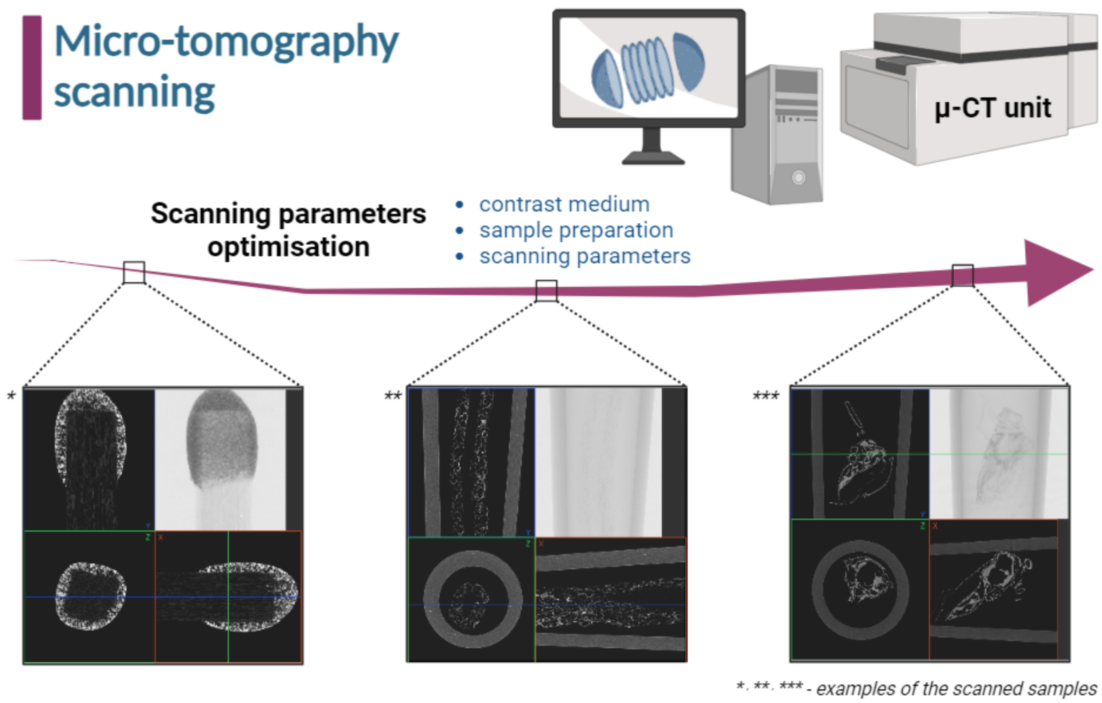
Discovering the inside – optimization of the scanning conditions to precisely explore the interior of 3D structures

Micro-computed tomography (μCT) is widely used for the study of mineralized tissues, but a similar use for soft tissues is hindered by their low X-ray attenuation. This limitation can be overcome by the recent development of different staining techniques. Staining with Lugol's solution stands out among these techniques for its low complexity and cost. During this project, the aim is to optimize the quality and reproducibility of the staining to increase the resolution of soft-matter visualization in the context of hydrogels for tissue regeneration. **The project include optimizing the Lugol staining process for hydrogel materials by evaluating the effect of different concentrations and a variation in sample storage times before/after staining**. Finally, the potential of staining techniques to evaluate interior porosity of soft hydrogel material will be demonstrated. This information is foreseen to help improve the understanding of the regenerative process involving soft tissues and hydrogels providing a 3D context to histological and SEM-based findings.



Abstract of the Master thesis project' created in Biorender.com

Related literature:

- https://doi.org/10.1155%2F2019%2F7483745
- https://doi.org/10.1002/adma.202309026
- https://doi.org/10.1007/s10856-017-6024-2
- https://doi.org/10.1016/j.matdes.2020.109312

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Bacterial Cellulose Structuring in Confined Environments for Bone Tissue Engineering

