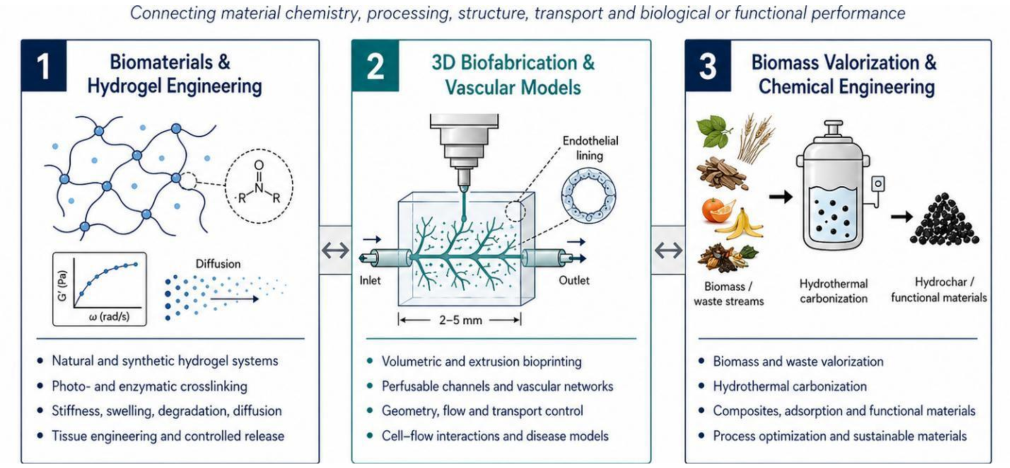
BIOMATTER LAB

Master's Thesis Topics

Academic Year 2026–2027



The BioMatter Lab studies and designs advanced material systems at the interface of biomaterials science, tissue engineering, biofabrication, and chemical engineering. Our work connects material chemistry, structure, mechanics, transport, and biological or functional performance. The Master's projects are experimental and interdisciplinary, ranging from hydrogel biomaterials and vascularized 3D models to biomass-derived functional materials and sustainable chemical processes.

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RESEARCH PILLARS AND AVAILABLE TOPICS

Research pillars at BioMatter

1	**Biomaterials and Hydrogel Engineering** Polymeric hydrogel biomaterials for tissue engineering, disease modelling and controlled delivery. Projects connect composition, crosslinking, mechanics, degradation, release and cell response.
2	**3D Biofabrication, Vascularized Models and Transport-Controlled Tissue Engineering** Volumetric and extrusion-based bioprinting, perfusable channels, vascular-like networks, flow–cell interactions, permeability and image-based analysis.
3	**Biomass Valorization and Sustainable Chemical Engineering** Conversion of biomass and waste streams into fuels and functional materials through hydrothermal or thermochemical processing, Design of Experiments and structure–property analysis.

Available Master's thesis topics

1. Redox-Active Hydrogel Scaffolds for Nanoparticle Encapsulation and Controlled Manganese Release in Postoperative Anticancer Applications
2. Dynamically Tunable Hydrogels for Vascular Stiffness Modulation
3. Light-Responsive Sacrificial Hydrogels for 3D Bioprinting Applications
4. Development of a Bioactive HAMA/GelMA Hydrogel for Volumetric Printing of Biomimetic Structures
5. Modular Volumetric Bioprinted Vascular Models to Study Cell–Flow Interactions
6. Development of PEG/Hydrochar Composite Materials Derived from Seafood Waste for Sustainable Functional Applications
7. Engineering Nitrogen-Enriched Hydrochar from Seafood Waste Using Microwave-Assisted Hydrothermal Carbonization
8. Enhancing Hydrochar Quality Derived from Seafood Waste via Co-Carbonization with Glucose and Fruit Waste: A Comparative Study
9. Tailored Hydrochar from Seafood Waste via Microwave-Assisted Hydrothermal Carbonization for Pollutant Removal from Water
10. Kinetic Analysis of Thermochemical Liquefaction of Industrial Post-Compost Fines
11. Optimization of Feedstock Blends for Biocrude Production from Industrial Post-Compost Fines

BIOMATERIALS AND HYDROGEL ENGINEERING

Topic 1. Redox-Active Hydrogel Scaffolds for Nanoparticle Encapsulation and Controlled Manganese Release in Postoperative Anticancer Applications

Hydrogel-based biomaterials are increasingly explored as localized platforms for improving postoperative cancer treatment by enabling the encapsulation and sustained release of therapeutic nanomaterials. In this context, manganese dioxide (MnO_2) nanoparticles offer redox-responsive properties and the ability to release manganese ions, which can induce oxidative stress and contribute to cancer cell cytotoxicity. This thesis proposes the development of MnO_2 nanoparticle-embedded photocrosslinkable hydrogels as systems for nanoparticle encapsulation and controlled, sustained manganese release for in vitro anticancer evaluation.

Two hydrogel matrices, Gelatin Methacryloyl (GelMA) and Carboxymethyl Cellulose Methacrylate (CMCMA), will be investigated in a comparative study. GelMA provides a biomimetic and biocompatible environment, while CMCMA offers enhanced mechanical stability and potential printability. The study will focus on the fabrication and mechanical characterization of MnO_2-loaded hydrogels, evaluating key properties including rheological behaviour, compressive strength, swelling ratio, degradation rate, gel fraction, and porosity. These parameters will be correlated with the hydrogel's ability to encapsulate nanoparticles and regulate their sustained release.

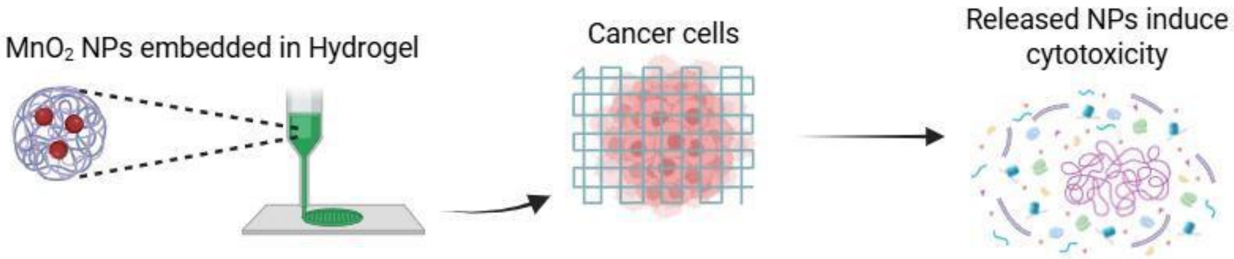

Figure 1. MnO_2-loaded hydrogel design, controlled manganese release and anticancer evaluation.

