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Waste Textiles Bioprocessing to Ethanol and Biogas

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Abstract

In the world today, the need for sustainable processes is increasing. The work of the present thesis has been focused on conversion of the cellulosic part of waste textiles into biogas and ethanol, and its challenges. In 2009, the global annual fiber consumption exceeded 70 Mt, of which around 40% consisted of cellulosic material. This huge amount of fibers is processed into apparel, home textiles, and industrial products, ending up as waste after a certain time delay. Regretfully, current management of waste textiles mainly comprises incineration and landfilling, in spite of the potential of cellulosic material being used in the production of different biofuels. The volume of cellulose mentioned above would be sufficient for producing around 20 billion liters of ethanol or 11.6 billion Nm^3 of methane per year. Nevertheless, waste textiles are not yet accepted as a suitable substrate for biofuel production, since their processing to biofuel presents certain difficulties and challenges, e.g. high crystallinity of cotton cellulose, presence of dyes, reagents and other materials, and being textiles as a mixture of natural and synthetic fibers. High crystallinity of cotton cellulose curbs high efficient conversion by enzymatic or bacterial hydrolysis, and the presence of non-cellulosic fibers may create several processing problems. The work of the present thesis centered on these challenges.

Cotton linter and blue jeans waste textiles, all practically pure cellulose, were converted to ethanol by SSSF, using *S. cerevisiae*, with a yield of about 0.14 g ethanol/g textile, only 25% of the theoretical yield. To improve the yield, a pretreatment process was required and thus, several methods were examined. Alkaline pretreatments significantly improved the yield of hydrolysis and subsequent ethanol production, the most effective condition being treatment with a 12% NaOH-solution at 0 °C, increasing the yield to 0.48 g ethanol/g textile (85% of the theoretical yield).

Waste textile streams, however, are mixtures of different fibers, and a separation of the cellulosic fibers from synthetic fibers is thus necessary. The separation was not achieved using an alkaline pretreatment, and hence another approach was investigated; pretreatment with N-methyl-morpholine-N-oxide (NMMO), an industrially available and environment friendly cellulose solvent. The dissolution process was performed under different conditions in terms of solvent concentration, temperature, and duration. Pretreatment with 85% NMMO at 120 °C under atmospheric pressure for 2.5 hours, improved the ethanol yield by 150%, compared to the yield of untreated cellulose. This pretreatment proved to be of major advantage, as it provided a method for dissolving and then recovering the cellulose. Using this method as a foundation, a novel process was developed, refined and verified, by testing polyester/cellulose-blended textiles, which predominate waste textiles. The polyesters were purified as fibers after the NMMO treatments, and up to 95% of the cellulose content was regenerated. The solvent was then recovered, recycled, and reused. Furthermore, investigating the effect of this treatment on anaerobic digestion of cellulose disclosed a remarkable enhancement of the microbial solubilization; the rate in pretreated textiles was twice the rate in untreated material. The process developed in the present thesis is promising for transformation of waste textiles into a suitable substrate, to subsequently be used for biological conversion to ethanol and biogas.