Revolutionizing Biodiesel Production with Rotating Tube Reactors for Optimal Efficiency

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Motivation

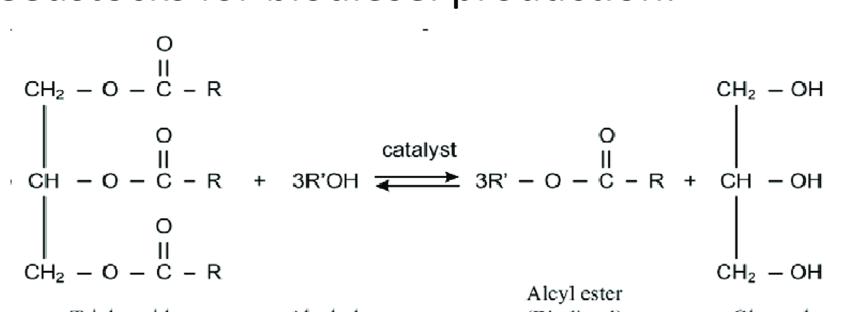
- Biodiesel offers potential as a low-carbon transportation fuel.
- Rising global energy consumption necessitates renewable energy alternatives.
- Process intensification technologies aim to enhance biodiesel production efficiency.

Introduction

- Biodiesel production involves transesterification of triglycerides with methanol.
- Alkali-catalyzed transesterification is commercially preferred.
- Rotating tube reactors (RTRs) offer intensified mixing and heat generation for improved biodiesel production.
- Previous studies lacked exploration of hydrodynamic regimes in RTRs for biodiesel production.

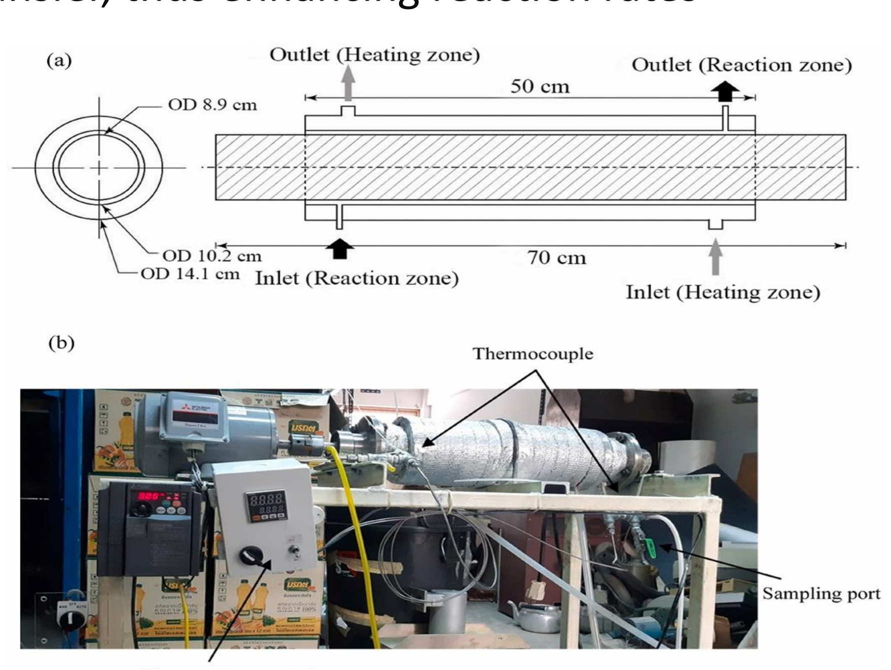
Transesterification

- Transesterification involves reacting triglycerides with alcohol (methanol) in the presence of a catalyst (alkali) to produce biodiesel and glycerol.
- Alkali-catalyzed transesterification is preferred due to higher efficiency and less corrosion issues.
- Vegetable oils, like palm oil, are commonly used as feedstocks for biodiesel production.