The cumulative release of manganese species will be monitored using UV–Vis spectrophotometry and colorimetric manganese detection assays, enabling analysis of MnO_2 degradation and Mn^{2+} ion release kinetics. The biological effects of released manganese species will be assessed using in vitro cancer cell models, with cell viability evaluated via the CellTiter-Glo® 3D assay (Promega) and Live/Dead staining to visualize cell survival and membrane integrity.

By correlating hydrogel structure, nanoparticle encapsulation, release behaviour, and cellular response, this work aims to establish MnO_2-loaded hydrogels as effective platforms for localized and controlled nanomaterial delivery in postoperative anticancer applications.

BIOMATERIALS AND HYDROGEL ENGINEERING

Topic 2. Dynamically Tunable Hydrogels for Vascular Stiffness Modulation

Hydrogel-based matrices are widely used to model the physical microenvironment of cells in engineered tissues. However, most current systems rely on static materials with fixed mechanical properties, limiting the ability to study how cells respond to mechanical changes over time. In native tissues, extracellular matrix properties such as stiffness evolve dynamically, influencing cell behaviour, barrier function, and mechanotransduction.

In this project, the student will develop phenol-modified hydrogels with controllable crosslinking and stiffness. Phenol-functionalized polymers enable enzymatic crosslinking reactions that allow the degree of crosslinking, and therefore the mechanical properties of the hydrogel, to be adjusted over time. By tuning crosslinking conditions, the material can undergo controlled stiffening after gel formation, creating a dynamic matrix whose mechanical properties can be programmed during experiments.

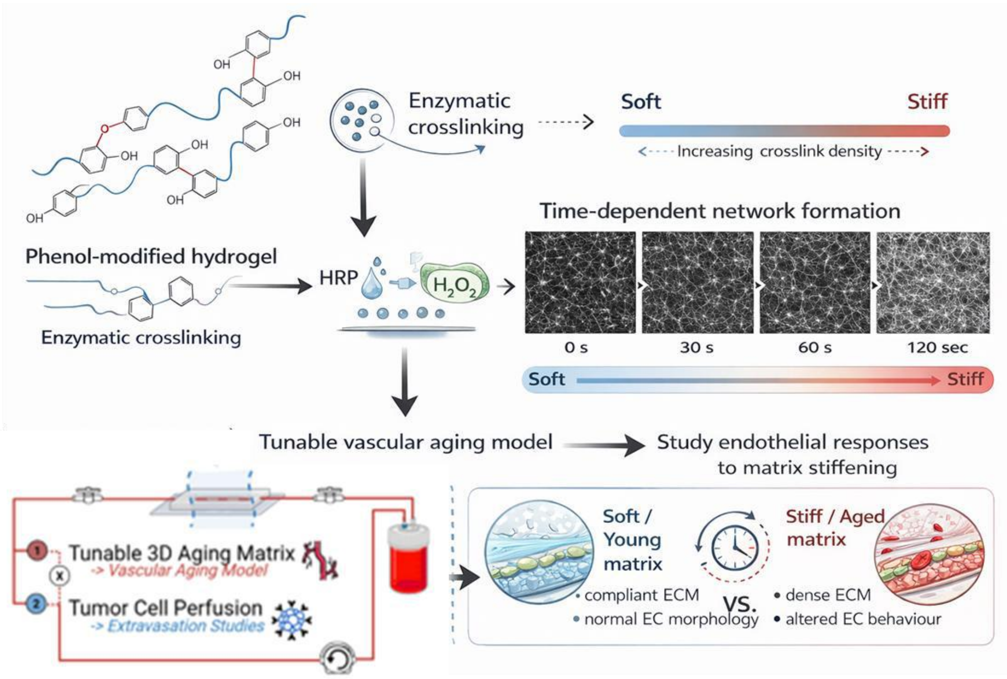

Figure 2. Enzymatic crosslinking of phenol-modified hydrogels for time-dependent stiffness modulation and vascular-cell studies.

Indicative tasks

- Tune enzymatic crosslinking conditions to control gelation and stiffness.
- Characterize hydrogel mechanical properties using rheology or mechanical testing.
- Develop protocols for inducing controlled stiffness changes over time.
- Test compatibility of the hydrogels with endothelial cell culture and perfused channel systems.

The resulting platform will enable dynamic control of the mechanical microenvironment and can be used to study how vascular cells respond to changes in matrix stiffness. Such systems may also serve as in vitro models of arterial stiffening, which is difficult to capture using conventional static materials.

Selected references

R. Schnellmann et al., "Stiffening Matrix Induces Age-Mediated Microvascular Phenotype Through Increased Cell Contractility and Destabilization of Adherens Junctions," Advanced Science, 2026.

J. Stanny et al., "Geometrical designs in volumetric bioprinting to study cellular behaviors in engineered constructs," Advanced Healthcare Materials, 2025.

3D BIOFABRICATION, VASCULARIZED MODELS AND TRANSPORT-CONTROLLED TISSUE ENGINEERING

Topic 3. Light-Responsive Sacrificial Hydrogels for 3D Bioprinting Applications

Three-dimensional (3D) bioprinting enables the fabrication of complex biological structures with spatial control over materials and cells. However, creating perfusable channel networks within these constructs remains a major challenge. Sacrificial hydrogels offer a promising solution by acting as temporary templates that can be removed after printing to form hollow structures.

This project focuses on the development of light-responsive sacrificial hydrogels that can be processed under mild conditions and selectively dissolved upon external stimulation. The material system can be tuned to function either as a support bath for embedded printing or as a printable sacrificial filament, enabling flexible fabrication strategies. The student will investigate how formulation and processing affect mechanical properties, printability, and removal behaviour, and will demonstrate the fabrication of simple perfusable structures.

The objective is to design and evaluate a tunable hydrogel system for use as a sacrificial material in 3D bioprinting. This includes understanding how material composition influences gel formation, mechanical behaviour, and responsiveness to light-based triggering, as well as demonstrating its applicability in creating defined structures and channels.

