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# COMPARATIVE STUDY ON ELECTRODIALYSIS SYSTEMS FOR GALACTURONIC ACID RECOVERY

K. BÉLAFI-BAKÓ✉, E. MOLNÁR, Z. CSANÁDI, N. NEMESTÓTHY

University of Pannonia, Research Institute on Bioengineering, Membrane Technology and Energetics,
10 Egyetem Str., 8200 Veszprém, HUNGARY
✉E-mail: bako@almos.uni-pannon.hu

Electrodialysis (ED) is an electromembrane separation process suitable for recovery of organic acids. In this work galacturonic acid (GA) obtained by enzymatic hydrolysis of pectins from various sources was separated by a laboratory scale, two-step ED stack and a scaled-up, complex ED system. The experimental results from the two systems were compared.

**Keywords:** electrodialysis, pectin, galacturonic acid

## Introduction

Galacturonic acid is the monomer of pectin, a polysaccharide [1] often occurred in agro-wastes, like sugar beet pulp, apple pomace, press cakes of fruits... etc. Pectin can be hydrolyzed by enzymes and the process results a galacturonate (Gat) solution. Since it is an acidic (charged) compound, its recovery and separation can be carried out by electrodialysis (ED). Electrodialysis is an electro membrane process, where charged components move in the direction of the oppositely charged electrode under electrical potential difference [2, 3].

ED has already been applied to separate various organic acids like citric acid, lactic acid, acetic acid, propionic adic, gluconic acid, maleic acid [4–8]. In case of pectin hydrolysates ED can be used for recovery and desalination of galacturonate ions (the counter ion is usually Na). A laboratory scale, two step ED stack and a Fumatech FT-ED-4-100-10 scaled-up complex module were applied in our laboratory to recover GA ([9 ,10]. In this work the stacks are compared from the aspects of yield, operation parameters, energy requirement and average current efficiency.

## Material and methods

Galacturonic acid (GA) applied in the model solutions was purchased from Sigma-Aldrich, while sodium sulphate from Spectrum (Hungary). Cation- (Fumasep FKB), anion-selective (Fumasep FAB) and bipolar (BP) membranes were purchased from Fumatech.

Hydrolysis of pectin solutions from sugar beet pulp and citrus was carried out by pectinase enzymes (Pectinex 100L enzyme preparation) in a shaking incubator. The process was followed by acid titration (0.5 M NaOH).

The laboratory scale ED set up consisted of two stacks (one conventional and the other contains bipolar membrane) was constructed in our workshop. The first stack was an symmetric ED cell (described in [9]), with 0.0225 $m^2$ membrane surface area. Here the galacturonate ions from the hydrolysate moved toward the anode and passed through the anion selective membrane, while sodium ions are transported in the other way. Thus a concentrate stream containing mainly Na-galacturonate was formed.

Then its desalination was carried out in the second ED cell, where 2 cation selective and a bipolar membrane were built in *(Figure 1)* altogether with 0.0135 $m^2$ membrane surface area. Separation of sodium and galacturonate ions was possible: galacturonate anions remained in the feed solution forming an acid solution, while Na ions passed through the cation selective membrane into the alkali solution forming NaOH.

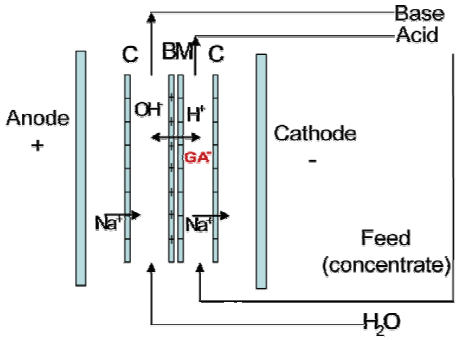


*Figure 1:* Set-up of the second laboratory scale ED module

The scaled-up complex module containing cation, anion selective and bipolar membranes was described in [10], its membrane surface area was 0.31 $m^2$.

Both ED stacks were operated by recirculation, using $Na_2SO_4$ solution (electrode solution). The experiments were followed by measuring the concentration of GA (DNS test [11]) in various streams, conductivity, pH, electric current and voltage, the data were collected by a data acquisition device (National Instruments USB-6008/6009) and recorded by the program LabVIEW.

The important stack and operation parameters for the laboratory scale stacks and the scaled-up complex ED module were summarized in *Tables 1* and *2*, respectively.

