23-271SB: Thermo-rheological behavior of biopolymer and biopolymer blends
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Objective:
Develop a comprehensive understanding of the thermo-rheological behavior of biopolymers and their blends for nonwoven applications by evaluating rheological behavior, degradation kinetics, phase separation, and thermal properties of PLA-PBS and PLA-PHA blends and correlating these fundamental parameters to fiber spinnability and mechanical properties of spun fibers.

Background:
Biopolymers, particularly polylactic acid (PLA), polybutylene succinate (PBS), and polyhydroxyalkanoates (PHA), have gained significant attention in fiber-spinning applications due to their biodegradability and renewability. PLA is known for its high tensile strength and ease of processing but suffers from brittleness and low heat resistance. Thus, blending PLA with other biopolymers like PBS and PHA aims to overcome these limitations while maintaining biodegradability. From this literature survey, it is seen that PLA-PBS blends showed improved ductility and thermal stability compared to neat PLA. Implementing such blends for nonwoven applications is hindered by limited knowledge regarding the thermal, rheological, and phase separation behavior of the blends used for fiber spinning. Hence, it is important to evaluate the rheological behavior and thermal characteristics of the blends.

Problem Statement and Approach:
- Evaluate the rheological behavior of biopolymer and their blends using steady-state shear and small amplitude oscillatory shear (SAOS) experiments
- Investigate the effect of biopolymer blend degradation kinetics on the rheological properties, identify the processing window for extrusion, and examine the phase separation tendency of biopolymer blends using a Scanning Electron microscope (SEM)
- Characterize thermal properties such as glass transition temperature, crystallization rate, and melting range of blends and compare the mechanical properties of biopolymer blends with conventional petroleum-based polypropylene (PP)

Status:
Key learnings from the literature:
- There are two main methods for preparing PLA blends: melt blending using single or twin-screw compounders, and solution blending. Melt blending is more advantageous because it is affordable and can be processed using commonly available technologies on an industrial and laboratory scale
- The current state of research has found that PLA blends with polypropylene (PP) and polystyrene (PS) exhibit shear-thinning behavior due to the alignment of polymer chain segments during melt flow, making them suitable for both extrusion and injection processes
- Also, in other studies, it was shown that PBS can be mixed with PLA in the ratio of 20/80 while maintaining miscibility, and beyond 20 wt.%, phase separation occurs in the blend
- In literature, it was seen that large amplitude oscillatory shear (LAOS) response is a useful tool for determining the phase separation of polymer blends. The LAOS response can reveal if the blend is highly phase-separated
- Developing biobased polymer blends with increased mechanical properties has been documented significantly in patent literature by describing blends of PBS and PHAs that allow for faster biodegradation rates and an improved elongation percentage
- Patents demonstrate a high interest in developing compatible biopolymer blends, most of which use rheological techniques to identify key processing variables

- **Key Issues**:
- To measure the fundamental melt properties of PLA, PHAs, and PBS due to breakdown when exposed to high temperatures and moisture via thermolysis and hydrolysis
- Documentation on relaxation time, degradation profile over time, and relevant processing window is not available
- Understanding phase separation of blends to optimize the processing conditions for nonwoven applications

Next Steps:
- Determine blend ratios of interest and develop biopolymer blends using single-screw or double-screw compounders
- Characterize rheological properties of blends using rotational rheometers and small amplitude oscillatory shear (SAOS) experiments
- Investigate hydrolytic and thermal degradation effects on rheological properties of PLA blends using SOAS experiments