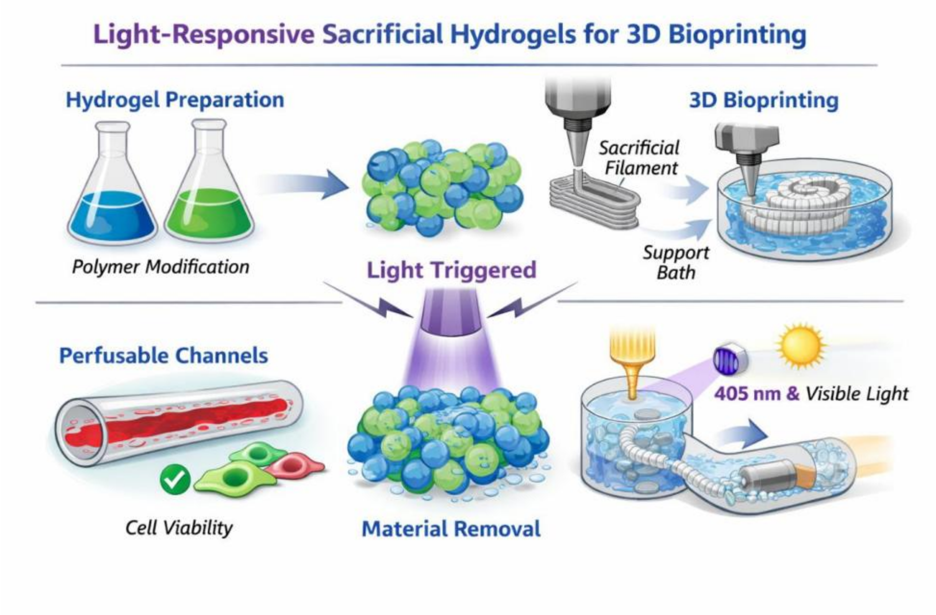

Figure 3. Light-responsive sacrificial hydrogel strategy for 3D printing and on-demand formation of perfusable channels.

Indicative tasks	Methods and techniques
• Polymer preparation and modification. • Formulation optimization for support baths and sacrificial filaments. • Rheological characterization and printability assessment. • Embedded and extrusion-based 3D printing. • Light-triggered material removal. • Hollow-channel fabrication and perfusion testing. • Basic cell-viability assessment.	• Hydrogel synthesis. • Rheometry and mechanical testing. • Extrusion-based 3D bioprinting. • Optical triggering experiments. • Microscopy and image analysis. • Cell culture and viability assays.

3D BIOFABRICATION, VASCULARIZED MODELS AND TRANSPORT-CONTROLLED TISSUE ENGINEERING

Topic 4. Development of a Bioactive HAMA/GelMA Hydrogel for Volumetric Printing of Biomimetic Structures

Volumetric 3D printing is an emerging approach in biofabrication that enables the rapid production of complex three-dimensional structures. Unlike layer-by-layer printing techniques, this method allows an entire volume of photosensitive resin to be polymerized in a matter of seconds. However, its use in tissue engineering remains limited by the small number of compatible bioinks, which must both possess suitable optical properties for printing and maintain a biologically favourable environment for cells.

This project aims to develop and characterize a new bioactive hydrogel formulation based on a GelMA (gelatin methacryloyl) and HAMA (hyaluronic acid methacrylate) mixture for volumetric printing. The goal is to design a resin that enables both efficient polymerization during printing and a supportive environment for cell viability. The potential addition of PEGDA may also be explored to fine-tune mechanical properties and crosslinking kinetics.

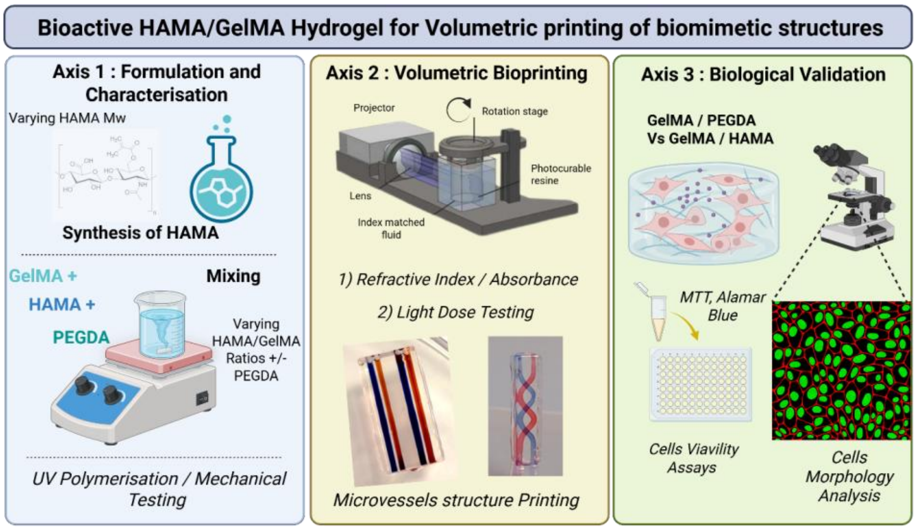

Figure 4. HAMA/GelMA formulation, volumetric-printing compatibility and biological-validation workflow.

Axis 1 – Formulation and characterization	Axis 2 – Volumetric printing	Axis 3 – Biological evaluation
• HAMA synthesis and molecular-weight variation. • Methacrylation analysis by NMR or FTIR. • GelMA/HAMA ratios with optional PEGDA. • UV polymerization and mechanical testing.	• Refractive-index and absorbance measurements. • Polymerization and light-dose optimization. • Printing of stable structures and microchannels.	• MTT or Alamar Blue viability assays. • Fibroblast or endothelial-cell models. • Fluorescent analysis of cell morphology.

The project will establish how formulation controls the mechanical, optical, printing and biological performance of HAMA/GelMA volumetric bioinks.

3D BIOFABRICATION, VASCULARIZED MODELS AND TRANSPORT-CONTROLLED TISSUE ENGINEERING

Topic 5. Modular Volumetric Bioprinted Vascular Models to Study Cell–Flow Interactions

Understanding how geometry and flow conditions influence cellular behaviour is crucial for studying vascular biology, disease development, and tissue engineering. Recent advances in volumetric bioprinting enable the rapid fabrication of complex hydrogel structures with precisely defined internal geometries. These structures can be used as model systems to investigate how physical cues affect cell responses in engineered microenvironments.