Abstract

Bacterial cellulose has been used for different biomedical application due to its biocompatibility and adaptable mechanical properties. However, little is known about how it forms and organizes in confined environments. Understanding these interactions could help develop predictive models for guiding bacterial cellulose biofabrication, particularly for bone tissue engineering. This study aims to explore how bacterial adhesion, biofilm formation, and fiber organization are influenced by spatial constraints, contributing to the development of biofabricated bone scaffolds with improved microarchitecture. The research will focus on creating controlled microenvironments using volumetric 3D printing, where bacterial cellulose-producing bacteria will be embedded in a bioresin matrix with tunable mechanical properties. Different confinement conditions will be tested by varying aspect ratios from 1:2 to 1:10 and stiffness levels between 100 Pa and 100 kPa. Fluorescence microscopy and SEM imaging will be used to analyze bacterial adhesion and cellulose fiber formation, while image analysis software (FIJI/ImageJ) will quantify fiber orientation and biofilm density, establishing links between confinement parameters and bacterial cellulose structuring. This study is expected to reveal how mechanical constraints shape bacterial cellulose formation. Higher stiffness may promote structured fiber alignment, while lower stiffness could lead to a more disordered architecture. By identifying the optimal conditions for bacterial cellulose structuring, this work will contribute to improving scaffold design for bone tissue engineering. Ultimately, these findings will support the development of predictive biofabrication strategies, enhancing the use of bacterial cellulose for biomedical applications.

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Oxygen Modulation for Controlled Bacterial Cellulose Assembly in Biofabricated Constructs

Abstract

This study explores the role of oxygen modulation in bacterial cellulose biofabrication by incorporating hydroxyapatite-coated calcium peroxide ($PDHAO_2$) particles for controlled oxygen release. The research will evaluate how oxygen gradients influence bacterial clustering, cellulose fiber formation, and scaffold structuring, providing insights for optimizing bacterial cellulose-based bone scaffolds. $PDHAO_2$ particles will be synthesized and characterized for their oxygen release kinetics (0.1–2 µM/h) using SEM and FTIR analysis. These particles will be integrated into bacterial cellulose bioinks and will be cultured under different oxygenation conditions. Fluorescence imaging will track bacterial clustering, while confocal microscopy and SEM will assess cellulose fiber organization. The mechanical properties of the biofabricated constructs will be evaluated through noncontact viscoelasticity mesurment and rheological testing. Controlled oxygen release is expected to enhance bacterial adhesion and fiber structuring, leading to more organized biofabricated scaffolds. By optimizing oxygen supply, this study aims to improve bacterial cellulose production and biofabrication strategies for bone tissue engineering applications.

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Design and Synthesis of Multifunctional Polymers for Amphiphilic Janus Nanoparticle Coating to Form Stimuli-Responsive Vesicle-Like Artificial Membranes

Abstract

The design and synthesis of multifunctional polymeric ligands for coating amphiphilic Janus nanoparticles (JNPs) enable the formation of stimuli-responsive vesicle-like artificial membranes. These bio-inspired vesicles mimic cellular membranes and exhibit controlled self-assembly and selective disassembly in response to tumor-mimicking conditions, making them promising for targeted drug delivery and theranostic applications.

The method involves the synthesis of hydrophilic and hydrophobic polymeric ligands, followed by surface modification of JNPs through ligand exchange, imparting amphiphilic properties essential for vesicle formation. The functionalized JNPs undergo self-assembly in an aqueous medium, forming stable vesicle-like structures. Their size, stability, and morphology will be assessed, and their stimuli-responsive behavior will be evaluated under hypoxic and oxidative conditions, where controlled vesicle disassembly is expected to enhance nanoparticle penetration and delivery.

This project focuses on polymer synthesis, nanoparticle surface engineering, vesicle formation, and structural characterization, contributing to the development of a bio-inspired nanoplatform with stimuli-responsive behavior for advanced biomedical applications.

