Thesis Portfolio

INVESTIGATION INTO POLYHYDROXYBUTYRATE AND BACTERIAL NANOCELLULOSE COMPOSITES FOR SINGLE-USE PAPER PACKAGING

(Technical Report)

A MULTI LEVEL PERSPECTIVE ASSESSING ALTERNATIVE CELLULOSE ADDITIVES IN PAPER PACKAGING

(STS Research Paper)

An Undergraduate Thesis

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Table of Contents

Sociotechnical Synthesis

With climate change looming, the technological transition to sustainable materials hinges on investigating deployable biomaterial solutions. Additionally, understanding the critical pathway for adoption of these sustainable technological solutions by industrial manufacturers is key as it targets the source of production instead of relying on changes to consumer tendencies. The technical component leverages existing biomaterials to create paper packaging additives aligned with industrial manufacturing infrastructure to yield increased sustainability for manufacturing and disposal outcomes. Specifically, the technical project examines the addition of two types of biomaterials: Bacterial Nanocellulose (BNC) and Polyhydroxybutyrate (PHB) to improve paper packaging performance. Established through literature review, BNC demonstrates the ability to increase tensile strength, smoothness, and the mechanical performance of paper even when added in small quantities to the fiber furnish (Arévalo et al, 2016). One of the limiting factors for the amount of recycled fiber from post consumer waste that can be added to paper packaging is the reduced mechanical performance due to the lower quality of recycled fiber. The technical project aims to increase the post-consumer waste fiber content by supplementing the fiber blend with BNC to maintain mechanical performance standards compared with lower post-consumer waste fiber. Metrics of success will be determined specifically by maximum tensile test strength performance. BNC will be sourced from the byproduct of Kombucha, a popular functional health beverage, as a potential under utilized waste stream.

PHB is a bacterial intermediary metabolite polymer that can be used as a single-use petroplastic replacement. Similar to petroplastics, coatings of PHB applied to paper blends improve functional barrier properties like hydrophobicity. Water absorption and retention by paper packaging leads to weakened mechanical performance and literature has shown that BNC increases water absorbance (Ondaral et al, 2015). As a hydrophobic polymer PHB coatings applied to sample sheets containing BNC measure water repellency via the wetting angle. Coated paper packaging is difficult to recover usable fibers and polymers from and are usually landfilled as a result. The biodegradability of PHB creates an opportunity to apply coatings to paper packaging while reducing petroplastic environmental escape and proliferation.

While working with lab scale technologies in the technical project the sociotechnical research portion evaluates paper packaging innovations that have progressed from lab scale to industrialization. Using two case

studies of technologies developed in the EU, the examination of plant derived micro fibrillated cellulose (MFC) and sustainably sourced switchgrass (Creapaper) fibers' pathway to industrialization offer a logical extension for challenges faced in market adoption after proof of concept is validated on the technical front. Specifically, MFC is very similar in fiber performance as BNC but is derived from a different origin. Evaluating the support structures for the development and industrialization of sustainable paper packaging additives is achieved by using a multi level perspective (MLP) lens supplemented by technological and market readiness level (TRL and MRL) analysis which could prove instrumental to de risking and understanding the pathway for the successful industrial integration of BNC fiber additives and PHB coatings into paper packaging.