EFFECT OF ANTIFOAM FOULING ON SOLUTE REJECTION BY ULTRAFILTRATION MEMBRANE

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Introduction

Membrane fouling is one of the most serious problems in the application of pressure-driven membrane separation processes to biotechnology^{1, 3)}. Antifoam is frequently added to fermentation broth to suppress foaming, not only in most aerobic fermentations²⁾ but also in some anaerobic fermentations with gas evolution^{5, 7)}. Antifoam often fouls the membrane and causes significant flux reduction in microfiltration^{4, 6)} or ultrafiltration processes^{8, 10)}. However, most researchers have focused their attention only on the effect of antifoam on flux. There is little information about the solute rejection property of antifoam-fouled membrane, which, like the flux, is an important characteristic in membrane separation performance.

In the present study the solute rejection property of antifoam-fouled membrane was measured, using two types of ultrafiltration membranes. The effects of operations on solute rejection were investigated.

1. Experimental

1.1 Materials and apparatus

Hydrophobic nonionic surfactant was used as a model antifoam. Two types of commercial ultrafiltration membrane (hydrophobic polysulfone membrane and hydrophilic polyolefin membrane) were used. Characteristics of the surfactant and the membranes were reported previously¹⁰⁾. The apparatus used was the same as that described in the previous paper¹⁰⁾.

1.2 Procedure

Pure water flux J_w of a virgin membrane was mea-

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Fig. 1 Effect of pressure applied in ultrafiltration of antifoam on observed rejection by antifoam-fouled polysulfone membrane. (Conditions other than pressure in the ultrafiltration of the antifoam were $T = 303$ K, $U = 0.65$ m/s and $C = 0.5$ kg/m³. Pressure applied in the ultrafiltration of the antifoam is shown in the figure.)

sured first. The surfactant was then ultrafiltered. Pressure P , liquid velocity U , temperature T and surfactant concentration C were varied in the ranges of 98 - 196 kPa, 0.65 - 1.95 m/s, 283 - 323 K, and 0.10 - 1.0 kg/m³ respectively. After the flux reached a constant value, the surfactant emulsion was replaced with pure water. The water was then replaced with a solution containing solute of known molecular weight, and solute rejection by the antifoam-fouled membrane was tested. Operational conditions in the solute rejection experiment was kept constant at $P = 98$ kPa, $U = 0.65$ m/s and $T = 303$ K. Solutes used were glucose, polyethylene glycols (PEGs) and dextrans of various molecular weights. Concentration of the solute was kept at 0.100 kg·m⁻³. Solute rejection was evaluated by the observed rejection. Concentration of the solute was determined by GPC analysis⁹.

2. Results and Discussion

2.1 Polysulfone membrane

Solute rejection by the antifoam-fouled membrane was evaluated by the relationship between the molecular weight of solute and its observed rejection, i. e. the solute rejection curve. **Figure 1** shows the effect of pressure applied in ultrafiltration of antifoam on the solute rejection curve. In the figure, the rejection curve denoted with open circles represents that of virgin membrane. The rejection curve of the virgin membrane differed from its nominal molecular weight cutoff. The difference was due to those in the testing conditions, such as solute concentration and liquid velocity. With increasing P , the rejection curve of the antifoam-fouled membrane shifted considerably to the lower-molecular weight side. When a pressure of 196 kPa was applied, molecular weight of 50% rejection decreased to about 5×10^3 , which was almost one-hundredth that of the virgin membrane. The

Fig. 2 Relationship between observed rejection of antifoam-fouled polysulfone membrane and flux reduction due to ultrafiltration of antifoam

Table 1. Operational conditions in the ultrafiltration of the antifoam with polysulfone membrane

key	T [K]	P [kPa]	U [m/s]	C [kg/m ³]
A	303	98	0.65	—
B	303	49	0.65	0.500
C	303	98	0.65	0.300
D	303	98	0.65	0.500
E	303	196	2.27	0.500
F	303	196	1.30	0.500
G	303	147	0.65	0.500
H	323	98	0.65	0.500
I	303	98	0.65	0.700
J	313	98	0.65	0.500
K	303	98	0.65	1.000
L	303	196	0.65	0.500

A: virgin membrane; B-L: antifoam-fouled membrane

rejection curve became rather broad as the pressure applied in ultrafiltration of the antifoam increased, although the reason was not clear in the present stage. The rejection curve shifted to the lower-molecular weight side with increasing T and C , and with decreasing U . **Figure 2** shows a typical relationship between flux reduction ($= 1 - J_v/J_w$) and observed rejection. **Table 1** summarizes the operational conditions adopted in the ultrafiltration of the antifoam. The data plotted on the ordinate represent rejection by the virgin membrane. The rejection of dextrans increased with increasing $(1 - J_v/J_w)$. Rejection of PEG ($M_w = 2 \times 10^4$) increased considerably with increasing flux reduction. Rejection of PEG ($M_w = 10^3$) increased slightly with increasing flux reduction. The effect of antifoam fouling on solute rejection was much more pronounced for solute having a molecular weight of around ten thousand. From the results, it should be noted that the rejection curve of the antifoam-fouled membrane differed drastically from of the virgin membrane.

Fig. 3 Relationship between observed rejection of antifoam-fouled polyolefin membrane and flux reduction in ultrafiltration of antifoam

Table 2. Operational conditions in the ultrafiltration of the antifoam with polyolefin membrane

key	T [K]	P [kPa]	U [m/s]	C [kg/m ³]
A	303	98	0.65	—
B	303	98	0.65	0.300
C	303	98	0.65	0.100
D	303	196	1.95	0.500
E	303	49	0.65	0.500
F	303	98	0.65	0.500
G	303	98	0.65	1.000
H	303	196	1.30	0.500
I	303	196	0.65	0.500
J	303	147	0.65	0.500
K	313	98	0.65	0.500

A; virgin membrane; B-L: antifoam-fouled membrane

2.2 Polyolefin membrane

Figure 3 shows a typical relationship between solute rejection and flux reduction for antifoam-fouled polyolefin membrane. Table 2 summarizes the operational conditions adopted in the ultrafiltration of the anti-

foam. Flux reduction in the polyolefin membrane was only 0.2 at most. The results show that the flux and the rejection by the polyolefin membrane are hardly affected by the antifoam fouling.

Conclusion

Antifoam fouling had significant effects not only on flux but also on solute rejection by the polysulfone membrane. On the contrary, the effect of antifoam fouling on rejection property by the polyolefin membrane was hardly observed.

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Nomenclature

C	= initial antifoam concentration	[kg/m ³]
J_v	= ultrafiltration flux	[m ³ /(m ² ·s)]
J_w	= pure water flux	[m ³ /(m ² ·s)]
M_w	= molecular weight	[-]
P	= pressure	[Pa]
R_{obs}	= observed rejection	[-]
T	= temperature	[K]
U	= liquid velocity	[m/s]

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