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Atık Trigliseritlerin Katyonik Türevlerinin Sentezi, Karakterizasyonu ve Anyon Giderme Özelliklerinin Değerlendirilmesi

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Anahtar Kelimeler

Trigliseritler,
Atık yemeklik yağlar,
Bitkisel yağların katyonik türevleri,
Anyon giderimi,
Sürdürülebilir kalkınma

Öz: Atık yemeklik yağlar (AYY), insan sağlığı ve çevredeki birçok ekosistem üzerinde olumsuz bir etkiye sahiptir. Geleceğimizi güvence altına almak için, bu malzemeleri geri dönüştürmemiz veya onları güvenli bir şekilde elimine edilmesi esastır. Bu çalışma, bitkisel yağlardan üretilen trigliseritlerin katyonik türevlerini tartışır ve değerlendirir. Ayrıca, araştırma sentezlenen malzemelerin anyonları ortadan kaldırma potansiyelini araştırır. Üç parçalı bir işlem katyonik türevler üretir. İşlem, kullanılmış yemeklik yağın (WCO) epoksidasyonu ile başlar. İşlemin bir sonraki adımı epoksitlenmiş atık yemeklik yağı (EWO) ve monokloroasetik asidi (MCA) birleştirecektir. İşlemin son aşaması olan kuaternizasyon reaksiyonu, üçüncül aminleri kullanır. Trietilamin ve piridin, kuaternizasyon prosedürü sırasında iki birincil bileşen olarak görev yaptı. Türevleri analiz etmek için sırasıyla FTIR ve ¹H NMR spektroskopisi gibi teknikler kullanıldı. Her bir değiştirilmiş trigliseritte toplam üç kuaterner amin grubunun sentezlendiği tespit edildi. Bu bileşiklerin çok değerlikli anyonlarla birleşmesi çözünmeyen katılma ürünlerine dönüşmesi gözlenir. sonuçları. QT-EWO-MCA, bileşiğin tek bir gramını kullanarak 0,059 gram karbonat, 0,0947 gram sülfat ve 0,0947 gram monohidrojen fosfatı absorbe etme yeteneğine sahiptir.

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Synthesis, Characterization, and Evaluation of Anion Removal Properties of Cationic Derivatives of Waste Triglycerides

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Abstract: Waste cooking oils (WCO) exert a detrimental effect on the environment. It is crucial for our future to either reuse or eliminate those materials. This study assesses the cationic derivatives of triglycerides derived from plant oils. Furthermore, the research also examines the potential of the synthesized materials to remove anions. The process of creating cationic derivatives involves three distinct phases. The initial

Keywords

Triglycerides,
Waste cooking oils,
Cationic derivatives of plant oils,
Anion removal,
Sustainable development

procedure involves the epoxidation of the utilized cooking oil (WCO). The next procedure involves the amalgamation of epoxidized waste cooking oil (EWO) with monochloroacetic acid (MCA). The last stage involves the quaternarization reaction using tertiary amines. Triethylamine and pyridine were employed for the process of quaternarization. The derivatives were investigated using FTIR and ^1H NMR spectroscopy techniques. It was determined that each altered triglyceride contains three quaternary amine groups. Insoluble adducts are generated when these chemicals are combined with multivalent anions. One gram of QT-EWO-MCA can absorb 0.059 g of carbonate, 0.0947 g of sulfate, and 0.0947 g of monohydrogen phosphate.

1. Introduction

The rise in global population has resulted in an escalation of garbage production. Waste cooking oils (WCO) are particularly emphasized among waste products. WCO's have negative impacts on human health and the environment in numerous ways. Improper disposal of WCO can lead to the contamination of water, soil and air. The process of WCO decomposition often results an increase in the emission of hazardous compounds and greenhouse gases, hence intensifying air pollution and contributing to the phenomenon of climate change. The utilization of WCO for culinary purposes can pose a risk to human health due to the generation of potentially hazardous chemicals. Therefore, the recycling and modification of waste cooking oil (WCO) for industrial purposes is an essential concern for ensuring sustainability (Lin, 2013; Mannu, 2020).

How WCO's will be recycled and reused are two key concerns that many scientists investigate. The most viable option to address those questions is to make alterations to WCO's. While the cooking process may induce some alterations in their structures, WCO is capable of undergoing nearly all of the reactions observed in conventional triglycerides.

