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The Effects of Antifoam Agent on Dead End Filtration Process

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Abstract. The formation of foam as a result from introducing gases during cell culture process in the bioprocess industry has indirectly affected the throughput of the product of interest. Due to that, antifoams were developed and established as one of the means to minimize the formation of foam in the cell culture. There are many types of antifoams but the silicone-type of antifoams are widely used in the bioprocess industry. Although the establishment of antifoam has aided the cell culture process, the impacts of its presence in the cell culture to the downstream process especially the dead end filtration is not widely discussed. The findings in the study emphasized on the dead end filtration performance that includes flux rate profile and the resulted filtration capacity. In this study, the concentrations of antifoam injected into the solution were varied from 0.2% v/v – 1.0% v/v and the solutions were filtered using constant flow method. The resulted maximum pressure readings and final flux rates indicated that the resistance exerted to the feed flow rate increased as the concentration of antifoam loaded in the solution increased. This later has led to the decline in the flux rates with percentage reduction between 32 – 68%. The calculated filter capacity for flux rate of 1000LMH ranged from 53 – 63L/m^2 while it is in the range of 40 – 43L/m^2 for flux rate of 2000LMH. The presence of antifoam agents in the feed load was determined to have negative effects on the dead end filtration performance and it may reduce the efficiency of the dead end filtration process.

1. Introduction

Antifoam agent or known as defoamer has been widely implemented in various industries including biological fermentation or cell culture. Since then, it has been the important compound to minimize the effects of foaming. In addition to that, there are research findings claimed that the antifoam agent has many advantages such as it can either prevent the foam generation or increase the rate of foam decay. However, the function of the antifoams is that they undermine the stability of liquid films in foam. Other than that, antifoam can boost the rate of the liquid discharge and thus increase the foam destruction [1]. Antifoam or defoamer is a chemical preservative which minimizes and avoids the creation of foams in the industrial process liquids. Method of using an antifoaming agent can be described into two; it is applied before the formation of the foam to prevent foaming or it is injected in the solution after foam formation in order to overcome it [2]. It is also widely used in various industries; bioprocess industries [3] - cell culture and microbial fermentation [4 - 5], anaerobic digesters [6] and biogas production [7]. Nonetheless, the biological effects of antifoam are poorly understood due to various range of models and inadequate data about their configuration and composition prepared by the manufacturers [8].

Since the introduction of membrane filtration over the last three decades, the usage of it has been getting more attention due to the faster evolution that it holds throughout the decades [9]. There are wide applications of membrane filtration and nowadays, much attention has been paid to the cell clarification process step with the purpose of removing the cell while obtaining the product of interest [10]. Different mode of filtration operation can be implemented during this stage of processing that are normal flow filtration or known as dead end filtration and crossflow filtration or known as tangential flow filtration. Both of them possess advantages and disadvantages depending on the objectives of process run and the scale of production [11].

This study covers the experimental exercises to evaluate the performance of filtration process with samples-containing antifoam agent. It focuses on the dead-end type of filters from the same membrane material with membrane area of approximately 15.2 cm^2. Apart from that, a silicone-based antifoam was used and different load of antifoam concentrations were tested. Throughout the experimental works, the data on volumetric rate and differential pressure were recorded in order to assess the changes of pressure applied on the filter membrane, especially the final maximum pressure. The volumetric flow rates were also analyzed to develop the flux rate pattern of each of the process runs.

2. Methodology

The materials used in this experiment were Lysogeny Broth (LB) broth and 10% silicone-type antifoam solution. A polyethersulfone (PES) disc filter with filter area of approximately 15.2 cm^2 from Cobetter was used for each of the process runs. The experiments were conducted using constant flow method where the initial flow rates were fixed. The initial flux rates were set for these experiments in order to normalize the constant data to filter membrane area. Two flux rates were set for the experiments, which were 1000 LMH and 2000LMH. The study was designed to have one control sample which was LB broth that did not contain antifoam agent for each of the initial flux rate and three running samples for three different antifoam concentrations loaded; 0.2%, 0.6% and 1.0%. The filter was connected to a peristaltic pump and a pressure gauge. The specific amount of antifoam were loaded in the feed containing LB broth according to the design concentration. The volume and differential pressure were observed and recorded at a specific time interval.

