STUDY ON MODELING FISH PROCESSING WASTEWATER ANAEROBIC TREATMENT

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Abstract

A simple model anaerobic treatment treats fish processing wastewater as necessary for small and medium factories. For this reason, several techniques have been proposed. However, they have been expensive and hardly operational. A simple technique with low cost of treatment and operations was applied. In this study, the hydraulic retention times (HRTs), including 4, 6, 8, 12 and 24 hours with various loading rate of 1.0 to 6.0 kg COD/m^3/day, were examined. A biomass as VSS in the model was at 10 to 11g/l. On the basis of the result the optimal hydraulic retention times (HRTs) with a 4.0 kg COD/m^3/day organic loading rate was 6 hours with BOD_5 and COD removal efficiency of 92% and 90%, respectively. By the end of the optimal hydraulic retention times, the total methane production volume collected was 3.2 litters.

Keywords: Anaerobic Treatment, Fish Processing Wastewater Treatment

Introduction

During the past two decades, anaerobic wastewater treatment biotechnology was extensively advanced by the development of up-flow anaerobic sludge blankets (UASB), anaerobic baffled reactors (ABR), anaerobic fluidized beds (AFB), anaerobic filters (AF) as well as expanded granular sludge blankets (EGSB) [3], [7], [9], [10]. These give various advantages over aerobic processes. Less energy is required, less biological sludge is produced, fewer nutrients are used, and methane is generated as a potential energy source, with suitable environmental conditions. These anaerobic processes can be grouped into two categories according to the mechanism of biomass retention: *fix film reactor,* where the bacteria are attached to a carrier material (e.g AF, AFB), and *suspended growth reactor,* without any carrier material (UASB, EGSB). For the suspended growth process, granular sludge formation has received much attention recently [2], [6], [10]. However, the mechanisms that trigger granulation are yet poorly understood. The development of granular sludge is affected by wastewater characteristics and is often successful with wastewater containing high levels of carbohydrates and sugar.

Wastewater from seafood processing operation can have very high levels of dissolved and suspended organic materials. This results in high biological oxygen demand (BOD) and chemical oxygen demand (COD). Fats, oil and grease are also present in high amounts. Suspended solids and nutrients such as nitrogen and phosphate can often be found in high levels also. Seafood processing wastewater has been noted to sometimes contain a high concentration of sodium chloride from boat unloading, processing water and brine solutions.

The major types of waste found in seafood-processing wastewater are blood, offal products, viscera, fins, fish heads, shell, skins and fine meat particles. . The major process operations include product receiving, boat unloading, sorting and weighing, preparation (butchering, scaling, filleting, skinning, evisceration), inspection, and trimming. Organic material in the wastewater is produced in the majority of these processes. However, most of it originates from the butchering process, which generally produces organic materials such as blood and gut materials.

It has been established that a few fish processing wastewater treatment techniques such as biological treatment have many problems, such as the high cost of treatment for meeting discharge standards and the instability of the treatment system. The effective and economical wastewater treatment of fish processing has become an important issue for the beginning development of seafood industry.

In the case of relatively low strength wastewater such as fish processing, the hydraulic retention time and organic loading rate are the most important parameters for successful operation of an anaerobic reactor.