Due to the complex nature of triglycerides, it is relatively simple to alter and create refined substances and polymers. The primary reactive sites in most triglycerides are ester groups, double bonds, allylic positions, and α -carbons adjacent to ester carbonyls (Işıkçı Koca, 2019; Miao, 2014). Of these, conversions involving ester groups and double bonds can industrially be applicable in large scales. Transesterification processes can be used to produce biodiesel and alkyd resins. Alkyd resins are synthesized by combining plant oil triglycerides with different polyols and carboxylic acids (Lorenz, 2004; Chiplunkar, 2016; Villada, 2023). Halogenated, hydrogenated and epoxidized triglycerides are produced industrially with the modification of double bonds.

Epoxidized triglycerides contain oxirane (epoxy) rings. Oxiranes are cyclic compounds consisting of a three-membered ring with an oxygen atom. Plant oil triglycerides react with peroxy acetic or peroxy formic acid to produce epoxidized triglycerides. Oxirane groups are reactive substances as a result of the ring strain. They can be used to create a wide variety of intermediates and polymers that are commercially available (Çaylı, 2010; Şahin, 2016, Savani, 2023). Epoxides readily undergo nucleophilic and electrophilic addition reactions. One method to produce acrylated epoxidized soybean oil (AESO) on a wide scale is by reacting epoxidized soybean oil with acrylic acid (Zhao, 2023; Zheng, 2023). Various carboxylic acids, not just acrylic acid, can react with ESO to produce diverse types of bio-based polyols (Gürbüz, 2022; Rajput, 2023; Chen, 2023; Çaylı, 2011).

When epoxidized waste cooking oil reacted with halogen containing carboxylic acids such as MCA. The product is a halogen bearing ester condensate. Upon reaction with tertiary amines, the halogenated derivative yielded quaternary ammonium salts. These cationic compounds are soluble in water and can form insoluble complexes by binding to multivalent anions. The presence of various anions in the environment has become a pressing concern, with far-reaching implications for ecosystems, human health, and sustainable development. A variety of methods have been investigated for anion removal, including ion exchange, membrane filtration, precipitation and adsorption. Among these, precipitation has emerged as a particularly promising approach due to its

simplicity, cost-effectiveness, and high efficiency (Maia, 2020; Lito, 2019). Starting from waste triglycerides, the synthesis and anion-binding ability of cationic derivatives of WCO's are presented in this work. To the best of our knowledge, this is the first example of such work documented in the literature.

2. Materials and Methods

Merck (Darmstadt, Germany) provided several chemicals including dichloromethane, chloroform, formic acid, 50% hydrogen peroxide, methylene blue, monochloroacetic acid, sodium dodecylbenzenesulfonate, sodium iodide, sodium carbonate, sodium sulfate, sodium hydrogen phosphate and tetrahydrofuran which were used as they were received. Waste cooking oil (WCO) was obtained from a local restaurant, filtered and dried prior to use. The compounds were characterized using Nicolet 380 series ATR spectrometer with diamond window for FTIR analysis. The Varian 400-MHz NMR instrument (Varian Associates, Palo Alto, CA) was used to record ¹H NMR spectra at a frequency of 399.986 MHz for proton. The solvent used was CDCl₃, and the spectra were recorded in ppm (δ).

2.1. Synthesis of Epoxidized Waste Cooking Oil (EWO)

Prior to mixing, the waste cooking oil (WCO) was subjected to a drying process in a vacuum oven. Following the drying process, 50 g of the WCO, which had been filtered, was combined with 28 g of formic acid in a 250-ml round-bottom flask. Subsequently, the mixture was chilled using an ice bath, and 8 g of a 50% solution of hydrogen peroxide was added gradually over a period of 30 minutes. The mixture was thereafter agitated for a duration of 16 hours until the reaction reached its completion. After completion, 100 ml of dichloromethane was introduced, and the combination was rinsed with 100 ml of tap water on three separate occasions. The raw product was dehydrated using anhydrous sodium sulfate, and the waste cooking oil (WCO) was utilized without any additional refinement.

2.2. Synthesis of EWO-monochloroacetic acid condensate (EWO-MCA)

A 250-ml round-bottom flask was utilized to combine 95.2 g of EWO with 28.3 g of monochloroacetic acid. The mixture was thereafter heated to a temperature of 110 °C and agitated in the presence of a nitrogen environment for a duration of 8 hours. The progress of the reaction was monitored by measuring the acid number. After 8 hours, the acid number reached a value of 0, indicating that the reaction was complete. The resulting EWO-MCA condensate was utilized without any further purification.

