (FAME). In this investigation, a comparative analysis was conducted using Gas Chromatography-Mass Spectrometry (GC-MS) to examine the FAME profiles of biodiesel derived from both fresh and waste cooking oil. Biodiesel produced from fresh cooking oil exhibited methyl oleate as the predominant constituent, accounting for 31.33%, succeeded by methyl palmitate at 23.84% and methyl linoleate at 10.39%. Conversely, biodiesel derived from waste cooking oil displayed noticeable alterations in its composition: the proportion of methyl oleate diminished to 26.43%, methyl linoleate experienced a substantial decline to 7.94% (representing a decrease of 2.45 percentage points), and methyl stearate saw an increase to 6.27%. These observed compositional shifts suggest that potential variations in quality may arise due to thermal and oxidative degradation processes incurred during repeated heating cycles. Nevertheless, the sustained predominance of methyl oleate in biodiesel from waste oil indicates that its quality remains acceptable. However, rigorous control over feedstock quality is paramount for accurately forecasting biodiesel performance and ensuring uniformity when utilizing waste cooking oil.

Keywords: Biodiesel, GC-MS, methyl esters, transesterification, waste cooking oil.

I. INTRODUCTION

The increasing global demand for energy and concerns over environmental sustainability have encouraged the development of renewable fuels. Biodiesel is considered a promising alternative because it is renewable, biodegradable, and produces lower emissions than petroleum diesel (Supriyanto et al., 2021). Biodiesel consists of fatty acid methyl esters (FAMEs) produced through transesterification, and its fuel properties are strongly influenced by FAME composition (Wang et al., 2021).

Cooking oil is one of the most widely used biodiesel feedstocks due to its availability and affordability. Waste cooking oil (WCO) is particularly attractive because it reduces production costs and minimizes environmental pollution. However, repeated heating during cooking may alter fatty acid composition through oxidation and thermal degradation, potentially affecting biodiesel quality.

Various analytical techniques have been employed for biodiesel characterization, including FTIR, HPLC, and GC. Among these methods, Gas Chromatography–Mass Spectrometry (GC-MS) is widely recognized for its high sensitivity and ability to identify both major and minor FAME compounds based on retention times and mass fragmentation patterns (Mahardika et al., 2024).

The utilization of WCO for biodiesel production has gained increasing attention; however, variations in feedstock quality remain a challenge. Therefore, evaluating compositional differences between biodiesel derived from fresh and waste cooking oil is important for understanding the influence of feedstock condition on biodiesel characteristics.

Previous studies have reported that biodiesel from vegetable oils is generally dominated by methyl palmitate, methyl oleate, and methyl stearate, while biodiesel quality is strongly influenced by feedstock characteristics and processing conditions (Bashir et al., 2022; Mahardika et al., 2024). Unsaturated FAME

compounds, particularly methyl linoleate, are also associated with oxidative stability (Wang et al., 2021).

Pradeep et al. (2020) demonstrated the usefulness of GC-MS for identifying oxidation-related compounds in biodiesel. Similarly, Mahardika et al. (2024) characterized FAME compounds in WCO biodiesel. However, these studies did not directly compare biodiesel produced from fresh and waste cooking oil or examine compositional changes associated with feedstock degradation.

Consequently, a research gap remains regarding comparative GC-MS profiling of biodiesel derived from fresh and waste cooking oil. Most studies focus on biodiesel production or general FAME composition without investigating how repeated heating influences individual FAME distributions, including minor compounds.

The novelty of this study lies in the direct comparison of biodiesel produced from fresh and waste cooking oil using GC-MS analysis. Unlike previous studies that focused on a single feedstock type, this work evaluates compositional differences between the two feedstocks and examines changes in both major and minor FAME components.

Therefore, this study aims to compare the FAME profiles of biodiesel derived from fresh and waste cooking oil and to assess compositional variations associated with feedstock condition. The results are expected to contribute to biodiesel characterization studies and support the sustainable utilization of waste cooking oil as a renewable energy resource.