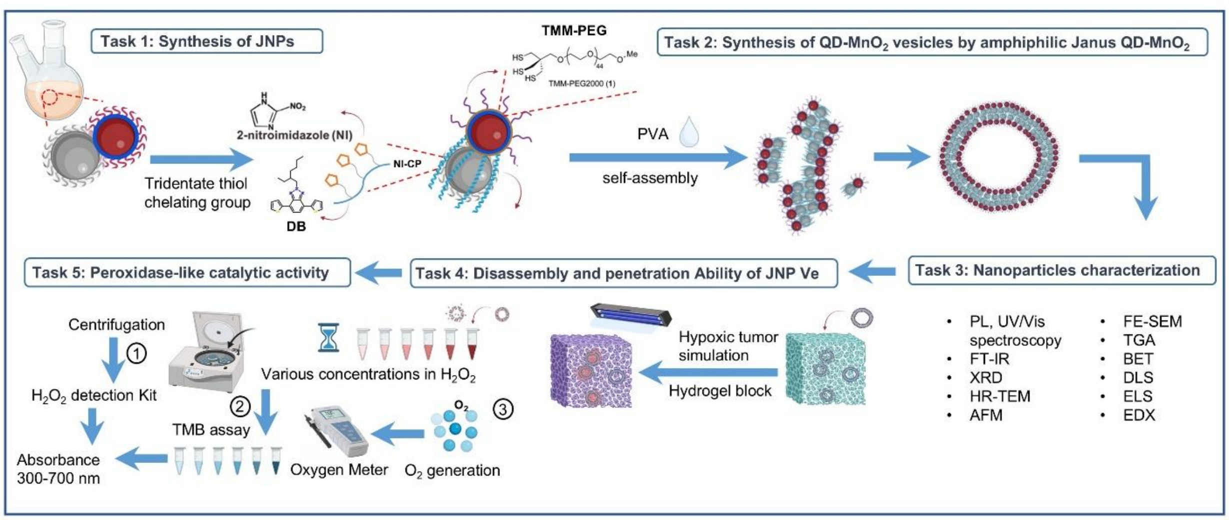

Figure: Summary of the tasks including the main experimental stages (Graphics created using BioRender.com)

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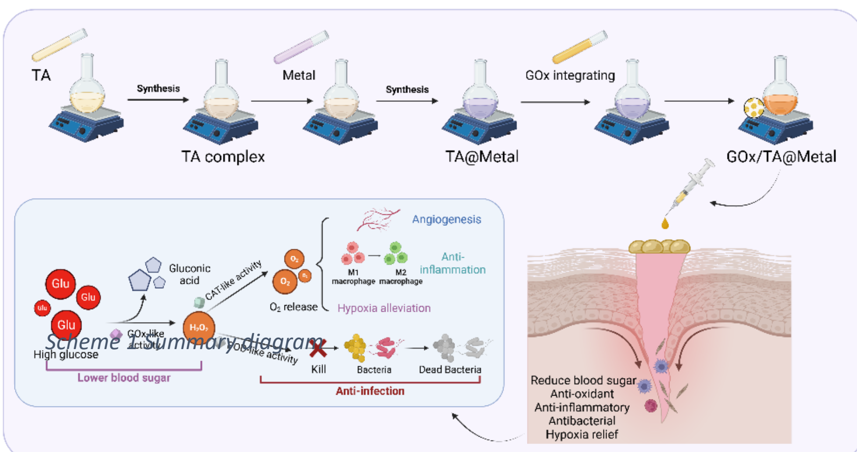
Construction of cascade nanozyme system

Effective glycemic control is paramount for optimal wound healing in diabetic patients. Traditional antibacterial and anti-inflammatory treatments, while important, often fall short in addressing the hyperglycemic conditions of diabetic wounds. Besides, the low efficiency of H_2O_2 self-decomposition and the damage to healthy tissues caused by high-dose H_2O_2 disinfection of wounds limit the recovery of the wound. Thus, the development of novel therapeutic strategies for accelerating diabetic wound healing has garnered escalating attention. Nanozymes, as a type of nanomaterials with biological enzyme characteristics, can improve the detrimental microenvironment of diabetic wounds by performing different kinds of enzyme-like activities, which have good potential in the treatment of diabetic wounds. Among the different kinds of enzymatic activities, glucose oxidase (GOx) can continuously oxidize the nontoxic and biocompatible glucose to generate hydrogen peroxide (H_2O_2) and gluconic acid. And the resulting H_2O_2 can be subsequently broken down into •OH via POD-like activity or O_2 via CAT-like activity, separately. The cascade reaction system not only reduces glucose levels but also helps to lower excess ROS and supply a continuous supply of O_2. In a word, the full utilization of blood glucose and the breakthrough of local pH and H_2O_2 limitations can improve the therapeutic efficacy for hyperglycemic wound sterilization. Based on the above, the purpose of this project is to prepare a cascade nanozyme reaction system. To achieve this goal, several steps must be taken:

A) Synthesize TA-based nanozyme and integrate it with natural enzymes GOx.
B) Characterize the integrated nanozyme and evaluate its multienzyme-like activities.
C) Evaluate the biocompatibility, antioxidant, anti-inflammatory, and antibacterial activities in vitro.