*Table 1:* Parameters of the two-step ED system for galacturonic acid recovery and desalination

| Features of the modules | Conventional asymmetric ED | Combined with BP membrane |
|---|---|---|
| Membranes | 3 cation selective, 2 anion selective | 2 cation selective, 1 bipolar |
| Membrane surface area | 0.0225 $m^2$ | 0.0135 $m^2$ |
| Volumes of solutions | feed (diluate): 100 ml, concentrate: 150 ml | feed (acid): 100 ml, alkali: 150 ml |
| Recirculation rate | 32 ml/min | 32 ml/min |
| Electrode solution | 200 ml 0.5 mol/l $Na_2SO_4$ | 200 ml 0.5 mol/l $Na_2SO_4$ |
| Recirculation rate | 60 ml/min | 60 ml/min |
| Applied voltage | 5 V | 5 V |
| Processes | galacturonate anions and Na cations pass through the membranes to accumulate in the concentrate | galacturonate anions remain, BP provides $H^+$, acid formation<br>Na cations pass through the membranes, form alkali solution |
| Final results | concentrate rich in Na-galacturonate | formation of galacturonic acid and NaOH solutions |

*Table 2:* Parameters of the scaled-up complex ED system

| Features of the module | Scaled-up complex module |
|---|---|
| Membranes | 10 anion selective, 11 cation selective, 10 bipolar |
| Membrane surface area | 0.31 $m^2$ |
| Volumes of solutions | feed (diluate): 400 ml, acid: 400 ml, alkali: 450 ml |
| Recirculation rate | 380 ml/min |
| Electrode solution | 500 ml 0.1 mol/l $Na_2SO_4$ |
| Recirculation rate | 500 ml/min |
| Applied voltage | 36 V |
| Processes | both galacturonic anions and Na cations pass through the membrane, formation of acid and alkali solutions |
| Final results | recovery and desalination of galacturonic acid in one step |

## Results

Pectin hydrolysates from sugar beet pulp and citrus were studied by using the two ED systems. The experimental results are compared in *Table 3*.

From the table it can be seen, that higher initial concentration feed was applied in case of the two-step laboratory module, since in the second step we had to use the result of the first step: the Na-galacturonate solution (recovered from the hydrolysate). It was desalinated in the BP module. In the scaled-up complex system the separation process (recovery and desalination) was achieved in one single step. Though the energy consumptions were much higher in the scaled-up system and the current efficiencies were lower (than in the laboratory scale stack), but larger amount of product solutions (pure galacturonic acid) were manufactured. If the product acid obtained were related to the energy consumption, we found that – in case of ED separation of sugar beet pectin hydrolysate – 1 Wh energy resulted in 0.09 g and 0.13 g GA production by the two-step, laboratory and the scaled-up, complex system, respectively. The scaled-up system worked with higher effectiveness, moreover it should be taken into account that its operation can be further optimised, and the energy consumption might be reduced even more.

*Table 3:* Comparison of the two ED systems

| Hydrolysate | | Two-step laboratory ED system | | Scaled-up complex ED system |
|---|---|---|---|---|
| | | asymmetric ED | BP module | |
| from sugar beet pulp pectin | feed volume<br>feed conc.<br>yield<br>current eff.<br>energy<br>final result | 100 ml<br>36.5g/l<br>63%<br>56%<br>9.2 Wh<br>150 ml 15.4 g/l Na-Gat solution | 100 ml<br>15.4 g/l<br>desalination – 4.6 Wh<br>100 ml 12.1 g/l desalinated GA solution | 400 ml<br>15 g/l<br>65%<br>41%<br>31 Wh<br>400 ml 9.8 g/l desalinated GA solution |
| from citrus pectin | feed volume<br>feed conc.<br>yield<br>current eff.<br>energy<br>final results | 100 ml<br>48.9 g/l<br>78%<br>63%<br>8.9 Wh<br>150 ml 25.4 g/l Na-Gat solution | no data | 400 ml<br>39 g/l<br>86%<br>54%<br>39 Wh<br>400 ml 33.5 g/l desalinated GA solution |

The yield, current effectiveness values are better for citrus pectin hydrolysate than for sugar beet pulp pectin hydrolysate, which may be explained by the higher purity of the citrus pectin preparation.

As a summary, we concluded that electrodialysis is a suitable method for recovery, desalination and purification of galacturonic acid from hydrolysates of various pectins. The complex module was able to separate the product in one step and it seems that the scaled-up system worked more efficiently: higher yield was achieved by less energy consumption. Therefore the complex ED system is suggested to apply for further experiments, aiming to study the possibilities of industrial applications.

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