Scale-up and Economic Assessment of a Split-Phase Glycolysis process for the Recycling of Flexible Polyurethane Foams Wastes

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INTRODUCTION

Polyurethane (PU) occupies the sixth position of the most used plastics in the world (Tessier S., Fleury M., et al., 2014). Due to its multitude of applications, it generates a large amount of waste whose deposits in landfills causes an environmental problem. The chemical recycling of PU would help to solve this problem, changing their life cycle to a more circular one. This research aims to scale-up a glycolysis process previously developed at lab scale up to pilot plant, demonstrating its further technical feasibility at industrial scale. Furthermore, it is intended to demonstrate its economic viability and profitability.

MATERIALS AND METHODS

The raw materials used in this study were industrial samples of flexible PU foam based on polyether polyol with a molecular weight of 3500 g/mol, crude glycerol with a purity of 80% as glycolysis agent and stannous octoate as catalyst. The glycolysis process reactions at lab and pilot plant scales are carried out in a jacketed tank reactor with stirring rate and temperature control, to keep it at 190°C, of 1 and 10 litters of volume, respectively. Further, had also a condenser with flowing cold water to avoid vapors scape and a nitrogen inlet to ensure an inert atmosphere. Foam waste scraps are fed by means of an Archimedean screw from a closed hopper. The product obtained is separated by decantation and both phases are analyzed by GPC and FTIR and employed as replacement of pure polyol in the synthesis of new polyurethane foams. On other hand, the NPV, IRR and payback period are estimated to analyze the profitability of the split-phase glycolysis process.

RESULTS AND DISCUSSION

Experimental setup scale-up

In order to achieve a proper scaled-up of the glycolysis process, it is necessary to take into shape factors requirements in the tank reactor, agitator dimensions, required agitator head power and rotational speed. The impeller size and pilot plant reactor dimensions are obtained keeping constant the shape factors from the lab scale to the pilot plant to preserve the geometrical similarity (Brodkey RS. and Hershey HC., 1988). Another crucial task is to determine the impeller power and rotational speed at pilot plant scale.

Glycolysis process at pilot plant scale

To confirm the suitability of the selected criteria for the scale-up process, the glycolysis process experiment is carried out at pilot plant scale at the same conditions than at lab scale (Simon, D., Borreguero A.M., et al., 2015). These conditions are 190ºC, inert atmosphere, crude glycerol to PU foam waste ratio of 1:1.5 and a catalyst concentration of 1.3wt%. As expected, a split phase product is obtained. Both phases are analyzed by GPC and FTIR demonstrating the process success, since the upper phase consists mainly of recovered polyol (approximately a 75%) and the bottom phase mainly of the glycolysis agent excess (9.5%) and the reaction by-products (90%). The upper phase is washed with pure water increasing the recovered polyol purity up to a 92%. Thus, it can be concluded that the split-phase glycolysis is technically feasible at larger scales. It is also possible to use the recovered polyol for the synthesis of new polyurethane foams.

Economic assessment of the split-phase glycolysis plant

Once confirmed the success in the scaling-up of the process, the design and the economic assessment of a split-phase glycolysis industrial plant are carried out. With the aim of determining the capacity of the glycolysis industrial plant it is necessary to know the wastes generated in our country. The design of the plant is carried out for the treatment of 270 Tm per year, which represents 1% of the waste generated in Spain.

Next, to find out if the process is economically profitable, firstly it is necessary to determine the investment required (fixed and working capitals investment). The fixed capital investment is estimated by means of the percentage's method based on the total cost of the equipment's (799,558€) and the working capital includes the raw materials stock, the products stock, the spare parts warehouse, and cash to attend to payments (84,396€) (Reference). Further, it is necessary carried out the estimation of the annual sales (773,506€) and annual costs (403,047€), which include the raw materials, the direct operating labor, the auxiliary services, the directive management, the maintenance, the taxes, the insurances and the commercial costs (Cabra L., de Lucas A., et al., 2010).

The cash flow analysis demonstrates the project economic viability, since it is obtained a NPV of 2,831,313 with an IRR of 28.63%, and a payback time between 4 and 5 years. The cash flow is calculated considering CPI average annual increase of 1.16%, a time horizon of 15 years, a linear amortization in 10 years and a tax rate of 30%. These parameters are very conservative, and the profitability could be even higher. Besides, even in the scenario of +20% investment, it would continue being economically profitable.

CONCLUSION

The scaled-up feasibility of the split-phase glycolysis process is confirmed by means of designing a pilot plant installation similar geometrically to that used for lab scale for a production 10 times higher than the lab scale one; obtaining analogous results in terms of recovered polyol properties Moreover, it is demonstrated the economic viability of a split-phase glycolysis industrial plant with a capacity for treating 270 Tm per year of flexible PU foams wastes.

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