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Ph.D. DISSERTATION DEFENSE

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Degree:	Doctor of Philosophy
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Date:	Monday, August 25, 2025
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Title:	Flow and Deformation Behavior of Viscoplastic Fluids Analyzed Using Machine Learning Algorithms: Insights from Food and Biomedical Applications
Chairperson:	Dr. Dilhan M. Kalyon, Department of Chemical Engineering and Material Science, School of Engineering and Science
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ABSTRACT

Designing viscoplastic, yield-stress fluids that flow smoothly under applied stress yet form solid-like structures when at rest remains a persistent challenge across fields such as food engineering and biomaterials. This dissertation presents an integrated rheological and data-driven framework that transforms standard laboratory measurements—small-amplitude oscillatory shear and torque data from steady torsional flow—into predictive tools for characterizing shear viscosity and guiding processing across a wide range of chemically diverse systems. Central to this framework is a slip-aware multigap protocol that first extracts the yield stress from torque versus apparent shear rate data, then corrects for wall slip to obtain the true shear rate. This enables accurate determination of both viscosity parameters and wall slip behavior. The corrected rheological data are then used to train an interpretable machine learning surrogate model that connects any imposed shear history—steady, oscillatory, or mixed—with the resulting flow and deformation states of the viscoplastic fluid. The differentiable nature of the surrogate allows for inverse design: target properties such as texture, viscosity, or elastic modulus can be directly mapped to processing parameters like flow rate, strain amplitude, and time.

The framework is applied to two case studies. For a commercial ketchup—a canonical viscoplastic food—the model reveals how routine unit operations (e.g., pumping, recirculation, acoustic mixing) alter rheological properties and processability. For a crosslinkable hydrogel used as a lung sealant, the model predicts both the shear viscosity during application and the viscoelastic behavior post-placement. In both cases, the surrogate provides uncertainty estimates that highlight poorly characterized regions and direct further experimentation for maximum information gain. By combining physics-based slip corrections with data-driven surrogates, this work advances rheological characterization into a predictive, bidirectional design tool suitable for closed-loop control of the manufacturing and functional performance of complex fluids.