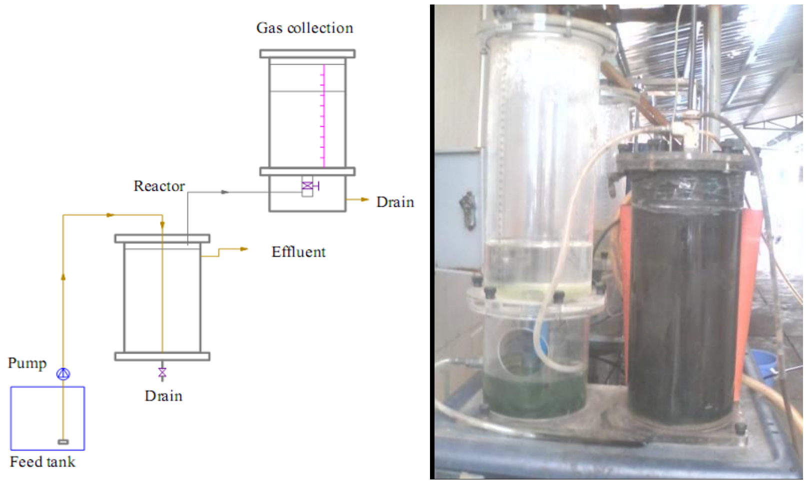
Methods

The Experimental Site

A pilot scale anaerobic reactor system was built in the laboratory department of Faculty of Environment, University of Technology, Ho Chi Minh City, Vietnam. Ho Chi Minh City has a tropical climate and two distinct seasons. During the rainy season, the average annual rainfall is about 1,800 millimetres (approximately 150 rainy days per year), from May to late November and the dry season begins from December to April. With an average humidity of 75%, temperatures range from 16^0C (61 °F) to 39 °C (102 °F) with an average temperature of 28 °C (82 °F).

Experimental Setup

The anaerobic reactor which was used in this study was made with a column with an inner diameter of 150mm, a total volume of 5 litters including reaction section of 4.8 litters and a gas zone of 0.2 litters. The wastewater was introduced into the bottom of the reactor though a tube with a diameter of about 3mm. The source of sludge was taken from the UASB of a factory of tapioca products in Chau Thanh district, Tay Ninh province, Vietnam. Sludge concentration in the reactor was 11.6g SS/L (10.2gVSS/L).



a) b)

Figure 1. Schematic diagram a) and Actual experimental set up b) of anaerobic reactor

The methane gas was collected with a tube to a column of 5 liter diameter. In this column, it took a 5 percent sodium hydroxide solution to absorption to absorb carbon dioxide (CO_2) and hydrogen sulfide (H_2S) gases. Influent and effluent samples were analyzed for pH, alkalinity, COD, BOD_5, suspended solid (SS) and VFAs on a daily basis. The volume of produced methane gas was measured at every loading rate.

Fish Processing Wastewater Influent

Fish processing wastewater which was taken at Ba Hat market, District 10, Ho Chi Minh City was diluted with tap water to intended concentration to serve an influent for this study. The characteristics of the wastewater included 1000 ± 50mg COD/l, 112 – 168 mg TN/l, 14 – 29 mg TP/l was 100 : (11.2 – 16.8): (1.4 – 2.9) which is similar to (200 – 500) : 5: 1 [16]. Sodium hydrogen bicarbonate ($NaHCO_3$) was used as buffer solution to adjust influent pH to about 7.

Analytical Techniques

COD, BOD_5, SS, VSS, VFAs, alkalinity, TN, TP: Filtered $COD_{effluent}$ and $BOD_{5effluent}$ (1.2µm) were measured by the closed reflux titrimetric method (SMEWW, 2005)[13] and 5 – day BOD test)[13], respectively. SS in effluent and VSS in sludge samples were measured by Total suspended solids dried at 103 – 105^0C and volatile solids ignited at 550^0C (SMEWW, 2005) [13], respectively.

VFAs were measured by distillation method (SMEWW, 2005) [13]. Alkalinity was measured by the titration method (SMEWW, 2005) [13]. Total Phosphorus (TP) was measured by the ascorbic acid method (SMEWW, 2005) [13]. Total nitrogen (TN) was measured by TCVN 6638 – 2000.

Gas was collected by a tube with a 5 liter column. Carbon dioxide (CO_2) and hydrogen sulfide (H_2S) were absorbed by a 5 percent sodium hydroxide solution. The volume of produced methane was the lost sodium hydroxide volume.

