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Research Article

PERFORMANCE STUDY OF HIGH RATE BIOMETHANATION FOR TREATMENT OF INDUSTRIAL SAGO WASTE WATER

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Abstract: In India, energy continues to be precious with continues hiking of oil prices unlike in the west, anaerobic digestion has far greater relevance then it has to many other regions of the world. The cassava starch production in India is mainly concentrated in small to medium scale factories, which generates 30,000 to 40,000 litres of effluent per tonne of sago produced. The effluent from these industries is acidic and highly organic in nature having COD of 5000 to 7000 mg/l during the season and 1000 to 5000 during the off-season. These effluents pose a serious threat to the environment and quality of life in the both rural and cities. Since the treatment of sago factory effluent through the normal biogas plant with 30 to 55 days retention period is very costly, attempts have been made to treat them through high rate biomethanation reactor with several hours of retention period. In the batch digestion of 4-5 week period there was no gas production at all from the sago waste water, when it was not neutralized and not added with inoculum without any addition of media. The maximum gas production of 34.5 Litres at 4.35m^3/Kg TS reduced with biogas production of 1.01/l of feed in the digestion with the weekly addition of 25,10 and 5 percent of inoculum respectively over the first three weeks without any addition of media. The performance of hybrid biomethanation reactor with the packing media of PVC pall rings was designed and performance was studied under different retention period. The specific gas production was 723l/Kg TS and 909l/Kg VS in PVC pall rings media reactor.

Keywords: *Hybrid reactor, Biogas, Anaerobic digestion, Biomethanation, Sago wastewater treatment*

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Introduction

Rapid urbanization coupled with industrialization, which led to increase waste generation and pollution, poses a serious hazard to public health as well as global environment. Hence, anaerobic digestion of agricultural, industrial and municipal wastes is of positive environment value since it combines waste stabilization with net fuel production and also allows the use of the ungasified solid or liquid residues as fertilizer or animal / fish feed. In India as well as in many developing countries, anaerobic digestion has been providing a means of decentralized energy generation via biogas digesters. Introduction of anaerobic filter, up-flow anaerobic sludge blanket reactor, expanded / fluidized bed anaerobic reactor and hybrid bioreactors have brought down the hydraulic retention times (HRTs) of anaerobic digesters from 35-40 days of typical unstirred reactors (like conventional biogas digesters) to a few hours. Such drastic reduction in HRT has a dramatically favourable impact in term of smaller digester sizes and consequently lesser digester costs, Further it has opened the possibility of treating high-volume low-strength wastes such as industrial waste water and sewage by anaerobic process. Such wastes earlier could be speedily treated only by the aerobic processes, which were considered as faster than anaerobic processes.

Methods

Description of the hybrid reactor

A pilot-scale hybrid reactor with acrylic sheet cylindrical shape was designed and developed by combing two concepts UASB and AFF as single reactor [1]. The hybrid reactor was made of Acrylic sheet and having provisions for a flow of influent and effluent, sampling ports at five different heights of the reactor and biogas outlet. The reactor was divided into three regions *viz*., gas-liquid separator region, AFF region, and UASB region. The AFF region was achieved by packing PVC corrugated fixed film media in the middle of the reactor. The packing height was fixed at an appropriate height from the middle of the reactor, which was 25 percent of the total height of the reactor. The lower and upper parts of the reactor would act as UASB and gas-liquid separator regions respectively.

Operation of the hybrid reactor

The reactor was operated in upflow mode to mix the medium. The influent feed was pumped to the reactor using a variable speed peristaltic pump. The effluent from the reactor was collected from the top of the reactor through overflow using a gas-liquid separator. The biogas produced from the reactor was collected in a movable gas holder reactor. Daily biogas production was measured using gas flow meter. The reactor was installed at Agriculture College and Research Institute, Madurai, Tamil Nadu, India.

Wastewater and Seed inoculum

The wastewater was collected at the common tank of the industry was used for this study. Before the wastewater fed into the reactor, a screen was used to remove foreign materials. For seeding, the inoculum was collected from an anaerobic lagoon, which was in successful in operation for wastewater treatment at the identified industry.