3. Results and Discussion

3.1 Flux rate profile

Figure 1 shows the resulted flux rate over time with initial flux rate of 1000LMH. The graph demonstrates that the flux rate decreased with time for all of the experimental runs. By comparing all of the data, the flux rates dropped as the concentration of antifoam loaded increased. The final flux rate for control sample was approximately 90LMH. Meanwhile, the recorded flux rate for antifoam concentration of 0.2%v/v, 0.6% and 1.0%v/v shows a continuous decreasing pattern where the starting flux rate of approximately 600LMH was reduced until approximately 60LMH, 50LMH and 40LMH respectively. Comparing with the final flux rate of the control sample, the filtration performance of sample containing various concentrations of antifoam has reduced by 10% each starting with 33% for 0.2% antifoam, 44% for 0.6% antifoam and 55% for 1.0% antifoam. This indicates that the filtration performance has been directly affected by increasing amount of antifoam agent loaded.

The flux rate pattern with respect to time for initial flux rate of 2000LMH is shown in Figure 2. The flux rate pattern possesses comparable behaviour to the initial flux rate of 1000LMH experimental runs that the graph verifies that the flux rate decreased with time for all of the experimental runs. However, the flux rate for all samples have decreased to similar final flux rate that ranged from 50LMH to 55LMH while the final flux rate for control sample was approximately 140LMH. This demonstrates a percentage reduction of final flux rate of around 60% for all samples containing antifoam agent that illustrates a higher declining rate as compared to the flux rates pattern for initial flux rate of 1000LMH. This indicates that higher initial flux rate can contribute to faster fouling action apart from the presence of antifoam as the fouling factor. The declining of the flux rate was supported by a study done by Liew et al. [12] as they observed a comparable flux decline profile when using PVDF microfilter to filter a yeast culture containing silicone-type antifoam agent. The reported flux reduction was approximately 42% with 1.0% concentration of antifoam added. PVDF membrane filter may pose similar attributes to PES membrane filter as both of them are hydrophobic naturally [12]. Thus, there may be some interactions between the silicone antifoam agent and the hydrophobic component of the PES membrane filter.

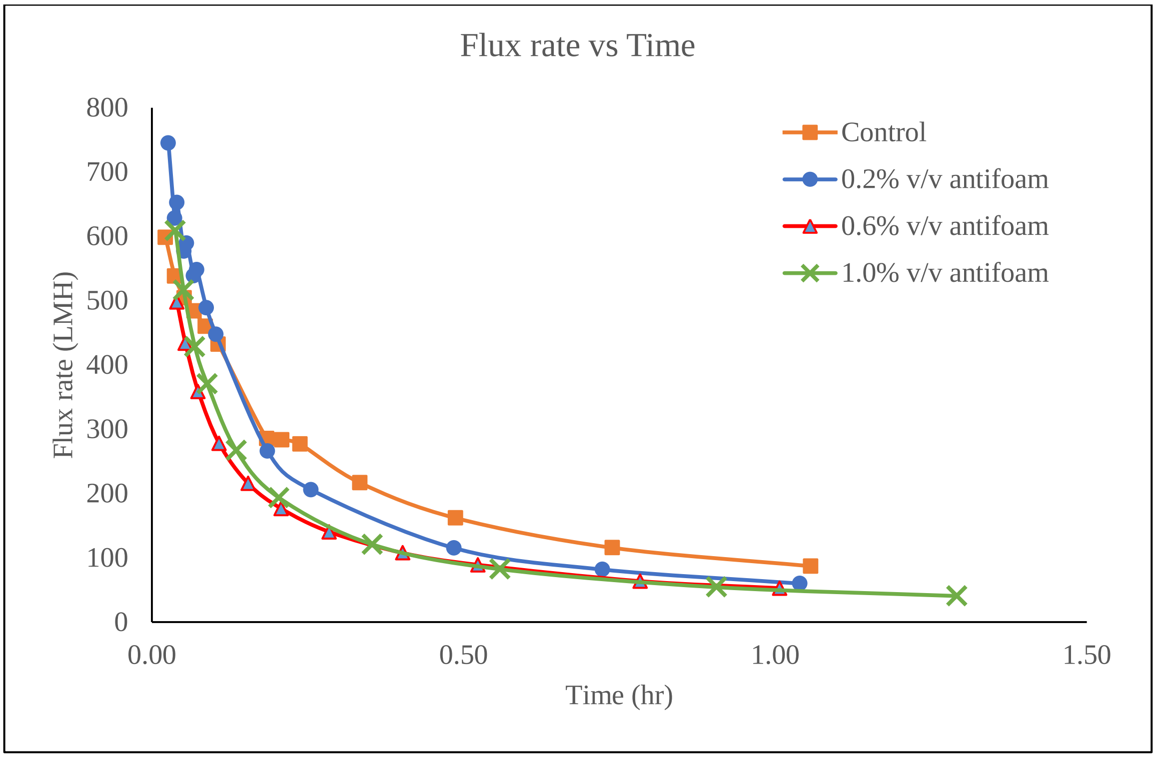

Figure 1: Flux rate versus Time (Initial Flux Rate: 1000 LMH).

