Lignin Yield Maximization of Lignocellulosic Biomass by Taguchi Robust Product Design using Organosolv Fractionation

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Abstract

Lignin, a byproduct of the organosolv fractionation process using lignocellulosic biomass from switchgrass (*Panicum virgatum*) and tulip poplar (*Liriodendron tulipifera*) is currently being explored for its potential use in the production of value-added chemicals and biobased polymers. Pretreatment is one of the most expensive processing steps in cellulosic biomass conversion. Optimization of the process is one of the major goals of the biomass-to-ethanol conversion process. Taguchi Robust Product Design (TRPD) provides an effective engineering experimental design method for optimizing a system and designing products that are robust to process variations. Given the results of several preliminary studies of the organosolv fractionation process, four controllable design factors (inner array) were used in the TRPD: process temperature (120°C, 140°C, 160°C), fractionation time (56 minutes, 90 minutes), sulfuric acid concentration (0.025 M, 0.05 M, 0.1 M), and feedstock ratio (switchgrass/tulip poplar ratios of 10%/90%, 50%/50%, 90%/10%, based on both mass and volume of feedstock). Process noise was induced in the experiment by using either the mass-based or volume-based feedstock charges of switchgrass and tulip poplar. A maximum mean lignin yield of 78.63 wt% was found in the study. Optimum conditions for maximum lignin yield were found at a 90 minute runtime, 160°C process temperature, 0.1 M sulfuric acid concentration, and a feedstock composition of 90% switchgrass and 10% tulip poplar. The most statistically significant factor influencing lignin yield was process temperature. There was statistical evidence that lignin yield increased after 120°C for both feedstock charges of switchgrass and tulip poplar (p-value < 0.0001 for mass based, p-value < 0.0001 for volume-based). The variance in lignin yield declined as the proportion of switchgrass increased (p-value = 0.0346 for mass-based and p-value = 0.0678 for volume-based). The finding of a local maximum for lignin yield for process temperature at 160°C suggests that high processing temperatures are required to receive high lignin yields. The finding that the variance in lignin yield declined as the switchgrass percentage of feedstock increased may provide a pathway for other researchers interested in maximizing switchgrass use in the pretreatment process.