In this project, the student will develop modular hydrogel building blocks containing internal channel geometries that can be linked together to form artificial vessel-like networks. Using volumetric printing, these building blocks will be fabricated with features such as constrictions, angles, and porous regions that create distinct flow regimes, including altered shear stress, recirculation zones, or diffusion-dominated regions.

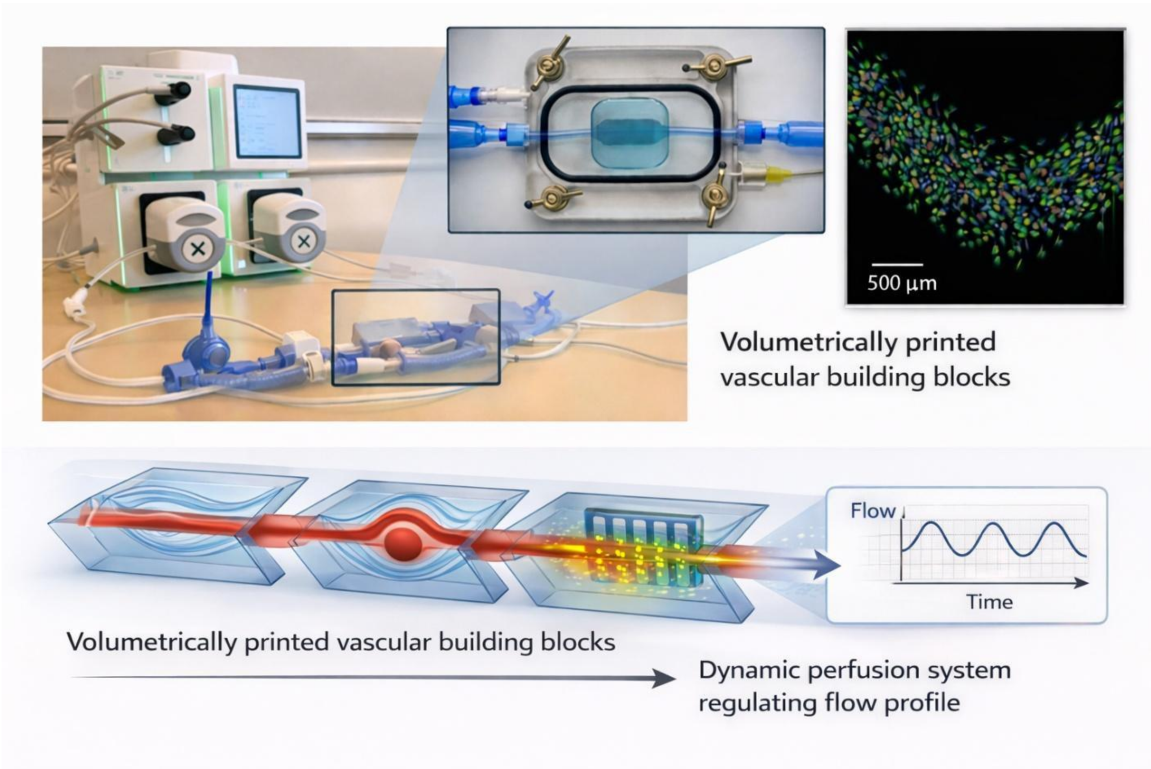

Figure 5. Modular volumetrically printed vascular building blocks and a controlled perfusion system for studying geometry–flow–cell interactions.

Indicative tasks

- Design and volumetrically print modular hydrogel blocks with embedded channels.
- Assemble the blocks into customizable artificial vascular systems.
- Introduce cells into the channels and apply controlled perfusion flow.
- Investigate how channel geometry, flow patterns and shear stress influence adhesion, morphology, migration and proliferation.
- Analyse how porous or structured regions affect diffusion and cell–material interactions.

The project combines advanced biofabrication, microfluidics, and cell biology to systematically examine how physical microenvironmental parameters regulate cellular responses in vascular-like environments.

Selected references

J. Stanny et al., "Geometrical designs in volumetric bioprinting to study cellular behaviors in engineered constructs," Advanced Healthcare Materials, 2025.

BIOMASS VALORIZATION AND SUSTAINABLE CHEMICAL ENGINEERING

Topic 6. Development of PEG/Hydrochar Composite Materials Derived from Seafood Waste for Sustainable Functional Applications

The integration of biomass-derived carbon materials into polymer matrices offers new opportunities for sustainable material development. Hydrochar derived from seafood waste serves as a low-cost, tunable carbon filler, while polyethylene glycol (PEG) provides a versatile, hydrophilic polymer matrix. This project aims to develop PEG/hydrochar composite materials using hydrochar derived from seafood waste, such as lobster shell waste, via microwave-assisted hydrothermal carbonization.

Hydrochar will be incorporated into PEG at varying loadings to produce composite materials with tailored properties. The influence of hydrochar incorporation on rheological behaviour, mechanical properties, and structural characteristics will be investigated. Rheological testing, mechanical analysis, FTIR spectroscopy, and microscopy will be used to assess material performance and interactions between hydrochar and PEG. The project will determine how hydrochar content and processing conditions affect composite functionality and will demonstrate the feasibility of using seafood-derived carbon materials in sustainable composite systems.

Core methods

- Microwave-assisted hydrothermal carbonization of seafood waste.
- PEG/hydrochar formulation at varied filler loadings.
- Rheological and mechanical characterization.
- FTIR spectroscopy and microscopy.
- Structure–property analysis of the composite materials.

BIOMASS VALORIZATION AND SUSTAINABLE CHEMICAL ENGINEERING

Topic 7. Engineering Nitrogen-Enriched Hydrochar from Seafood Waste Using Microwave-Assisted Hydrothermal Carbonization

The valorization of seafood-processing waste into functional materials presents an opportunity to advance circular-bioeconomy initiatives. Waste such as lobster shells contains organic carbon, proteins, and minerals and can serve as a feedstock for hydrothermal carbonization (HTC). HTC converts moist biomass directly into carbon-rich hydrochar without requiring prior energy-intensive drying.