Table-1 *Important characteristics of sago industry wastewaters*

SN	Parameters	Concentration (mg l^{-1})[a]		
		Primary tank	Secondary tank	Tertiary tank
1	Colour	Dirty white	Dirty white	Dirty white
2	pH	5.4	5.2	4.5
3	Total solids (TS)	5290	4137	4187
4	Volatile solids (VS)	4313	3293	3147
5	Total biochemical oxygen demand	6820	5800	5520
6	Total chemical oxygen demand	10363	9020	9733
7	Total kjeldahl nitrogen	92	90	88
8	Total organic carbon	3353	3247	3150
9	Total alkalimetric normality	1234	1318	1513
10	Total volatile acids	1727	2043	2253
11	BOD : COD ratio	0.65:1	0.64:1	0.57:1

[a]*all values in mg l^{-1} except colour and pH.*

Table-2 *Performance evaluation of the reactor with varying HRTs*

SN	Parameters	Magnitude at different HRTs					
	Hydraulic retention time, d	10	7	5	3	2	1
1	Average COD influent, mg l^{-1}	9815	9793	9699	9646	9673	9711
2	Average COD removal efficiency, %	77	79	76	71	70	67
3	Average BOD influent, mg l^{-1}	5664	5665	5684	5693	5687	5693
4	Average BOD removal efficiency, %	80	82	81	76	74	72
5	Average gas production, l d^{-1}	3288	6149	7917	8786	9577	9871
6	Average BOD loading rate, kg BOD m^{-3} d^{-1}	0.57	0.81	1.14	1.9	2.84	5.69
7	Average BOD removal rate, kg BOD m^{-3} d^{-1}	0.45	0.67	0.92	1.44	2.12	4.11
8	Average COD loading rate, kg COD m^{-3} d^{-1}	0.98	1.4	1.94	3.22	4.84	9.71
9	Average COD removal rate, kg COD m^{-3} d^{-1}	0.76	1.11	1.48	2.29	3.41	6.51

Analytical and operational methods

During the experimental trials, the samples of influent and effluent collected from sample ports of the reactor and analyzed. The physicochemical characteristics of the wastewater were determined according to standard methods [2]. The reactor was initially fed with a low concentration of the sago industry wastewater (diluted up to 20 times with tap water with a pH of 7.2) and inoculated with granular sludge. Then, influent feed strength was gradually increased in steps until the influent was the same as that of industrial wastewater. The daily feeding was done in semi-continuous mode at the rate of 0.53 m h^{-1} upward velocity. The reactor was fed with combined wastewater at different values of HRTs (10, 7, 5, 3, 2 and 1 d) corresponding to their organic loading rates (0.98, 1.40, 1.94, 3.22, 4.84, and 9.71 kg COD m^{-3} d^{-1}) respectively. For each HRT studied, steady-state performance usually occurred after three times the HRT has passed, and it was marked by near-constant effluent pH values and COD values with less than 5 percent variations.

Results and discussion

The experimental trials were conducted to optimize conditions for biogas production from anaerobic digestion of sago (tapioca starch) industry wastewater via hybrid reactor and results are discussed as below.

Wastewater generation at different stages of sago production

The tubers were collected after harvesting tapioca from the field, transported to the factory by lorry or truck and delivered to the industry. The tubers were washed preliminarily, and the wastewater generated at this stage was 850 litre per tonne of the tubers. This wastewater cannot be utilized for the anaerobic treatment as it contains more fine sand particles and other inert materials. In the next stage, the outer skin or corky portion was removed by allowing the tubers through the sieve shaker and water spraying operations. During this stage of processing, a quantity of 571L wastewater per tonne of tuber was generated. The peeled tuber was sent to second washing (1000 l wastewater generated per tonne of tuber) and followed by grinding. After grinding, the paste was washed to separate the fiber and starch. The fiber materials were collected by using a screen. The starch along with the water was sent to a settling tank, and starch was collected after gravity settling. In this stage, a quantity of 1286 l wastewater per tonne of tuber processed was produced as the supernatant of settling. The settled starch was collected and rewashed. During the washing stage, the wastewater generated was 1143L for one tonne of tubers washed. Next step was the rewashing of the starch recovered from the settling tank. For rewashing process, freshwater was mixed with the starch and washed thoroughly. Once again the starch was allowed to settle, and the supernatant water was discharged, which was referred to tertiary wastewater.

Characteristics of the wastewater and fixed film reactor

The average physicochemical characteristics of the sago industry wastewater at different stages are given in [Table-2]. The total BOD and COD were found to be high in all, and this was due to letting of wastewater without fine settlement of starch during the starch separation process. The pH was high in the primary tank as the wastewater was generated in a short period whereas, in the tertiary tank, the pH was lower and acidic as it was generated from stored starch. In the case of the TSS content, it was found in the reverse order as that of pH. Hien *et al*, (1999) [3] reported a similar trend for treating the tapioca wastewater. The wastewater collected from all the three tanks, the BOD to COD ratio was found to be 0.61 ±0.04 indicating the complexity of wastewater. Bories *et al.* (1988) [4], Athanasopoulos *et al.* (1990) [5], Borja *et al.* (1995) [6] and Elmitwalli *et al.* (2002) [7] studied the fixed film reactor and reported that media-specific area of 230, 100, 250 and 500 m^2 m^{-3} porosity with 95, 94, 63, and 97 percent respectively were found effective. These values were different from the combination of the study with sago industrial wastewater and properly suited the purpose as these fixed films are Corrugated Poly Vinyl Chloride (CPVC) sheets and vertically placed sheets without movement.