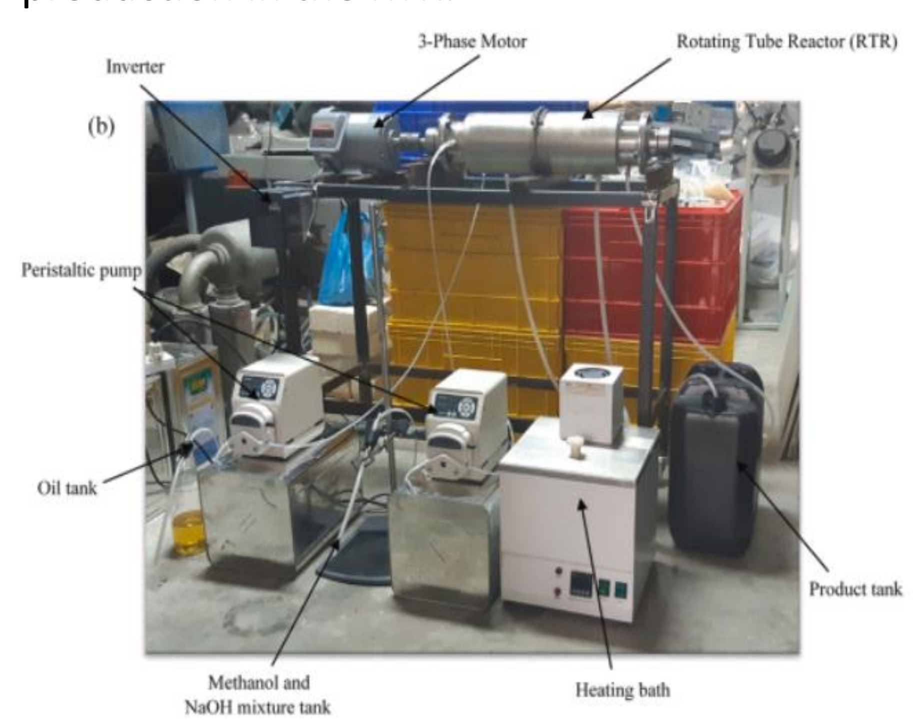
RTR

- The Rotating Tube Reactor (RTR) is a process intensification technology used in various chemical processes, including biodiesel production.
- It consists of a rotating inner tube and a stationary outer tube, creating intense mixing and heat transfer, thus enhancing reaction rates

