Middle-East Journal of Scientific Research 8 (3): 590-593, 2011
ISSN 1990-9233

Anaerobic Fixed Film Biotreatment of Dairy Wastewater

[1]*Javed Iqbal Qazi*, [2]*Muhammad Nadeem*, [3]*Shagufta S. Baig*,
[2]*Shahjahan Baig* and [2]*Quratulain Syed*

[1]Department of Zoology, University of the Punjab, Lahore-54590, Pakistan
[2]Food and Biotechnology Research Centre, PCSIR Labs. Complex, Lahore-54600, Pakistan
[3]Environment Protection Department, Punjab, Opposite LCCA Ground, Lahore, Pakistan

Abstract: A number of biofilm support media including foam cubes, bamboo rings, fire bricks, PVC rings and gravels were employed to immobilize biomass for reduction in BOD_5, COD and VSS of dairy wastewater in batch and repeated batch cultivation systems. The efficiency of COD removal is associated with the nature and properties of support material. Eventually, the maximum percentage removal of COD, BOD_5 and VSS turned out to be as 96 %, 93 % and 90 %, respectively, with the application of 21 Kg COD/m^3/d loading in batch reactor filled with gravels. Subsequently, the dynamics of repeated batch was evaluated in three cycles that indicated that almost 89% reduction of volatile suspended solids (VSS) occurred after 12 d hydraulic retention time (HRT) in each cycle. These results provide a suitable biotreatment process for high conversion of organic fraction to combustible methane gas.

Key words: Waste water COD · Waste water BOD_5 · methane production · Volatile suspended solids

INTRODUCTION

Water management in dairy industry is well documented but suitable disposable of effluents in waste water remains a challenging issue for dairy industry. Anaerobic treatment of organic fractions of agro-industrial wastewater is an attractive process in sustainable approach [1-3]. Anaerobic treatability depends on the type of wastewater and the microbial consortium employed in the process which together determine as to what extent it should be treated [4-6].

The composition of dairy industrial wastewater corresponds to organic and inorganic constituents of milk. In ice-cream factories, spillage can be a major source of effluent strength because of the original organic concentration of ice-cream which includes milk fat, vegetable oils, non-fat milk solids, sugars, fruits and colorings [7,8]. Other components in dairy wastewater are cleaners and sanitizers. These organic fractions, persistent in dairy waste water, are efficiently degraded into simple compounds by anaerobic bacteria [9].

The interest in anaerobic reactors has increased rapidly with the realization that cost-effective anaerobic treatment is generally not possible without some form of biomass retention [10-12]. It is further added that the loading capacity of any biological wastewater treatment system is essentially directed by the amount of active biomass retained in the reactor providing a sufficient contact between active biomass and organic waste. Therefore, high rate anaerobic reactors are those which retain biomass for periods longer than the hydraulic retention time. In addition to lowering the capital cost of a waste treatment process, the generation of CH_4 gas as a by-product is a supplementary economic motivation for the utilization of anaerobic digestion for wastewater treatment [13]. This paper reported results of the effects of dairy waste strength on the performance of batch and repeated batch reactors with the application of different packing media to facilitate high rate anaerobic digestion in fixed film growth process.

MATERIALS AND METHODS

Inoculum Development: About 300 g fresh sewage sludge was collected from main outfall of Lahore city, Pakistan and dried at 105°C in an oven. Approximately 100 g oven dried sewage was suspended in 300 mL distilled water in one liter saline bottle. The suspension was then sparged with a mixture of N_2 and CO_2 gases (3:1) for 5 min to create anaerobic conditions at ambient temperature and

Corresponding Author: Muhammad Nadeem, Food and Biotechnology Research Center, PCSIR Labs. Complex, Lahore-54600, Pakistan. Tel: +92-42-9230689.

Table 1: Characteristics of dairy wastewater media employed in biotreatment.

