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Extraction of lactic acid from aqueous feeds in PTFE-membranes

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Master thesis, Chemical engineering

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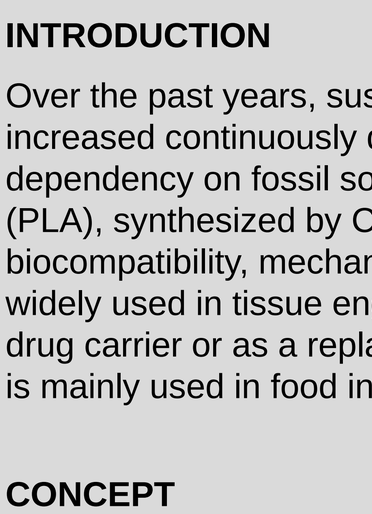
INTRODUCTION

Over the past years, sustainable production of bio-fuels and bio-plastics has increased continuously due to a higher demand but also to have less dependency on fossil sources [1] . One of these polymers is poly-lactic acid (PLA), synthesized by Carothers in 1932 out of lactic acid. Due to the excellent biocompatibility, mechanical properties and its nontoxicity to human body, PLA is widely used in tissue engineering, as function restoration of impaired tissues, as drug carrier or as a replacement of standard plastic in daily products. Lactic acid is mainly used in food industry as preservative and pickling agent [2].

CONCEPT

Currently a large portion of lactic acid is produced by fermentation of carbohydrates. The existing production processes use homolactic organisms such as Lactobacillus delbrueckii. To keep the fermentation running the pH needs to be kept at 5-6, for this $Ca(OH)_2$ is added to neutralize the produced lactic acid. Afterwards the built lactate gets acidified with H_2SO_4 to gain the L-lactic acid, a side effect is the production of gypsum as waste. Per ton produced lactic acid a ton of gypsum is produced. To prevent this side effect an extraction process was developed, to extract the lactic acid continuously without adding base or acid.



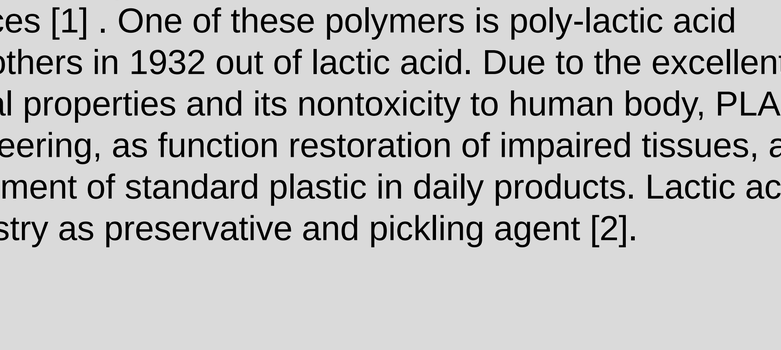


Fig. 1 and 2: Emulsification after extraction and clear phases using a PTFE membrane

The extraction of lactic acid with N,N-Didodecylpyridin-4-amine/Trioctylamine in 1-octanol was described by Krzyzaniak [3]. Although the extraction was efficient, there were some limitations such as emulsification (figure 1) due to stirring and too low S/F ratio during the primary extraction, which is not suitable for regular liquid-liquid extraction contactors.

However, the extraction-system described above was applied in this project on a liquid-liquid membrane extraction system using a porous PTFE membrane (figure 2) and the limitations were resolved. The dissolved lactic acid in the organic phase was separated in a following back extraction. The aim of the work was a continuous extraction of lactic acid out of fermented grasspressjuice or a carbohydrate fermentation and back extraction with a membrane, reaching a purification of the lactic acid and a concentration of 10 wt%, which is comparable to the industrial process (figure 3).

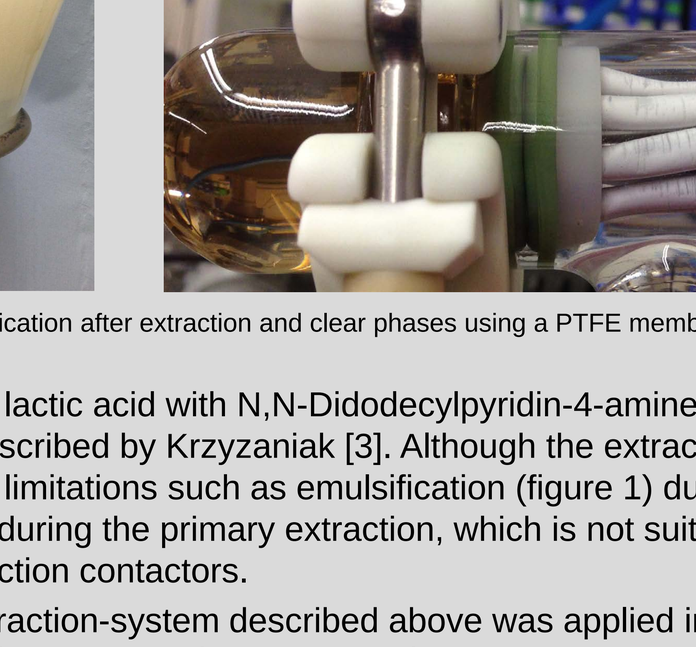
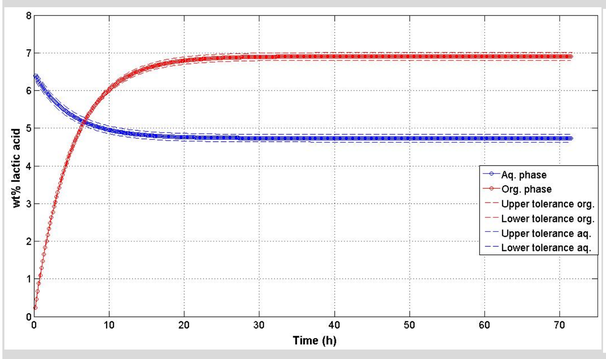


