Direct electrodialysis of fermentation broth with periodic removal of fouling layers

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Electrodialysis is a process for the selective removal of ions from solutions. Combined with a fermentation it can be used to seperate ionic fermentation products such as organic acid, which inhibit the growth of the bacteria continuously. These concepts have already been used successfully to increase the production rate.

Since biofouling at the membranes is a problem the biomass is usually seperated by ultra- or microfiltration and the cell free feed is fed to the electrodialysis stack. In this way the fouling problem is shifted into the filtration unit and because of the very low permeate flux a large filtration area is necessary

In the present investigation the fermentation broth is fed directly into the electrodialysis module without prefiltration. Under these conditions a biofouling layer of living and dead parts of the fermentation broth builds up primarily on the anion exchange membranes. The mainly negatively charged fouling producers, for example protein ions, are transported by the electric field to the anion exchange membranes.

Using the example of continuous lactic acid fermentation with lactobacillus casei (DSM 2648) different rinsing and cleaning methods to prevent or remove fouling layers from ion exchange membranes have been investigated A continuous fermenter with a volume of 1.5 to 3 5 l at temperatures of 40 to 45 °C and a controlled pH of 5.5 has been used. The nutrient solution was a modified MRS medium The electrodialysis stack had a total membrane area of 200 cm^2 using commercialy available membranes (CMV, Asahi Glass and AMX, Tukuyama Soda)

Fig (1) shows the experimental plant A part of the fermenter outlet stream is pumped through the electrodialysis stack where it is desalted and recycled back to the fermenter. The flow rate through the electrodialysis stack was adjusted between 100 and 200 l/h.

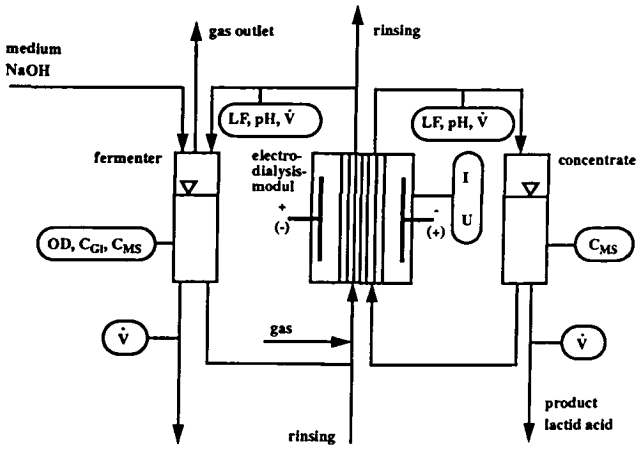

Figure 1: Experimental plant: fermenter, electrodialysis and concentrate

Several cleaning methods have been investigated:

- periodic input of gas (air) into the liquid feed
- reversal of the direction of the electric current
- rinsing with acids, desinfection solutions and tensid solutions
- combinations

Independent of the cleaning method used, an irreversible fouling layer builds up on the anion exchange membranes. The ohmic resistance increases, the effective membrane area decreases and leads to a decrease of the desalting efficiency. The fouling layer also reduces the flow area and increases the pressure drop in the module.

It turned out that the shear forces of the periodic gas liquid flow combined with acid rinsing were only able to remove thin fouling layers.

A thick fouling layer, however could only be totally removed by rinsing with a strong caustic tensid (RBS 35, Fa. Roth). In this case the desalination is interupted and the electrodialysis stack is rinsed for 20 min. with the tensid solution. After this the membranes were clean and the pressure drop returned to a low value.

To exclude a bacteriocidic effect of the tensid and a disturbance of the fermentation process, a purge period with citric acid followed to destroy residues of the tensid. Then the desalination process was continued. This cleaning method was repeated every 24 hours. A successful fermentation without membrane blocking for four weeks could be achieved.

Two representative results are presented. The effect of the combination between reversal of the electric current and rinsing with hydrochloric acid can be seen in Fig. (2). Fig.(3) and Fig (4) show the removal of the fouling layer with a caustic tensid.