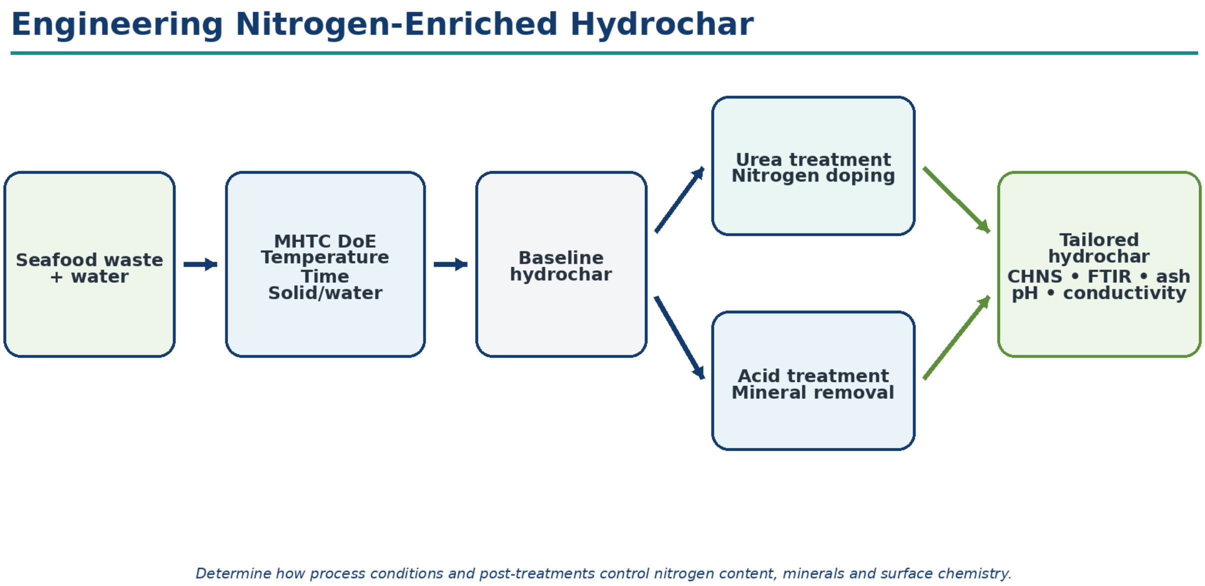

Figure 6. Microwave-assisted hydrothermal carbonization and post-treatment routes for tailoring nitrogen content, mineral content and surface chemistry.

This project will systematically investigate hydrochar production from seafood waste using microwave-assisted hydrothermal carbonization (MHTC) and establish relationships between processing conditions and material properties. A Design of Experiments approach will evaluate temperature, residence time, and solid-to-water ratio as determinants of hydrochar yield, composition, and physicochemical characteristics.

The project will also assess targeted modification strategies, including nitrogen doping using urea and acid treatment for mineral removal. The produced materials will be characterized by CHNS elemental analysis, FTIR spectroscopy, and proximate analysis to assess ash content. Measurements of pH and electrical conductivity will provide further insight into surface chemistry. The results will support the development of optimized production strategies for sustainable carbon materials derived from marine biomass.

Core methods

- Design of Experiments for temperature, residence time and solid-to-water ratio.
- Nitrogen doping using urea and acid treatment for mineral removal.
- CHNS elemental analysis, FTIR spectroscopy and proximate analysis.
- pH and electrical-conductivity measurements.

BIOMASS VALORIZATION AND SUSTAINABLE CHEMICAL ENGINEERING

Topic 8. Enhancing Hydrochar Quality Derived from Seafood Waste via Co-Carbonization with Glucose and Fruit Waste: A Comparative Study

Improving the carbon content and surface functionality of hydrochar remains a key challenge in hydrothermal carbonization, particularly when using mineral-rich marine biomass such as lobster-shell waste. Co-carbonization with additional carbon-rich precursors offers a promising strategy for enhancing hydrochar properties.

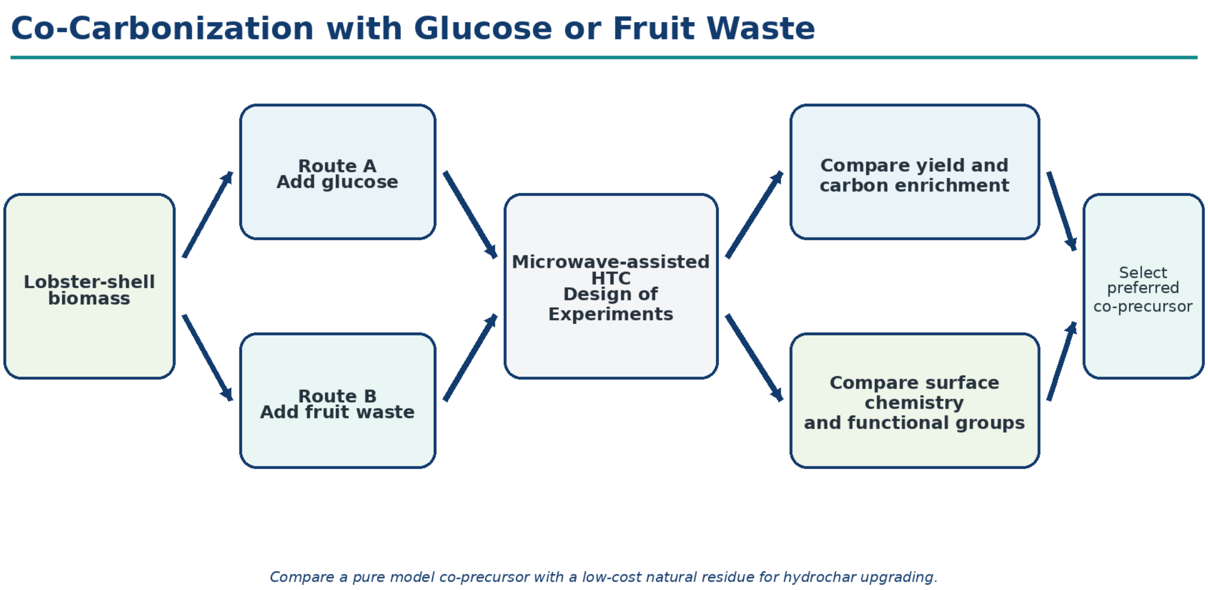

Figure 7. Comparative co-carbonization strategy using glucose or fruit-waste co-precursors.