Scheme 1 Summary diagram

Related literature:
https://doi.org/10.1016/j.redox.2024.103217
https://doi.org/10.1021/acsnano.3c04134
https://doi.org/10.1002/adhm.202301474
https://doi.org/10.1016/j.jconrel.2024.06.040

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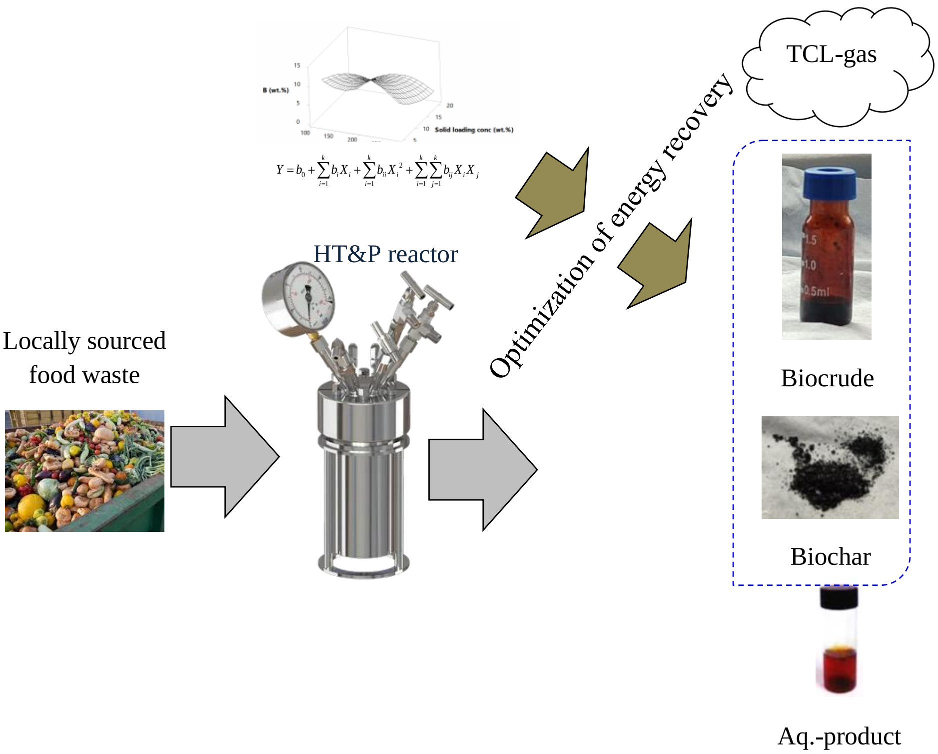
Process intensification of thermochemical liquefaction for enhanced energy recovery from organic waste streams



Abstract

Maximizing the energy recovery potential of thermochemical liquefaction (TCL) systems requires a comprehensive understanding of how process parameters influence the conversion of complex organic feedstocks into energy-rich products. The high thermal energy demand necessary to sustain supercritical solvent conditions, combined with challenges in effective heat integration, imposes significant limitations on the scalability of TCL due to its energy-intensive nature. This study will employ food waste as a representative heterogeneous biomass to optimize energy recovery through systematic variation of key operational factors, including reaction temperature, residence time, solid-to-solvent mass ratio, and particle size distribution. The objective is to maximize total energy recovery by quantifying the combined energy contributions of biocrude and biochar products under supercritical processing conditions as opposed to the widely employed approach of focusing on maximizing the biocrude yield. An experimental design based on response surface methodology (RSM) will be used to evaluate both individual and interactive effects of these parameters on reaction pathways, phase separation behavior, and chemical energy transfer. Energy recovery efficiency will be assessed using higher heating values (HHVs) of the products relative to the initial feedstock energy content, while detailed physicochemical characterization, including CHNS elemental analysis, hydrogen-to-carbon (H/C) ratios, calorific values, molecular composition, and surface morphology (for biochar), will be performed to evaluate product quality and stability. Furthermore, the impact of particle size on heat and mass transfer limitations will be critically examined to inform reactor design and scale-up strategies for continuous operation. By integrating energy efficiency metrics with process optimization models, this work aims to identify

optimal TCL operating conditions that maximize energy recovery while minimizing solvent usage and thermal input. The outcomes of this study are expected to advance the development of scalable, high-performance TCL systems, supporting sustainable bioenergy production and contributing to circular economy initiatives through the valorization of organic waste streams.

Keywords: *hydrothermal liquefaction; response surface methodology; optimization; food waste; circular economy*.

Requirements

1. The candidate should have a good academic background preferably a BSc (or BEng.) degree in Chemical/Process Engineering.
2. The candidate should be motivated and must have a strong desire to learn and improve.