II. METHODS

An experimental study conducted under laboratory conditions was designed for this research to verify and evaluate differences in the methyl ester (fatty acid methyl esters/FAME) profiles of biodiesel produced from fresh and waste cooking oil. Gas Chromatography–Mass Spectrometry (GC-MS) was employed as the primary analytical technique for FAME characterization. The study was carried out at the Research Laboratory of the Department of Chemistry using a Thermo Scientific TRACE 1310 Gas Chromatograph coupled with a Thermo Scientific ISQ 7000 Mass Spectrometer. The experimental procedure was conducted systematically, including feedstock preparation, biodiesel synthesis through transesterification, purification, GC-MS characterization, and qualitative as well as semi-quantitative data analysis. GC-MS analysis was performed without replication

The research equipment consisted of standard laboratory glassware, including three-neck flasks, reflux condensers, hot plates equipped with magnetic stirrers, thermometers, graduated cylinders, volumetric pipettes, and separatory funnels. The three-neck flask functioned as the transesterification reactor vessel, accommodating the condenser, thermometer, and stirring system simultaneously. Heating was controlled using a temperature-regulated hot plate to maintain the reaction temperature within the range of 55–65°C. Continuous agitation was provided by a magnetic stirrer to maintain homogeneity between the immiscible methanol and oil phases. Separatory funnels were utilized to separate biodiesel from glycerol based on density differences. A drying oven was also employed to remove residual moisture after the washing process. The principal analytical instrument used for biodiesel characterization was a Thermo Scientific TRACE 1310 GC coupled with an ISQ 7000 Mass Spectrometer.

Fresh cooking oil and waste cooking oil were used as the primary feedstocks for biodiesel production. The type of fresh cooking oil used comes from palm oil. The used cooking oil used was taken randomly from various kitchens so that the specific type of food fried, temperature and duration of frying are not known. Prior to processing, the waste cooking oil was filtered to remove suspended food residues and other impurities. The free fatty acid (FFA) contents of both fresh and waste cooking oil samples were quantitatively determined using an acid–base titration method following the AOCS Official Method Cd 3d-63. Approximately 5 g of oil sample was dissolved in neutralized ethanol and titrated with standardized 0.1 N KOH using phenolphthalein as an indicator until a stable pale pink endpoint was achieved. The FFA value was

calculated as the percentage of oleic acid equivalent. The analysis confirmed that waste cooking oil possessed a higher FFA content than fresh cooking oil due to repeated heating during frying processes. Methanol was used as the alcohol reagent for esterification and transesterification, while sulfuric acid (H_2SO_4) and sodium hydroxide (NaOH) served as acid and base catalysts, respectively. Anhydrous sodium sulfate (Na_2SO_4) was utilized as a drying agent during biodiesel purification. Because elevated FFA levels can interfere with base-catalyzed transesterification through soap formation, an initial esterification step was performed for waste cooking oil samples. The esterification process involved reacting waste cooking oil with methanol at a 1:6 molar ratio in the presence of sulfuric acid catalyst at approximately 1–3% of the oil mass. The mixture was heated to approximately 60°C for 60 minutes with continuous stirring. After the reaction was completed, the mixture was allowed to settle until two distinct layers formed, and the upper oil layer was collected for further processing. Subsequently, transesterification was carried out by mixing the oil with methanol at a 1:6 molar ratio and approximately 1 wt% NaOH catalyst dissolved in methanol to form methoxide solution. The reaction mixture was maintained at 60°C for 60–90 minutes under continuous stirring. Following the reaction, the mixture was transferred into a separatory funnel and allowed to stand for approximately 24 hours to separate biodiesel from glycerol. The biodiesel layer was then washed with warm water until clear wash water was obtained and subsequently dried using anhydrous Na_2SO_4.

