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STUDIES OF EFFICIENCY IN A PERFORATED ROTATING DISC CONTACTOR USING A POLYMER-POLYMER AQUEOUS TWO-PHASE SYSTEMS

L. A. Sarubbo[1], L. A. Oliveira[2], A. L. F. Porto[3], G. M. Campos-Takaki[1] and E. B. Tambourgi[2] *

[1]NPCIAMB - UNICAP, Recife-PE-Brasil
[2]DESQ-FEQ, UNICAMP, C.P. 6066 CEP 13081,
Fax: +(55) (19) 3788-3946, Campinas - SP, Brasil.
E-mail: eliastam@feq.unicamp.br
[3]UFRPE, Recife-PE-Brasil

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Abstract - The mass transfer process in a perforated rotating disc contactor (PRDC) using a polymer-polymer aqueous two-phase system was investigated. The results show that the efficiency did not show a regular trend with the increase of the dispersed phase velocity and increased with the rotation velocity. The separation efficiency was higher for three rotating discs than for four discs. The increase in tie-line length decreased the efficiency. The separation efficiency reached high values, about 96% under conditions studied in this work.
Keywords: Extraction efficiency; Liquid-liquid extraction; Perforated rotating disc contactor.

INTRODUCTION

For isolating a desired protein or an enzyme from a complex mixture, the two-phase aqueous extraction technique offers the advantages of gentle environment, favourable processing time and easy scale-up (Albertsson 1986).

Methods of conventional extraction such as Spray columns can be conveniently applied to aqueous two-phase systems (Jafarabad *et al.*, 1992; Pawar *et al.*, 1993; Sawant *et al.*, 1990). Perforated rotating disc contactors were used with aqueous biphasic systems (Porto *et al.*, 1997; 2000). Recently, we characterised the bovine serum albumin mass transfer mechanisms using a laboratory PRDC with a polymer-polymer system based on PEG and Cashew-nut tree gum. The effect of dispersed phase velocity, system composition and discs rotation speed on either protein mass transfer coefficients or column holdup was studied (Sarubbo *et al.*, 2003).

The present work reports the experimental results of the extraction efficiency related to operational conditions, structurals aspects and physical characteristics of the aqueous biphasic system.

MATERIALS AND METHODS

Chemicals

Crude gum (molar mass 110 000) was collected as natural exudate from cultivated *Anacardium occidentale* trees of various localities in Pernambuco State, Brazil. Common-type plants about 20 years old yellow cashew producers were utilised. Poly (ethylene glycol) (PEG) 4000 was obtained from

*To whom correspondence should be addressed

Sigma Chemical Co (St. Louis, Mo, USA). Bovine serum albumin (BSA) with a molar mass of 67 500 was obtained from Sigma Chemical Co. (St. Louis, Mo, USA). All other chemicals were analytical grade.

Purification of Gum

Clear nodules free of bark were selected to be purified *via* ethanol purification by use of the Rinaudo-Millas method previously described (1991).

Preparation of Phase Systems

Phase systems (700g) were prepared using stock solutions of the polymers in water: 30% w/w cashew-nut tree gum and 50% w/w PEG. The polymer solutions were weighed out and mixed with 15 mM sodium phosphate buffer pH 6.0. The components were stirred for two hours and phase separated by gravity overnight. After separation, the equilibrated phases were introduced into the column by peristaltic pumps. The PEG and the cashew-nut tree gum rich phases were fed through the bottom and the top of the column, respectively. Two tie-line lengths were studied: the first, 18% w/w PEG4000 / 9% w/w cashew-nut tree gum and the second, 20% w/w PEG4000 / 11% w/w cashew-nut tree gum. In all experiments the PEG-rich phase was the upper and the cashew-nut tree gum-rich phase formed the lower phase of the system. For the mass transfer experiments, BSA powder was directly dissolved in the PEG-rich phase to a final concentration of 2 mg mL^{-1}. The experiments were performed at room temperature (25°C ± 2).

Experimental Aapparatus

The perforated rotating disc contactor (Figure 1) was made of Perspex tube 32-mm internal diameter and 16 mm high. Perforated discs (30 mm diameter and drilled with six holes of 6 mm diameter and 3 mm deep) were mounted on a central shaft, which was rotated at different velocities (60, 140 and 220 rpm). They were placed at various constant spacing distances in the column. Three and four discs were employed. The apparatus was maintained at room temperature (25º C±2).