Table 1. Summary of Conditions Used During Operation of Anaerobic Reactor

Day	Parameter									
	OLR kg COD/m^3/d	**HRT** h	**COD_i** mg/l	**COD_e** mg/l	**BOD_{5i}** mg/l	**BOD_{5e}** mg/l	**VFAs** mg/l	**SS_e** mg/l	**pH_i**	**pH_e**
1	0.5	48	1093	115	-	-	-	-	7.32	7.68
2	0.5	48	1000	99.6	-	-	-	56	7.44	7.56
6	0.5	48	1000	92	-	-	-	56	7.08	7.21
7	0.5	48	1000	82	-	-	-	16	7.3	7.34
8	0.5	48	1000	75	-	-	-	40	7	7.12
10	0.5	48	1000	74.6	-	-	-	30	7.32	7.51
11	0.5	48	1000	75	-	-	-	30	7.32	7.52
13	0.5	48	1000	74.6	-	-	-	35	7.28	7.45
15	1.0	24	1080	160	-	-	-	170	7.10	7.32
19	1.0	24	980	148	-	-	-	-	7.42	7.47
20	1.0	24	980	125	-	-	-	-	-	-
23	1.0	24	1025	130	-	-	-	240	7.13	7.30

24	1.0	24	1025	88.3	-	-	56	68	6.90	7.31
25	1.0	24	1025	85.3	-	-	-	66	6.90	7.33
26	1.0	24	987	82.6	-	-	52	58	7.03	7.24
27	1.0	24	1000	84.5	824	62	52.5	62	7.2	7.37
29	2.0	12	1013	122	-	-	-	100	6.9	7.18
31	2.0	12	1000	90	-	-	54	68	7.18	7.22
32	2.0	12	-	-	-	-	-	-	6.87	7.19
34	2.0	12	1066	94	-	-	60	116	7.14	7.28
35	2.0	12	1066	94	-	-	50	118	7.14	7.35
39	2.0	12	1108	106	-	-	48.2	-	7.13	7.28
41	2.0	12	1080	102	794	58	-	80	6.9	7.13
43	3.0	8	1093	138	-	-	-	124	6.94	7.06
47	3.0	8	1093	104	-	-	62.4	266	6.88	7.15
48	3.0	8	1093	104	-	-	64	162	6.97	7.21
51	3.0	8	1080	102	-	-	56.5	360	7.11	7.27
53	3.0	8	1080	96	-	-	45.2	580	7.07	7.21
54	3.0	8	973	88	-	-	56.5	580	7.1	7.36
55	3.0	8	973	98	785	51	75.2	580	7	7.25
59	4.0	6	973	109	-	-	69.2	124	6.92	7.21
62	4.0	6	1100	130	-	-	72.4	-	6.94	7.42
65	4.0	6	1103	105	-	-	75	510	6.80	7.14
66	4.0	6	973	109	-	-	66	320	6.69	7.12
67	4.0	6	1013	92	-	-	53.6	210	6.85	7.20
68	4.0	6	1146	96	-	-	55	380	6.76	6.86
69	4.0	6	1146	126	768	64	53.6	210	6.90	7.12
73	6.0	4	1050	216	-	-	146.1	340	6.99	7.23
74	6.0	4	1050	206	-	-	146.1	670	6.8	7.21
76	6.0	4	1100	218	-	-	132	580	7.03	7.36
78	6.0	4	1100	185	-	-	142	620	6.98	7.31
81	6.0	4	1060	204	-	-	138	580	7.21	7.42
84	6.0	4	1038	230	720	158	152	650	7.06	7.28

Results

Reactor Start Up

The reactor was started up with an organic loading rate (OLR) 0.5 kg COD/m^3/d (HRT of 48h), considering the results of previous studies [4], [13], [20]. During the first 14 days of reaction operation, the COD removal efficiency was about 93%. The volume of methane produced was 218 cm^3. Suspended solid (SS) effluent was lower than 56 mg/l. Even SS was of 16 mg/l after eight days of the reaction operation.