For biodiesel characterization, approximately 1 µL of purified biodiesel sample was injected into the GC-MS system using split injection mode. Separation was carried out using a TG-5MS capillary column (30 m × 0.25 mm × 0.25 µm) with helium as the carrier gas at a constant flow rate of 1.4 mL/min. The injector temperature was maintained at 250°C with a split ratio of 40:1. The oven temperature program started at 70°C for 1 minute, increased at 7.5°C/min to 250°C, and was held for 5 minutes. The mass spectrometer operated in Electron Impact (EI) ionization mode at 70 eV with a scanning range of m/z 50–500. Compound identification was conducted by comparing retention times and mass fragmentation patterns with the NIST Mass Spectral Library (version 2020). Relative quantification of FAME compounds was determined based on chromatographic peak area percentages relative to the total detected FAME peak area.

If the titration results indicated a high FFA content, an esterification pretreatment was carried out. This esterification process involved reacting the waste cooking oil with methanol at a 1:6 molar ratio in the presence of sulfuric acid (H_2SO_4) catalyst at approximately 1–3% of the oil mass. The mixture was heated to about 60°C for 60 minutes with continuous stirring to ensure adequate contact between the reactants. After the reaction period, the mixture was allowed to settle until two distinct layers were formed, and the upper oil layer was carefully separated and collected. This esterification step was performed to reduce the FFA content to an acceptable level, thereby allowing the subsequent base-catalyzed transesterification to proceed efficiently without causing soap formation that could reduce biodiesel yield (Abdullah et al., 2021).In the transesterification procedure, the oil (fresh or used) was mixed with methanol in a 1:6 molar ratio. Approximately 1% by weight of oil of NaOH catalyst was dissolved in methanol first to produce a methoxide solution. The methoxide solution was then added to the oil in the reaction flask. The mixture was heated to 60°C for 60–90 minutes with constant stirring, a condition identified as optimal for base-catalyzed transesterification (Knothe et al., 2017). During the reaction, triglycerides are converted to methyl esters and glycerol via a stepwise mechanism. After the reaction was complete, the mixture was allowed to stand in a separatory funnel for approximately 24 hours to separate the biodiesel phase (top) from the glycerol phase (bottom). The separated biodiesel phase was then washed with warm water to remove residual catalyst, soap, and glycerol. Washing was continued until the rinse water was clear. The final step involved drying the biodiesel using anhydrous Na_2SO_4 to remove any remaining water. This method is a conventional procedure commonly employed in biodiesel production, achieving conversion

efficiencies exceeding 90% under optimal conditions.

Characterization analysis relied on Gas Chromatography–Mass Spectrometry (GC-MS) as the primary instrument. The capillary column used was a TG-5MS column with dimensions of 30 m length, 0.25 mm internal diameter, and 0.25 µm film thickness. Helium was employed as the carrier gas at a constant flow rate of 1.4 mL/min. The GC-MS operational conditions included an injector temperature of 250°C, split injection mode with a split ratio of 40:1, and an injection volume of 1 µL. The oven temperature program was initiated at 70°C and maintained for 1 minute, followed by an increase at a rate of 7.5°C/min to 250°C and held for 5 minutes to ensure complete elution of FAME compounds. The total analysis time for each sample was approximately 30 minutes. The mass spectrometer was operated in Electron Impact (EI) ionization mode at 70 eV with a scanned mass range of m/z 50–500. The ion source and transfer line temperatures were maintained at 200°C and 250°C, respectively. Chromeleon 7 software was used for data acquisition and analysis. Compound identification was carried out by comparing retention times and mass fragmentation patterns with the NIST Mass Spectral Library (version 2020). Relative quantification was determined by calculating the percentage peak area of each detected compound relative to the total peak area of all identified FAME compounds. This semi-quantitative approach is commonly applied in biodiesel characterization studies to evaluate FAME composition (Knothe, 2017).

To identify the formed FAME compounds, the biodiesel composition was characterized by GC-MS. Approximately 1 µL of the purified biodiesel sample was injected into the oven's gradient-temperature program helped separate compounds based on their volatility. Compounds with shorter carbon chains tend to elute earlier, while those with longer carbon chains require longer retention times. Compound identification was performed by matching the resulting mass spectra with the NIST database. Major components identified in the biodiesel included methyl palmitate, methyl oleate, methyl linoleate, and methyl stearate, which also served as indicators of successful transesterification (Mahardika et al., 2024). Quantification was performed semi-quantitatively by measuring the peak area of the chromatogram. The relative proportion of each compound was calculated by dividing its peak area by the total peak area. This approach is common in biodiesel analysis as it provides an estimate of composition without requiring external standards (Knothe et al., 2020).

