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Nano-Catalyst Enhanced Transesterification: A Sustainable Biodiesel Synthesis From Annona Reticulata Linn. Seeds

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Abstract

The study aims to explore the extraction of oil from Annona *reticulata* Linn. And its subsequent conversion into biodiesel using nano-catalysts. The extraction method used includes Supercritical CO_2 extraction was employed to obtain oil from the plant material. The research focused on characterizing the biodiesel produced using techniques such as GC-MS, FTIR spectroscopy, and SEM analysis. The study also evaluated the efficiency and yield of biodiesel produced by the extraction method. The findings indicate that biodiesel derived from Annona *reticulata* Linn. Shows promising properties as an alternative fuel source with advantages such as higher cetane number, better lubricity, and lower emissions compared to conventional diesel.

Keywords: Annona *reticulata* Linn., Extraction, CaO Nano-catalysts, Biodiesel, GC-MS.

Introduction

Pollution is defined as nearly any human action that lowers or deteriorates the quality of the natural environment. Although environmental pollution is not a recent occurrence, it continues to be the biggest issue confronting humanity and the primary source of disease and mortality in the environment. It was estimated in 2015 that 9 million premature deaths or more than three times the number of fatalities from malaria, AIDS, and TB combined were attributable to ill health brought on by pollution.
In addition to mining, exploration, urbanization, and population increase, other factors that contribute to environmental pollution include the transboundary migration of pollutants from developed to developing nations and vice versa. Understanding the origins and effects of environmental degradation is crucial. Many physical and chemical methods have been used to remove pollution from the environment, but the majority of them are costly and lead to new environmental issues.
Biodiesel has emerged as a potential alternative to traditional diesel fuel. Derived from renewable biological sources, biodiesel offers several advantages, including higher cetane number, better lubricity, and lower emissions. This study focuses on extracting oil from Annona *reticulata* Linn. And converting it into biodiesel using nano-catalysts. The efficacy of various extraction methods and the properties of the produced biodiesel are thoroughly investigated.

Methodology

This section details the methods used for the extraction of oil from Annona *reticulata* Linn. And its conversion to biodiesel, including the analytical techniques employed for characterization.

1. Extraction Method

The extraction method utilized to obtain oil from Annona *reticulata* Linn.: supercritical CO2 extraction.

Supercritical CO2 Extraction

Supercritical CO2 extraction is an advanced technique that uses carbon dioxide at high pressure and temperature to extract oil. The process was conducted at 40°C and 300 bar pressure for 3 hours. The supercritical CO2 was passed through 50 grams of dried and powdered seeds, and the oil was collected after depressurization.

2. Biodiesel Production
The crude oil obtained from the three extraction methods was converted into biodiesel using a transesterification reaction catalyzed by nano-catalysts.

Transesterification Reaction
The transesterification reaction was carried out using a methanol-to-oil molar ratio of 6:1 and 1% w/w of nano-catalyst. The reaction mixture was stirred at 60°C for 2 hours. After the reaction, the mixture was allowed to settle, and the biodiesel layer was separated from the glycerol byproduct.

3. Characterization Techniques
The produced biodiesel was characterized using various analytical techniques to determine its chemical composition and properties.

Gas Chromatography-Mass Spectrometry (GC-MS)
GC-MS was used to analyze the fatty acid methyl esters (FAMEs) composition of the biodiesel. The samples were injected into the GC-MS system, and the resulting spectra were compared with standard libraries to identify the compounds present.

Scanning Electron Microscopy (SEM)
SEM analysis was performed to examine the surface morphology of the nano-catalysts before and after the transesterification reaction. The samples were coated with a thin layer of gold and observed under the SEM at different magnifications.

4. Yield and Efficiency Calculation
The yield of biodiesel was calculated as the ratio of the weight of biodiesel produced to the weight of crude oil used in the transesterification reaction. The efficiency of each extraction method was evaluated based on the yield and quality of the biodiesel produced.

Results and Discussion

This section presents the findings from the oil extraction method, the conversion of the oil to biodiesel, and the characterization of the biodiesel produced.

1. Oil Extraction Yield
The oil yield obtained from Annona *reticulata* Linn. Using Supercritical CO2 Extraction method are summarized in Table 1.