Table 2. Average COD, BOD Removal Efficiency

OLR (kg COD/m^3/d)	HRT (hour)	parameter COD (mg/l)	BOD (mg/l)
0.5	48	91.5 ± 1.3	-
1.0	24	88.8 ± 3.1	92.5
2.0	12	90.4 ± 1.3	92.7
3.0	8	90.1 ± 1.3	93.5
4.0	6	89.7 ± 1.3	91.5
6.0	4	80.3 ± 1.8	78.1

Table 3. Average SS, VFAs, CH_4 Effluent

OLR (kg COD/m^3/d)	HRT (hour)	parameter		
		SS (mg/l)	**VFAs** (mg/l)	**CH_4**(l/kg COD)
0.5	48	37.6 ± 14.6	-	7.3
1.0	24	110.7 ± 76.4	53.5 ± 2.2	9.7
2.0	12	96.4 ± 22.0	53.1 ± 5.2	8.6
3.0	8	378.8 ± 202.6	60 ± 10	8.2
4.0	6	292.3 ± 139.8	65.2 ± 9	13.3
6.0	4	573.3 ± 119.9	130 ± 34.3	15

Table 4. Calculated Biomass Loss from System with VSS: SS = 0.7 and Overall Yield = 0.08

HRT (h)	Q(l)	Parameter				
		Effluent biomass (mgVSS/l)	COD removed (g/d)	Biomass produced (gVSS/d)	Biomass concentration (mgVSS/l)	Biomass loss (mgVSS/l)
48	2.4	26.32	2.19	0.17	73.12	-46.8
24	4.8	77.49	4.32	0.34	72.00	5.49
12	9.6	67.48	9.08	0.72	75.68	-8.2
8	14.4	265.16	13.69	1.09	76.08	189.08

6	19.2	204.61	18.33	1.46	76.40	128.21
4	28.8	401.31	21.13	1.69	58.72	342.59

Reactor Performance

A continuous operation was maintained for 85 days, during which the OLR was increased to 6.0 kg COD/m^3/d.

Removal Efficiency of COD

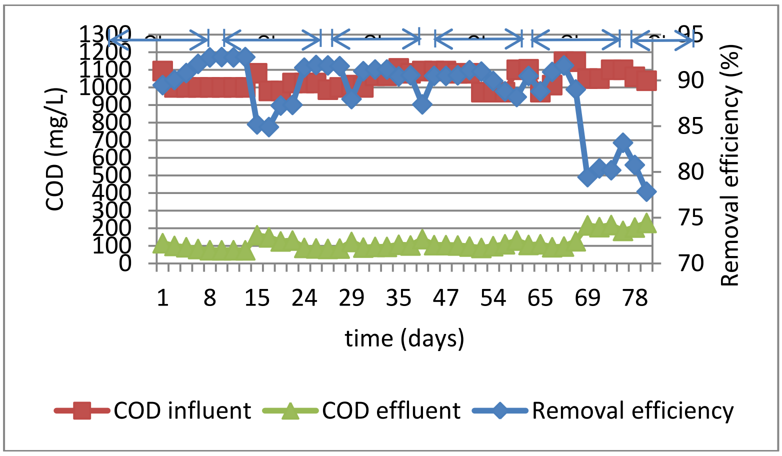


Figure 2. Daily changes in COD removal efficiency at different OLRs (kg COD/m^3/d)

Figure 2 shows the treatment efficiencies during the entire experimental period. When OLR was increased from 1.0 to 4.0 kg COD/m^3/d (HRT was decreased from 24h to 6h), COD removal efficiency was from 85 to 92%. However, COD removal efficiency above 90 percent was achieved by the stable reaction operation in these OLRs. COD removal efficiency was only about 78 to 83% of 6.0 kg COD/m^3/d (HRT of 4h). Therefore, COD removal efficiency was highest at 4 kg COD/m^3/d with HRT of 6h.

