ΔΗΜΟΚΡΙΤΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΡΑΚΗΣ DEMOCRITUS UNIVERSITY OF THRACE

Green upgrading of biodiesel derived from biomass wastes

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INTRODUCTION & AIM

Transportation contributes significantly to the global greenhouse gas (GHG) emissions, primarily through the combustion of fossil fuels. Compared to fossil diesel, biodiesel can achieve lifecycle GHG emission reductions of up to 85%, depending on feedstock and production processes. Utilizing *waste cooking oils* (WCOs) as a raw material for *biodiesel production* represents a multifaceted solution to global energy challenges and environmental concerns. Leveraging a waste product avoids the ethical considerations and land-use competition associated with food-based biofuels like soybean or palm oil. WCOs are cheaper than virgin oils, significantly reducing the cost of biodiesel production. Nevertheless, the broader utilization of biodiesel is hindered by key limitations, including low oxidative stability and suboptimal cold flow properties, which are intrinsically tied to the composition of fatty acid methyl esters (FAMEs). These challenges have steered research toward innovative solutions, such as *partial hydrogenation in aqueous/organic biphasic* catalytic systems, which selectively target polyunsaturated FAMEs for conversion to cis-monounsaturated FAMEs. The primary aim of this work is to enhance the fuel properties of biodiesel by altering its FAME composition through partial hydrogenation in aqueous/organic biphasic catalytic systems using transition metal complexes.

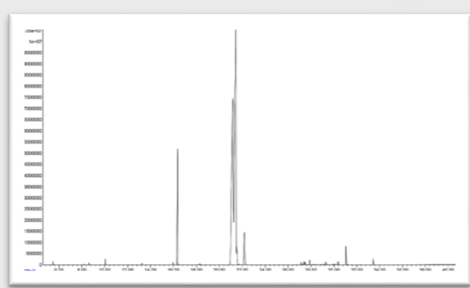
METHODS

This study employs a structured methodology to enhance WCO biodiesel properties through partial hydrogenation while ensuring compliance with quality standards. EN ISO standard methods are used to evaluate critical biodiesel properties, while gas chromatography-mass spectrometry (GC-MS) is employed to identify the specific FAMEs present in the biodiesel, including saturated, monounsaturated, and polyunsaturated compounds. A biphasic catalytic system of Ru/TPPTS is utilized, where the catalyst is dissolved in the aqueous phase without solvent utilization and the biodiesel in the organic phase, allowing catalyst recovery and reuse across multiple reaction cycles, reducing waste and the need for fresh catalysts.