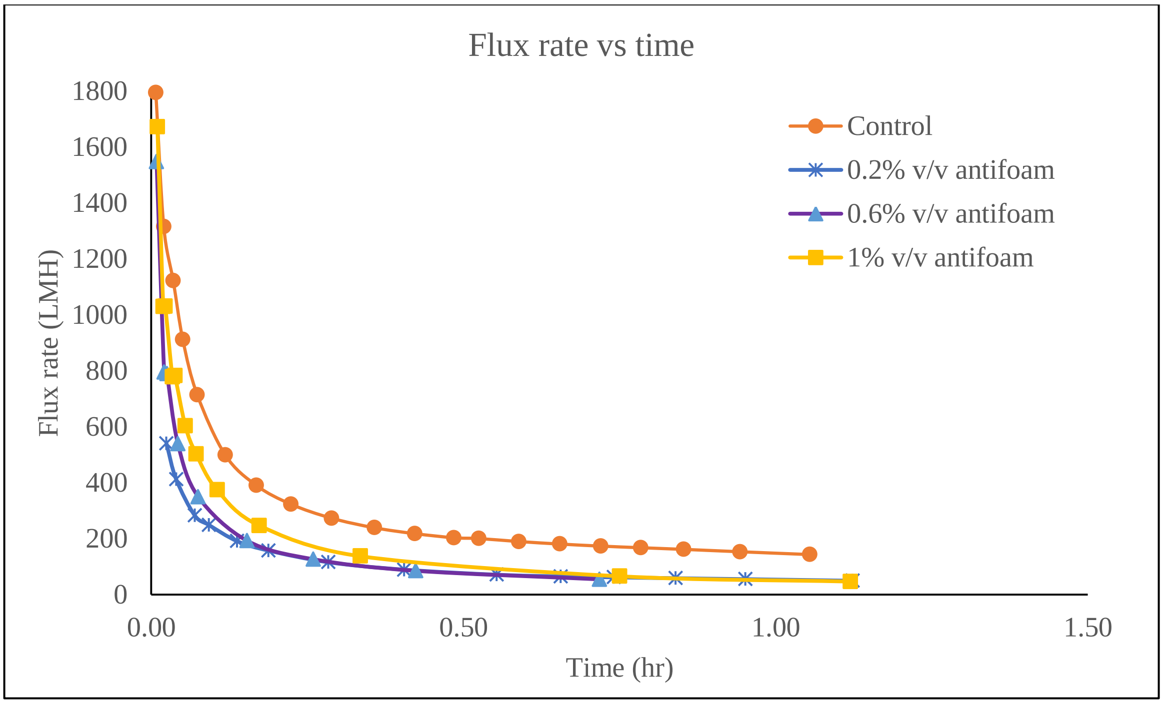

Figure 2: Flux rate versus time (Initial Flux Rate: 2000 LMH).

3.2 Filtration capacity

The relationship between resistances with the feed load of initial flux rate of 1000LMH is shown in Figure 3. The control sample demonstrated that the maximum resistance occurred during the experimental run was approximately 0.1psi/LMH with feed load of about 92L/m^2. Besides, the resistance towards the feed load increased with increasing antifoam concentration where the maximum resistance was around 0.2psi/LMH for all samples containing antifoam with loading capacity ranged from 53L/m^2 for 0.6% and 1.0% antifoam to 63L/m^2 for 0.2% antifoam. Although all of the filtration runs for samples containing antifoam agent experienced similar resistance towards the feed load, the reduction of filtration capacity slightly differs from one another where 0.2% antifoam shows a reduction around 32% while 0.6% and 1.0% antifoam shows a reduction of around 43% from the control run.