Removal Efficiency of BOD_5

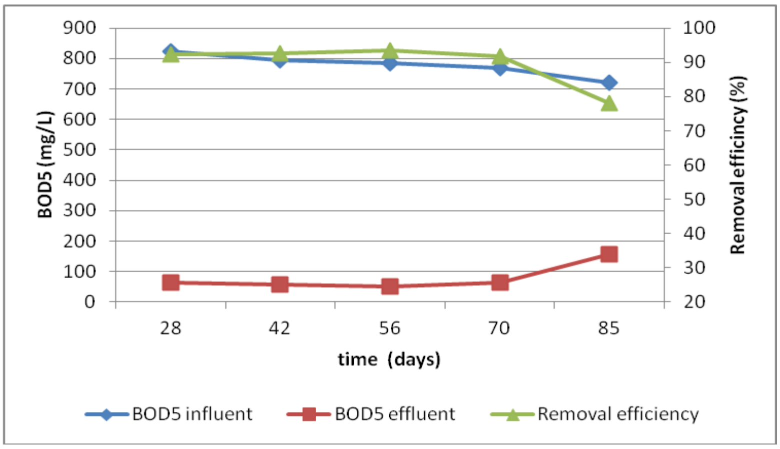


Figure 3. Daily changes in BOD_5 removal efficiency at different OLRs (kg COD/m^3/d)

Figure 3 shows OLR was increased from 1.0 to 4.0 kg COD/m^3/d (HRT was decreased from 24h to 6h), BOD_5 removal efficiency was about 92 to 94%; BOD_5 removal efficiency was highest at 3 kg COD/m^3/d (HRT of 8h) and BOD_5 removal efficiency was lowest at 4.0 kg COD/m^3/d (HRT of 6h). However, these BOD5 removal efficiencies were higher than 90%. BOD_5 removal efficiency was only about of 78% of 6.0 kg COD/m^3/d (HRT of 4h).

VFAs Effluent

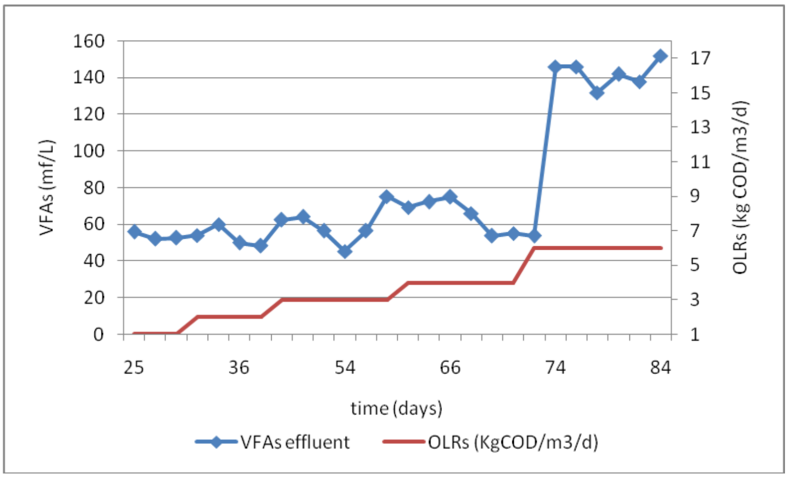


Figure 4. Daily changes in VFAs effluent at different OLRs (kg COD/m3/d)

Figure 4 shows OLR was increased from 1.0 to 3.0 kg COD/m^3/d (HRT was decreased from 24h to 8h), VFAs concentration effluent was from 45 to 64 mg as CH_3COOH/l; however, VFAs concentration was achieved of 75.2 mg as CH_3COOH/L once at fifty sixth day of 3.0 kg COD/m^3/d. The higher VFAs concentration in the effluent was from 54 to 75 mg as CH_3COOH/l at OLR of 4.0 kg COD/m^3/d. Therefore, the low VFAs concentration effluent was achieved of these OLRs. When OLRs were increased to 6.0 kg COD/m^3/d, VFAs concentration effluent was from 132 to 152 mg as CH_3COOH/l. This concentration was better compared with the one with the low OLRs.

