Expanded Polyurethane Foams and Waterborne-Polyurethanes from Vegetable Oils

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Abstract : Nowadays, the growing environmental awareness and the dwindling of fossil resources stimulate the polyurethane (PU) industry towards renewable polymers with low carbon footprint to replace the feed stocks from petroleum sources. The main challenge in this field consists in replacing high-performance products from fossil-fuel with novel synthetic polymers derived from 'green monomers'. The bio-polyols from plant oils have attracted significant industrial interest and major attention in scientific research due to their availability and biodegradability. Triglycerides rich in unsaturated fatty acids, such as soybean oil (SBO) and linseed oil (ELO), are particularly interesting because their structures and functionalities are tunable by chemical modification in order to obtain polymeric materials with expected final properties. Unfortunately, their use is still limited for processing or performance problems because a high functionality, as well as OH number of the polyols will result in an increase in cross-linking densities of the resulting PUs. The main aim of this study is to evaluate soy and linseed-based polyols as precursors to prepare prepolymers for the production of polyurethane foams (PUFs) or waterborne-polyurethanes (WPU) used as coatings. An effective reaction route is employed for its simplicity and economic impact. Indeed, bio-polyols were synthesized by a two-step method: epoxidation of the double bonds in vegetable oils and solvent-free ring-opening reaction of the oxirane with organic acids. No organic solvents have been used. Acids with different moieties (aliphatic or aromatics) and different length of hydrocarbon backbones can be used to customize polyols with different functionalities. The ring-opening reaction requires a fine tuning of the experimental conditions (time, temperature, molar ratio of carboxylic acid and epoxy group) to control the acidity value of end-product as well as the amount of residual starting materials. Besides, a Lewis base catalyst is used to favor the ring opening reaction of internal epoxy groups of the epoxidized oil and minimize the formation of cross-linked structures in order to achieve less viscous and more processable polyols with narrower polydispersity indices (molecular weight lower than 2000 g/mol^{-1}). The functionality of optimized polyols is tuned from 2 to 4 per molecule. The obtained polyols are characterized by means of GPC, NMR (^{1}H, ^{13}C) and FT-IR spectroscopy to evaluate molecular masses, molecular mass distributions, microstructures and linkage pathways. Several polyurethane foams have been prepared by prepolymer method blending conventional synthetic polyols with new bio-polyols from soybean and linseed oils without using organic solvents. The compatibility of such bio-polyols with commercial polyols and diisocyanates is demonstrated. The influence of the bio-polyols on the foam morphology (cellular structure, interconnectivity), density, mechanical and thermal properties has been studied. Moreover, bio-based WPUs have been synthesized by well-established processing technology. In this synthesis, a portion of commercial polyols is substituted by the new bio-polyols and the properties of the coatings on leather substrates have been evaluated to determine coating hardness, abrasion resistance, impact resistance, gloss, chemical resistance, flammability, durability, and adhesive strength.

Keywords : bio-polyols, polyurethane foams, solvent free synthesis, waterborne-polyurethanes
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