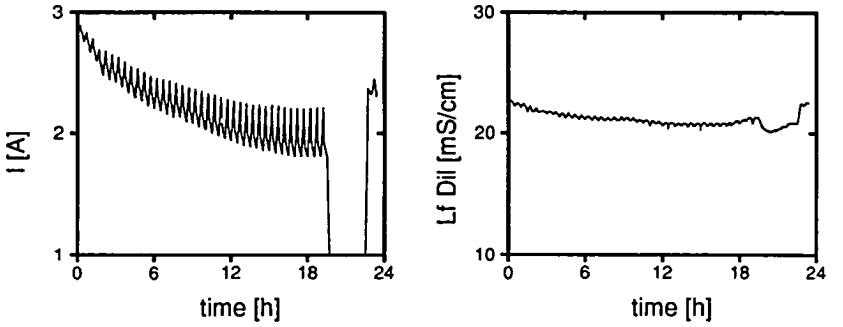

Figure 2: Current (I) and conductivity (Lf_{Dil}) in the diluat vs. time. Every 30 min. the direction of the electric current was reversed for 5 min. such that the fouling producers were transported away from the membrane back to the bulk. After 24 hours a rinsing with hydrochloric acid followed and the current increased. It was possible to run the fermentation process for over a week without problems.

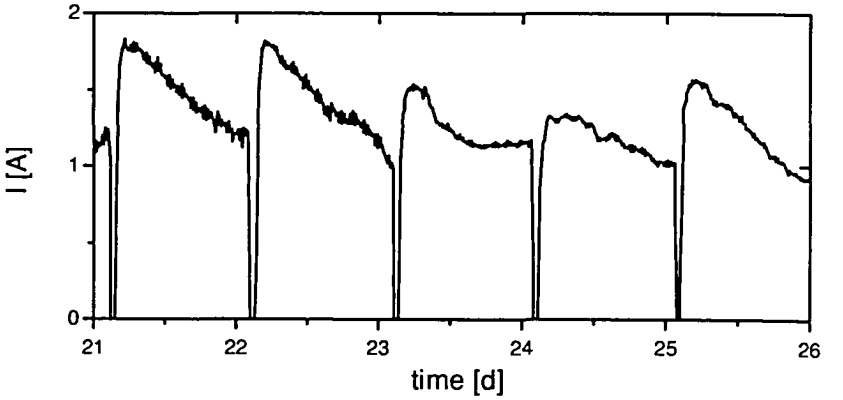

Figure 3: Current vs. time. Part of a continuous fermentation which was carried out for a total of four weeks. Every 24 hours the electrodialysis stack was rinsed with a strong caustic tensid to remove the fouling layer.

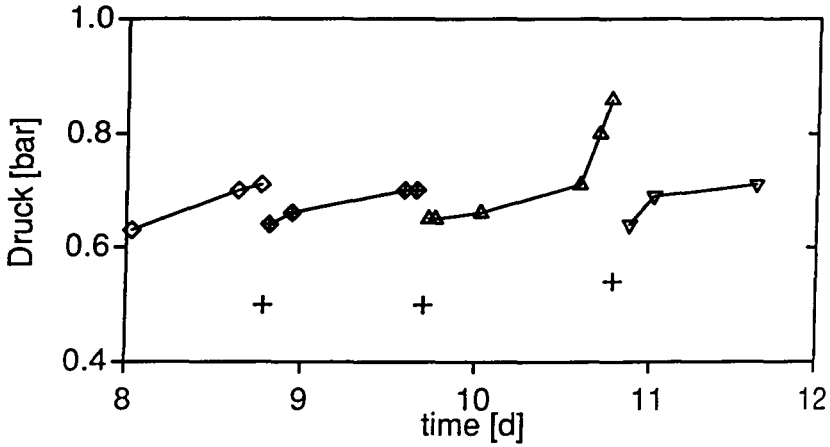

Figure 4: Pressure drop vs. time. Part of a fermentation period of four weeks. After every rinsing the pressure returns to a low value.

Summary

Combination of lactic acid fermentation and direct removal by electrodialysis of the lactid acid produced has been tested without prefiltration of the biomass. To achieve a long period of continuous fermentation a total removal of the fouling layer on the anion exchange membranes is necessary periodically. Several cleaning methods have been investigated. Only rinsing with a strong caustic tensid lead to a complete cleaning of the membranes. In this way continuous fermentation without membrane blocking was possible for four weeks successfully.

References

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