Use of Fast Pyrolysis Bio-Oils in Synthesis of Polyurethane Foams

Alok G. Shenoy (alok.shenoy@aggiemail.usu.edu) and Dr. Foster A. Agblevor (foster.agblevor@usu.edu)
Utah State University, Logan, Utah.
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Abstract

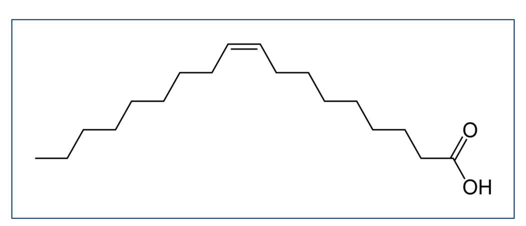
Fast pyrolysis of biomass under various conditions produce bio-oils with varying contents of sugars (eg. Levoglucosan). We present a method to synthesize poly-urethane foams (PUF's) using fast pyrolysis bio-oils.
By varying the amount of water and the surfactant used in the reaction mixture, the quality of the foam obtained differs in terms of density and compressibility. We present preliminary results obtained through our experiments herein.

Background

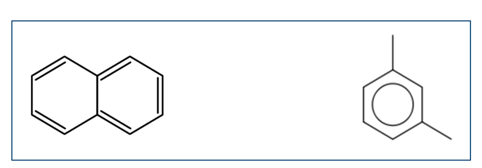
Fast pyrolysis of biomass results in three main products:
- **Syngas** (a mixture of Carbon monoxide and Hydrogen)
- **Bio-oil** (a liquid phase rich in organics – sugars and aromatics)
- **Bio-char** (a charcoal encapsulate containing various salts)

These products can be upgraded or processed to generate more consumer friendly products like **gasoline** (from bio-oil), **fertilizer pellets** (from bio-char).

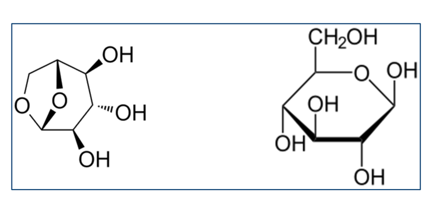
The bio-oil obtained from fast pyrolysis contains various organic molecules ranging from long chain alkanes to polycylic aromatics and sugars, some of which are shown in Figure 1. The concentration of these products vary depending on the pyrolysis conditions.



Fatty Acids



Aromatic Hydrocarbons



Sugars

Figure 1. Some of the molecules identified in fast pyrolysis bio-oils.

The bio-oils obtained can be used as raw materials for synthesis of polymers like polyurethane foams (Figure 2) due to the high hydroxyl values provided by the sugars.

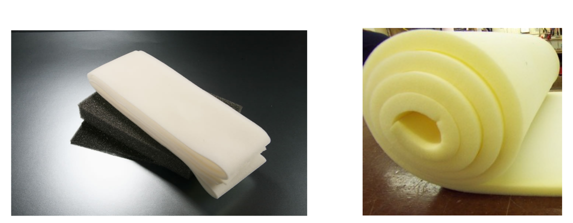


Figure 2. Polyurethane foams are manufactured in various shapes with varying levels of compressibility and density.

Materials & Methods

Polyurethane foams are synthesized by reacting organic units carrying hydroxyl groups with isocyanates to produce carbamate linked chains (Figure 3). The reaction also involves several other components like blowing agents and chain extenders that effect the quality of the foam synthesized. We seek to identify the effects of the quantity of blowing agent and surfactant used on the compressibility of the foams produced. To this effect we have carried out experiments varying the quantity of these agents to qualitatively identify the effect on the polyurethane foam produced using fast pyrolysis bio-oils.