Fig. 3: Continuous extraction and recovery of lactic acid

RESULTS

The membrane extractions were measured by refraction index as an in-process control (figure 4 and 5). On table 1 the most important results can be seen.



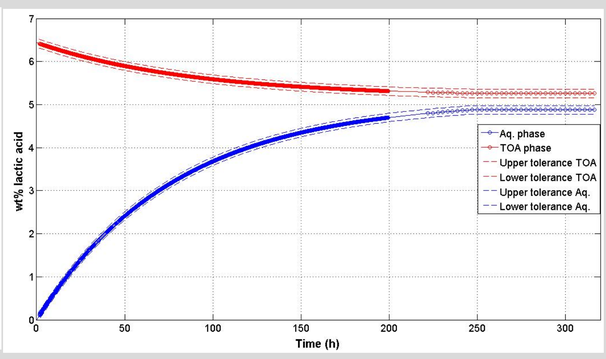


Fig. 4 and 5: Membrane extraction and back extraction of lactic acid with trioctylamine with the phase ratios 4:1 and 1:4

Table 1: Results of the most important membrane extractions

Aqueous phase (Water)	Organic phase (1-octanol)	Phase ratio	Temperature (°C)	Equilibrium conc. (lactic acid)
6.5 wt%	20 wt% TOA	4:1	25	4.7 wt% (aq. phase) 6.9 wt% (org. phase)
6.5 wt%	20 wt% TOA	10:1	25	5.0 wt% (aq. phase) 15.2 wt% (org. phase)
6.5 wt%	20 wt% TOA	4:1	45 (aq. phase) 25 (org. phase)	5.2 wt% (aq. phase) 4.2 wt% (org. phase)
0 wt% (back extraction)	20 wt% TOA + 6.5 wt% lactic acid	1:4	70 (aq. phase) 25 (org. phase)	4.9 wt% (aq. phase) 5.2 wt% (org. phase)

As a practical and possible industrial application (figure 6) grass was harvested, fermented, pressed, the gained grasspressjuice extracted and backextracted with both used extractants for comparison.

The membrane extraction with Trioctylamine reached with a concentration in the back extraction of 6.3 wt% the higher yield than with N,N-Didodecylpyridin-4-amine 5.0 wt%.

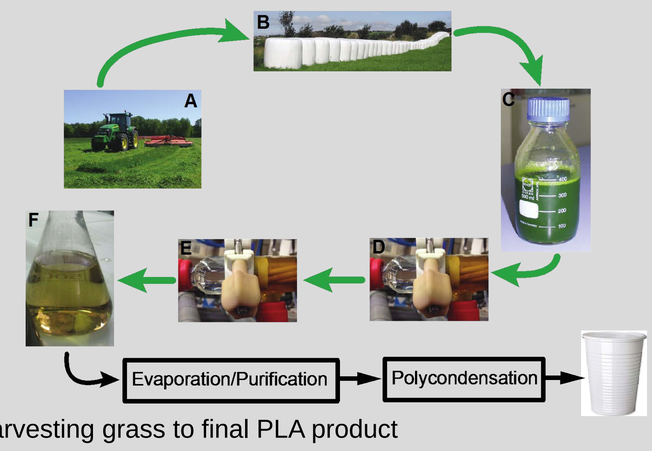


Fig. 6: Process cycle from harvesting grass to final PLA product

CONCLUSION

The membrane extraction and back extraction of lactic acid were successfully performed with the used extractants without any emulsifications in any of the phases. Also the final concentration of lactic acid of 6.3 wt% after the back extraction of grasspressjuice corresponds to approximately 63 % of the concentration reached in industrial scale with the addition of base and acid. All in all the membrane extraction as a method for the separation and recovery of lactic acid is very promising but needs further experiments, also with other sources as a fermentation broth where especially continuous experiments should can performed.

REFERENCES

[1] Stevens, C. ,The bio-based economy: step by step from demand push to market pull. *Biofuels, Bioproducts and Biorefining,* 2012, *6*, pp. 495-496.

[2] Astrid J.R. Lasprilla, e. a. ,Poly-lactic acid synthesis for application in biomedical devices — A review . *Biotechnology Advances ,* 2012, *30*, pp. 321–328.

[3] Krzyżaniak, A., Novel extractants for the recovery of fermentation derived lactic acid. *Separation and Purification Technology*, 2013, 111, pp. 82–89.

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