Parameters	Characteristics/ values
Color	Turbid grey - Dark brown
Odor	Sewage like
PH	7.2 - 7.5
Total solids	8,000 - 10,000 mg/L
Dissolved solids	72,000 - 80,000 mg/L
Volatile suspended solids	800 - 1000 mg/L
COD	2,500 - 3,000 mg/L
BOD_5	1,300 -1,600 mg/L
Fat and Oil	20 -70 mg/L

Table 2: Dimensions of various packing media used in fixed film bioreactor for the treatment of dairy waste water

Materials	Diameter (mm)
Bamboo rings	10.0
PVC rings	5.0
Foam cubes	15.0
Firebricks	15.0
Gravels	8.0

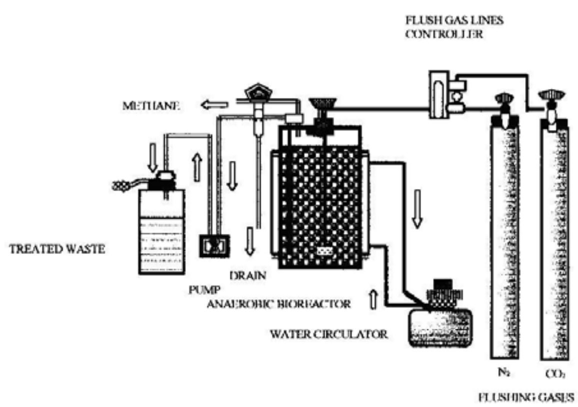


Fig. 1: Schematic diagram of Anaerobic Bio-treatment System

inoculated with 5% v/v culture broth prepared in low phosphate buffer medium (LPBM), containing mixed population of methanogens isolated from cow dung, as described by Bryant [14]. The inoculated sewage sludge was incubated at 35±0.5°C for 7 days in an anaerobic jar. The developed mixed methanogenic bacterial population was utilized (5% v/v) as an active inoculum in the biotreatment studies.

Biotreatment Process: Dairy waste water (Table 1) was anaerobically treated by batch and repeated batch processes with the application of certain growth supporting material individually in glass aspirator of 10 L capacity used as bioreactor with working volume of 6L (Fig. 1).

Support materials used for immobilization of bacterial population is given in Table 2. Each reactor material was sealed with rubber stopper facilitated with thermometer, gas measuring system, gas sampling port and Hg manometer to measure gas pressure over the surface of the liquid. The bioreactor temperature was maintained at 35±0.5°C by circulating thermostatically controlled water around the vessel through the jacket of rubber tubing, thoroughly insulated with glass wool pads to minimize the heat loss. Each bioreactor was also covered with black plastic sheet to protect it from the bacterial photosynthesis and algal growth during cultivation operation. A mixture of N_2 and CO_2 gases (3:1) was sparged in the culture vessel for 10 min to create anaerobic conditions prior to inoculation with enriched culture of mixed population of methanogenic bacteria. The samples of the treated effluent were taken from the bottom of the reactor through drain line.

In the repeated batch process, 80% v/v treated waste was replaced with fresh medium based on initial concentration of volatile suspended solids (VSS). However, each cycle of the repeated batch was terminated after 12d hydraulic retention time (HRT). The characteristics of wastewater and packing material used in the treatment studies are shown in Tables 1 &2.

RESULTS AND DISCUSSION

The nature of wastewater discharged from dairy industries varies throughout the working day. The present study has been performed using batch and repeated-batch test techniques which provide a quick and easy assessment of attached active biomass.

Fig. 2 compares the percentage reduction in COD in batch-wise attached growth processes. In these experiments, the organic load was kept constant at 2Kg $COD/m^3/d$, while the HRT was progressively increased from 1 to 8 days. It can be seen that substantial amount of COD was reduced (72%) in reactor packed with fire bricks after 6 days HRT. Similarly, foam cubes exhibited efficient removal (46%) of COD within 6 days. The percentage removal of oxidizable material was optimal at 6 day HRT, in the presence of fire bricks, foam cubes, PVC rings or gravels. In general an increase in HRT caused a corresponding increase in COD reduction up to forth sampling period. It is also apparent from these experiments that the efficiency of COD removal is associated with the nature and properties of support material involved in the attachment of biomass. It can be categorized as follow: fire bricks>gravels >foam

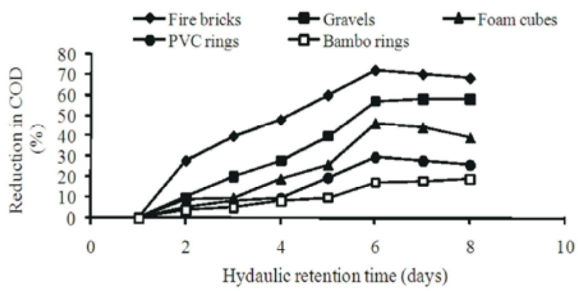


Fig. 2: Influence of hydraulic retention time on reduction of dairy wastewater COD using different suport media in batch reactors