2.3. Quaternarization of EWO-MCA

A 250 ml round bottom flask was utilized to dissolve 12.4 g of EWO-MCA in 50 ml of tetrahydrofuran. Subsequently, 3.4 grams of triethylamine and 0.1 grams of sodium iodide were introduced into the mixture, followed by refluxing the resultant solution for a duration of 24 hours. After reaction completed, the solvent and surplus triethylamine were eliminated utilizing a rotary evaporator. The QT-EWO-MCA, which is the Triethylamine derivative of EWO-MCA, was utilized without undergoing any further purification.

To obtain the pyridine derivative, 0.1 g of sodium iodide and 2.4 g of pyridine were added to the EWO-MCA solution. The resultant solution has been used without any further purification as the Pyridine derivative (QP-EWO-MCA). Figure 1 displays the configurations of QT-EWO-MCA and QP-EWO-MCA.

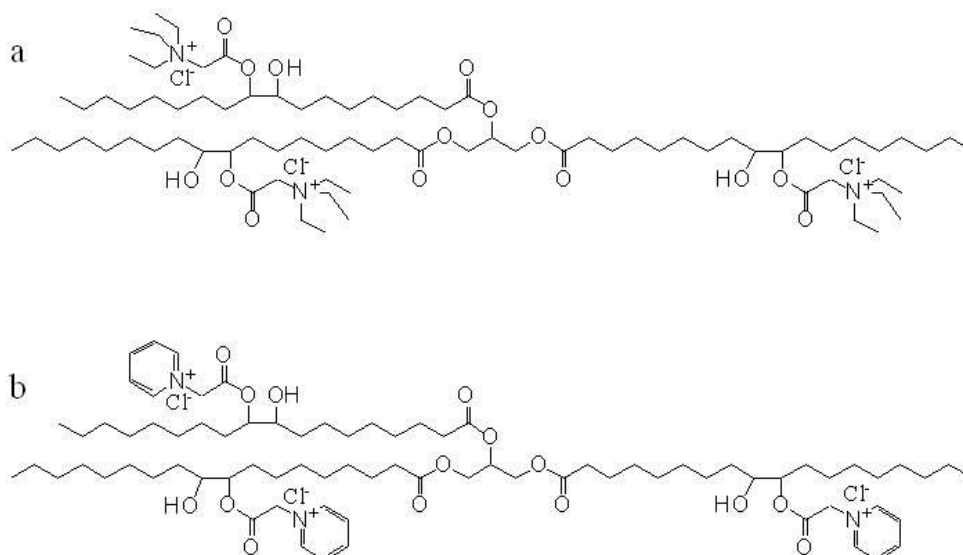


Figure 1: Structures of a-QT-EWO-MCA and b- QP-EWO-MCA

2.4. Determination of Quaternarization Yield

The process of quaternarization was monitored using the methylene blue two-phase titration method (Tsubouchi, 1981; Cui, 2024). This approach relies on the distribution of the methylene blue indicator between the aqueous and organic phases. Methylene blue is a positively charged and easily dissolvable chemical in water. Upon the addition of an anionic surfactant to the reaction medium, methylene blue formed a complex that was soluble in the organic phase. The tests utilized chloroform as the organic phase. A 0.5-gram sample is extracted and dissolved in 25 milliliters of water. Subsequently, 25 ml of a standard solution of methylene blue and 25 ml of chloroform are introduced into the aforementioned solution. Next, the combination is titrated using a solution of sodium dodecylbenzenesulfonate (SDBS) with a concentration of 10 g/l. At the endpoint of the titration, the chloroform phase exhibited a blue color. For complete conversions, 35 ml of SDBS was utilized for QP-EWO-MCA, whereas 34 ml of SDBS was utilized for QT-EWO-MCA.

2.5. Anion Removal Experiments

The anion removal capabilities of QT-EWO-MCA and QP-EWO-MCA were measured based on variations in time, temperature, and pH. The most prevalent divalent anions, including carbonate (CO_3^{2-}), monohydrogen phosphate (HPO_4^{2-}), and sulfate (SO_4^{2-}), were selected. The studies were conducted using a 1% solution of cationic triglyceride derivatives and a 1% solution of anion salts. The reactions were conducted in a 250 ml sealed Erlenmeyer flask. The two solutions were combined in flasks and agitated using a magnetic stirrer that was equipped with a constant temperature bath. Following the completion of the reaction, a 20 ml sample of the aqueous phase was extracted for anion analysis. The experimental settings for eliminating the anion are listed in Table 2. A cationic derivative of triglyceride and anion salts were combined in equal volumes in a closed erlenmeyer flask and swirled at specific time intervals. Measurements were conducted at temperatures of 10, 25, 40, and 60 degrees Celsius. Three distinct pH values were selected. The anion binding capabilities of QT-EWO-MCA and QP-EWO-MCA were assessed at pH 4, 7, and 10.