Furthermore, gas chromatography-mass spectrometry (GC-MS) was used to quantitatively analyze the distribution of saturated and unsaturated fatty acids in the biodiesel. The proportion of unsaturated fatty acids, such as methyl oleate and methyl linoleate, directly correlates with the fuel's flow characteristics and operational performance. Meanwhile, saturated fatty acids, including methyl palmitate and methyl stearate, are known to play a crucial role in determining the oxidative stability of biodiesel. The data analysis process employed was descriptive, comparing the fatty acid methyl ester (FAME) component profiles obtained from biodiesel derived from fresh and waste cooking oil. This comparative analysis is critical for quantifying the extent to which initial feedstock degradation influences the final composition of the produced biodiesel. The selection of the GC-MS method was based on its superior ability to provide detailed data on molecular architecture, quantitative and qualitative composition, and overall biodiesel quality aspects. An additional advantage of this technique is its capability to detect and identify minor compounds that might be inaccessible to other analytical methods.

III. RESULT AND DISCUSSION

The study analyzing biodiesel methyl ester profiles from fresh and waste cooking oil samples using GC-MS indicated that the distribution of fatty acid methyl ester (FAME) compounds was dominated by long-chain fatty acids, both saturated and unsaturated. Analysis of the resulting chromatograms (see Figures 1 and 2) revealed similar patterns in both types of oil samples. Nevertheless, distinct differences in peak intensity and peak-area distribution were

detected, indicating changes in chemical composition due to repeated heating. Specifically, the analytical findings showed that both samples produced chromatograms with complex, consistently distributed peak patterns over the retention time range of 10 to 26 minutes. The chromatogram of biodiesel derived from cooking oil showed dominant peaks with very strong intensity and a stable baseline, indicating homogeneity in FAME composition. Conversely, the chromatogram of biodiesel obtained from waste cooking oil showed secondary peaks of lower intensity at earlier retention times (around 6–12 minutes). The emergence of these peaks suggested the possible presence of additional volatile compounds that may be associated with compositional changes occurring during repeated heating and frying processes. However, because peroxide value and acid value analyses were not performed in this study, the detected minor peaks cannot be conclusively attributed to thermal or oxidative degradation products.

