Optimization of Hydraulic Retention Time (HRT) and Inoculums Addition in Wastewater Treatment Using Anaerobic Digestion System

Sakunda Anggarini*, Nur Hidayat, Nimas Mayang Sabrina Sunyoto, Putri Siska Wulandari

Abstract

This research aims to get the optimum combination of Hydraulic Retention Time and addition of inoculums in tofu’s wastewater treatment using anaerobic system. Research was done using Central Composite Design (CCD) with two factors, which were Hydraulic Retention Time (12; 18; and 24 hours) and addition of inoculums (5%; 10%; and 15%). The desired responses was percentage decrease of COD, BOD, and TSS; and also increase of pH. According to CCD analysis, the best result was optimally gained on HRT 24 hours and 15% inoculums addition. Those combined factors could decrease COD up to 86.76%, whereas the decreasing amount of BOD was up to 79.23%, and TSS was up to 67.88%. In addition to those combination, pH of tofu’s wastewater increased up to 4.5. That showed that anaerobic system could reduce COD, BOD, and TSS but it couldn’t significantly neutralize pH of tofu’s wastewater yet. Due to a 24-hours-anaerobic treatment, the degradation process was still in hydrolytic phase. HRT increase and additions of inoculums, as well as the usage of double treatment system (anaerobic-aerobic; aerobic-anaerobic; anaerobic-anaerobic; or aerobic-aerobic) are required to obtain optimal result.

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Keywords: Anaerobic; Hydraulic Retention Time; Inoculums; Tofu’s Wastewater; Optimization
1. Introduction

In Indonesia, it is common that tofu industry’s liquid waste is directly discharged into nearby water bodies by performers in that industry. Besides, it is well known that tofu’s wastewater still contains high organic contaminants that can pollute environment. Treatment using microorganisms can be used as an alternative way to treat this waste (Jasmiyati et al, 2010). Wastewater with high content of organic contaminants, reflected from COD content above 5,000 mg/L can be processed using an anaerobic digestion system (Metcalf and Eddy, 2003). Previous research (Husin, 2008), asserted that addition of 10% (v/v) microbial culture and also the process of 12, 18, and 24 hours of Hydraulic Retention Time (HRT) to tofu’s wastewater, could reduce its COD content up to approximately 60%. The involved microbial culture was isolated from sludge, taken from tofu’s waste effluent.

In this study, determination of treatment point was also based on the inoculum addition approach and usage of retention time. The 12, 18, and 24 hours were used as HRT as well as the addition of inoculum in the amount of 5%, 10%, and 15%. The main objective of this study is to determine optimal process condition in anaerobic system, which was expressed in COD, BOD and TSS removal as well as the rise of pH in tofu’s wastewater.

2. Material and Methods

2.1 Inoculum and Wastewater Preparation

Inoculum culture was prepared by isolating microbe from the sludge, lying in the river’s flow close to the tofu’s wastewater sewerage. The filtered sludge was maintained in the sterilized tofu’s liquid waste, then cultured for several days. After 2 days, with the assumption that microorganism had already grown, it was raised in Nutrient Broth (NB) media and maintained in anaerobic conditions. Subsequently, the inoculum culture was scaled up once every two days until it was complied with the requested volume for waste treatment process. Tofu’s whey was sourced from Tofu’s industry in Malang, Indonesia. Its characteristics are presented in Table 1. It was advised to use at least 2 day fresh wastewater, to prevent deep alteration before applied in the anaerobic system.

<table>
<thead>
<tr>
<th>No</th>
<th>Parameter</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>COD</td>
<td>29,700 mg/L</td>
</tr>
<tr>
<td>2</td>
<td>BOD</td>
<td>8,852 mg/L</td>
</tr>
<tr>
<td>2</td>
<td>TSS</td>
<td>936 mg/L</td>
</tr>
<tr>
<td>3</td>
<td>pH</td>
<td>3,6</td>
</tr>
</tbody>
</table>

2.2 Anaerobic Digestion System Performance

Treatment process was conducted in the anaerobic reactor tank system (the design is presented in Fig 1). Every system had a different treatment according to combination of the HRT and inoculum added. It started with a 7-day-adaptation phase and continued with the given HRT respectively. Adaptation phase was executed when inoculum and liquid waste mixing were in total volume of 25L. In the tank reactor, a catcher was made to mediate the formation of microorganisms’ biofilm. It was designed from gauze and left hanging to get spreadly desirable biofilm in the reactor. Passing the determined HRT, samples were taken, then kept for 24 hours. Precipitation served to precipitate the suspended solids fetched at the time of sampling. Hence, several quality parameters were obtained by assigning the served samples.
2.3 Wastewater quality assay

Performing of wastewater quality, main parameters employed in this study consisted of COD, BOD, TSS, and pH. COD analysis was performed with a spectrophotometric (Greenberg et al., 1992). BOD analysis was performed using the BOD5 method (Sirnivas, 2008). TSS analysis was done using gravimetric method (Bassett et al., 1994), while the pH analysis was performed with a pH electrometer (Bassett et al., 1994).

