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Submission date: 12-Jan-2023 03:19PM (UTC+0700)

Submission ID: 1991667360

File name: SequencingBatchReactor-JEENG.pdf (1.39M)

Word count: 3296

Character count: 17044

³ Sequencing Batch Reactor to Treatment Tofu Wastewater Using Impeller Addition

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³ ABSTRACT

The characteristics of the wastewater produced by the tofu industry are high viscosity, slipperiness, and foaming resulting from the continuous fermentation of the tofu bacteria. This made it difficult to reduce the organic content of tofu wastewater, namely biological oxygen demand (BOD₅), phosphate (PO₄), and Total Nitrogen. A wastewater processor that is designed to handle dense and slippery tofu wastewater is known as a Sequencing Batch Reactor. The impeller is used to create turbulent flow, resulting in more evenly distributed DO, which is difficult to distribute due to the viscous tofu wastewater. The SBR was operated with a hydraulic retention time (HRT) of 24, 36, and 48 hours and an impeller stirring speed of 50, 100, and 150 rpm. The results of the research found that there was an effect on the stirring speed of the impeller and that the low stirring speed of the impeller was not optimal. HRT that was regulated in the SBR cycle has affected the performance of the bacteria. *Pseudomonas* sp. was found in this study and *Bacillus* sp., which can degrade up to 90% of phosphate and nitrate.

Keywords: sequencing batch reactor (SBR), stirring speed of impellers, degradation of suspended bacteria.

INTRODUCTION

The tofu industry is one of the food industries that are increasingly in demand by the public in the era of the COVID-19 pandemic due to its low yet safe prices in Indonesia. However, the rapid growth of the tofu industry has not been followed by adequate wastewater processing. Tofu wastewater is often discharged directly into water bodies by the tofu industry, so as a result which can cause environmental issues. Tofu wastewater has a high pH, BOD, COD, TSS, ammonia, nitrate, and nitrite material, among other things [Bakare 2017; Chen et al. 2020]. As a consequence, efficient processing technology is needed, which can be utilized by domestic tofu industries to reduce pollution. One of the technologies for effective and safe wastewater management is the Sequencing Batch Reactor (SBR). Because of its simple design and high-efficiency levels in reducing

organic compounds, SBR is one of the technologies that has been used as an effective wastewater treatment technology [Fotone et al. 2011; Fernandez et al. 2013; Duta 2015]. SBR is one of the activated sludge processes, but it differs from traditional activated sludge processing in several ways. SBR processing takes place in a single tank, while traditional activated sludge processing is done in several tanks. Fill and draw is the operating principle of SBR, which consists of five stages: filling, reaction, settling, decant, and idle disposal [Gao & Wang 2020; He et al. 2016].

Many studies have been carried out on the SBR process as a wastewater treatment technology [Hendrasarie et al. 2019; Hyeongok et al. 2020], using it with intermittent aeration and the addition of a paddle-type mechanical mixer to reduce the parameters of COD by 96%, Total Nitrogen 96%, and Total Phosphorus 99% in slaughterhouse wastewater. However, the wastewater

concentration in this study was low in organic content. As a result, the goal of this research was to see whether adding an impeller to an SBR to treat wastewater with a high organic content makes it more effective. Tofu wastewater contains a lot of organic material. The addition of an impeller is expected to improve the SBR efficiency.

RESEARCH METHODS

Tofu wastewater was used in the experiment. BOD₅ of 1788.8 mg/L; PO₄ of 76 mg/L; Total nitrogen of 181 mg/L pH of 4.9 are some of the initial characteristics of tofu wastewater. BOD₅, PO₄, and total nitrogen were the parameters to be tested.

Optimization of hydraulic retention time (HRT) and impeller steering speed

The Sequencing Batch Reactor, 4 flat blades turbine vaned disc impeller, air stone, air pump, pH meter, and thermometer were used in this study. The SBR impeller and reactor are illustrated in Figure 1 below.