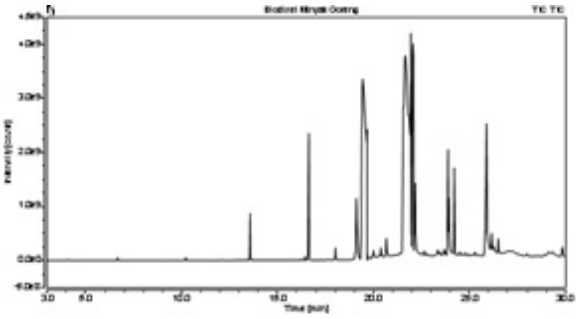


Figure 1. Chromatogram of Cooking Oil Biodiesel

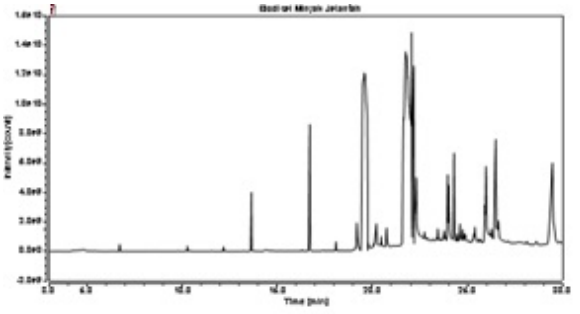


Figure 2. Chromatogram of Waste Cooking Oil Biodiesel

The main peak detected at 19.3 minutes (Figure 3) was identified as methyl palmitate, and its identity was confirmed by a high mass-spectral match to the library. Generally, retention times in gas chromatography are influenced by carbon chain length and degree of unsaturation, with retention times increasing as both parameters increase. The mass spectra of the major peaks showed strong agreement with the NIST Mass Spectral Library (version 2020), with match score values of 96.4% for methyl palmitate (C16:0), 94.8% for methyl stearate (C18:0), 97.1% for methyl oleate (C18:1), 95.6% for methyl linoleate (C18:2), and 92.7% for methyl linolenate (C18:3). The presence of these FAME compounds was further supported by the detection of characteristic fragment ions such as m/z 74, corresponding to fragmentation of the methoxy-carbonyl group in FAME compounds, m/z 143 associated with acylium ion formation, and intact molecular ions within the range of m/z 270–296 depending on carbon chain length and unsaturation degree (Knothe, 2017). The observed retention times were 19.3 minutes for methyl palmitate, 21.87 minutes for methyl oleate, and 21.6 minutes for methyl linoleate, indicating effective chromatographic separation without significant peak overlap.

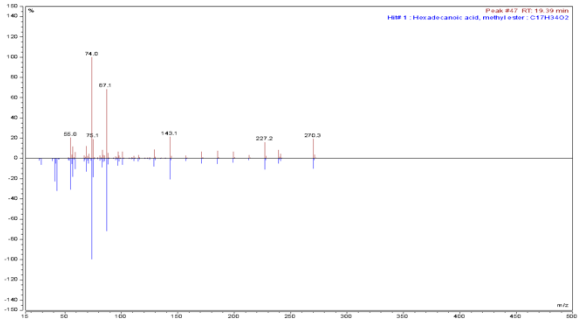


Figure 3. Comparison of the sample spectrum with the library at 19.3 minutes

Analysis of biodiesel produced from cooking oil revealed a predominance of methyl oleate (C18:1) with an estimated proportion of 31.33%. Other significant components present were methyl palmitate (C16:0) at approximately 23.84% and methyl linoleate (C18:2) in the range of 10.39%. Additionally, minor fractions such as methyl myristate (C14:0), methyl stearate (C18:0), and methyl arachidate (C20:0) were successfully identified. The high methyl oleate content indicated that the cooking oil feedstock was rich in monounsaturated fatty acids. Based

on the literature, biodiesel with higher monounsaturated fatty acid composition is generally estimated to exhibit favorable flow characteristics compared with biodiesel dominated by saturated fatty acids. However, specific fuel property analyses such as viscosity, cold flow properties, pour point, or cold filter plugging point (CFPP) were not evaluated in this study.

In contrast, biodiesel sourced from waste cooking oil exhibited a different FAME composition profile. Methyl oleate remained the primary component with an estimated content of 26.43%, followed by methyl palmitate at approximately 24.13%. However, an interesting finding was a significant increase in the methyl stearate fraction to around 6.27%, while the methyl linoleate content decreased to approximately 7.94%. This compositional shift strongly suggested the presence of degradation processes in unsaturated compounds resulting from repeated oxidative exposure during the frying cycles. The changes in FAME composition due to UCO degradation do not necessarily diminish quality absolutely, but rather shift the balance of fuel properties. This is why FAME analysis is so crucial—from this profile, we can predict biodiesel performance without directly testing all parameters. The detection of minor compounds, including methyl caprylate (C8:0) at a retention time of approximately 6.7 minutes in biodiesel derived from waste cooking oil, indicated the presence of low-abundance methyl ester components that were not prominently observed in biodiesel from fresh cooking oil. Based on the literature, short-chain methyl esters such as methyl caprylate may originate from partial thermal decomposition, oxidative cleavage of longer-chain unsaturated fatty acids, or secondary reactions occurring during repeated frying processes. However, because peroxide value, acid value, and other oxidation parameters were not comprehensively evaluated in this study, the detected compound cannot be conclusively identified as a direct degradation product. The possibility of minor contamination originating from repeated cooking practices or residual food-derived lipid components should also be considered. Nevertheless, the appearance of this minor peak suggests compositional differences between fresh and waste cooking oil biodiesel that may be associated with changes occurring during repeated thermal exposure.

