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

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Solvents represent a major category of chemicals due to their necessity in a variety of industries: dissolution, dilution and removal other chemicals without generating chemical changes. The majority of solvents derived from fossil carbons are hazardous to both human health and the environment. At the same time, the European Commission tends 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 consists of converting the 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, more and more researchers emphasize on this topic (Wu et al., 2019). These properties provide a lower disposal cost, a safer working environment and promote greener habits to the consumers (Yang et al., 2012).

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. The substrate for biosolvents production was biowaste derived from food industry. The raw material was characterized and the results are presented in the following Table 1.

Table 1. Composition of biowaste stream of a food industry.

Parameter	Value (% d.b.)
Total Solids	99.2 ± 0.4
Moisture	0.8 ± 0.4
Volatile Solids	96.1 ± 0.0
Ash	3.9 ± 0.0
Oils	2.5 ± 0.1
Water-Soluble Solids	36.2 ± 1.0
Starch	39.8 ± 0.2
Insoluble Acid Residue	7.5 ± 0.4
Lactose	19.1 ± 2.3
Free Glucose	1.1 ± 0.1

Lactic acid is traditionally produced from glucose, lactose, dairy plant wastes, starch, molasses and glycerol from biodiesel industry (Ma et al., 2021). A mixture of Lactic Acid Bacteria (LAB), including hetero-fermentative lactobacillus strains, was grew in Man-Rogosa-Sharp medium at 35℃, 130 rpm for 24h and was utilized for anaerobic fermentation, where carbohydrates (hexoses and pentoses) were converted into a mixture of products (lactic acid, ethanol, acetic acid). LABs can only consume the fermentable sugars directly (Meade et al., 2020); 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 $mg/g_{Lactose}$ and 20 $mg/g_{Lactose}$) 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 $\mu L/g_{starch}$) and the temperature (35℃) remained stable. After several tests and after collecting samples at regular intervals, it was found that the lactic acid concentration reached almost 17.3g/L after 144 hours with $5mg_{LactozymePure}/g_{lactose}$ 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, using enzymes 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.

On the other hand, esters of natural organic acids are produced by fermentation of carbohydrates, fatty acid esters, bioethanol, terpenic compounds, isosorbide or glycerol derivatives (Khemthong et al., 2021). In particular, ethyl lactate is an environmentally benign solvent, which could substitute petrol-based VOCs in many applications. From 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. This reaction works in an acidic environment and for this reason either homogeneous or heterogeneous acid catalysts are used.

For ethyl lactate production, purified bioethanol (99% v/v and 89% v/v) produced from biowaste stream was used, along with commercial lactic acid (80% w/w and 88% w/w). The reactants in molar ratio $n_{Ethanol} / n_{LacticAcid} = 3$, along with the addition of Amberlyst 15 catalyst at a weight fraction of $w_{cat} = 0.1$ were mixed and were heated at 100°C. 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. Furthermore, lactic acid conversion and consequently ethyl lactate production was not achieved, using bioethanol and lactate from fermentation broth. It was thus proved that impurities in the lactic acid fermentation broth inhibited ethyl-lactate production.

Overall, the production of these biosolvents from biowaste provides a sustainable approach to the circular economy, limiting waste and minimizing the environmental effect of industrial processes.

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