3. Results and Discussions

3.1. Synthesis of Cationic Derivatives

The characteristics of triglycerides might vary depending on the source. The acid number and iodine numbers were initially observed for the purpose of standardization. If the acid number was elevated, it was then decreased to 0 through the utilization of basic alumina. The iodine value was determined using the Hanus technique. The iodine values of the waste cooking oils (WCO) used in this

investigation were determined to be 110. WCO underwent epoxidation through the Prilezhaev reaction. Subsequently, the EWO compound underwent a reaction with MCA at a temperature of 120 °C. The condensation reaction between EWO and MCA was monitored by measuring the acid number. The acid number was first measured as 135 at the start of the process. At a temperature of 120 degrees Celsius, the acid number values reached close to 0 after a duration of 8 hours. Nepomuceno, Tran, and Zen have also documented congruent results (Zeng, 2017; Tran, 2020; Nepomuceno, 2024).

The process of quaternarization of EWO-MCA was carried out using triethylamine and pyridine. The kinetics of quaternarization were investigated with respect to concentration, time, temperature, and catalyst quantity. The optimal outcomes are presented in Table 1. The minimal concentration of tertiary amine was three times the molar number of EWO-MCA. When the molar ratios of the amines were increased to nine times the number of moles of EWO-MCA, the yields shifted slightly from 96 to 98 in the case of triethylamine and from 93 to 96 in the case of pyridine. Furthermore, it was noted that the most substantial yields were achieved following a reaction period of 24 hours. Aliphatic tertiary amines exhibit more basicity compared to aromatic tertiary amines. Consequently, the conversion rates for triethylamine are somewhat greater. The conversions likewise rose proportionally with the rise in temperature. The maximum yields were recorded after 24 hours at a temperature of 90 °C for QT-EWO-MCA and at a temperature of 120 °C for QP-EWO-MCA. Sodium iodide (NaI) was employed as the catalyst. The catalytic activity occurs through the creation of alkyl iodides. The quantity of catalyst also significantly influenced the conversion process. The most favorable outcomes were achieved when a concentration of 0.1% of NaI was utilized. The presence of an excessive amount of catalyst led to the production of dark colored products, most likely as a result of the creation of elemental iodine. After 24 hours, the conversion rates were recorded as 97% for QT-EWO-MCA and 95% for QP-EWO-MCA, indicating the highest levels of conversion.

3.2. Characterization of Cationic Derivatives of Plant Oil Triglycerides

The characteristics of the basic materials and their derivatives were evaluated using the FTIR and ¹H NMR methods. Figure 2 displays the FTIR spectra of EWO and EWO-MCA, emphasizing peaks at different wavenumbers that signify the existence of distinct chemical groups. Specifically, there were found peaks at 3009 and 2950 cm⁻¹ corresponding to the vinyl hydrogen and aliphatic hydrogens, respectively. The presence of an ester moiety was indicated by the peak at 1740 cm⁻¹, while the presence of a carbon-carbon double bond was suggested by the peak at 1650 cm⁻¹. The intensities of the peaks at 3006 and 1650 cm⁻¹ reduced following the process of epoxidation, suggesting the reduction in the presence of double bonds. In addition, a distinct peak at 830 cm⁻¹ was detected, indicating the presence of epoxide groups. Furthermore, OH peaks at 3500 cm⁻¹ were discovered as a consequence of the reaction. The interaction between EWO and MCA resulted in a reduction in the intensity of the peak at 840 cm⁻¹ and the emergence of a novel ester peak at 1739 cm⁻¹. The intensity of the signal at 3500 cm⁻¹ also heightened, suggesting that nearly all epoxy groups underwent a reaction with MCA. Observations revealed the emergence of fresh ester groups, resulting in new peaks at 1025, 950, and 900 cm⁻¹. Additionally, the presence of -O-CO-CH₂- groups was indicated by the peak at 1413 cm⁻¹. The ring opening reactions of epoxidized plant oil triglycerides with carboxylic acids have been extensively researched and similar findings have been reported in the literature [Menager, 2020; Nepomuceno, 2024]. In addition, the signal observed at 785 cm⁻¹ signifies the existence of C-Cl chemical bonds.