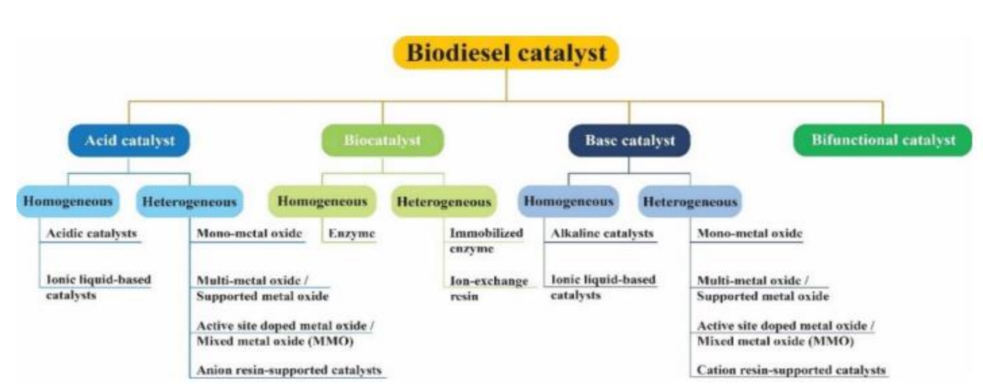


Biodiesel Production using RTR

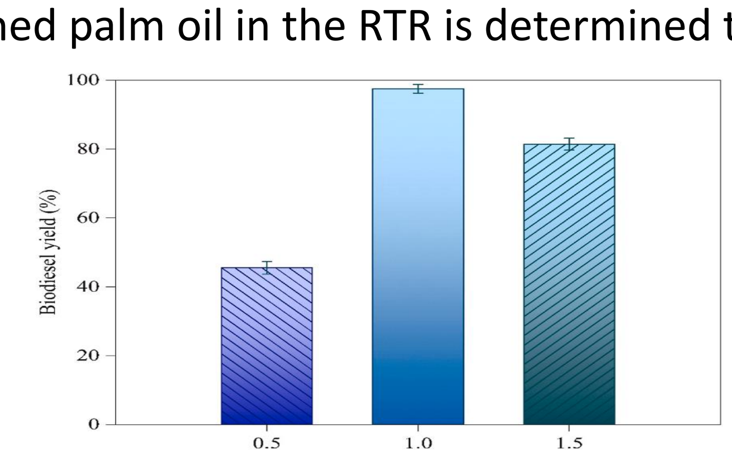
- Continuous biodiesel production using the RTR involves a 3-phase motor directly connected to the rotating tube reactor, operated by an inverter.
- Two peristaltic pumps facilitate the feeding of substances, while three vessels contain refined palm oil, methanol-NaOH mixture, and products.
- An optional heating system from a heating bath controls the reaction temperature during biodiesel production in the RTR.



Catalyst



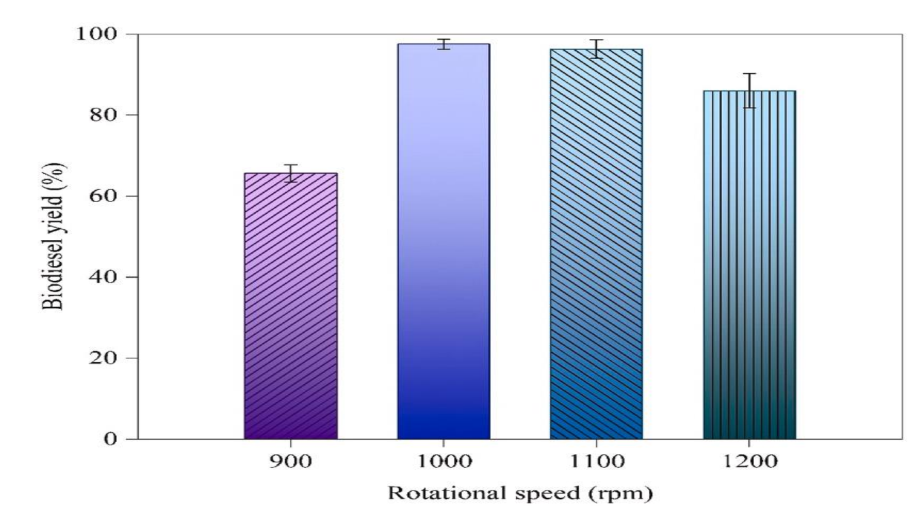
- NaOH loading significantly impacts biodiesel yield in the RTR.
- The lowest biodiesel yield occurs with the smallest NaOH loading (0.5 wt%), attributed to incomplete reaction due to insufficient active sites.
- Increasing NaOH loading to 1 wt% enhances biodiesel yield by providing more active sites for transesterification.
- Biodiesel yield decreases with the highest NaOH loading (1.5 wt%) due to excess alkali catalyst leading to saponification reactions.
- Excessive alkali catalyst generates emulsion phases, increasing saponification of triglycerides and biodiesel, resulting in soap and glycerol production.
- The optimal NaOH loading for transesterification of refined palm oil in the RTR is determined to be 1 wt%.



Factors influencing

1. Effect of rotational speed

- Rotational speed significantly impacts biodiesel yield in RTR, affecting mass transfer efficiency.
- Increasing speed from 900 to 1000 rpm enhances yield due to improved shear force and interfacial contact.
- Yield slightly decreases (~10%) at 1200 rpm due to counterbalancing effects on shear force and increased heat dissipation.
- Optimal speed for biodiesel production falls between 900 and 1000 rpm, balancing efficient mass transfer and minimizing methanol vaporization and viscosity effects.