Startup of the reactor

During the startup of the experiment, the reactor was started in a fed-batch mode introducing diluted raw wastewater at increasing OLRs of 0.17, 0.24, 0.40, 0.47, 0.60 and 0.65 kg COD m^{-3} d^{-1} during six weeks. The native anaerobic biomass responded very well by yielding increased biogas production from 93.85 to 256.52 L kg^{-1} of COD removed. The variation in the methane content of biogas was found between 20 to 65 percent. The pH of the effluent was found to be in the range of 7 ± 0.2. The startup period was longer (40 days) to achieve optimal biogas production, to control the alkalinity, to retard the CO_2 toxicity, and to cut off any possible draining of the active biomass.

Performance of the reactor

After attaining a consistent, stable carbon removal at OLR of 0.65 kg COD m^{-3} d^{-1} (startup period), the reactor was operated with higher loading rates to assess the performance of the reactor at different HRTs.

The performance of the reactor was evaluated up to 1 day HRT at 9.71 kg COD m^{-3} d^{-1} OLR. The performance of the reactor at various HRTs is presented in [Table-2]. From the table, it is evident that a decrease in HRTs marked inhibition in the reactor performance by decreasing the COD removal efficiency. The reduction in COD removal efficiency may be attributed to the increase in OLR, which requires sufficient acclimatization period for native microflora to sustain to the changed environmental conditions of the system [8]. It was clear that the coefficient of determination (R_2) for both BOD and COD removal efficiency was found high except 10 d HRT. The low R_2 value for 10 d HRT was obtained due to the lower value of removal efficiency during the second week at 10 d HRT. According to Sameh Sayed and Willem de Zeeuw (1988) [9], an excellent linear regression line could be made with a high R_2 value for continuous operation of flocculent sludge UASB reactor. The average BOD loading rates were increased from 0.567 to 5.693 kg m^{-3} d^{-1} as the decrease of HRT from 10 d to 1 d HRT conditions. The reactor was able to withstand the increase in loading rate by operating reactor with stepwise loading. The average BOD removal rate improved from 0.452 kg BOD m^{-3} d^{-1} during 10 days of HRT to 4.109 kg BOD m^{-3} d^{-1} during 1 day HRT. Similarly, the average COD removal rate improved from 0.758 kg COD m^{-3} d^{-1} for 10 d of HRT to 6.507 kg COD m^{-3} d^{-1} for 1 d HRT. In other words, the biogas production, both BOD and COD removal rate was improved by reducing HRT from 10 to 1 d in the hybrid reactor.

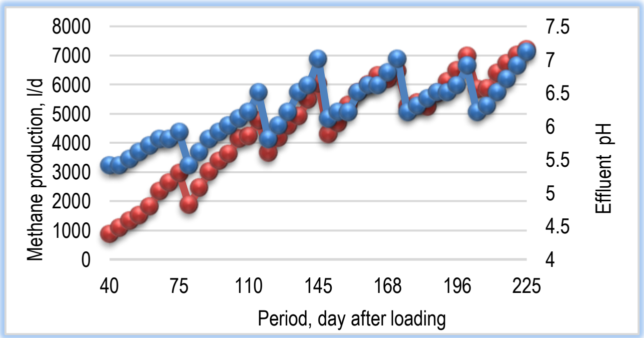

Fig-1 Variations of methane production against pH during different HRTs

Fig-2 Pilot scale high rate biomethanation reactor for sago waste water treatment

Methane production and pH variation during different HRTs conditions

During the operation of the reactor at different HRTs, the average gas production has risen from 3288 to 9871 l d^{-1} for operating the reactor at 10 to 1 d HRT. This increase in biogas production indicated a satisfactory result on the performance of the reactor. It is clear that as the HRTs decreased, the methane increased. The highest methane achieved for 1 d HRT was 7186 l d^{-1}. An interesting factor observed from the [Fig-1] that pH value was reaching optimal value for better biogas production while HRT decreased from 10 d to 1 d. The pH of wastewater in the reactor had changed from 5.4 to 5.9 for 10 d of HRT, 5.4 to 6.5 for 7 d of HRT, 5.8 to 7.0 for 5 d of HRT, 6.1 to 7.0 for 3 d of HRT, 6.2 to 7.1 and 6.2 to 7.1 for 1 d of HRT. The maximum change of pH for wastewater was occurred at 5 d HRT, and further changes in pH value were takes place based on loading rates [10-25].

