Scalable and Sustainable Synthesis of a Novel, Bio-Based Polyurethane Foam System Incorporating Industrial Byproducts and Waste

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Polyurethane foam, a material valued across countless industries for its high performance and versatility, is composed of hazardous, nonrenewable petrochemicals that continuously off-gas into the atmosphere, threatening the environment. These chemicals are synthesized using complex, inefficient methods that involve excessive reagents and costly energy expenditures. In response, two novel biochemicals were developed for sustainable polyurethane foam: a biopolyol was synthesized through cellulose liquefaction, and Wohl-Ziegler bromination of triglycerides and subsequent isocyanate group substitution yielded a bio-isocyanate. Scalability and sustainability were promoted throughout synthesis by chemical recovery and regeneration, minimal reagent use and loss, and incorporation of prolific industrial byproducts and waste. Substantiated by metrics of green chemistry, synthesis routes and chemical compositions were found to be highly economically efficient (Avg Atom Econ: 84.25%; Avg Rxn Eff: 126.35%). Developed biochemicals were then tested with each other and with corresponding petrochemicals to synthesize three partially or fully bio-based polyurethane foam systems. Material performance was measured for each foam: two of three, including the fully bio-based system, performed similarly to standard foam ($p = 0.59$; $p = 0.14$), suggesting high functionality. Environmental safety was also measured: all three bio-foams exhibited superior safety characteristics when compared to standard foam (ALL: $p < 0.001$). Of all samples developed, the fully bio-based polyurethane foam system demonstrated optimal properties; this rigid, non-emitting material may best be applied in construction, boasting the world’s first scalable, sustainable polyurethane foam synthesis method and composition.

Awards Won:
United States Environmental Protection Agency: The Patrick Hurd Sustainability Award winner will travel to EPA's National Sustainable Design Expo
NC State College of Engineering: Award to attend NC State Engineering Summer Camp