Background reading

1. **Okoro, O. V.**, Romano, L., Karimi, K., Nie, L., Gunduz, O., & **Shavandi, A.** (2024). The technical, economic, and environmental assessment of solvothermal liquefaction processes: An experimental and simulation study on the influence of solvent reichardt parameter. *Chemical Engineering Research and Design*, *208*, 380-390.
2. **Okoro, O. V.,** & Sun, Z. (2021). The characterization of biochar and biocrude products of the hydrothermal liquefaction of raw digestate biomass. *Biomass Conversion and Biorefinery*, *11*(6), 2947-2961.

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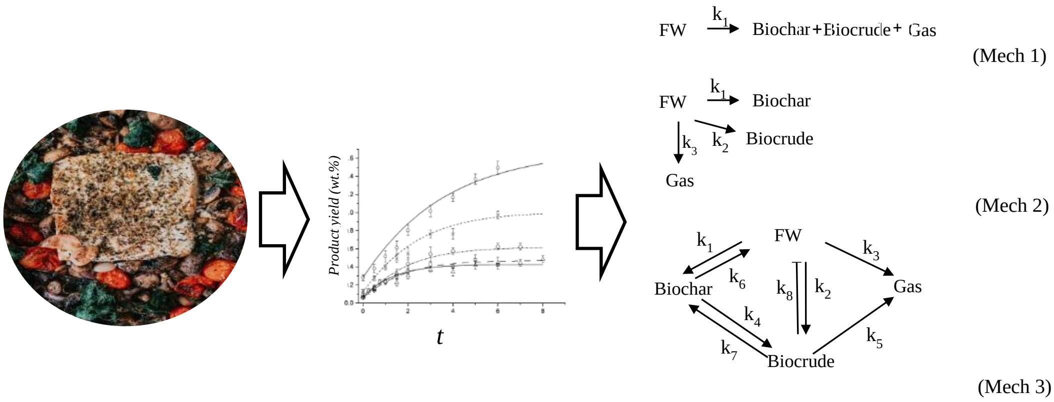
Investigating food waste liquefaction: kinetics modelling, reaction mechanisms, process parameters, and biocrude fuel properties



Abstract

The thermochemical liquefaction of food waste employing environmentally benign (green) solvents under subcritical and supercritical conditions offers a promising pathway for sustainable biofuel production while addressing organic waste valorization within the framework of a circular economy. This study aims to systematically investigate the reaction kinetics of non-catalytic food waste liquefaction in green solvents to maximize biocrude yield and conversion efficiency. Experimental liquefaction processes will be conducted within a temperature range of 200 to 280°C under controlled pressures, with residence times varying from 10 to 30 min, to elucidate the effects of thermal and temporal parameters on the extent of biomass conversion. Three mechanistic kinetic models will be proposed to describe the complex decomposition behavior of food waste during liquefaction: (i) a consecutive reaction scheme (Mech 1), (ii) a parallel reaction pathway (Mech2), and (iii) an equilibrium-controlled reaction system (Mech 3). Kinetic parameters, including rate constants and activation energies, will be determined by solving ordinary differential equations (ODEs) derived from conventional reaction rate expressions and fitting experimental data using the Arrhenius correlation. These kinetic parameters will be critically compared with values reported in existing literature and further validated through experimental observations. In addition, the physicochemical properties of the produced biocrude will be comprehensively characterized, including higher heating value (HHV), hydrogen-to-carbon (H/C) atomic ratio, elemental composition (CHNS analysis), and molecular speciation via chromatographic and spectroscopic techniques to assess its suitability as a fossil fuel alternative. The findings of this project will advance the understanding of green-solvent-mediated thermochemical liquefaction kinetics, providing valuable insights into optimizing process conditions and product quality for sustainable biofuel production from food waste feedstocks.

Keywords: *thermochemical liquefaction; kinetic modeling; catalyst-free; biocrude; circular economy.*

Requirements

3. The candidate should have a good academic background preferably a BSc (or BEng.) degree in Chemical/Process Engineering.
4. The candidate should be motivated and must have a strong desire to learn and improve.

Background reading

3. **Okoro, O. V.,** Romano, L., Karimi, K., Nie, L., Gunduz, O., & **Shavandi, A.** (2024). The technical, economic, and environmental assessment of solvothermal liquefaction processes: An experimental and simulation study on the influence of solvent reichardt parameter. *Chemical Engineering Research and Design*, *208*, 380-390.
4. **Okoro, O. V.,** & Sun, Z. (2021). The characterisation of biochar and biocrude products of the hydrothermal liquefaction of raw digestate biomass. *Biomass Conversion and Biorefinery*, *11*(6), 2947-2961.

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