Table 1. Estimated FAME content (%) of cooking oil biodiesel based on retention time.

Retention time (Min)	Common Name: FAME	Estimated content (%)
10.217	Methyl caprate (C10:0)	0.05
13.57	Methyl laurate (C12:0)	0.72
16.635	Methyl myristate (C14:0)	2.67
19.107	Methyl palmitoleate (C16:1)	2.32
19.390-19.662	Methyl palmitate (C16:0)	23.84
21.594	Methyl linoleate (C18:2)	10.39
21.696-21.947	Methyl oleate (C18:1)	31.33
22.059	Methyl stearate (C18:0)	8.68
24.209	Methyl arachidate (C20:0)	1.81
26.501	Methyl behenate (C22:0)	0.50

Table 2. Estimated FAME content (%) of waste cooking oil biodiesel by retention time

Retention time (Min)	Common Name: FAME	Estimated content (%)
6.700	Methyl caprylate	0.08
10.268	Methyl caprate	0.07
13.635	Methyl laurate	1.17
16.706	Methyl myristate	2.61
19.111 - 19.291	Methyl palmitoleate	0.99
19.546 - 19.808	Methyl palmitate	24.13
21.682 - 21.699	Methyl linoleate	7.94
21.746 - 22.056	Methyl oleate	26.43
22.121 - 22.175	Methyl stearate	6.27
24,015	Methyl eicosenoate	1.26
24.294	Methyl arachidate	1.77
26.627	Methyl behenate	0.62

Significant differences were also observed in the chromatograms of waste cooking oil, with a

greater number of minor peaks than in fresh oil. This situation indicated the formation of degradation products, including aldehydes, ketones, and other oxidation products, which were not fully converted to FAME during the transesterification process. The changes in FAME profiles between fresh and waste cooking oil can be explained by a deep understanding of the chemical reactions that occur during heating, primarily oxidation, hydrolysis, and polymerization. Unsaturated fatty acids, such as linoleic acid (C18:2), have double bonds that are highly susceptible to oxidation when heated. This oxidation process typically proceeds via a free-radical chain reaction mechanism, initiating with the formation of lipid radicals (L•), followed by peroxyl radicals (LOO•), and culminating in the production of hydroperoxides (LOOH). Subsequently, hydroperoxide compounds formed during lipid oxidation may undergo further decomposition into secondary oxidation products such as aldehydes, ketones, and other volatile compounds, as reported by Wang et al. (2021). However, specific aldehyde or ketone compounds were not conclusively identified in the present GC-MS analysis; therefore, the occurrence of these degradation products in the analyzed biodiesel samples cannot be directly confirmed in this study.

Based on the literature, repeated heating of cooking oil may promote triglyceride hydrolysis, leading to the formation of free fatty acids (FFAs) that can interfere with the efficiency of the transesterification reaction. Previous studies have reported that elevated FFA levels may contribute to soap formation during base-catalyzed transesterification, thereby reducing biodiesel yield and complicating phase separation processes (Maniam et al., 2023). In the present study, biodiesel derived from waste cooking oil showed a relative increase in saturated FAME compounds such as methyl palmitate and methyl stearate, accompanied by a decrease in methyl linoleate compared with biodiesel from fresh cooking oil. These compositional differences suggest that repeated thermal exposure of the feedstock may influence the distribution of saturated and unsaturated fatty acid methyl esters in the resulting biodiesel. The higher thermal stability of saturated fatty acids may explain their relatively greater abundance in the waste cooking oil biodiesel sample.

The FAME profiles obtained in this study are generally consistent with previous reports on vegetable oil-based biodiesel. Methyl palmitate, methyl oleate, and methyl linoleate were identified as the dominant compounds in both biodiesel samples, in agreement with the findings of Knothe and Razon (2017). In addition, the lower proportion of methyl linoleate observed in waste cooking oil biodiesel compared with fresh cooking oil biodiesel is comparable to the trend reported by Plata et al. (2021), who associated repeated heating with reductions in unsaturated fatty acids. In the present study, methyl oleate remained the predominant compound in both samples, indicating that monounsaturated fatty acids were still retained despite compositional shifts in the waste cooking oil biodiesel. This observation supports previous findings by Suherman et al. (2023), which reported that waste cooking oil can still produce biodiesel with acceptable compositional characteristics. Based on the literature, the dominance of methyl oleate is also generally associated with balanced biodiesel fuel properties, although direct fuel performance parameters were not evaluated in this study.