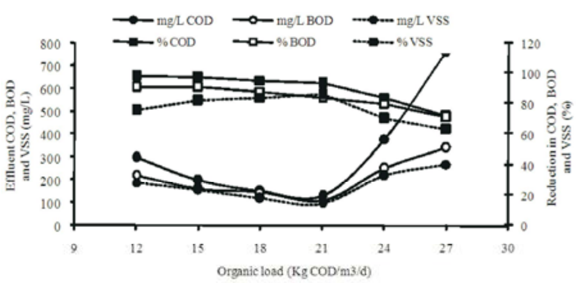


Fig. 3a: Influence of organic laoding on reduction of COD, BOD5 and VSS of dairy effluents using fixed-film growth process in batch reactor packed with fire bricks

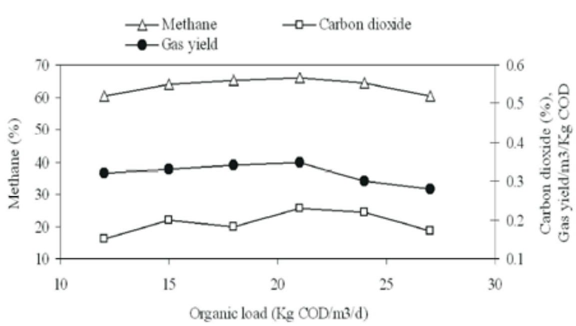
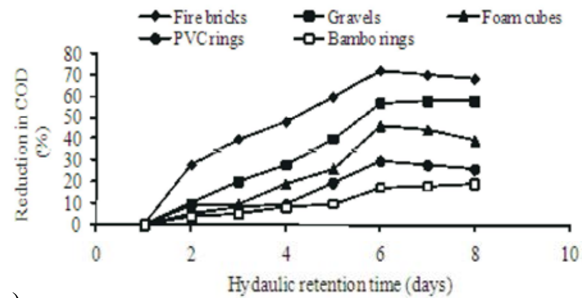
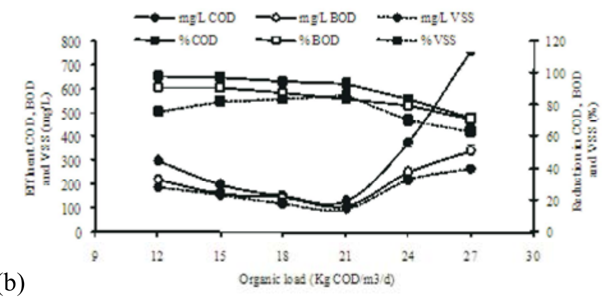


Fig. 3b: Influence of organic laoding on production of methane and carbon dioxide gases using dairy effluents in fixed film batch reactors packed with fire bricks

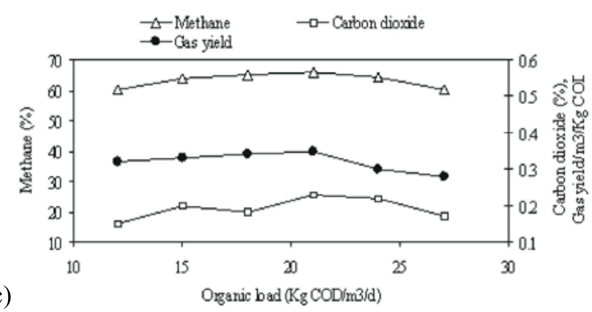
cubes>PVC rings>bamboo rings. In addition, the performance of support material might be attributed to chemical properties interlinked with its physical properties. Eventually, fire bricks were utilized as an effective support material in subsequent studies conducted both in batch (Fig. 3a & b) and repeated batch reactors (Fig. 4).



(a)



(b)



(c)

Fig. 4: Repeated batch biotreatment of dairy waste water
a: First cycle, b: Second cycle and c: Third cycle

Figure 3a shows the relationship between BOD_5, COD and VSS determined in the presence of different organic loadings ranging between 12 to 27 Kg COD/m^3/d. The computed values indicated that biodegradation of organic matter in terms of COD, BOD_5 and VSS was progressed in sufficient quantities. Despite these gradients, variation in gas yield was also proportionate of degradation frequency (Figure 3b). It appears that maximum percentage removals of COD, BOD and VSS achieved were around 90% levels, with the application of 21Kg COD/m/day loading in batch reactor. In addition, a substantial gas evolved constituting 67% methane incorporating 33% CO_2 with the expense of 0.35/m^3/Kg of COD (Figure 3b).