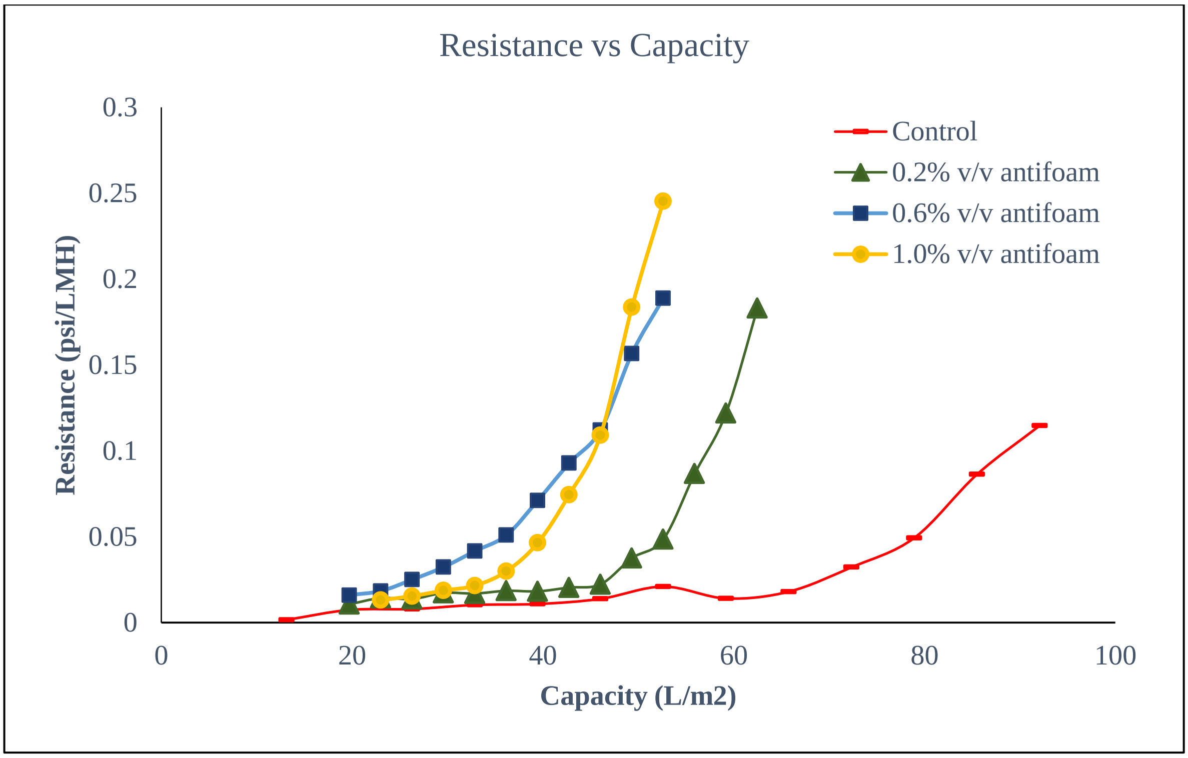

Figure 3: Resistance vs Capacity (Initial Flux Rate: 1000 LMH).

On the other hand, Figure 4 illustrates the correlation between resistances on the filter membrane with the feed load capacity of experiment runs for initial flux rate of 2000LMH. The maximum resistance on the membrane filter for control sample was 0.1psi/LMH with resulted loading capacity of 130L/m^2. The resistance towards the feed load of these experimental runs elucidated comparable behaviour with the experimental runs for 1000LMH, which they increased with increasing antifoam concentration. The maximum resistance exerted for all of samples containing antifoam agent was also 0.2psi/LMH. Due to that, the resulted maximum loading capacity for all the samples containing antifoam agent was ranged from 40L/m^2 to 43L/m^2. The filter membrane may experience similar occasion with that of 1000LMH experimental runs, but the high initial flux rate has led to faster resistance build up towards the filter membrane which then resulted in lower feed load capacity that can be processed by the filter which was proved by higher percentage reduction that is approximately 68%. The results for both initial flux rate runs have illustrated the effect of the antifoam load on the dead filtration performance. Typically, these outcomes were may be due to the cake formation on the filtration membrane over the time as the filtration mode executed was normal flow filtration where there was no filter recovery action throughout the experimental runs [13]. However, the fouling action has accelerated with the addition of the antifoam agent in the feed solution. Previous work suggested that a process solution containing silicone antifoam agent can probably be ultra-filtered at a lower temperature that is below the cloud point of the antifoam agent to reduce the fouling effect based on their study on ultrafiltration process that was run using cross flow filtration. Apart from that, they also suggested using a 100% silicone antifoam agent as impure silicone antifoam agent may contain other components that may pose hydrophobic characteristic; which is supported by the attributes of an antifoam agent that has the capability to reduce the surface tension in the liquid system [14]. Nevertheless, the resulted flux rate profile and loading capacity from this study has shown an improved technology of membrane filters as dead end filtration process does not pose the membrane recovery action throughout the process run as compared to the cross flow filtration process.