The reactor used in this experiment has a total volume of 6 L and a volume that will operate with a 5 L reactor. The reactor was filled with wastewater. The SBR was cycled once for 24, 36, and 48 hours of HRT. Before being pumped into the SBR, the tofu wastewater was collected in an influent storage tank. For 10 minutes, the fill stage (filling) was completed. Following that was the reaction stage, which has two conditions: anaerobic and aerobic. The combination of these two conditions results in a high degree of

nitrogen reduction efficiency [Luo 2018; Khan 2018; Mohammed 2020]. The anaerobic reaction was followed by the aerobic reaction after the filling stage. The settling stage follows the reaction stage; aeration and stirring were turned off at this point, and the activated sludge or biological solid was allowed to settle. The draw stage began after the settling stage was completed. The influent was replaced at the end of each cycle, with the influent volume equivalent to the effluent volume. Then, any excess sludge was removed; this stage is referred to as preparation for the next cycle. Five repetitions were carried out, with the average results obtained.

The process of seeding and acclimatization

The initial testing of the characteristics of tofu and seeding wastewater with biomass acclimatization formed the basis of the preliminary analysis of this study. MLSS (Mixed Liquor Suspended Solids) was conditioned in sludge at a concentration of 2000 to 5000 mg/L [Obaja 2005; Sekarani 2020]. The sludge was then filled into the reactor.

The seeding technique aimed to develop and reproduce microorganisms from tofu wastewater. In batches, the seeding process was carried out naturally for 14 days. During the seeding process, wastewater was changed once a day daily. The nutrients needed by microorganisms as food material were carried out during the seeding phase so that microorganisms could thrive. Microorganisms require specific nutrients in the form of a C: N: P ratio to expand and reproduce optimally. For microorganisms, the C: N: P ratio was 100: 5: 1; for aerobes, it was 100: 5: 1. [Terekegu 2014;

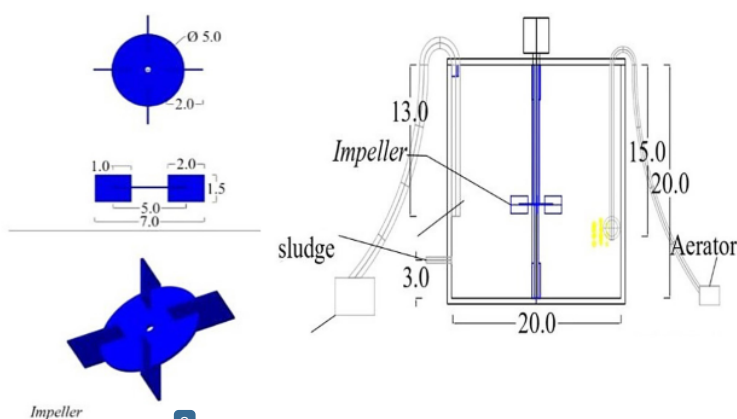


Figure 1. Sketch of sequencing batch reactor

Wang 2020]. The MLSS analysis was performed on the tenth day, giving a result of 2069.8 mg/L. MLSS (Mixed Liquor Suspended Solids) was conditioned in sludge at a concentration of 2000 to 5000 mg/L [Wei et al. 2021]

Acclimatization takes place in the SBR component. The acclimatization process involves applying various amounts of tofu wastewater. Acclimatization was accomplished in stages, beginning with a volume ratio of 30% wastewater to distilled water and gradually increasing to 100% wastewater [Wei et al. 2012]. Acclimatization is done gradually so that microorganisms can adapt properly. The acclimatization process is completed when the COD removal reaches 50% and is constant. When COD removal has reached 50% and has remained steady, the acclimatization process is complete [Hendrasarie et al. 2021; Zao et al. 2021].

Microorganisms isolated and identified

The microbes discovered were those that were suspended in wastewater during treatment. To determine the characteristics of microbes that can

degrade in the form of a suspension in tofu wastewater treatment, two dominant microbes were chosen.

