Biowaste as substrate for biosolvents production focusing on lactic acid and ethyl lactate

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Introduction

Solvents represent a major category of chemicals due to their necessity in a variety of industries. Nevertheless, the majority of solvents that derive from fossil carbons are hazardous to both human health and the environment. At the same time, the European Commission is trying to adapt to a circular economy. Therefore, the industry will be forced to use closed resource loops in the future to limit waste and diminish the environmental effect of their processes. The optimum approach shall include the conversion of biomass into new alternative greener solvents, which would replace the volatile and toxic to human and the environment conventional solvents. Due to the high biodegradability and the lower release of volatile organic compounds (VOCs) during the production of 'green' solvents, more and more researchers emphasize on this topic. These properties provide a lower disposal cost, a safer working environment and promote greener habits to the consumers. Bio – based solvents are generated from starchy and lignocellulosic crops via novel technologies and processes. The present study concentrates on the production of two biosolvents; namely lactic acid and ethyl-lactate from biowaste derived from food industry.

Biosolvents production

Lactic acid production

Lactic acid is traditionally produced from glucose, lactose, dairy plant wastes, starch, molasses and glycerol from biodiesel industry. Therefore, the substrate for biosolvents production was biowaste derived from baby food production industry. The raw material was characterized to determine its composition. The starch content was **39.2 %** of dry matter, while lactose was **19.1 %** of dry matter.

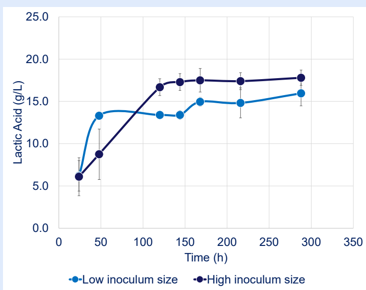


Figure 1. Effect of inoculum size on lactic acid production.

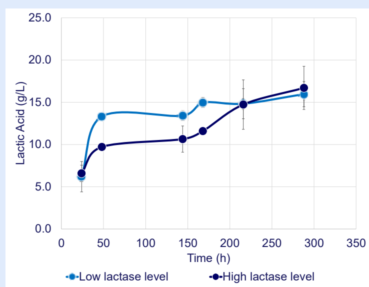
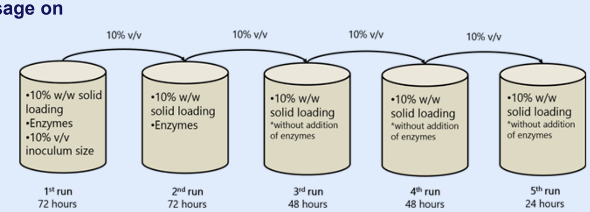


Figure 2. Effect of lactase dosage on lactic acid production.

A mixture of Lactic Acid Bacteria (LAB) was grown on Man-Rogosa-Sharp medium at 35℃, 130 rpm for 24h and was utilized for anaerobic fermentation. LABs can only consume the fermentable sugars directly; therefore, two enzymes were used in order to accelerate the process, Spirizyme Excel XHS and Lactozyme Pure from Novozymes.

In this study, the dosages of Lactozyme Pure enzyme (5 mg/gLactose and 20 mg/gLactose) and inoculum size (5% v/v and 10% v/v) were examined, while the solid loading (10% w/w), the dosage of Spirizyme Excel XHS (40 μL/gstarch) and the temperature (35℃) remained stable. After several tests and after collecting samples at regular intervals, it was found that the maximum lactic acid concentration reached almost **17.3g/L** after 144 hours with 5mg LactozymePure/glactose and 10%v/v inoculum size, corresponding to **0.12 g/L** h productivity of lactic acid.

In an effort to increase the productivity of lactic acid, repeated fermentation was applied examining the addition of enzymes. After **5 runs**, and by adding enzymes only in the first two runs, lactic acid productivity reached **0.97 g/L·h**, which is 8 times higher than the respective value achieved with conventional batch lactic acid fermentation.



Ethyl – lactate production

On the other hand, esters of natural organic acids can be produced by fermentation of carbohydrates. In particular, ethyl lactate is an environmentally benign solvent, which could substitute petrol-based VOCs in many applications. From a chemical point of view, ethyl lactate is an ester produced by the esterification of lactic acid with ethanol – two important chemical building blocks of biorefineries that are available at industrial scale.

Lactic acid + Ethanol ↔ Ethyl- lactate + Water

For ethyl lactate production, purified bioethanol (99% v/v and 89% v/v) produced from the biowaste stream was used, along with commercial lactic acid (80% w/w and 88% w/w). The reactants in molar ratio $n_{Ethanol}$ / $n_{LacricAcid}$ = 3, along with the addition of Amberlyst 15 as catalyst at a weight fraction of w_{cat} = 0.1 were mixed and heated at 100℃.

Ethyl-lactate production by bioethanol and commercial lactic acid was achieved, with the maximum lactic acid conversion **59.9%** at 255 min. Comparable values (**57.5%**) were achieved at 180 min. The water content in the reaction mixture strongly influenced the esterification reaction. Thus, the higher the grade of reactants, the higher the lactic acid conversion.

Conclusions

Overall, the production of lactic acid and ethyl-lactate from biowaste provides a sustainable approach to the circular economy, limiting waste and minimizing the environmental effect of industrial processes.

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