Figure 3 displays the FTIR spectra of pyridine and the triethylamine derivative of EWO-MCA. The spectra of the triethylamine derivative has a prominent peak at 755 cm⁻¹, which signifies the existence of the triethylammonium group. The signal observed at 785 cm⁻¹ has had a shift to 791 cm⁻¹, suggesting that the -CH₂-Cl groups have undergone a conversion into quaternary ammonium ions. Regarding the pyridinium derivative, the peak observed at 785 cm⁻¹ undergoes a shift to 781 cm⁻¹, indicating the presence of a pyridinium group. Further evidence of quaternarization is evident from the emergence of additional peaks at 3061 and 1636 cm⁻¹, which indicate the existence of vinylic hydrogens and carbon-carbon double bonds in the pyridinium moiety. Furthermore, the peak seen at 1491 cm⁻¹ indicated the existence of the -CH=N- functional group. Yang, Khan, and their colleagues

conducted a study on the FTIR spectra of quaternary ammonium salts and obtained comparable findings (Yang, 2019; Khan, 2021).

^1H NMR is another technique used to characterize materials. The ^1H nuclear magnetic resonance (NMR) spectra of QT-EWO-MCA and QP-EWO-MCA are displayed in Figures 4 and 5, respectively. Hydrogens bonded to the double bond of WCO were observed at 5.5 ppm. Other unique hydrogen atoms were identified with chemical shifts of 2.3, 2.1, and 1.6 ppm, respectively, indicating the presence of α carbon hydrogens, allylic hydrogens, and β carbon hydrogens. Additionally, the hydrogens of the glycerol moiety were shown at chemical shifts of 4.5 and 5.2 ppm. Epoxidation led to the formation of epoxide groups, resulting in the appearance of new peaks at 3.0 and 3.2 ppm (Slabu, 2023).

EWO-MCA is formed via the condensation of EWO and MCA. The methylene carbon of the monochloro acetyl groups was determined at 4.0 ppm. The peaks at 3.0 and 3.2 ppm disappeared at the completion of the reaction as a result of the consumption of epoxide groups. A new peak at 3.9 ppm was observed due to the formation of the ester group of MCA's surrounding hydrogens. A new peak at 3.2 ppm was seen during the process of quaternarization using triethylamine, which can be attributed to the adjacent $-\text{CH}_2-$ hydrogens present near the quaternarized N atom. Regarding QP-EWO-MCA, the presence of hydrogen in the pyridine ring resulted in the emergence of three extra peaks at 8.4, 8.8, and 9.2 ppm. The hydrogen atoms attached to the carbon atom of the acetyl group exhibited a chemical shift of 6.3 ppm upon connection with the pyridinium group.

