

Study on the Loading Capacity Profile for Filtration Process of Media Containing Antifoam

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The use of membranes is widely common in industries as a means to separate constituents of a liquid. Meanwhile, antifoams are chemicals used in bioprocess to eliminate the formation of foam during a process. It is normally used in conjunction with a nutrient rich broth that is used as a media to cultivate cells. When antifoam is present in a nutrient rich broth and is passed through a membrane, it may cause premature fouling of the membrane used. This study investigates the effects of antifoam presence in a cell free lb broth on the loading capacity of the membrane. That is, it is to investigate whether if antifoam will cause a large increase in overall resistance of the filtration system with membrane capacity. It was discovered that the presence of antifoam did not cause an overall increase to the resistance but rather helped to decrease it as compared to when virgin lb broth was filtered. Therefore, the presence of antifoam in a nutrient rich medium enhanced flux rate in the filtration process which decreases the overall resistance.

Membrane filtration, Dead-End, Loading capacity, Polyether sulfone, Antifoam, lb broth, Cell free, Non-silicone antifoam

I. INTRODUCTION

It is extremely common in the bioprocess industry for antifoams to be used in conjunction with a nutrient rich broth usually used in fermentation. Because fouling is inevitable when it comes to membrane filtration (Abdelrasoul, A. et al., 2013), choosing the right antifoam for a process is important to reduce fouling potential (McGregor, W. C. et al., 1988). Not only do antifoams cause a drastic reduction in flux rate of ultrafiltration processes, it also changes the solute rejection properties of a hydrophobic polyether sulfone membrane (Yamagiwa, K. et al., 1994). Therefore, this study was conducted to determine whether antifoam causes a decrease in the loading capacity profile of a Polyether Sulfone membrane. This study can provide useful to understand the logic and reasoning behind how fouling occurs when dealing with antifoam and a nutrient rich medium.

In industries such as wastewater treatment and bioprocess, the production of a liquid mixture is almost certain. Most often than not, a form of filtration is required to eliminate or separate a component from the bulk fluid. In Bioprocess, the use of a filtration process is common when separating algae from the broth that was processed with it (Harun Razif, R., 2010). If a liquid has surface active components, there is a tendency for the formation of foam (Pugh, R. J., 1996) which may cause an increase in operating costs (Soddell, J. et al., 1990). The membranes used for separation processes are semipermeable that it is selective to a certain constituent in a mixture (McCabe, W. et al., 2005). The usage of Polyether Sulfone (PES) membranes are common due to its impressive stability (Shi, Q. et

al., 2007) that is due to the alternating linkage of repeated ether and sulphone between aromatic rings giving the membrane good rigidity and excellent strength (Rahimpour, A. et al., 2007). PES does have its drawbacks and a major one is that it is hydrophobic which has an affinity to fouling by protein rich mediums (Ahmad, A. L. et al., 2013). It was reported by Rahimpour (2007) that by increasing the hydrophilicity of the membrane it could combat the easily fouled nature of the membrane (Wang, C. et al., 2012). In dead-end filtration a feed solution is forced through a membrane by external means and the permeate is usually collected at a specified volume and its time measured (Modise, C. M. et al., 2005). This method is to identify whether there is a flux decline across the membrane that can be caused by loading in the membrane.

The fouling of filtration membranes can be defined as a modification in the membrane due to physical/chemical interactions with the filtration liquid (Le-Clech, P. et al., 2006). A combination of membrane properties, operating conditions, and suspension characteristics influences the fouling rate (Vera, L. et al., 2015). A method of fouling caused by protein adsorption on the membrane surface considerably surges resistance to flow henceforth causing a decline in flux rate and efficiency (Marshall, A. D. et al., 1997). Numerous approaches have been studied and provided good results in surface modification for improving adsorption resistance (Shi, Q. et al., 2007). Most membrane fouling is reversible given that all foulants are removed from backwashing as the membrane will deteriorate faster if there are any left (Çulfaz, P. Z. et al., 2011).

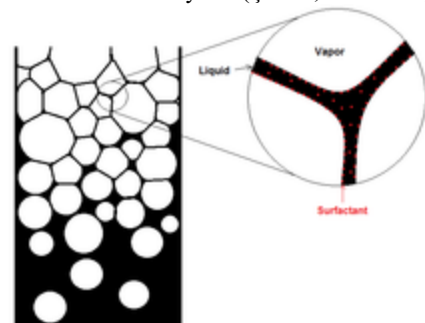


Figure 1: Thin film of liquid (Lamella)