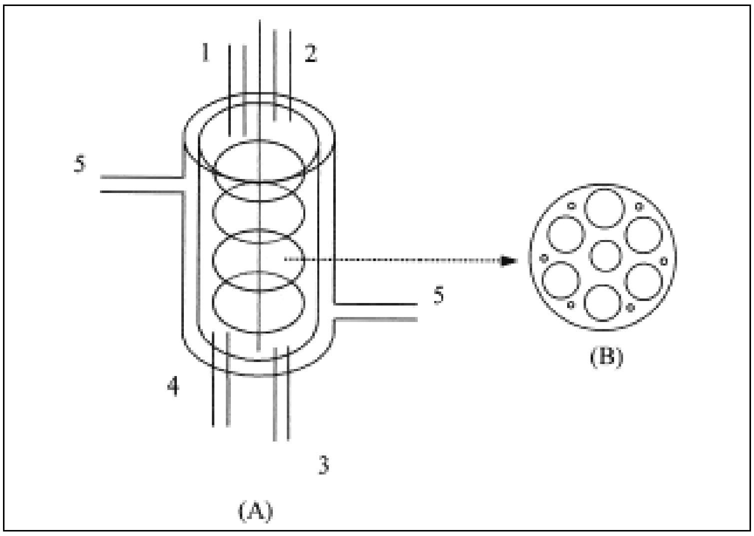

Figure 1: (A) Perforated rotating disc contactor; 1. Cashew-nut tree gum-rich phase inlet (continuous); 2. PEG-rich phase outlet (raffinated); 3. Cashew-nut tree gum-rich phase outlet (extracted); 4. PEG-rich phase inlet (dispersed). (B) perforated disc

Experimental Procedure

The mass transfer efficiency was measured in a perforated rotating disc contactor (PRDC) for different dispersed phase velocities. The column was operated in a continuous mode. The flow rates of dispersed, continuous, raffinated and extracted phases were maintained constant by using two multi channel peristaltic pumps with a flow of 1.0 ml/min for the continuous phase while the dispersed phase velocity varied for values of 2.0, 3.0 and 5.0 ml/min. The samples were collected from the extracted (Cashew-nut tree gum) and raffinated (PEG) phases at 55 minutes.

Protein Quantification

The BSA content from the samples of the phases collected after steady state was achieved was determinate by the Bradford method (1976). The initial concentration of BSA in the dispersed phase was 2 mg/ml.

Determination of Separation Efficiency

The separation efficiency (E) was calculated by Kawase's (1990) method as follow:

$$E = (C_1 - C_2 / C_I) \times 100$$

Where C_1 and C_2 are the solute concentrations in dispersed phase inlet and outlet (raffinated) respectively. The result obtained is better defined as solute recovering rate.

RESULTS AND DISCUSSION

Effect of Disc Rotation Speed

The influence of the discs rotation speed on the separation efficiency was investigated at different velocities (60, 140 and 220 rpm). All the results were obtained under steady state conditions of flow rates of both phases and rotation speed of discs. Samples at the inlet and outlet dispersed phase were taken and the contents of BSA were determined.

Figure 2 shows the experimental results where the solute recovering rate is plotted versus the rotating velocity for the first tie-line length. It could be seen a slight influence of the rotating velocity on the extraction efficiency for velocities of 60 and 140 rpm. On the other hand, the efficiency showed an increase when the rotation velocity increased at 220 rpm. Rabelo (1995) studying a rotating blade extraction column using the acetic acid-water-butanol system observed the increase of the process efficiency with the rotating velocity. On the other hand, Porto *et al*., (1997) studying a PRDC observed the independence of the separation efficiency with the rotation speed of the discs.

It was not possible to determine the influence of the disc rotation speed on the extraction efficiency for the second tie-line length, once flooding occurred for lower velocities (60 and 140 rpm). As described earlier (Sarubbo *et al*., 2003), the cashew-nut tree gum-rich phase viscosity did not permit the phase mixing.