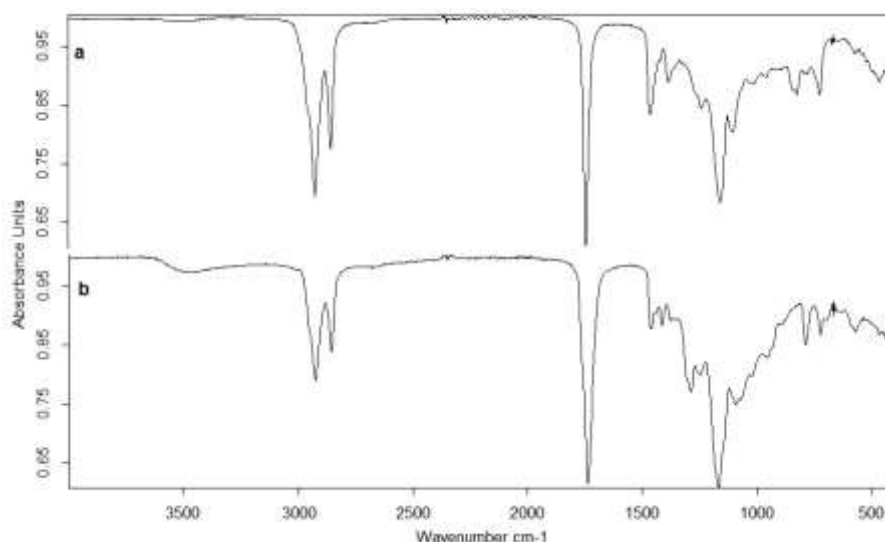


Figure 2: FTIR spectrum of a-EWO and b-EWO-MCA

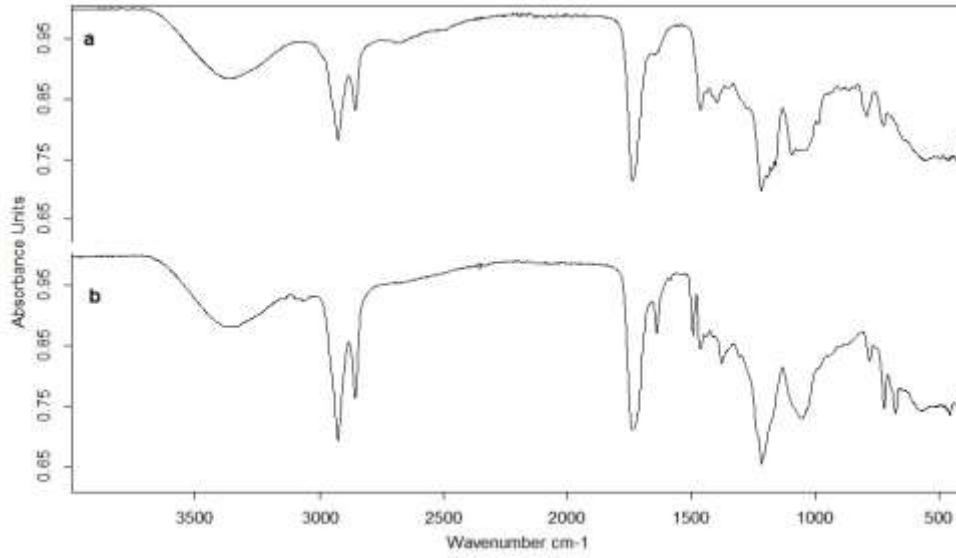


Figure 3: FTIR spectrum of a-QT-EWO-MCA and b-QP-EWO-MCA

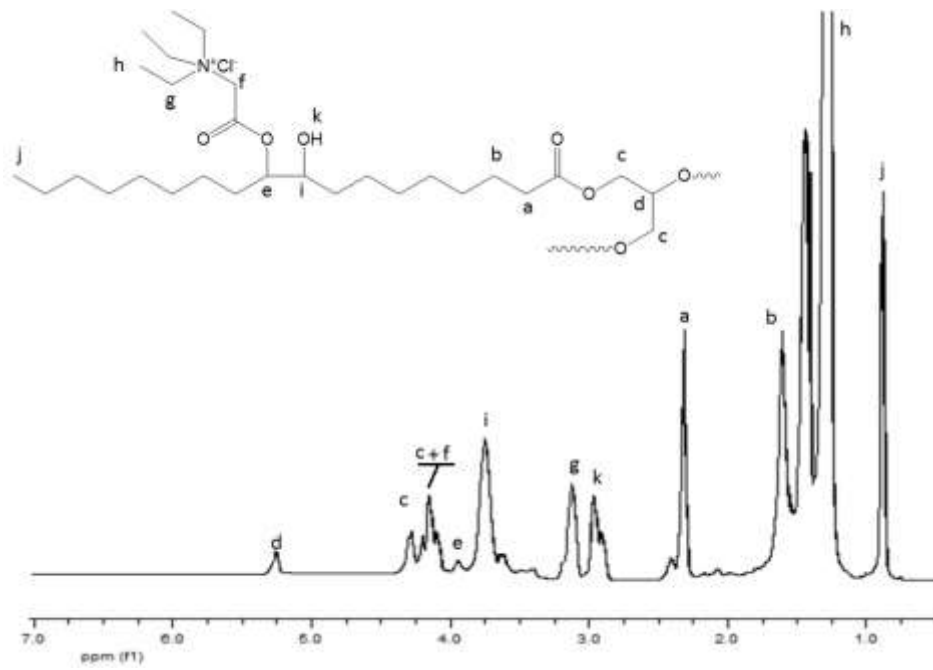


Figure 4: ¹H NMR spectrum of QT-EWO-MCA

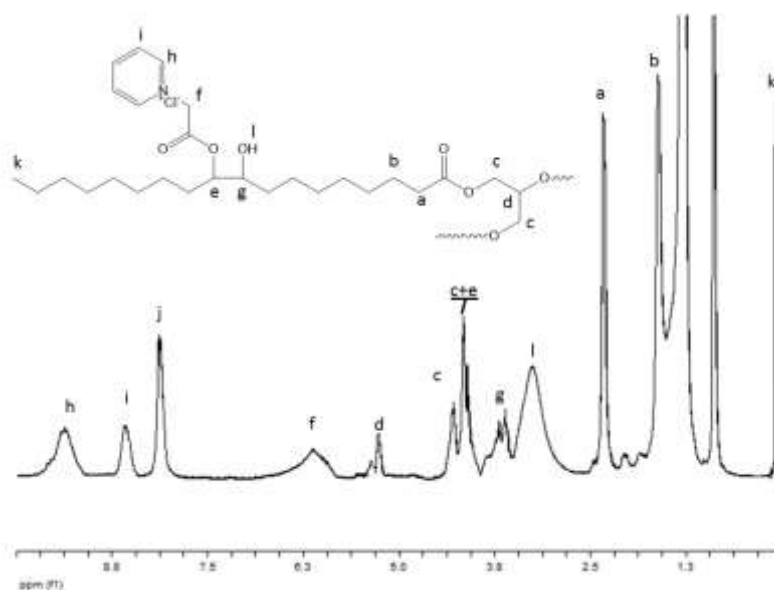


Figure 5: ^1H NMR spectrum of QP-EWO-MCA

3.3. Anion removal Experiments

The selection of carbonate, sulfate, and monohydrogen phosphate anions in this study was based on their prevalence in the natural environment. A 100 ml solution of cationic derivatives of WCO, with a concentration of 1% (w/v), was combined with a 100 ml solution of divalent anions, also with a concentration of 1% (w/v), in a closed 250 ml Erlenmeyer flask. The mixture was agitated at regular intervals. The quantity of the remaining anion was determined using several methods. The carbonate anion was quantified using volumetric titration. The remaining sulfate anion was measured using a turbidimeter at a wavelength of 420 nm. The quantity of the residual monohydrogen phosphate anion was evaluated by a UV spectrophotometer at a wavelength of 650 nm.

The preliminary trials were carried out at a temperature of 25°C and a pH level of 7. The pH of 1% solutions of QP-EWO-MCA and QT-EWO-MCA was determined to be around 4. Next, the pH of QP-EWO-MCA and QT-EWO-MCA solutions was modified to 7 using a 0.5 N NaOH solution. Subsequently, equivalent amounts of 1% solutions of carbonate, sulfate, and monohydrogen phosphate were added to these modified solutions. The mixtures were allowed to undergo a specified duration of time, ranging from 30 minutes to 24 hours, after which the solid substances generated by anions and cationic oil derivatives were isolated from the liquid solution using centrifugation. The residual negatively charged ions in the water-based solution were examined using appropriate analytical techniques. Upon comparing the anion binding timeframes, it was noted that both QP-EWO-MCA and QT-EWO-MCA achieved maximum binding within a duration of 4 hours, which was deemed satisfactory. The extent of binding at the conclusion of the 4-hour duration was assessed in subsequent trials conducted at various temperatures and pH levels.