Foam is defined as a dispersion of gas in liquid and comprises of tiny bubbles generated inside a liquid. Pure liquids therefore do not foam. Foaming occurs when these bubbles accumulate at the top faster than they decay. Because the volume fraction of foam is mainly gaseous, the bulk density is more of gas than liquid. It is said that true foaming is achieved when the liquid in between bubbles thin down to a lamella as shown in figure 1 instead of rupturing. The distance between adjacent bubbles is small therefore it differs from common gas-liquid dispersion. Foams are thermodynamically unstable due to its high specific surface area relative to separated gas and liquid phase (Vardar-Sukan, F., 1998). Foam formation always

accompanies processes with fermentation due to the high foaming tendencies of solutions containing biomaterials (Etoc, A. et al., 2006). In some industries such as paper, food, and drugs, foam production is highly undesirable as it affects the quality of the product (Routledge, S. J., 2012). Therefore to combat the formation of foam a form of foam control that is usually in chemical form is used (Vardar-Sukan, F., 1998).

A past study discovered that some antifoams are more fouling than others (Liew, M. s. et al., 1997). They also hypothesized that adhesion of broth onto the membrane surface caused an increase in resistance with membrane capacity and was not caused by the presence of antifoam. An experiment conducted by this group of scientists also supported the hypothesis when they discovered that with increasing concentration of an antifoam the resistance decreases.

II. METHODOLOGY

A. Materials

In this study the LB broth used was from Merck that exists in powder form. 10g was diluted with 400 mL of distilled water to prepare fresh LB broth which was used immediately. The antifoam used was Antifoam 204 from Sigma Aldrich which is a non-silicone antifoam. To prepare media with 0.2%, 0.6% and 1% antifoam, 0.8, 2, and 4 mL of antifoam was added respectively to fresh LB broth. A polyether sulfone membrane was used by Cobetter with a pore size of 0.2 μ m and a diameter of 47 mm. The pump used was a Masterflex peristaltic pump (Easy-Load II Head) with tubing of size 15.

B. Method

To investigate the loading capacity of the membrane the time taken and pressure reading for every 10 mL of filtrate collected was taken. Once the media has been prepared in a beaker, the beaker is set atop a hot plate to be mixed by a magnetic stirrer while the experiment is running to ensure a well-mixed medium. The medium is initially pumped into the system by the Masterflex peristaltic pump at the lowest flowrate that is 10mL/min. To avoid air from clogging the membrane prematurely, the membrane casing was loosened as a means to purge the air out of the system. Once the system is filled with medium and all air is purged, the case is tightened and the first 10 mL reading was taken. The flowrate was then adjusted to 1000 LMH which after calibrations is 13 mL/min. 4 sets of data was collected at flux 1000 LMH at 0%, 0.2%, 0.6%, and 1% antifoam. The experiment was also repeated for 2000 LMH. To show the loading capacity profile of the membrane at 1000 and 2000 LMH, the time and pressure recorded was used to calculate flux, resistance, and capacity as follows.

i. Flux Formula

$$\text{Flux (LMH)} = \frac{\text{Volume of filtrate collec (L)}}{\text{Time taken (hr)} \times \text{Membrane area (m}^2\text{)}}$$

ii. Resistance Formula

$$\text{Resistance} = \frac{\text{Pressure (psi)}}{\text{Flux (LMH)}}$$

iii. Capacity formula

$$\text{Capacity} = \frac{\text{Volume of filtrate (L)}}{\text{Membrane area (m}^2\text{)}}$$

III. RESULTS AND DISCUSSION

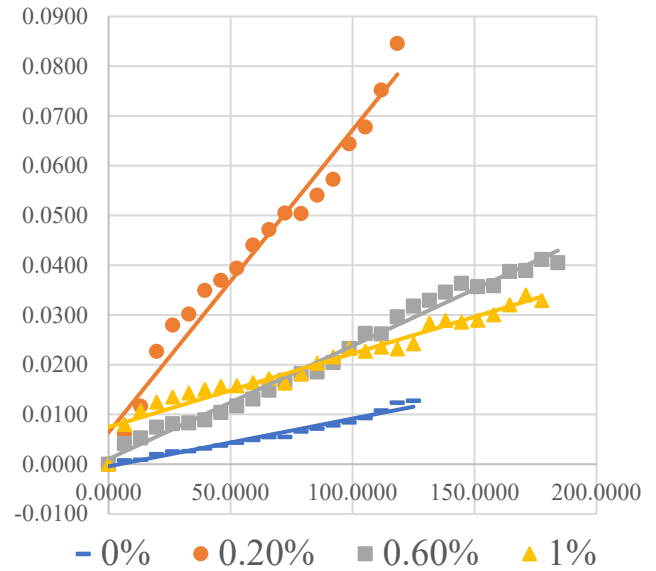


Figure 2: Loading Capacity Profile at 1000 LMH (Resistance Vs Capacity)