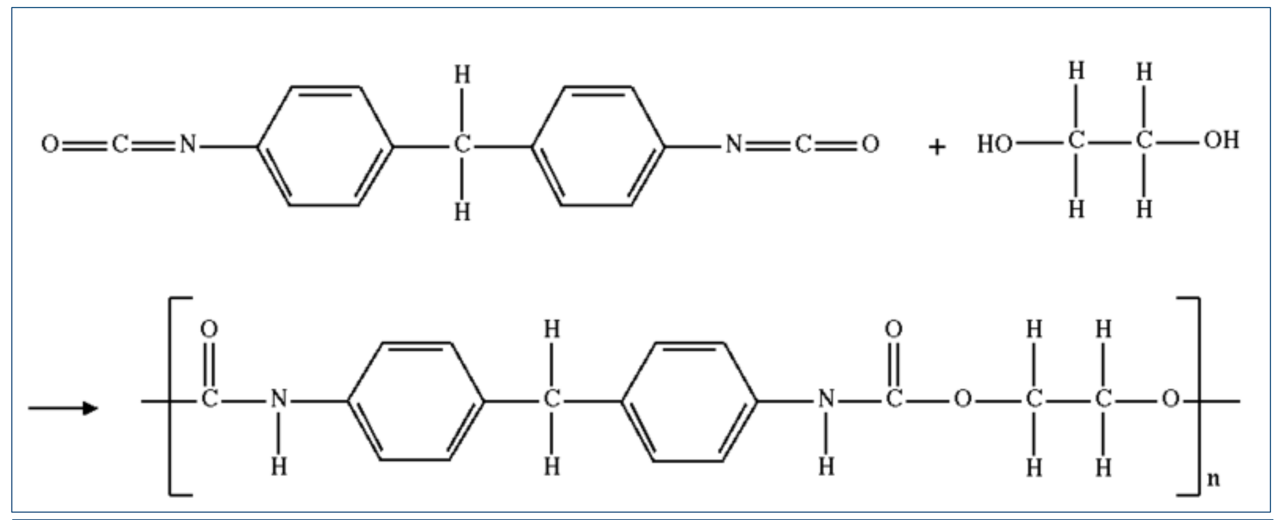


Figure 3. Schematic representation of reaction between polyol and diisocyanate.

The reaction mixture consists of several components which affect the quality of the foam produced.

Polyol: Bio-oil (1.0 eq)
Isocyanate: Toluene diisocyanate (TDI) (1.6 eq)
Extender: Polyethylene glycol 400 (PEG 400) (0.6 eq)
Surfactant: Polyether modified polysiloxanes
Blowing Agent: Water
Catalyst: Stannous 2-ethyl hexanoate (0.005 eq)

The bio-oil (source of the sugar levoglucosan) is mixed with the extender, PEG 400, and the surfactant, polysiloxanes, until a uniform phase is obtained. The catalyst is then mixed in along with required amount of water. Finally, TDI is added and the reaction mixture stirred at 1200 rpm for up to 30 seconds. The reaction vessel is set aside to allow the foam to rise and left overnight to harden. This foam is then cured in an oven at temperatures ranging from 80ºC to 100ºC.

Results

Role of polysiloxanes as surfactant: The surfactant stabilizes the windows formed during the foaming process. This helps in reducing the density of the foam. Increasing amounts of surfactant did not significantly affect the density of the foams, Figure 5, but consistently produced brittle/hard foams with low compressibility.

Figure 5. Increasing amounts of surfactant do not affect the quality of foam, but consistently produce brittle foams.

Role of water as the blowing agent: The density of the foam decreases as amount of water increases, as shown in Figure 6. Increasing amount of water also increases compressibility of the foam.

Figure 6. Foams produced using bio-oil with constant quantity of surfactant and increasing amounts of water, from left to right.

Results

Having identified the effects of the concentration of both surfactant and blowing agent individually, we chose to use a factorial design to identify the optimal conditions for soft bio-foams. It was seen that a high concentrations of blowing agent (up to 1.3 eq) and high concentrations of surfactant (up to 0.7 eq) resulted in soft bio-foams with low density and high compressibility.

Figure 7. Foams produced using 1.3 eq of blowing agent and 0.7 eq of surfactants result in foams with low density and higher compressibility.

Conclusions

- Bio-oils with high sugar content can be used to synthesize polyurethane foams.
- The compressibility of the foam produced depends on the quantity of surfactant and blowing agent present in the reaction mixture.
  - High levels of surfactants result in brittle but low density foams.
  - High levels of blowing agent result in low density soft foams.
  - High concentrations of both surfactant and blowing agent result in foams with higher compressibility.

References

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2. Yan, Y., Pang, H., Yang, X., Zhang, R. and Liao, B. (2008), Preparation and characterization of water-blown polyurethane foams from liquefied cornstalk polyol. J. Appl. Polym. Sci., 110: 1099–1111.

Acknowledgements

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