RESULTS AND DISCUSSION

Hydraulic retention time-optimal

The importance of effluent concentration and the resulting removal efficiency was affected by hydraulic retention time (HRT). The longer the HRT was used, the more efficient it was at removing it. The HRT used in this analysis were 24, 36, and 48 hours, because the processed wastewater contains a high organic content, a long HRT is used. The optimal HRT for reducing tofu wastewater was found in Figure 2 using the parameters of BOD, Phosphate, and Total Nitrogen. Based on these findings, the optimum hydraulic retention time (HRT) for reducing the BOD₅ levels in this study was 48 hours, with all variants of stirring speed having a higher percentage of BOD reduction at 48 hours HRT than the 24-hour and 36-hour HRT variations. In terms of reducing BOD, the effect of HRT for at least 24 hours is optimal

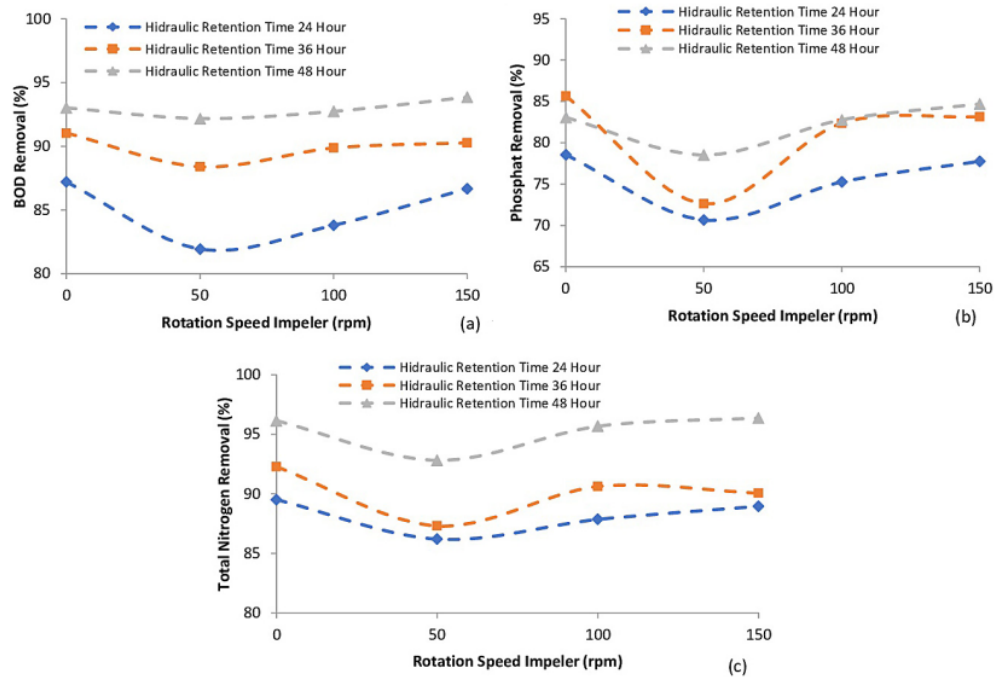


Figure 2. The decrease in (a) BOD₅, (b) phosphate, and (c) total nitrogen in the sequencing batch reactor in terms of hydraulic retention time

for lowering BOD_5 above 85%. As far as the phosphate reduction is concerned, HRT 36 hours, was able to recover above 85% on the SBR without the addition of an impeller, only a diffuser was used. When using an impeller, a minimum speed of 100 rpm can remove phosphate at a rate of more than 80%. HRT for at least 24 hours was able to minimize total nitrogen by 89% in SBR using only the diffuser. The HRT was 24 hours when an extra impeller was used, at least at a speed of 100 rpm. However, since the microbes that degrade Total N take longer than phosphate reduction in tofu wastewater, the best HRT for Total Nitrogen is 48 hours. Since nitrification and denitrification processes play a role in reducing the total N content in both aerobic and anaerobic reactions, the total N efficiency increased. An adequate supply of oxygen is required for the nitrification and denitrification processes. The failure to oxidize ammonium to nitrate was due to a lack of oxygen. The presence of anaerobic and aerobic reactions, with the aerobic reaction lasting longer than the anaerobic reaction,

allows for a very small number of microorganisms to denitrify, preventing them from competing with autotrophic microorganisms or microorganisms in the nitrification process [Wang 2021].