WCO

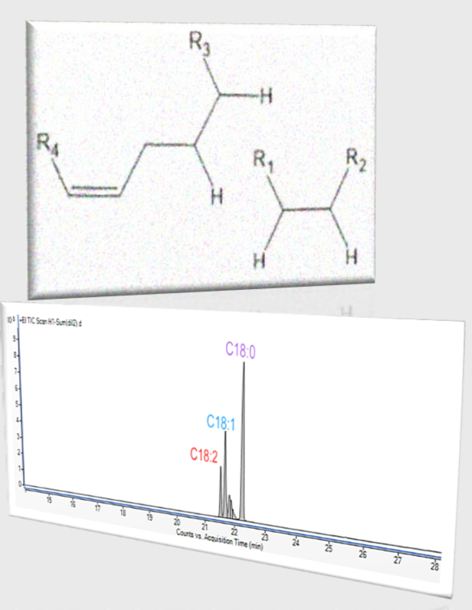

TRANSESTERIFICATION

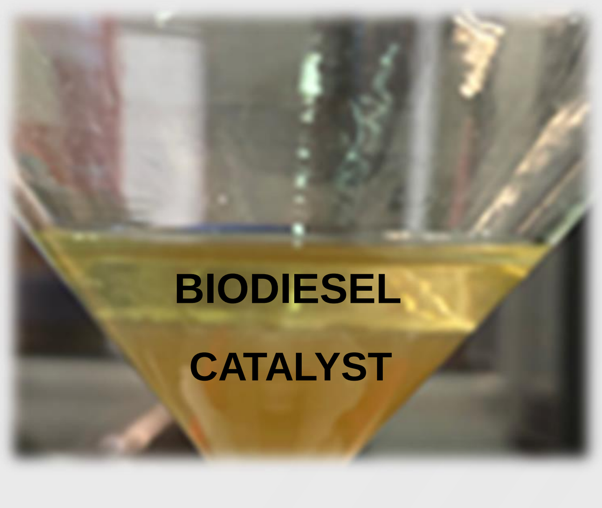

WCO BIODIESEL



Test Method
EN ISO 12185
EN ISO 3104
EN ISO 14104
EN 116
EN 14112

PROPERTIES AND FAMEs COMPOSITION DETERMINATION


COMPOSITIONAL CHANGES AFTER HYDROGENATION



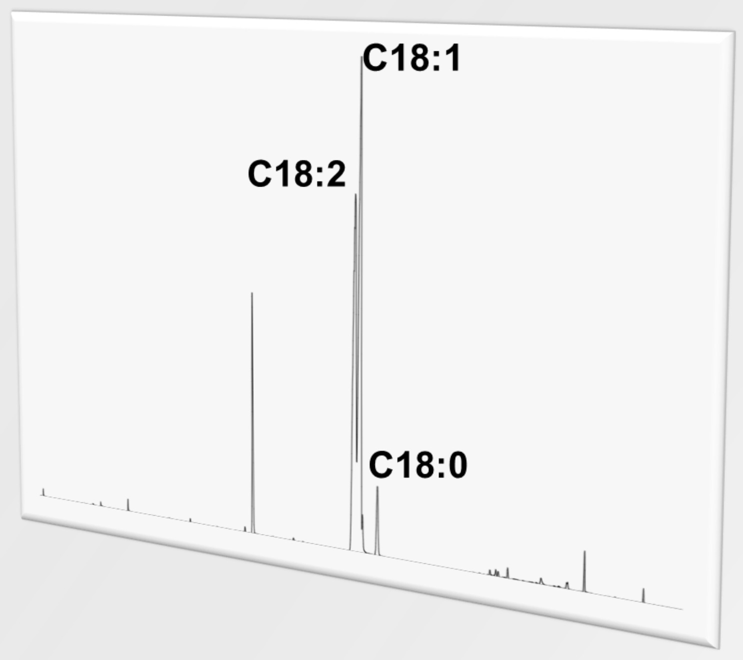
HYDROGENATED WCO BIODIESEL


Partial hydrogenation
In-situ catalyst formation

RESULTS & DISCUSSION

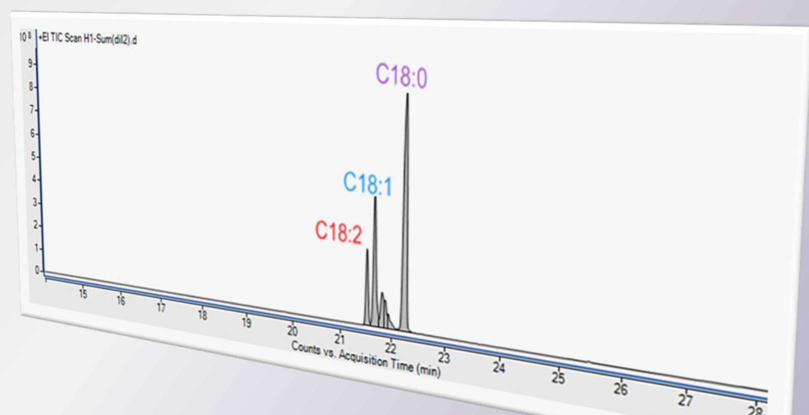
The highlighted results are (i) the research and development of an aqueous/organic biphasic catalytic system for the partial hydrogenation of biodiesel and (ii) the improvement of biodiesel properties that do not meet EN ISO standard specifications.

Property	Measured value	Specs EN 14214	Test Method
Density at 15°C, $g \cdot cm^{-3}$	0.8868	0.86-0.91	EN ISO 12185
Acid number, mg $KOH \cdot g^{-1}$	0.40	< 0.5	EN ISO 14104
CFPP, °C	-2.0	Country Specific Max. +5°C	EN 116
Oxidative stability at 110 °C, h	0.34	> 8	EN 14112



While all other properties of the biodiesel might have met EN 14214 standards, oxidative stability is a critical parameter for practical usability. The higher the degree of unsaturation, the more susceptible the FAME is to oxidative degradation. As the percentage of unsaturated FAMEs exceeded 85%, the measured oxidative stability of WCO biodiesel did not meet the EN outlined limit. The selected biphasic system indicates an efficient and environmentally friendly method for modifying the FAMEs composition of biodiesel.

This significantly improved the oxidative stability of hydrogenated biodiesel, with an increase of more than 135%. Nevertheless, as it falls short of the industry standard set by EN 14112, continued optimization of hydrogenation conditions and catalyst efficiency is needed to achieve the required stability for biodiesel's broader use.



CONCLUSION

The catalytic upgrading of biodiesel using partial hydrogenation in aqueous/organic biphasic systems is a promising frontier in renewable energy research. This method optimizes fuel properties and contributes to the development of cleaner, more sustainable energy sources. Nevertheless, further research in catalytic upgrading, feedstock optimization, advanced reactor systems, and sustainability assessments is critical for advancing biodiesel production and application. These efforts will address current limitations and ensure biodiesel's competitiveness in the renewable energy landscape, enabling its broader adoption and contribution to global decarbonization goals.

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