Daily Changes in SS Effluent

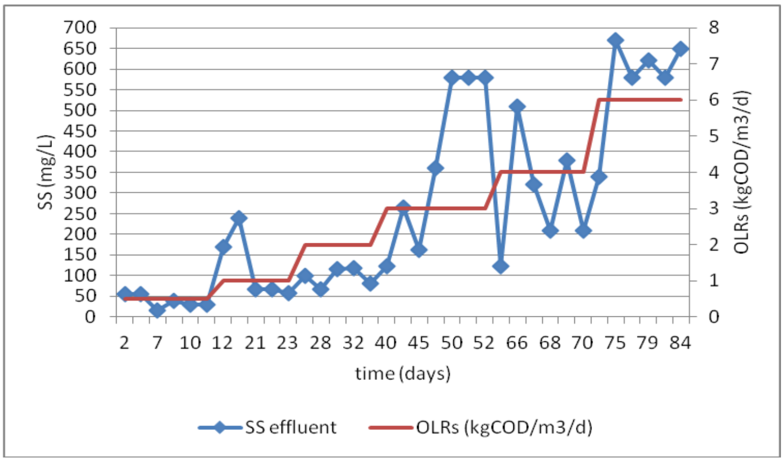


Figure 5. Daily changes in SS effluent at different OLRs (kg COD/m^3/d)

Suspended solid (SS) concentration effluent had unstable exchanges as shown in Figure 5. However, SS concentration was increased when the OLR was increased. The highest concentration of 3 kg COD/m^3/d and 6 kg COD/m^3/d achieved were 580 mg/L and 670 mg/L, respectively. SS concentration influent was high enough to lead high levels of turbid water effluent and COD, while BOD_5 removal efficiency was decreased respectively.

Methane Production

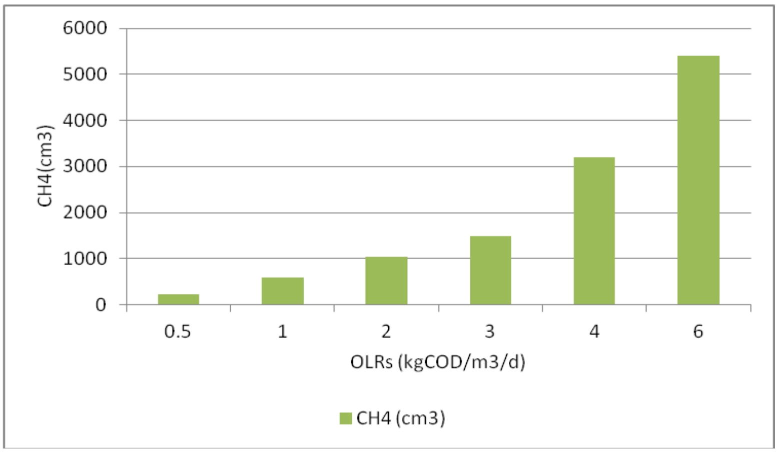


Figure 6. The total methane volume produced at different OLRs (kg COD/m^3/d)

Figure 6 shows the total methane volume production after the end of time reaction operation of each OLR. When OLR was increased from 0.5 to 6.0 kg COD/m^3/d, the methane volume production was 218, 582, 1028, 1480, 3200 and 5400 (cm^3), respectively. The methane gas was collected and used for fresh fuel.

Daily Changes in pH

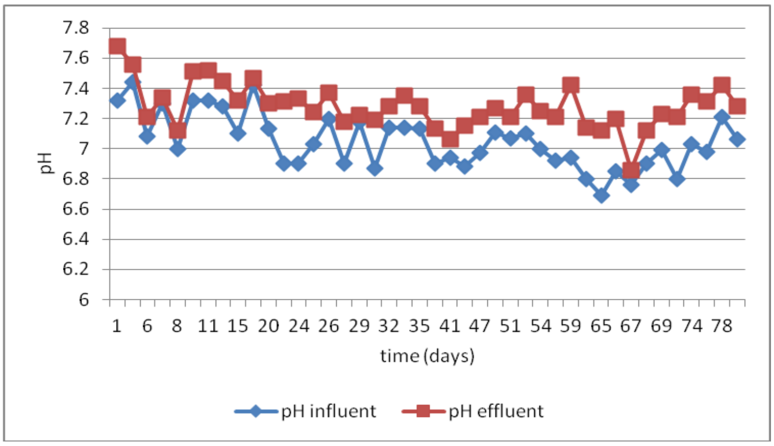


Figure7. Daily changes in pH

Figure 7 shows the stability parameter pH influent and pH effluent was always within the optimal ranges; however, pH effluent was always higher than the pH influent. pH in the reactor varied between 6.69 and 7.68, so the reactor was always optimally self buffered.