The best mixing speeds

Figure 3 shows the reduction of BOD_5 , phosphate, and total nitrogen from the addition of an impeller in the Sequencing Batch Reactor in tofu wastewater, which has a high viscosity and is characterized by easy foaming. The optimal stirring speed for reducing BOD_5 , PO_4 , and total N is 150 rpm, as shown in Figure 3. At the stirring variation of 150 rpm, the best efficiency of reducing BOD_5 , PO_4 , and total N parameters were shown at 24 hours, 36 hours, and 48 hours HRT. This is because the stirring speed can speed up the homogeneity of the liquid during the mixing phase. As a result, the faster the stirring speed, the less time it takes to achieve homogeneity in the mixture [Hendrasarie et al. 2021]. The SBR was also measured without

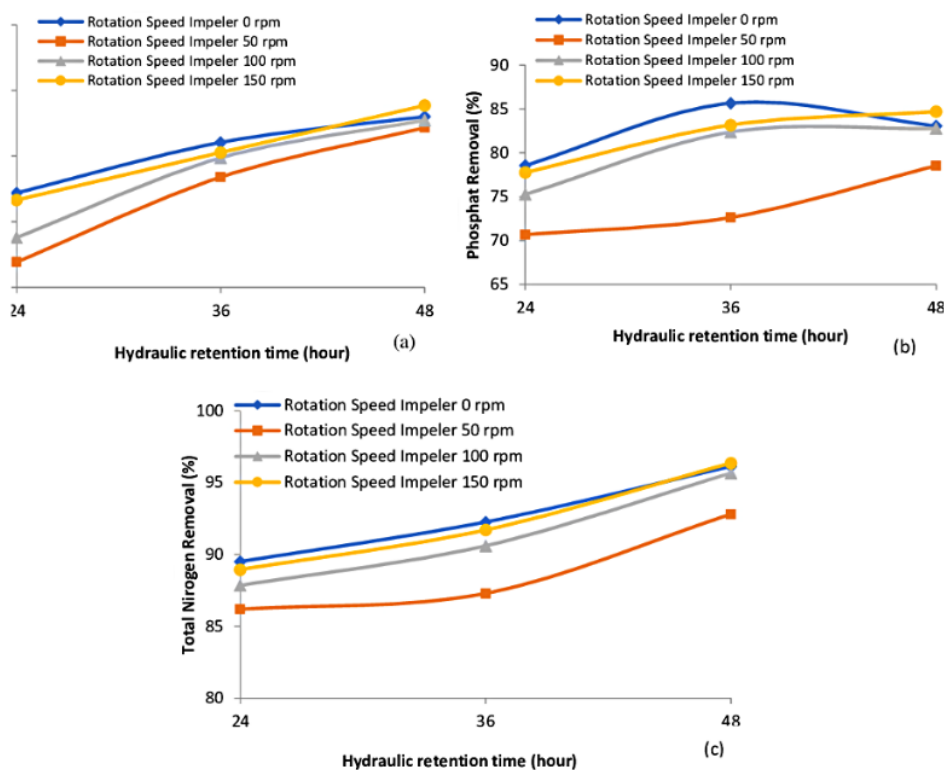


Figure 3. The addition of an impeller in the sequencing batch reactor resulted in a decrease in (a) BOD_5 , (b) phosphate, and (c) total nitrogen