This project will investigate the addition of glucose and fruit waste as co-precursors during microwave-assisted hydrothermal carbonization of lobster-shell biomass. The study will compare the influence of pure glucose with natural fruit waste, such as citrus or apple residues, on hydrochar yield, carbon content, and surface chemistry. A Design of Experiments approach will optimize temperature, residence time, and additive concentration.

The resulting hydrochars will be characterized using CHNS analysis, FTIR spectroscopy, and proximate analysis to assess elemental composition and functional groups. The study will determine how the two co-carbonization strategies affect carbon enrichment and functionalization and will identify sustainable approaches for upgrading hydrochar using low-cost organic additives.

Core methods

- Comparative use of glucose and fruit-waste co-precursors.
- Design of Experiments for temperature, residence time and additive concentration.
- CHNS analysis, FTIR spectroscopy and proximate analysis.
- Comparison of hydrochar yield, carbon enrichment and surface functionality.

BIOMASS VALORIZATION AND SUSTAINABLE CHEMICAL ENGINEERING

Topic 9. Tailored Hydrochar from Seafood Waste via Microwave-Assisted Hydrothermal Carbonization for Pollutant Removal from Water

Seafood-processing waste, particularly lobster-shell residues, is an abundant and underutilized biomass resource with strong potential for conversion into functional carbon-based materials. Hydrothermal carbonization, particularly when assisted by microwave heating, enables efficient processing of wet biomass without energy-intensive drying.

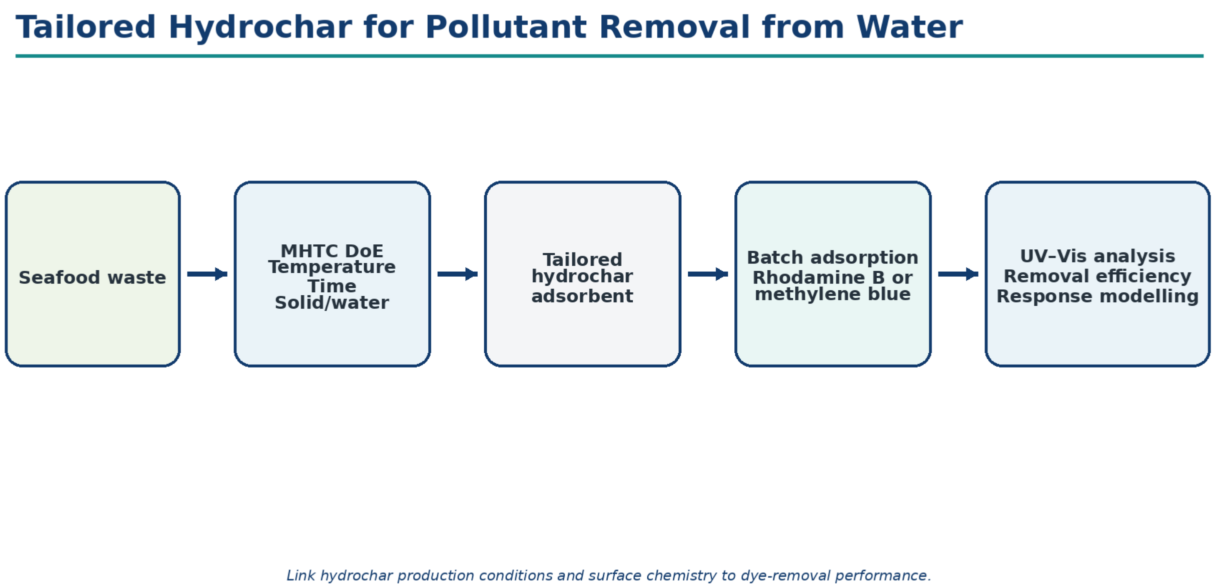

Figure 8. Hydrochar production and batch-adsorption workflow for pollutant removal from water.

This project aims to develop tailored hydrochar from seafood waste using microwave-assisted hydrothermal carbonization (MHTC) and evaluate its performance in removing pollutants such as Rhodamine B or methylene blue from aqueous systems. Temperature, residence time, and solid-to-water ratio will be optimized using a Design of Experiments approach, with pollutant removal assessed under defined pH, contact-time, and dye-concentration conditions.

The hydrochars will be characterized using CHNS analysis, FTIR spectroscopy, and proximate analysis. Adsorption performance will be evaluated through batch experiments examining the effects of pH, contact time, dye concentration, and other influential parameters. UV–Vis spectroscopy will quantify dye removal. The project will establish relationships between production conditions, surface chemistry and adsorption performance, demonstrating a sustainable route for converting seafood waste into functional adsorbents.

Core methods

- MHTC optimization using Design of Experiments.
- CHNS analysis, FTIR spectroscopy and proximate analysis.
- Batch adsorption experiments at varied pH, contact time and dye concentration.
- UV–Vis quantification of pollutant removal.

BIOMASS VALORIZATION AND SUSTAINABLE CHEMICAL ENGINEERING

Topic 10. Kinetic Analysis of Thermochemical Liquefaction of Industrial Post-Compost Fines

Summary of work

Industrial post-compost fines (PCFs) are heterogeneous organic residues containing varying proportions of carbohydrates, proteins, lipids, lignin, and inorganic components. Their complex composition results in multiple simultaneous reactions during thermochemical liquefaction (TCL), making it difficult to understand the reaction behaviour governing feedstock conversion and biocrude formation.

Previous research has established suitable TCL operating conditions for PCFs; however, the kinetic behaviour of these materials under different temperatures and reaction times remains insufficiently understood. Developing kinetic models for PCF conversion and biocrude formation could provide fundamental information for understanding reaction pathways and identifying conditions that favour biocrude production over secondary degradation [1].

This MSc project will investigate the kinetics of PCF conversion during TCL using experimental data obtained at different temperatures and reaction times. Kinetic models will be developed to describe overall feedstock conversion and the formation and subsequent degradation of biocrude.

Aim and specific objectives

The overall aim is to develop and evaluate kinetic models describing the thermochemical liquefaction of industrial PCFs and to determine the kinetic parameters governing feedstock conversion and biocrude formation.