Moreover, upon doing studies at various temperatures, it was noted that the measurements at 10°C and 25°C exhibited a high degree of similarity, however a decline in anion binding capabilities was noticed above 40°C. The binding rate was found to be highest at pH 7 and lowest at pH 10 in the conducted studies. QP-EWO-MCA exhibited a greater anion binding capacity % than QT-EWO-MCA. However, they demonstrated comparable rates of anion binding. Upon calculating the number of binding anions per gram for both materials, as indicated in Table 3, it was noted that these values fell within a comparable range as that of industrial anion exchange resins (Chu, 2020; Zeidan, 2019).

3.4. Environmental Impact of the Synthesized Materials

Waste cooking oils are highly dangerous substances produced by humans. Wildlife conservation organizations (WCOs) have adverse effects on land, water, and air quality. A single liter of waste

cooking oil has the potential to pollute as much as 1 million gallons of water. Improper disposal of waste cooking oils can lead to the pollution of extensive soil regions. For example, if 100 liters of waste cooking oil infiltrate the ground, it has the potential to pollute hundreds of square meters of soil. The combustion of one liter of waste cooking oil can release almost 3 kilos of carbon dioxide into the atmosphere, so contributing to the emission of greenhouse gases and the phenomenon of climate change. Furthermore, the quantity of waste cooking oil (WCO) rises in tandem with population expansion. Therefore, it is imperative to discover novel techniques for transforming waste cooking oils (WCOs) into valuable and eco-friendly substances (Di Pietro, 2020; Dahdouh, 2023; Uguz, 2023; Azzena, 2023).