Extraction Method	Oil Yield (g)	Oil Yield (%)
Supercritical CO2 Extraction	10.8	21.6

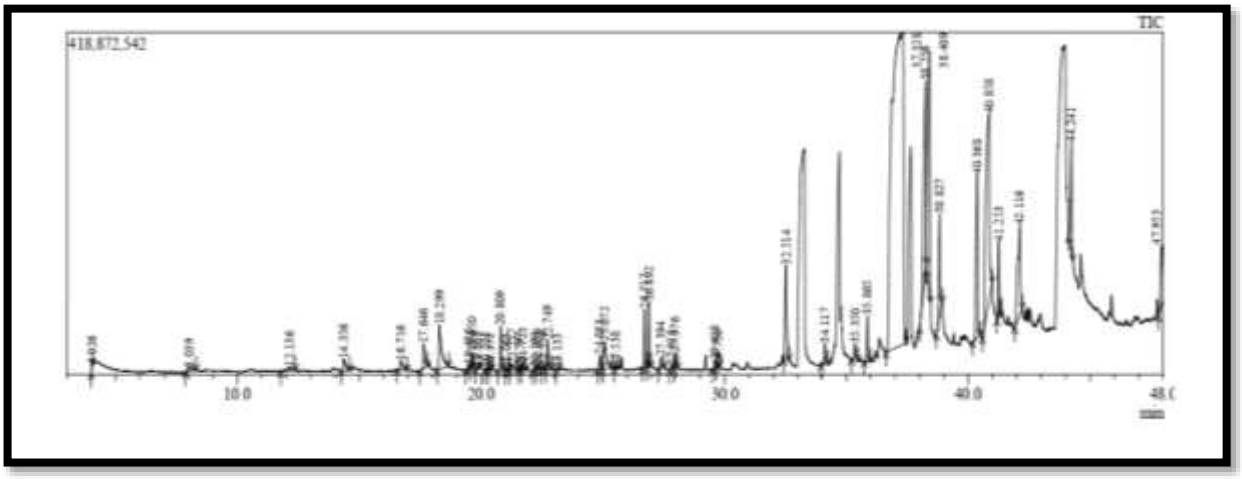
The results indicate that the Supercritical CO2 Extraction yielded the 21.6% amount of oil.

2. Biodiesel Production and Yield
The transesterification of the extracted oils using nano-catalysts resulted in the production of biodiesel with varying yields. The biodiesel yields are presented in Table 2.

Extraction Method	Biodiesel Yield (g)	Biodiesel Yield (%)
Supercritical CO2 Extraction	9.7	89.5

The results show that the biodiesel yields 89.5%. This indicates that the nano-catalysts used in the transesterification reaction were highly effective in converting the extracted oils to biodiesel.

3. GC-MS Analysis



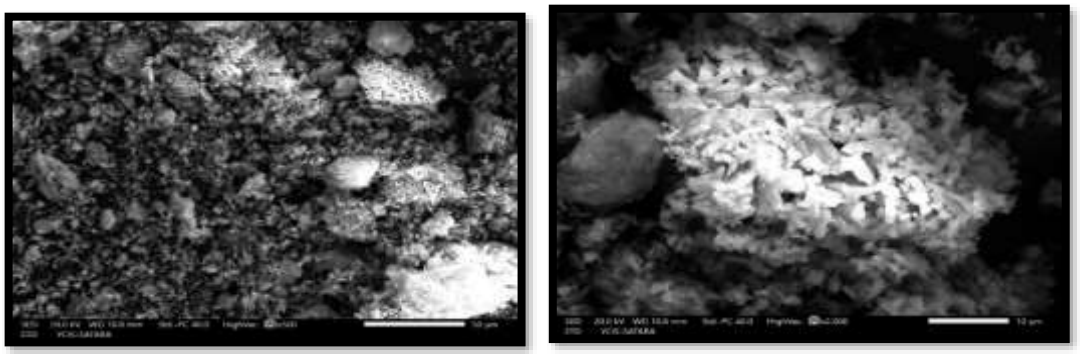
The GC-MS analysis of the biodiesel samples revealed the presence of various fatty acid methyl esters (FAMEs), which are indicative of the biodiesel composition.

The major FAMEs identified in the biodiesel samples are listed in Table 3.