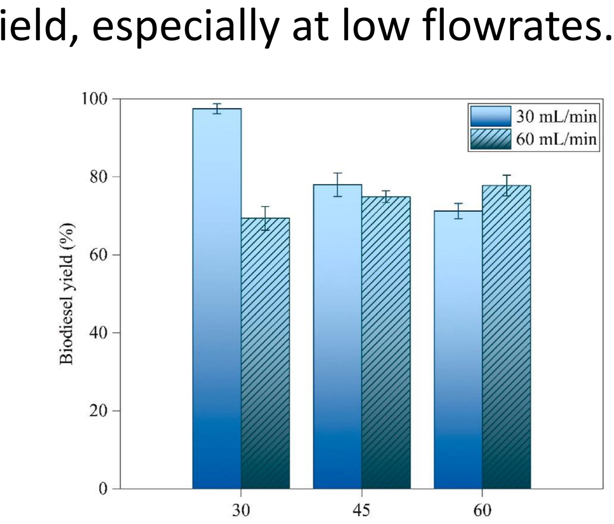


2. Effect of total flowrate

- Total flowrate significantly influences steady-state biodiesel yield in continuous biodiesel production.
- Increasing total flowrate reduces residence time, impacting reaction efficiency and biodiesel yield.
- Short residence times (<11.23 min) result in lower biodiesel yields due to insufficient reaction time.
- Higher total flowrates may disrupt the hydrodynamic regime inside the RTR, affecting mixing efficiency and biodiesel production

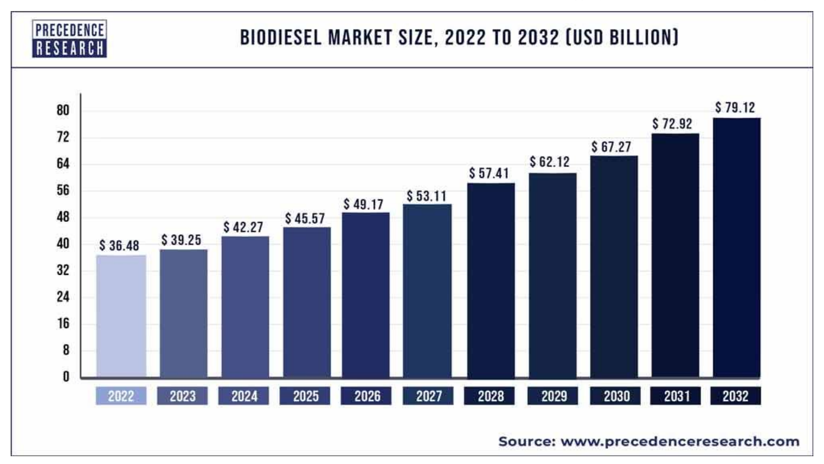
3. Effect of temperature on biodiesel production

- Temperature plays a significant role in biodiesel yield in RTR, impacting reaction rate and mixture properties.
- Low temperatures and flowrates increase viscosity, enhancing shear force and mass transfer for higher yield.
- Higher temperatures accelerate methanol vaporization, reducing viscosity and yield, especially at low flowrates.
- Higher flowrates at increased temperature can offset viscosity reduction, slightly boosting yield and reducing time to steady state



Market Demand

- Growing environmental concerns drive increasing demand for biodiesel as a renewable alternative to traditional fossil fuels.
- Government mandates and incentives encourage the adoption of biodiesel, stimulating market demand.
- Fluctuating crude oil prices make biodiesel an attractive option for price stability and energy security.



Conclusion

- Successful construction of RTR for biodiesel production via alkali-catalyzed transesterification.
- Optimal operating conditions identified: 6:1 methanol-to-oil ratio, 1 wt% NaOH, 30 mL/min flowrate, 1000 rpm rotational speed at room temperature.
- Modulated wavy vortex flow regime suggested for cost-effective biodiesel production.
- RTR offers low energy consumption and cost-effective biodiesel production at room temperature.

Future scope

- Further optimization of operating parameters for enhanced biodiesel yield.
- Investigation of alternative feedstocks and catalysts for biodiesel production in RTRs.
- Exploration of cooling systems to mitigate excessive heat generation at higher rotational speeds.
- Study of RTRs in conjunction with other process intensification technologies for biodiesel production.

Acknowledgement

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References

1. *Chanthon, Ngaosuwan, Kiatkittipong, Wongsawaeng, Appamana, Quitain, Assabumrungrat (2021)* High-efficiency biodiesel production using rotating tube reactor: New insight of operating parameters on hydrodynamic regime and biodiesel yield.
2. *Miss Narita Chanthon (2021)* Development of rotating tube reactor for biodiesel production from palm oil. [Chulalongkorn University Theses and Dissertations (Chula ETD)]