2.4 Data Analytical Method

Data was obtained from quality assay, then processed using Design-Expert program 8.0.7.1. Data was then tabulated by composite centralized design with two factors and five repetitions at the midpoint of levels of COD, BOD, TSS and pH as responses. The data was processed following Design-Expert 8.0.71 procedures program to obtain the optimal combination of treatments.

3. Result and Discussion

3.1 COD and BOD Removal Response

The result showed that HRT and inoculums addition interaction didn’t result in COD removal. The absence of interaction between those two factors is mainly caused by inoculums factor. This is presumable that the system of microorganisms didn’t grow simultaneously, therefore the degradation ability to COD of wastewater was not optimal. In addition, the availability of nutrients for microorganisms could also affect the performance of them. This term is in line with opinions of Jasmiyati et al. (2010), that in environment, the ability of microorganisms to do their metabolism might vary. Along with the growing amount of the added inoculum, competition among microorganisms became higher and resulted in microorganisms decrease. Therefore bioremediation of waste process didn’t optimally work. The result of COD removal in the system is depicted in Fig. 2A.

Fig.2A shows at the initial process with each passing HRT, COD reduction become higher until it reaches a certain peak point (HRT 18 hours). However after passing 18 hours, descending of COD reduction happened. This is because microorganisms didn’t work in optimal condition any longer (Rahayu et al., 2012). Jasmiyati et al. (2010) suggested that microorganisms’ activity decreased along with the decrease of growth nutrient source.
Fig. 2. (A). Effect of HRT on COD reduction; (B). Effect of Inoculum addition on BOD reduction

HRT also didn’t give a significant effect on BOD reduction, due to in the range of given HRT, BOD degradation process was not running optimally yet. At the relatively short time, microorganisms in the anaerobic reactor was still in the adjustment phase. Consequently, the active microbes which stayed in the biofilm was still in a few numbers (Husin, 2008). Thus, decomposition process of complex organic substance in the wastewater by anaerobic microbes into simpler compounds has not optimally been transpired.

Inoculum was added in the biological processing can degrade the contaminants present in the wastewater. However, it took the appropriate amount of inoculums addition in order to reduce BOD level in the wastewater optimally. Result of inoculum effect on BOD reduction is presented in Fig. 2B. In Fig. 2B, it noted that the pattern of the existing data shows that microorganisms which work to degrade the waste continually increases. It means that the addition of inoculum at various concentrations hasn’t reached the optimum point of degradation yet. Mishra et al. (2001) suggested the conformity between inoculums ratio and substrate composition could affect wastewater degradation process. Therefore, the precision of determining inoculum amount is required in wastewater anaerobic treatment process. This is in line with Mulyani et al. (2012), that the optimal number of microorganisms would assist in organic compounds degradation, characterized by the decreasing number of BOD.

3.2 TSS Removal Response

In the TSS decreasing response, a substantial reduction in the various treatments wasn’t obtained. This is because the used HRT in this case wasn’t sufficient to reduce the TSS level from the effluent. Result of TSS decreasing response is presented in Fig. 3. TSS removal response showed that there weren’t significant effects, by either individual or interaction of these two factors. At the given time period, microorganisms which worked within the system were still in hydrolytic phase. In this phase, the degradation process was not running perfectly and not able yet to reduce levels of TSS in wastewater. In the hydrolytic process, the decomposition of complex organic compounds into the monomer-monomer, occurred. Thus, TSS wasn’t optimally degraded.

Husin (2008), in his previous research revealed similar results that in a short time, microorganisms in the anaerobic reactor was still in the adjustment phase. As a result, the number of active microbes in the biofilm also still in relatively small number. Thus, the process of decomposition of complex organic compounds in wastewater by anaerobic microbes into simpler compounds didn’t optimally last. Determination of the proper HRT would produce optimum waste treatment in lower TSS levels.
3.3 pH Response

According to the results of performed pH test, after process was completely done, it was known that the highest reached pH was in the level of 4.5. That was obtained from HRT treatment for 10 and 18 hours and the addition of inoculum by 10%. Analysis of variance showed there were no significant results for the pH response model. This means that pH response data didn’t have major differences in the various treatments.

