SUSTAINPOLY: Fermentation-Engineered Hydrogel-Based Biopolymers for Agro-Industrial Waste Upcycling and Sustainable Agriculture

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Brazil accounts for 70% of global passion fruit production (736,000 tons per year). However, 75% of this production becomes waste. Due to inadequate management, this waste can generate significant environmental impacts. Meanwhile, Brazilian agriculture relies on more than 900,000 tons of pesticides and over 650,000 tons of synthetic polymers each year. These inputs are used to address pest pressure, weed infestations, water scarcity, and post-harvest losses. This project explores a different approach: it converts passion fruit waste into a multifunctional biodegradable compound capable of replacing multiple synthetic agricultural inputs. A semi-solid hydrogel derived from the mesocarp was co-fermented with epicarp extract using Acetobacter aceti. This process formed a network of nanoexopolysaccharides (nEPS) and polymeric bands (PB) as a secondary fraction. A 2^2 factorial design was used to optimize formulations based on physicochemical and morphological properties. The optimized formulation produced hydrophilic nEPS (contact angle < 90°), maintained soil moisture for 21 days and achieved 87% weed suppression. PB-derived films showed > 99% pest repellency against D. melanogaster, C. capitata, and Atta spp., without toxicity to Apis mellifera. They also reduced post-harvest fruit weight loss by 64%. Production costs were US$0.032 for nEPS and US$0.013 for PB (per 200 g). All films exhibited biodegradation rates above 98% within two months. Environmental modeling estimated reductions of 120–180 kg of plastic/ha and 0.45–0.62 t CO_2 e/ha per cycle when using these biopolymers. These results indicate that biocomposites may be viable replacements for synthetic inputs used in agriculture with environmental, social, and economic benefits.

Awards Won:

Fourth Award of $600

Sigma Xi, The Scientific Research Honor Society: First Life Science Award of $1,200