Hydrodynamic of a semi-continuous fixed growth process was subsequently evaluated by repeated-batch system (Figure 4). In fact, the system was based on three cycles; each cycle terminated after 12day detention. The performance of first growth cycle indicated almost 88.8% reduction of VSS. The methane gas generated, however, increased to 55.0 ml/L. Similarly, pH of medium gradually decreased to 5.0 within 12 day HRT. It is obvious that salts present in dairy industrial wastewater are often used as balancing material [15- 17] and hence provide certain amount of buffering capacity to maintain the pH of reactants in the range of 6 and 7.

In conclusion material used for packing provided a large surface/volume ratio that permitted tremendous growth of microorganisms in the interstices; the amount of biofilm was great and the system operated at short HRT in the bioreactor.

REFERENCES

1. Cordoba, P.R. and F. Sineriz, 1994. The biomass in up flow anaerobic filters. Revista Argen. de Microbiología, 26: 87-95.
2. Bley, E.M., E.D. Musibono and W. Verstraete, 2003. Start up of multi stage system for biogas production and solid waste treatment in low-tech countries. Water Science and Technol., 48: 239-243.
3. Jajesh Banu, J., S. Anandan, S. Kaliappan and Y. Ick-Tae, 2008. Treatment of dairy wastewater using anaerobic and solar photocatalytic methods. Solar Engineering, 82: 812-819..
4. Stayanarayan, S., Ramakant, R.S. Dhodapaker, R.D. Vyas and S.N. Kaul, 2003. Treatment of spent broth from an antibiotic manufacturing unit using anaerobic fixed film fixed bed reactor. J. Environ. Sci. Health Part A, Toxic/Hazardous Substances and Environment Engineering, 38: 1971-1979.
5. Gulsen, H., M. Turan and B. Armagan, 2004. Anaerobic fluidized bed reactor for the treatment of landfill leachates. J. Environ. Sci. Health Part A, Toxic/Hazardous Substances and Environment Engineering, 39: 2195-2204.
6. Zhao, H.W. and T. Viraraghavan, 2004. Analysis of the performance of an anaerobic digestion system at the Regina waste water treatment plant. Bioresource Technol., 95: 301-307.
7. Switzenbaum, M.S. and S.C. Danskin, 1982. Anaerobic expended bed treatment of whey. Agricultural Wastes, 4: 411-426.
8. Zellner, G., P. Vogel, H. Kneifel and J. Winter, 1987. Anaerobic digestion of whey and whey permeate with suspended and immobilized complex and defined consortia. Applied Microbiology and Biotechnol., 27: 306-314.
9. Hawkes, F.R., R. Dinsdale, D.L. Hawkes and I. Hussy, 2002. Sustainable fermentative hydrogen production: challenges for process optimization. International J. Hydrogen Engineering, 27: 1339-1347.
10. Wildenaner, F.X. and J. Winter, 1985. Anaerobic digestion of high strength acidic whey in a pH-controlled up-flow fixed film loop reactor. Applied Microbiology and Biotechnol., 22: 367-372.
11. Barford, J.P., R.G. Cail, I.J. Callander and E.J. Floyd, 1986. Anaerobic digestion of high-strength cheese whey utilizing semi-continuous digesters and chemical flocculant addition. Biotechnology and Bioengineering, 289: 1601-1607.
12. Bojra, R. and C. Banks, 1994. Treatment of palm oil mill effluent by upflow anaerobic filtration. J. Chemical Technology and Biotechnol., 61: 103-109.
13. Mohan, S.V., G. Mohanakrishna, S.V. Ramanaiah and P.N. Sarma, 2008. Integration of acidogenic and methanogenic processes for simultaneous production of biohydrogen and methane from wastewater treatment. International J. Hydrogen Energy, 33: 2156-2166.
14. Bryant, M.P., 1979. Microbial methane production-ttheoretical aspects. J. Animal Sci., 48: 193-201.
15. Chartrain, M. and J.G. Zeikus, 1986. Microbial ecophysiology of whey biomethanation: intermediary metabolism of lactose degradation in continuous culture. Applied Environment and Microbiol., 51 : 180-187.
16. Chartrain, M., L. Bhatnagar and J.G. Zeikus, 1987. Microbial ecophysiology of whey biomethanation: comparison of carbon transformation parameters, species composition and starter culture performance in continuous culture. Applied Environment and Microbiol., 53: 1147-1156.
17. Mohan, S.V., V.L. Babu and P.N. Sarma, 2007. Anaerobic biohydrogen production from dairy wastewater treatment in sequencing batch reactor (AnSBR): effect of organic loading rate. Enz. Microb. Technol., 41: 506-515.