Furthermore, the increase in methyl stearate detected in biodiesel produced from waste cooking oil is consistent with observations reported by Gonzaga et al. (2021), who found that repeated thermal exposure tends to increase the relative proportion of saturated fatty acid derivatives. The present results indicate that compositional changes in biodiesel are influenced not only by the transesterification process itself but also by the prior thermal history of the feedstock. Since waste cooking oil originates from different cooking conditions and heating cycles, variations in FAME distribution are expected to occur more readily than in biodiesel derived from fresh cooking oil. This explains why, although methyl oleate remained dominant in both samples, the relative abundance of other FAME compounds differed noticeably between the two biodiesel feedstocks.

Interpretation of the results from this study must consider several limitations inherent in the

methodology employed. The first limitation lies in the semi-quantitative nature of GC-MS analysis; peak-area measurements without internal standards limit the absolute quantification accuracy of identified compounds. The second limitation is the absence of evaluation for vital biodiesel quality attributes, including viscosity, density, cetane number, and oxidative stability. Consequently, a holistic relationship between FAME composition and fuel performance cannot be fully elucidated. Furthermore, a third limitation concerns the lack of strict control over variable factors in waste cooking oil use, such as the number of thermal cycles, temperature levels, and the types of food fried, all of which can potentially modify the product's chemical composition. Lastly, minor compounds originating from degradation processes may not have been identified, possibly due to limited spectral references or limitations in the analytical instrument's sensitivity.

The findings from this study strongly indicate that waste cooking oil still holds significant potential for utilization as an effective biodiesel feedstock. This is supported by the fact that its resulting fatty acid methyl ester (FAME) composition closely resembles that of fresh oil. The persistent dominance of methyl oleate in waste cooking oil indicates that the resulting biodiesel exhibits favorable flow characteristics and adequate oxidative stability. From an environmental preservation perspective, adopting waste cooking oil as a biodiesel source has the potential to substantially reduce household waste volume and minimize environmental pollution risks, aligning with the implementation of circular economy principles and the development of renewable energy. Moreover, from an industrial standpoint, employing waste cooking oil as a primary feedstock offers a significant opportunity to substantially lower biodiesel production costs. Nevertheless, it is essential to recognize that a pretreatment step is imperative to reduce free fatty acid (FFA) content, thereby enhancing the efficiency of the transesterification process. Furthermore, the observed fluctuations in FAME composition underscore the critical importance of implementing stringent quality control of the feedstock throughout the entire biodiesel production process to ensure the consistency and superior quality of the final product.

IV. Conclusion

This study demonstrated that differences in feedstock conditions between fresh and waste cooking oil influence the FAME composition of the resulting biodiesel. GC-MS analysis showed that both biodiesel samples contained similar major methyl ester compounds, including methyl palmitate, methyl oleate, methyl stearate, methyl linoleate, and methyl linolenate. However, biodiesel derived from waste cooking oil exhibited compositional changes, particularly a lower proportion of unsaturated fatty acid methyl esters and a relative increase in saturated components compared with biodiesel from fresh cooking oil.

The findings indicate that repeated heating of cooking oil may contribute to changes in biodiesel composition prior to the transesterification process. This study also confirms that GC-MS is an effective analytical technique for identifying both major and minor FAME compounds in biodiesel samples. Furthermore, waste cooking oil remains a promising alternative feedstock for biodiesel production, although feedstock quality control and appropriate pretreatment are important to maintain biodiesel consistency and quality.

Future studies are recommended to include direct fuel property analyses, such as viscosity, oxidative stability, cetane number, and cold flow properties, in order to establish a more comprehensive relationship between feedstock degradation and biodiesel performance.

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