The research will characterize selected PCF samples and evaluate their TCL behaviour at different temperatures and reaction times. Product yields will be determined and used to develop kinetic models describing PCF conversion, biocrude formation, and, where supported by the data, secondary biocrude degradation. The study will determine reaction-rate constants, apparent activation energies, and pre-exponential factors; assess how feedstock composition influences the estimated kinetic parameters; and validate the developed models against experimental results.

Research hypothesis and questions

It is hypothesized that PCF conversion and biocrude formation during TCL can be represented by temperature-dependent kinetic models and that the resulting kinetic parameters will vary according to feedstock composition.

The research will assess how temperature and reaction time affect PCF conversion and biocrude formation; whether a simplified kinetic model adequately describes the observed behaviour; whether biocrude formation and degradation can be represented as consecutive or parallel reactions; and how differences in PCF biochemical composition influence apparent reaction rates and activation energies.

Experimental methodology

Selected PCF samples representing different compositions will be characterized using proximate, ultimate, biochemical, ash, and higher-heating-value analyses. TCL experiments will be conducted at selected temperatures and reaction times using ethanol as the reaction solvent while other operating conditions are held constant. Biocrude, solid, and gaseous product fractions will be quantified where experimentally feasible. Biocrude yield and energy recovery will be determined for each condition, and the data will be analysed as functions of temperature and reaction time.

Kinetic Analysis of PCF Thermochemical Liquefaction

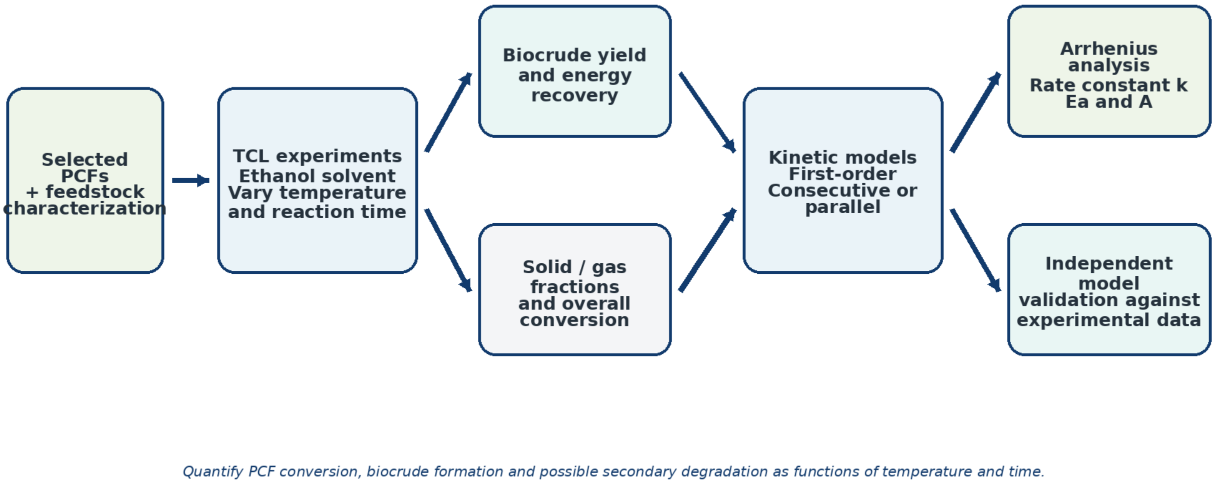

Figure 9. Experimental and modelling workflow for PCF thermochemical-liquefaction kinetics.

Kinetic modelling and validation

Experimental conversion and product-yield data will be fitted using appropriate kinetic models. Simplified first-order or pseudo-first-order models will first be evaluated to describe overall PCF conversion [2, 3]. Where sufficient experimental evidence is available, parallel or consecutive reaction models will be developed to describe PCF conversion, biocrude formation, and secondary biocrude degradation.

The temperature dependence of reaction-rate constants will be evaluated using the Arrhenius relationship to determine apparent activation energies and pre-exponential factors. Model parameters will be estimated through nonlinear regression and evaluated using statistical indicators, residual analysis, and comparison of predicted and experimental values. The best-performing model will be independently validated using conditions not included in model development.

Expected outcomes and scientific significance

The study is expected to establish kinetic parameters describing industrial-PCF conversion during TCL and provide quantitative information on the temperature dependence of conversion and biocrude formation. It will identify whether biocrude formation and degradation can be represented through simplified reaction pathways and determine how feedstock composition influences apparent kinetic behaviour.

The resulting models and parameters could support future reactor modelling, process optimization, and scale-up of TCL systems treating heterogeneous industrial organic residues. The student will gain advanced experience in thermochemical conversion, experimental design, kinetic modelling, nonlinear regression, Arrhenius analysis, and scientific data interpretation.

Keywords: *Solvothermal liquefaction; kinetic modelling; end-of-life waste; circular economy.*

Candidate profile / requirements

- Good academic background in Materials, Chemical or Process Engineering.
- Strong motivation and willingness to learn and improve.

Selected references

1. Guirguis, P.M., et al., "Review and assessment of models for predicting biocrude yields from hydrothermal liquefaction of biomass." RSC Sustainability, 2024, 2(4), 736–756.
2. Mishra, R.K., et al., "Hydrothermal liquefaction of biomass for bio-crude production: A review on feedstocks, chemical compositions, operating parameters, reaction kinetics, techno-economic study, and life cycle assessment." Fuel, 2022, 316, 123377.
3. Kumar, R., "A review on the modelling of hydrothermal liquefaction of biomass and waste feedstocks." Energy Nexus, 2022, 5, 100042.

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BIOMASS VALORIZATION AND SUSTAINABLE CHEMICAL ENGINEERING

Topic 11. Optimization of Feedstock Blends for Biocrude Production from Industrial Post-Compost Fines

Summary of work

The increasing generation of organic waste has intensified the need for sustainable waste-to-energy technologies capable of recovering renewable fuels while supporting circular-economy objectives. Thermochemical liquefaction (TCL) has emerged as a promising technology for converting wet organic residues into energy-dense biocrude [1, 2]. However, the heterogeneous composition of industrial post-compost fines (PCFs), arising from seasonal fluctuations in feedstock characteristics and composting operations, often leads to inconsistent biocrude yield and quality.