This research hasn’t been able to neutralize the pH. However it was able to reduce levels of contamination of COD, BOD, and TSS. Within 24 hours, the anaerobic degradation process had already run but was still in the hydrolytic phase. Therefore the ability of system in pH neutralizing of wastewater was still low. That highly acidic pH showed that the effluent wasn’t feasible directly discharged into the environment. Furthermore future research can be conducted by increasing the HRT where anaerobic degradation process can take place perfectly to generate methane (methanogenesis phase).

3.4 Optimization of COD, BOD, TSS and pH by Centralized Composit Designed

This study aims to find the optimal solution of the decreasing response of COD, BOD, TSS, and increasing pH within the HRT and inoculums addition in a wider experimental area. Specified limits in this optimization were factors used in the experimental design. Therefore the values were in accordance with the treatments. HRT had a lower limit and upper limit of 12 and 24 hours respectively, whereas the lower and upper limit of inoculum addition was in amount of 5% and 15% respectively. In those ranges, the optimum expected reduction in COD, BOD, TSS, and an increase in pH will be achieved. The upper limit and lower limit for COD and BOD response were determined according previous research (Said and Firly,2005), that anaerobic process could reduce levels of COD contamination level in the range of 78-87%, whereas BOD level ranges between 78 and 89%. Maximum and minimum values of TSS response was determined according to Nurullita and Mifbakhudin (2010) research, in which the decrease reached 41.32 to 64.32%. Determination of the limit can be seen in Table 2.

<table>
<thead>
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<th>Criteria</th>
<th>Parameter</th>
<th>Direction</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
<td>HRT (hour)</td>
<td>Is In Range</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>Factor</td>
<td>Inoculum (%)</td>
<td>Is In Range</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Response</td>
<td>COD (%)</td>
<td>Maximize</td>
<td>78</td>
<td>87</td>
</tr>
<tr>
<td>Response</td>
<td>BOD (%)</td>
<td>Maximize</td>
<td>78</td>
<td>89</td>
</tr>
<tr>
<td>Response</td>
<td>TSS (%)</td>
<td>Maximize</td>
<td>41.32</td>
<td>64.32</td>
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<tr>
<td>Response</td>
<td>pH</td>
<td>In target = 7</td>
<td>4.2</td>
<td>7</td>
</tr>
</tbody>
</table>

According to the specified limits presented in Table 2, the optimal solution results were obtained using Design Expert DX 8.0.7.1 that can be seen in Table 3. Based on Table 3, optimal solution was reached at the...
24-hour HRT treatment and the addition of 15% inoculum, with the desirability of 0.320. This means that the level of optimization accuracy of this data is 32%. The optimal solution is known to reduce the COD level up to 86.76% from the initial COD content of 29,700 mg / L. BOD has decreased to 79.23%, whereas the content of TSS in wastewater can be reduced up to 67.88%. And lastly, pH increased from initially 3.6 to 4.5

### Table 3. Optimal Solution Calculated using Design Expert 8.0.7.1

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Parameter (unit)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor HRT (hour)</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Factor Inoculum (%)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Response COD (%)</td>
<td>86.76</td>
<td></td>
</tr>
<tr>
<td>Response BOD (%)</td>
<td>79.23</td>
<td></td>
</tr>
<tr>
<td>Response TSS (%)</td>
<td>67.88</td>
<td></td>
</tr>
<tr>
<td>Response pH</td>
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<td></td>
</tr>
<tr>
<td>Desirability</td>
<td>-</td>
<td>0.320</td>
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</table>

This study was justified to be more effective than Husin’s (2008), which is only able to reduce COD up to 58.97%. However, optimal solution results in HRT 24 h and inoculum addition of 15% make up as the upper limit in this study. These results show that in real conditions, the range of given treatment was not optimal yet to reduce wastewater contaminants levels. This is proven by the obtained test results (it isn’t detailed to present here) that processed whey’s COD content was still in amount of 3580 mg / L, BOD content was 1453.6 mg / L, TSS content was 202.2 mg / L, and pH was at 4.5.

These results suggested that the HRT at 24 h and inoculum addition of 15% are not the substantive optimal solution to anaerobic treatment system. As within 24 hours, the anaerobic degradation process is still in the hydrolytic phase. Therefore it needs to run similar research by extending the HRT to gain perfect running of anaerobic degradation. Besides, the usage of double treatment system (anaerobic-aerobic; aerobic-anaerobic; anaerobic-anaerobic; or aerobic-aerobic) are suggested to obtain more optimal result.

### 4. Conclusion

The optimum solution obtained from the wastewater anaerobic treatment system was constituted by combination of Hydraulic Retention Time (HRT) treatment for 24 hours and the addition of inoculum treatments by 15%. That combination can reduce COD levels up to 86.76%, 79.23% BOD, 67.88% TSS and pH level of the tofu’s whey now can now be increased from 3.6 to 4.5.

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### References