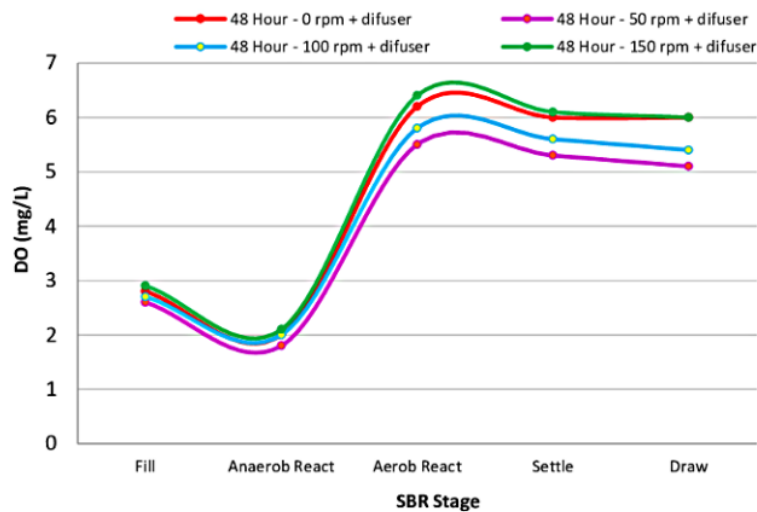


Figure 4. DO characteristics during cycle changes in SBR during 48 hours of HRT

an impeller, using only a diffuser, which was an important aspect of this research. Figure 3 shows the removal percentages of BOD₅, phosphate, and total nitrogen after adding a 150-rpm impeller, with HRT having the highest removal percentages of BOD₅, phosphate, and total nitrogen after 36 hours.

Microbes that degrade organic matter were identified

The aim of identifying microorganisms in the SBR is to decide which microorganisms degrade organic and pollutant content during the removal process in the reactor operation process. *Pseudomonas* sp. and *Bacillus* sp. bacteria are active in the SBR process. The existence of *Pseudomonas* sp. bacteria, which belong to the phylum *Proteobacteria*, indicates that the dissolved oxygen (DO) levels in the wastewater are adequate to create aerobic condition. These bacteria are involved in the denitrification process, which involves converting nitrate to nitrite and then releasing nitrogen gas. From nitrification to the decomposition of pollutant levels, the denitrification process becomes a further digestion process. *Bacillus* sp. is aerobic to facultatively anaerobic, indicating that facultative anaerobic conditions have been well developed in the anaerobic conditioning cycle. Extracellular enzymes can be generated by *Bacillus* sp. to break down cellulose and hemicellulose. *Bacillus* sp. is involved in the process of denitrification. *Bacillus* sp. can use organic matter in wastewater by

releasing the enzymes that decompose organic compounds into carbon dioxide (CO₂), hydrogen (H₂), methane (CH₄), water (H₂O), and energy, all of which are used to promote metabolic activity. One of the most common elements found in activated sludge flocks is bacteria. Bacteria help in the oxidation of organic matter and the transformation of nutrients during the processing process. Bacteria produce polysaccharides and polymeric materials that assist biomass flocculation. Dissolved oxygen is one of the limiting factors. Figure 4 illustrates an image, of dissolved oxygen characteristics during cycle changes in SBR at 48 Hours of HRT. Figure 4 shows the DO characteristics in the sequencing batch reactor across different cycles. The DO characteristics follow the cycle pattern, which means that in the anaerobic react, the DO conditions are at their lowest, ranging from 1.8 to 2.2. At a rotation speed of 150 rpm, DO reach a limit of 6.6 for HRT in the aerobic react period after 48 hours. The reactor in this study that does not have an additional impeller has DO characteristics that exceed a speed of 150 rpm. As a result, the addition of an impeller to the Sequencing Batch Reactor works best at high rotation speeds, at least 150 rpm.

CONCLUSIONS

In this study, the 48-hour HRT was found to be the best for tofu wastewater treatment using SBR. The optimum stirring speed in the tofu

wastewater treatment process using SBR was 150 rpm after 48 hours, which reduces the parameters of BOD₅, PO₄, and total nitrogen to 93.33%, 90.97%, and 93.73%, respectively. However, the capacity of the SBR without an impeller, which only uses a diffuser, is almost identical to that of an impeller with a speed of 150 rpm. The degraded microorganisms were aerobic to facultatively anaerobic, with DO characteristics by the SBR cycle, and were classified, namely in the *Pseudomonas* sp. and *Bacillus* sp.

Acknowledgments

⁵ The authors gratefully acknowledge the financial support for this work by the Ministry of Higher Education Indonesia, 2021.

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