Combining PCFs collected at different production periods may produce a more consistent feedstock and potentially generate synergistic effects that improve energy recovery. Mixture design provides a suitable statistical framework because the independent variables are the proportions of the individual feedstocks and their sum is constrained to 100% [5]. This MSc project will investigate whether strategic blending of seven industry-sourced PCF samples collected at different production periods can improve TCL performance compared with the individual feedstocks. The study will combine detailed feedstock characterization, experimental mixture design, TCL experiments, statistical modelling, numerical optimization, and experimental validation.

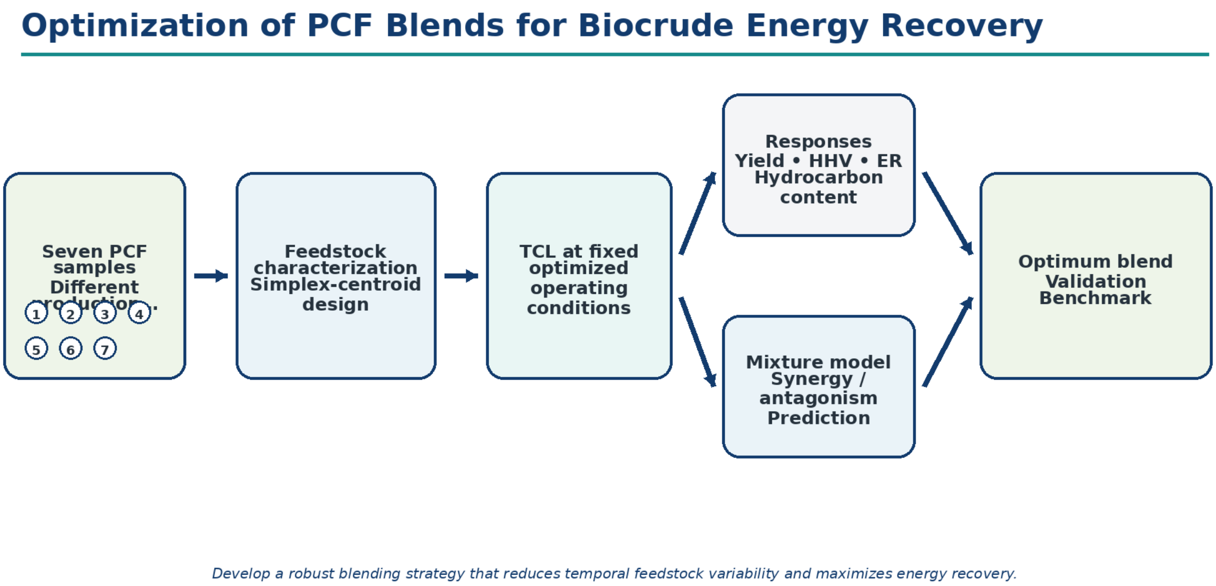

Figure 10. Mixture-design workflow for optimizing PCF blends and biocrude energy recovery.

Aim of the research

The overall aim is to develop and experimentally validate an optimized blending strategy for industrial post-compost fines that maximizes energy recovery during thermochemical liquefaction under previously optimized operating conditions.

Research questions

1. How does the physicochemical composition of industrial PCFs vary between production periods?
2. How does PCF blend composition influence biocrude yield, biocrude quality, higher heating value, and energy recovery?
3. Are there synergistic or antagonistic interactions between PCF samples during TCL?
4. Can mixture-regression models accurately predict TCL performance as a function of feedstock composition?
5. What feedstock blend maximizes energy recovery under the selected TCL conditions?
6. Does the experimentally validated optimum blend outperform the individual PCF samples?

Specific objectives

1. Characterize the physicochemical properties of seven industry-sourced PCFs collected at different production periods.
2. Develop a simplex-centroid mixture design for the seven feedstocks.
3. Evaluate the effect of blend composition on biocrude yield, higher heating value, energy recovery, and hydrocarbon content.
4. Develop predictive mixture-regression models relating blend composition to process performance.
5. Identify synergistic or antagonistic interactions among the feedstocks.
6. Determine and experimentally validate the optimum blend composition.
7. Compare the optimized blend with each individual feedstock to quantify improvements in energy recovery.

Hypothesis

It is hypothesized that strategic blending of industry-sourced PCFs collected at different production periods will significantly influence TCL performance and that an optimized blend will achieve higher biocrude energy recovery than the individual PCF samples processed under identical operating conditions. A secondary hypothesis is that interactions between PCF samples will not be purely additive and that synergistic or antagonistic effects can be identified through mixture-regression modelling.

Expected novelty

This study represents the first application of simplex-centroid mixture design to optimize industrial post-compost fines for thermochemical liquefaction. Unlike previous studies that focused on optimizing process operating conditions, this work addresses feedstock optimization to mitigate seasonal variability, identify interactions among feedstocks, and establish an industrially relevant blending strategy for maximizing renewable-energy recovery. The study will quantify the effect of temporal feedstock variability on TCL performance, develop predictive models linking blend composition with energy recovery, and experimentally validate an optimized PCF blending strategy.

Keywords: *Solvothermal liquefaction; end-of-life waste; circular economy; mixture design; optimization.*

Candidate profile / requirements

- Good academic background in Materials, Chemical or Process Engineering.
- Strong motivation and willingness to learn and improve.

Selected references

1. Okoro, O.V., et al., "The technical, economic, and environmental assessment of solvothermal liquefaction processes: An experimental and simulation study on the influence of solvent Reichardt parameter." 2024, 208, 380–390.
2. Okoro, O.V., S.Z. and B.J., "Thermal depolymerization of biogas digestate as a viable digestate processing and resource-recovery strategy." Advances in Eco-Fuels for a Sustainable Environment, Woodhead Publishing Series in Energy, 277–308.
3. Okoro, O.V., et al., "Unlocking synergies in low-temperature co-liquefaction of food residues for biocrude production: Experimental and simulation insights into food-waste valorisation." Chemical Engineering Research and Design, 2025, 218, 468–480.
4. Ming, H., et al., "Recent Advances of Solvent Effects in Biomass Liquefaction Conversion." Energies, 2024, 17, 2814.
5. Okoro, O.V., et al., "Mapping compositional trends in biocrude from mixed food waste: methodological insights from regression and neural networks." Biomass and Bioenergy, 2026, 210, 109013.

Topic contacts: oseweuba.okoro@ulb.be; armin.shavandi@ulb.be