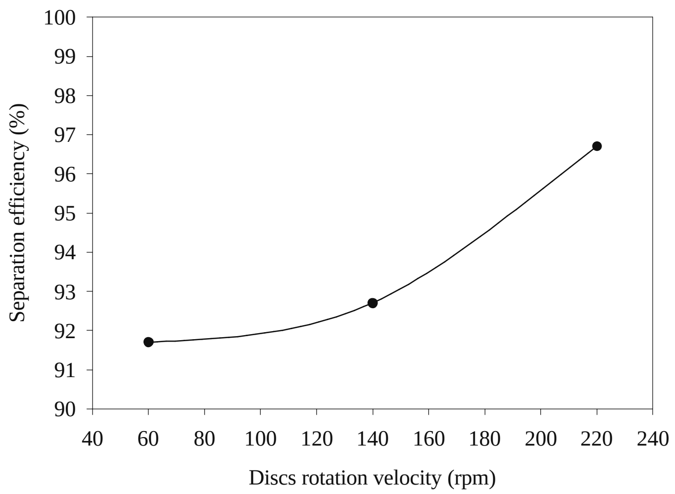

Figure 2: Influence of disc rotation speed (3 discs) on BSA separation efficiency in perforated rotating disc contactor for 9% PEG4000-18% Cashew-nut tree gum system at dispersed phase velocity of 5 mL/min

Effect of the Dispersed Phase Velocity

The effect of dispersed phase velocity was studied for values of 2.0, 3.0 and 5.0 mL/min The protein extraction efficiency was expected to increase in the PRDC with the phase velocity, as smaller drop sizes at higher velocities produced higher mass transfer area. Figure 3 shows the variation of the separation efficiency with the dispersed phase velocity. It could be observed that the solute recovering rate was very high for the studied conditions but did not show a regular trend with the increase of the dispersed phase velocity.

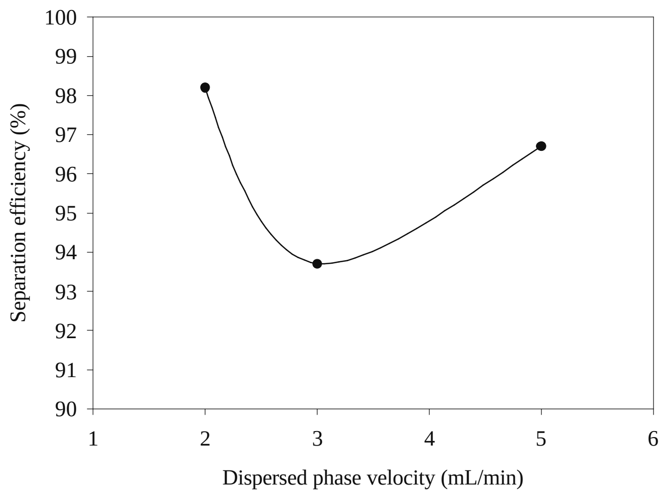

Figure 3: Influence of dispersed phase velocity effect on the BSA separation efficiency in perforated rotating disc contactor for 9% PEG4000-18% Cashew-nut tree gum system at rotation velocity of 220 rpm (3 discs)

Effect of System Composition

The effect of two phase compositions was investigated for two tie-line length, as described earlier. Results showed separation efficiencies of 96% for the first tie-line and of 94% for the second one, at discs rotation velocity of 220 rpm. With an increase in the phase concentration the interfacial tension increases. As a result, the drop diameter increases, which in turn, decreases the mass transfer coefficient and the separation efficiency.

Effect of Number of Discs

The separation efficiency was studied for three and four rotating discs. For a three disc PRDC is found a higher efficiency of separation than for the four disc of 96% and 92%, respectively. It would be expected that a higher degree of agitation should cause higher rates of phase dispersion, higher interfacial area for mass transfer and higher mass transfer coefficients. Tambourgi and Pereira (1993) studying a PRDC with an organic solvent-water system obtained a higher efficiency of separation for seven discs than for five discs. Probably, the increase of the number of discs constituted a flow resistance, causing entrainement of the continuous phase thus reducing the mass transfer coefficient and the separation efficiency of the protein.

CONCLUSIONS

The results obtained with a PRDC show that this apparatus can be successfully used as a continuous extraction equipment for protein extraction using aqueous two-phase systems. The study of mass transfer efficiency discussed in this work is still being explored, trying to verify the influence of other parameters on the extraction efficiency.

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