Biodiesel is one of the most highly regarded compounds derived from waste cooking oils in industrial applications. Biodiesel refers to the esters of fatty acids derived from short chain alcohols. Regrettably, there will be a decline in diesel fuel use in the near future as a result of regulatory measures. Therefore, the conversion of waste cooking oils (WCOs) into biodiesel would not provide a viable alternative. Alkyd resins are one of the industrially suitable compounds that can be generated from waste cooking oil (WCO). Alkyd resins are effective substances for creating films, and they are commonly employed in painting applications. In addition to the industrially suitable materials mentioned above, cationic derivatives of WCO possess the potential to be considered industrially acceptable derivatives. The manufacturing process for the QP-EWO-MCA and QT-EWO-MCA would be both uncomplicated and cost-effective, when compared to the synthesis of biodiesel and alkyd resin. These compounds exhibit water solubility and possess significant potential for utilization in a diverse range of applications (Llorca, 2023; Awogbemi, 2021; Kahraman, 2016; Landi, 2022).

Table1: Optimized Conditions for the Best Yields of Cationic Derivatives

Type of Cationic Derivative	Maximum Yield Obtained	Time (h)	Temperature (°C)	[Amine] / [EWO-MCA]	Catalyst Amount (g/100 g EWO-MCA)
<u>QT-EWO-MCA</u>	97 %	24	90	3	0,01
<u>QP-EWO-MCA</u>	95 %	24	120	3	0,01

Table2: Experimental Conditions and Anion Binding Percentages of QP-EWO-MCA and QT-EWO-MCA

Conditions		QT-EWO-MCA			QP-EWO-MCA		
		CO ₃ ²⁻	SO ₄ ²⁻	HPO ₄ ²⁻	CO ₃ ²⁻	SO ₄ ²⁻	HPO ₄ ²⁻
Time (hours)	0	0	0	0	0	0	0
	0,5	50	43	70	60	47	75
	1	70	65	80	85	80	86
	2	85	75	90	95	95	95
	4	98	92	96	98	96	98
	8	98	92	96	98	96	98
	16	98	90	97	98	96	98
	24	98	92	97	98	96	98
Temperature (°C)	10	95	95	95	96	95	96
	25	98	98	96	98	96	98
	40	95	95	95	96	95	96
	60	70	65	80	75	75	82
pH	4	85	40	45	90	50	50
	7	98	92	98	98	98	85
	10	70	65	75	75	65	75

A specific example of such applications is water treatment. Because three quaternary ammonium groups are added to each triglyceride, QP-EWO-MCA and QT-EWO-MCA can function as cations with a charge of three positive. When QP-EWO-MCA and QT-EWO-MCA react with polyvalent anions, they generate an insoluble complex that can be readily isolated from water. Carbonate, sulfate,

and monohydrogen phosphate are three of the most common divalent anions found in aqueous environments. Anion binding tests demonstrate that the maximal capacity of 1 gram of QP-EWO-MCA or QT-EWO-MCA to bind anions can range from 90 to 99 milligrams, depending on the specific type of anion. These values are appropriate for industrial applications of anion exchange resins.

Table 3: Anion Binding Capacities of QP-EWO-MCA and QT-EWO-MCA
(at room temperature and after 4 hours mixing)

Anion type	Anion Binding Ability of 1 g of QT-EWO-MCA	Anion Binding Ability of 1 g of QP-EWO-MCA
Carbonate	0,0592	0,0619
Sulfate	0,0947	0,0991
Monohydrogen phosphate	0,0947	0,0991

4. Conclusions

This study presents a highly effective method for synthesizing and enhancing the ability of cationic compounds derived from waste cooking oil to remove anions. The synthesis comprises many sequential processes, namely the epoxidation of the waste cooking oil, the condensation reaction between the epoxidized waste cooking oil and monochloro acetic acid, and the quaternarization reaction with tertiary amines such as triethylamine and pyridine. The synthesized compounds exhibit high water solubility and demonstrate exceptional capacity for removing anions. This innovation also introduces a cost-effective method for transforming waste cooking oil into valuable items.

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