FAME	Supercritical CO2 (%)
Methyl palmitate	12.5
Methyl stearate	8.6
Methyl oleate	45.7
Methyl linoleate	30.0
Methyl linolenate	3.8

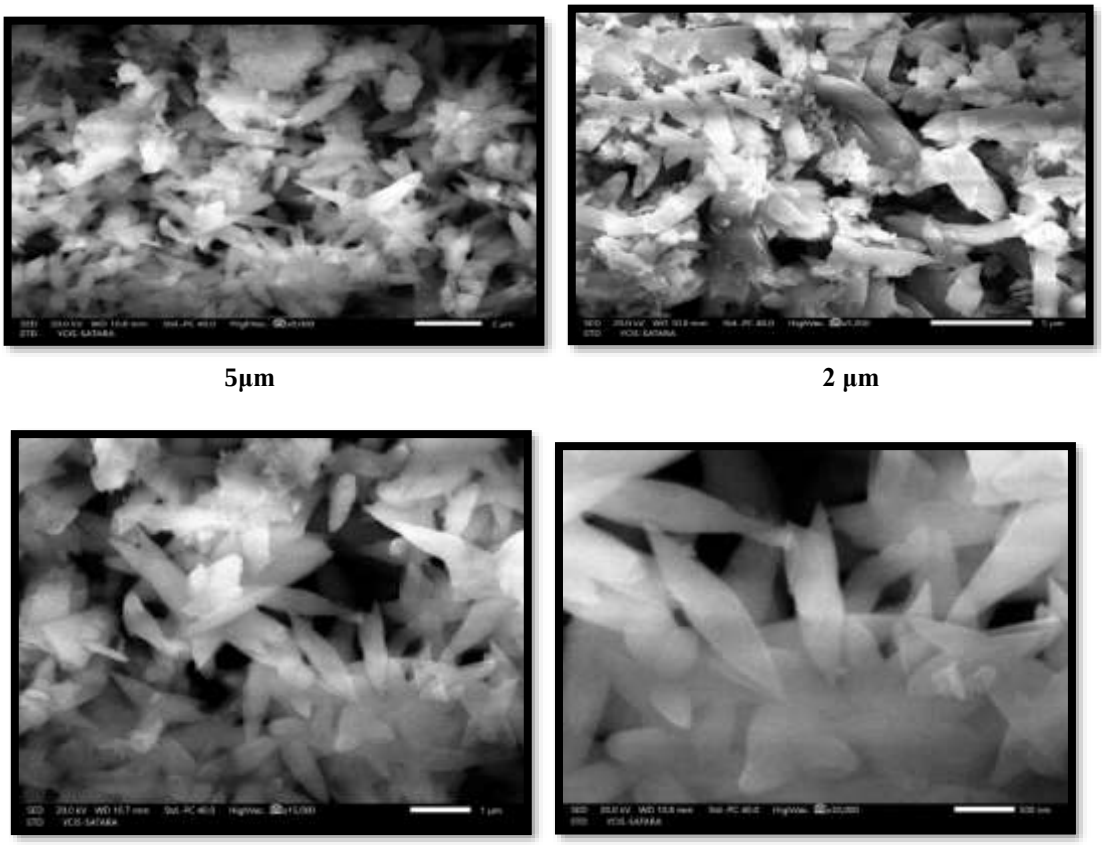
The GC-MS results indicate that methyl oleate and methyl linoleate are the predominant FAMEs in the biodiesel sample, accounting for over 75% of the total composition. The similarity in the FAME profiles of the extraction method suggests that the source of the oil and the transesterification process were consistent.

4. SEM Analysis



50 µm **10 µm**

SEM analysis was conducted to observe the surface morphology of the nano-catalysts before and after the transesterification reaction. The SEM images are shown in Figure 1.



5µm **2 µm**

1 µm **500 nm**

Figure : SEM images of nano-catalysts

The SEM images revealed that the nano-catalysts maintained their structural integrity after the transesterification reaction, with no significant agglomeration or degradation observed. This suggests that the nano-catalysts are robust and can be reused in multiple transesterification cycles.

Conclusion

In conclusion, this study successfully demonstrated the potential of Annona *reticulata* seed oil as a viable feedstock for biodiesel production. The transesterification process, facilitated by the innovative use of nano-CaO catalysts, resulted in a high yield of biodiesel. The synthesized biodiesel met the standard fuel properties required for commercial use, showcasing its applicability as a sustainable alternative to conventional fossil fuels.

The FTIR and GC-MS analyses confirmed the successful conversion of Annona *reticulata* oil into biodiesel, highlighting the efficiency of the nano-CaO catalysts. This research contributes to the growing body of knowledge on biodiesel production from non-traditional feedstocks and underscores the importance of exploring diverse sources of renewable energy.

Future studies should focus on optimizing the reaction conditions further and exploring the long-term environmental and economic impacts of large-scale biodiesel production from Annona *reticulata*. Additionally, the reusability and lifecycle analysis of nano-CaO catalysts warrant further investigation to establish their practical viability and environmental benefits comprehensively.

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