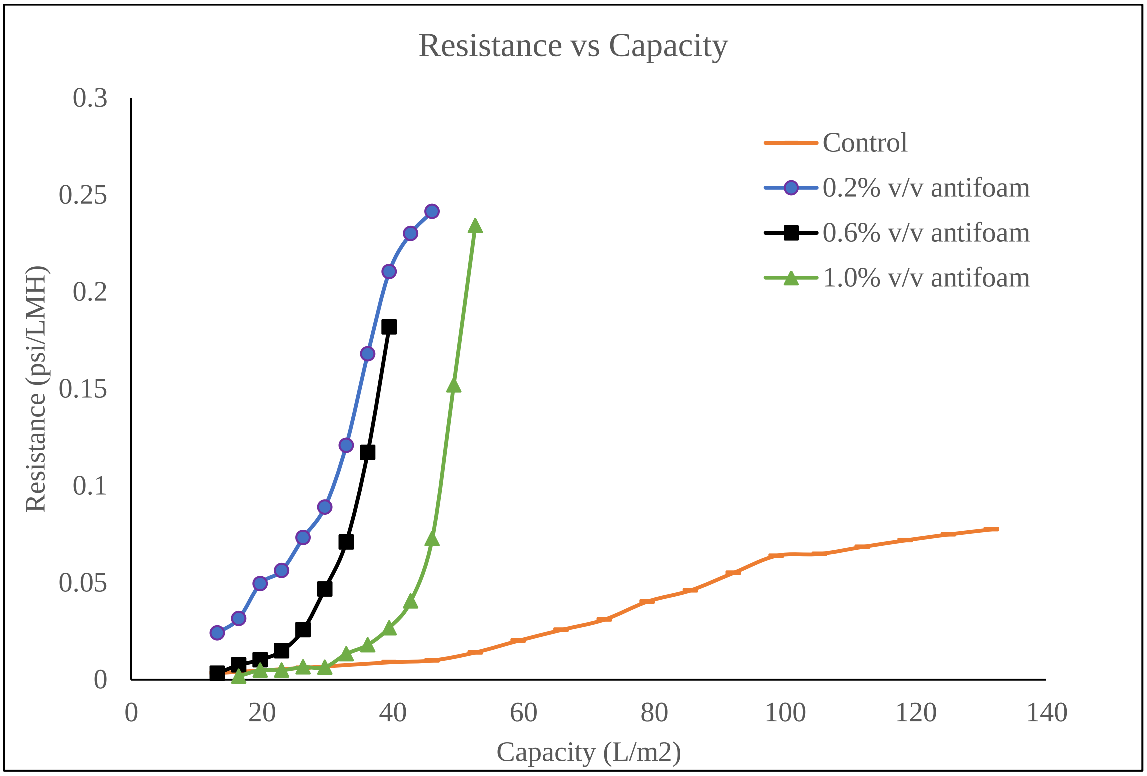

Figure 4: Resistance vs Capacity (Initial Flux Rate: 2000 LMH)

4. Conclusion

This study aimed to evaluate the dead end filtration performance based on flux rate profile and the filtration loading capacity with the presence of different concentration of antifoam agent in the feed load. The process was accomplished through the constant flow mode of filtration to filter samples containing different concentrations of antifoam agent using two initial flux rates and the resulted flow rate and pressure was observed at certain time interval. The flux rate profile shows continuous reduction of flux rate as concentration of antifoam load increased at a range of 33% to 55% for 1000LMH initial flux rate while there was a reduction of 60% of flux rate regardless of concentration of antifoam load for 2000LMH initial flux rate. Meanwhile, the calculated filtration capacity for initial flux rate of 1000LMH was in the range from 53L/m^2 to 63L/m^2 and 40L/m^2 to 43L/m^2 for initial flux rate of 2000LMH and the percentage of drop of the filtration capacity was around 32% to 43% and 68% respectively. The results of flux rate profile and filtration capacity support that the presence of silicone-type antifoam agent may contribute to the fouling action of the dead end filtration process. These values are expected to reduce more with the increase in variety of the components in the feed load passing through the filter membrane that may later increase the resistance exert towards it.

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