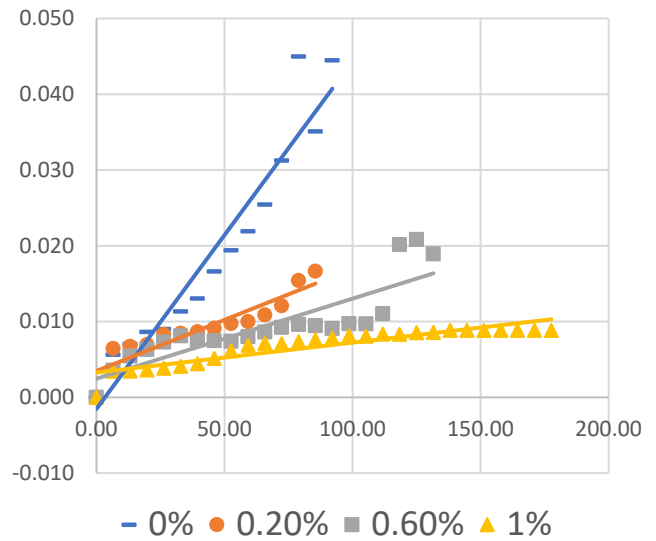


Figure 3: Loading Capacity Profile at 2000 LMH (Resistance Vs Capacity)

In the report provided by Liew et al (1997) they discovered that some antifoam did not cause fouling of membranes but rather helped enhance and improve flux. It was mentioned in their report that fouling of membranes was caused by the adhesion of broth particles themselves and was not resulted from antifoam. They hypothesized that the improvement in flux was caused by the adsorption of antifoam onto hydrophobic parts of the broth that if not would attach onto the membrane. In their study, an antifoam called B5600 caused a reduction in resistance of the system by improving the flux. This hypothesis sits well with the results at 2000 LMH. In Figure 3, the trendline for filtration of pure broth that is at 0% depicts a sharp increase in resistance at a relatively small membrane capacity. This means that the membrane was being increasingly fouled within a short period of time. It may be due to the broth components having adhered to the membrane which was further aggravated by the high flux rate of 2000 LMH causing the fastest flux decline compared to broth with antifoam. It can be observed from Figure 3 that the addition of antifoam caused a significant reduction in total resistance for the media to pass through the filter. This indicates that a higher flux was achieved with the addition of antifoam. Based on the study conducted by Liew et al, (1997), When more B5600 antifoam was added flux increased as compared to pure broth. This is true for this study also that with increasing amounts of antifoam, the resistance decreases. In Figure 2 it appears that at 0% antifoam and 1000 LMH

the filtration system had low overall resistance. This contrasts with the hypothesis that with increasing antifoam concentration the resistance decreases. However, if the overall trend is to be scrutinized it can be said that indeed the hypothesis is confirmed. This is because the trendline of 0.2% has the steepest slope followed by 0.6%, then 1% which indicates that resistance is decreasing with increasing antifoam concentration. Therefore, it could be said that the reason why the 0% trendline did not follow the hypothesis is because of human error during the data collection process or during preparation of samples.

IV. CONCLUSION

This study was conducted to study the effects of the presence of antifoam in a nutrient rich broth on the loading capacity of a polyether sulfone membrane set up in dead end filtration. It was initially hypothesized that antifoam may cause premature fouling on the membrane. Based on the data collected and analyzed, the combination of antifoam and LB broth did not cause an increase in fouling but rather the opposite. That is, compared to when fresh LB broth was filtered with virgin membrane the antifoam caused a decrease in resistance. The fresh LB broth was found to have the steepest slope which means it fouled the fastest. In comparison, when 1% antifoam solution was used it showed the shallowest slope which meant that it fouled the slowest. This agrees with the hypothesis by Liew et al, (1997) that fouling of the membrane was caused by adhesion of broth particles onto the membrane surface. When antifoam was introduced to the broth, the antifoam attached to hydrophobic parts of the broth thus producing a more hydrophilic solution.

To further enhance this study, future researchers could explore different types of membranes that are both hydrophobic and hydrophilic to compare which are more suited when dealing with broth and antifoam. Besides that, a more recent study on the adhesion of different types of broth on membrane surfaces could prove beneficial to the community. Another suggestion would be to study the viscosity and turbidity of media with proper equipment which the author failed to do. When conducting the experiment, care should be taken when storing the materials such as the LB powder to ensure that contaminated materials are not used which may alter the findings.

ACKNOWLEDGMENT

I would first and foremost like to thank my supervisor Madam Syazana for being my guide to which this would not be possible without her. I would also like to thank my co-supervisor Ir Normadyzah for taking over when Madam Syazana was unavailable. Also, a special acknowledgement to my experiment partner Adibah who has helped me countless times.

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