Cost-Effective Fabrication of Biodegradable Paper Towels from Food-Waste Derived Cellulose and Pectin Crosslinked with Ca2+: A Novel Biopolymer Composite Strategy for Enhancing Wet Strength and Absorbency

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The pulp and paper industry drives massive deforestation and CO2 emissions, while 1.3 billion tonnes of biopolymer-rich food waste are discarded annually, representing a vast, untapped resource for sustainable materials. This research engineers the first food-waste-derived cellulose into a biodegradable absorbent sheet reinforced by Ca2+-crosslinked pectin networks to match commercial paper towel performance. Food scraps were oven-dried, pulverized, and subjected to sequential acid, base, and bleaching treatments to isolate cellulose-rich fibers, blended with pectin, cast into sheets, and crosslinked using calcium chloride, whose Ca2+ ions form ionic junction zones with pectin carboxylate groups that stabilize the network during hydration. Absorption was modeled using Washburn capillary flow dynamics and pseudo-first-order saturation kinetics. Multivariable response surface modeling and Pareto optimization identified optimal formulations within ~30-60 gsm and 15-25% binder loading, corresponding to effective pore radii of ~20-30 μm and a 20-40% reduction in absorbency rate in exchange for a 2-3x increase in strength. Introducing Ca2+ crosslinks increased wet tensile strength by 75-90% (0.19 to 0.34 N) relative to uncrosslinked sheets. Pareto analysis confirmed formulations achieving both high absorbency (5-6 mL per 5×5 cm sheet) and robust wet strength (0.19-0.34 N). At scale, prototypes cost $2.98 per 100 sheets, below sustainable alternatives such as Who Gives A Crap (˜$3.40 per 100 sheets). These results demonstrate that mixed food-waste biomass can be transformed into durable, cost-competitive biodegradable paper towels using non-toxic, scalable processes compatible with paper production, and a scalable platform for wipes, packaging, and absorbent mats.

Awards Won:
First Award of $6,000