Discussion

It is observed as shown in Figures 2 and 3 that anaerobic reactor for COD and BOD_5 removal efficiency increases and becomes stable after reducing HRT from 48 to 6 h, with increasing OLRs from 0.5 to 4 kg COD/m^3/d. High COD removal (>85%) and high BOD_5 removal (>90%) were achieved. This was due to high quality and high settling velocity of seed added during each 2 week study period. However, the results indicate that there was little benefit in operating the reactor at an HRT exceeding 6h because little additional removal of COD and BOD_5 was achieved. Increasing HRT to more than 6 h (OLR exceeding 4 kg $COD/m^3/d$) increased F/M ratio, leading to a shock in the reactor. Therefore, the optimum HRT for COD and BOD_5 removal could be considered 6 h (OLR = 4 kg $COD/m^3/d$). Other studies [1], [5], [16], [17] are in good agreement with the result presented here. There was low COD and BOD_5 removal efficiency in HRTs less than 6h where an increased SS effluent was observed with decreased activated sludge concentration in reactor.

The typical anaerobic reactor operated at a sludge retention time (SRT) with a much higher HRT. The sludge in the reactor was mixed by biogas generated and velocity of inflow. It helped to increase contact between sludge and wastewater and increase effectiveness of process. However, it also limited biomass settling as well as biomass accumulation. Introduced seed sludge was stably maintained and grew in the reactor as calculated in Table 4. When the reactor was operated at HRT from 48h to 6h, it resulted in biomass accumulation. There was no biomass accumulation unit in reactor and biomass was lost from reactor unit when the reactor was operated at a HRT exceeding 6h (OLR exceeding 4 kg $COD/m^3/d$).

VFAs production decreased pH and passive bacteria. Low VFAs concentration effluent was observed (Figure 4) might lead to a high pH effluent. This proved that methanogenesis step was good. However, operating the reactor at HRT exceeding 6h, the results indicated that there was an increase in VFAs effluent but that was not to lead to a low pH effluent. VFAs effluent increase was achieved by decreasing the metabolization of acetic acid into methane and carbonic gas.

Average methane production at optimal HRT (6h) was achieved of 13.3 l/kg COD removed. The rate was too low. The other study was achieved with 0.22 m^3/kg COD removed [18]. This could have caused by the leaking of the gas pipe. Hydrogen generated which had a partial pressure higher inhibited methanogenesis step. The generated hydrogen, which had higher partial pressure, inhibited the methanogenesis.

Biological conditions might also be changed according to the change of OLR. Methanogens can exist in a stable form in this reactor under such low HRT conditions. This one was proven by the results for COD and BOD removal shown in Figure 2 and Figure 3.

The removal performance of the anaerobic reactor in terms of COD and BOD_5 depends on HRT, organic loading rate (Table 1). On the basis of the obtained results, construction of the anaerobic reactor with an HRT of 6 h (OLR of 4 kg $COD/m^3/d$) will be economical for a fish processing wastewater treatment.

Conclusions

The results obtained in this research demonstrated that the anaerobic reactor may be used as an effective pre-treatment alternative for fish processing wastewater in tropical regions. From the data presented here, the following conclusions can be drawn:

- The optimum HRT in the anaerobic reactor with an organic loading rate of 4.0 kg $COD/m^3/d$ was 6 h. The medium removal efficiency for COD and BOD_5 was 90 and 92%, respectively.
- The SS concentration effluent was from 210 to 510 mg/L.
- The methane volume production was 229 cm^3/d (3200cm^3/14d).

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