Conclusion

The sago industry is one of the agro-based industries generates a huge quantity of wastewater per day, and there is a need for a sustainable, eco-friendly solution for wastewater treatment and safe disposal. Generally, anaerobic reactors are a viable solution for treating of the industrial wastewater and possible outcomes of these technologies are generation of energy in biogas form, offers safe disposal of effluent and also protect the environment. This study reveals the possibility of treating sago wastewater using the hybrid reactor, which operates on the innovative idea by combing the UASB and AFF concepts for biogas generation. In order to handle the huge wastewater generation in the sago industry, an attempt was made to operate the hybrid reactor with different HRTs and their influence on biogas production. The average biogas production in the reactor has risen from 3288 l/d for 10 d HRT to 9871 l/d for 1 d HRT. Also, the average COD removal rate during 1 d HRT was 6.507 kg of COD m^{-3} d^{-1}.

Application of research: The study was the hybrid reactor performed well and showed better biogas yield at 1 d HRT with improved COD/BOD removal rate. The produced biogas can be used to meet out the energy requirement of sago roasting process in the industry.

Research Category: Waste water management

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References

[1] Kamaraj A. (2005) *Ph.D thesis. Tamil Nadu Agricultural University, Coimbatore, 641003, Tamil Nadu, India*

[2] American Public Health Association (1992) *Standard Methods for the Examination of Water and Wastewater, APHA, Washington DC.*

[3] Hien P. G., Oanh L. T. K., Viet N. T. and Lettinga G. (1999) *Water Science Technology*, 39(5), 89-96.

[4] Bories A., Raynal J. and Bazile F. (1988) *Biological Wastes*, 23, 251-267.

[5] Athanasopoulos N., Kouinis J. and Papadimitriou A. (1990) *Biological Wastes*, 32, 91-97.

[6] Borja R., Banks C. J. and Wang Z. (1995) *Applied Microbial Biotechnology*, 43, 351-357.

[7] Elmitwalli T. A., van Dun M., Bruning H., Zeeman G. and Lettinga G.

(2000) *Bioresource Technology*, 72, 235-242.
[8] Gangagni Rao A., Venkata Naidu G., Krishna Prasad K., Chandrasekar Rao N., Venkata Mohan S., Annaurana Reddy and Sarma N. (2005) *Bioresource Technology*, 96, 87-93.
[9] Sameh Sayed and Willem de Zeeuw (1988) *Biological Wastes*, 24, 19-21.
[10] Ayoob Torkian, Eqbali A. and Hashemian S. J. (2003) Resources, *Conservation and Recycling*, 1-13.
[11] Castro-Gonzalez Alejandra, Manuel Enriquez-Poy and Carmen Duran-de-Bazua (2001) *Anaerobe*, 7, 143-149.
[12] Daratana S., Ploypattarapinyo P. and Klinsukont C. (1991) *International center for cooperation and research in biotechnology, Osaka, Japan*, 430-440.
[13] Delia T.S. (2001) *Enzyme and Microbial Technology*, 29, 417-427
[14] Elmitwalli T.A., Vladmir Skylar, Grietje Zeeman and Lettinga G. (2002) *Water Sci. Technol*., 82(5), 233-239.
[15] Kennedy K.J. and Droste R.L. (1991) *Water Sci. Technol*., 24 (8), 157-177.
[16] Lettinga G., Van Velsen A.F.M., Hobma S.W., de Zeeuw and Klapwijk A. (1980) *Biotechnology and Bioengineering*, XXII, 699-734.
[17] Lo K.V. and Liao P.H. (1985) *Biotechnol. Bioeng*., 27, 266-272.
[18] Lo K.V. and Liao P.H. (1988) *Canadian Agricultural Engineering*, 61-63.
[19] Mulyanto A. and Titiresmi (2000) *Report of Institute for Environmental Technology, Indonesia*, 1-20.
[20] *Shigeki U. and Hideki H. (2000) Bioresource* Technology, 72, 275-282.
[21] Soji J Arceivala (2000) *Wastewater treatment for pollution control, second ed. Tata McGraw-Hill publishing company limited, New Delhi*.
[22] Trim D.S., Nanda S.K., Curran A., Anantharaman M. and Nair J. (1993) *The International Symposium on tropical root crops, 6-9, November. Thiruvananthapuram, India.*
[23] Uemura S. and Harada H. (1995) *Applied Microbiology Biotechnol*., 43, 358-364.
[24] Young J.C. and Dahab M.F. (1983) *Water Sci. Technol*., 15 (8/9), 369-383.
[25] Young J.C. (1991) *Water Sci. Technol.,* 24 (8), 133-155.