[ENV10] Anaerobic wastewater treatment to yield biogas

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Introduction

Anaerobic treatment of industrial wastewater has became a viable technology in recent years due to the rapid development of high-rate reactors, such as anaerobic filter, upflow anaerobic sludge blanket (UASB) (Fang *et al*., 1996; Dinsdale *et al*., 1997) both upflow and downflow stationary packed beds (Nebot *et al*., 1995), and fluidized or expanded beds (Chen *et al*., 1988; Breintenbucher *et al*., 1990; Hickey *et al*., 1991; Iza, 1991; Perez *et al*., 1997a; Seckler *et al*., 1996). This development is due to the fact that the method combines a number of significant advantages, including low energy consumption, low excess sludge production and enclosure of odours.

Anaerobic digestion is among the oldest biological wastewater treatment processes, having first been used more than a century ago. The most important reasons for the choice of anaerobic digestion as a treatment method are the feasibility to treat wastewaters with a high organic load. According to international experience (Hartmann, 1993), the aerobic treatment of such a wastewater requires biological purification systems with high construction and operational costs (energy consumption), besides which stabilisation of the biological reactions is not assured (activated-sludge tanks), or the wastes cause clogging of installations such as aerobic biological filters and biodiscs. In the case of seasonal operation of the production units, the disadvantage of a slow start-up after the non-feeding conditions makes the aerobic treatment unacceptable for the treatment of mill wastewater. With bioreactors for anaerobic fermentation these problems are not present (Dalis *et al.,* 1996).

Anaerobic digestion of high-strength industrial wastewaters becomes more attractive as higher influent concentration and shorter hydraulic retention times (HRTs) reduce capital and operating costs (Ripley *et al.,* 1986). The anaerobic filter is one of the more common of the anaerobic digestion options for the treatment of industrial wastes and extensive research on design and modeling has greatly increased the understanding of the impacts of the fundamental controlling phenomena (Tilche and Vieira, 1991). Changes in temperature, both increases and decreases, may adversely affect the digestion performance (Parkin and Owen, 1986). A sudden temperature change causes a simultaneous increase in the concentration of all the volatile fatty acids (VFA), especially in acetic and propionic acids (Dohanyos *et al*., 1985). The extent of the impact depends on factors such as the magnitude of the temperature change applied, the exposure time and the bacterial composition of the sludge. At temperatures exceeding the maximum value for growth, decay exceeds the growth rate of bacteria, which will then result in a decrease of the sludge activity and consequently in the reactor removal capacity (Visser *et al*., 1993). Industrial full-scale reactors tend to have high process stability but sudden environmental changes, e.g. temperature shocks, may cause severe effects on the reactor performance (Ahn and Forster, 2002).

The treatment capacity of an anaerobic digestion system is primarily determined by the amount of active population retained within the system which in turn is influenced by wastewater composition, system configuration and operation of anaerobic reactor (Tang and Fan, 1987; Fox *et al*., 1990; Suidan *et al*., 1996; Perez *et al*., 1997a). The objective of this study is to determine the optimum conditions (HRT, OLR, temperature and pH) for biogas production using biological cellulose recovery wastewater as substrate.

Materials and methods

Feedstock Material

Wastewater collected from biological cellulose recovery process was used directly in the study. The characteristics of each batch of wastewater used in an experimental run were monitored. The average characteristics are given in Table 1.

TABLE 1 Characteristics of wastewater from biological cellulose recovery process

Parameter	Average composition
pH	4.5 – 5
Chemical oxygen demand (COD)	10000 mg/l
Suspended solids (SS)	10 g/l

Inoculum

The inoculum for seeding the reactor was using rotten banana stem sludge. The sludge was initially passed through a screen to remove the foreign material. The methanogenic activity was found to be 0.08 l CH^4/g MLSS day. The sludge was acclimatized with wastewater from biological cellulose recovery process for four weeks under anaerobic conditions. After acclimatization, the methanogenic activity raised to 0.11 l CH^4/g MLSS day and same was inoculated.

Experimental set-up

All experiments were done in 10 l anaerobic batch reactor with gas outlet (Figure 1). All the reactors were seeded with anaerobic acclimatized banana stem sludge. The anaerobic digestion system was varied at reaction temperatures between 26°C to 40°C using water bath. The pH, hydraulic retention times (HRT) and organic loading rates (OLR) of the reactors were varied for different experimental runs (Table 2). Daily withdrawal of an appropriate volume from the reactor corresponding to the determined HRT or OLR was done by a draw-and-fill method. pH was controlled by using $NaHCO_3$ as buffer solution. Biogas evolved from the reactor was measured and collected in a gas holder by water displacement. Samples were collected and analysed for performance evaluation.

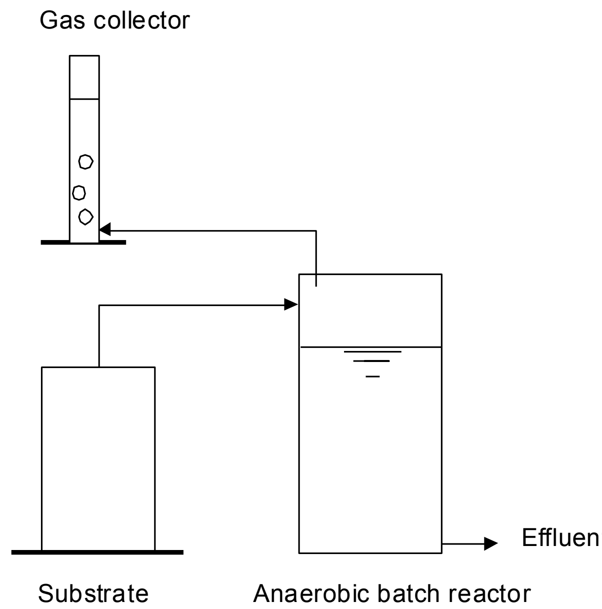

FIGURE 1 Experimental set-up for biogas production from biological cellulose recovery wastewater

TABLE 2 Parameter variations for biogas production

Parameter	Variation
Temperature (°C)	26,30,35,40
pH	4.5,6,7,8,9
HRT (days)	3,5,10,15,20
OLR (kg SS/m^3 day)	7.2,10,19,33,50

Analytical methods

COD concentration was spectrophotometrically analysed using a spectrophotometer and methods as in Spectrophotometric Instrument Manual. Gas collection was done using water displacement daily. Substrate concentration was measured as suspended solid according to Standard Methods for The Examination of Water and Wastewater. 20 ml well-mixed sample was filtered through a weighed standard glass-fiber filter and the residue retained on the filter is dried to a constant weight at 103°C to 105°C. The increase in weight of the filter represents the total suspended solids (Greenberg *et al*., 1992).

Results and Discussions

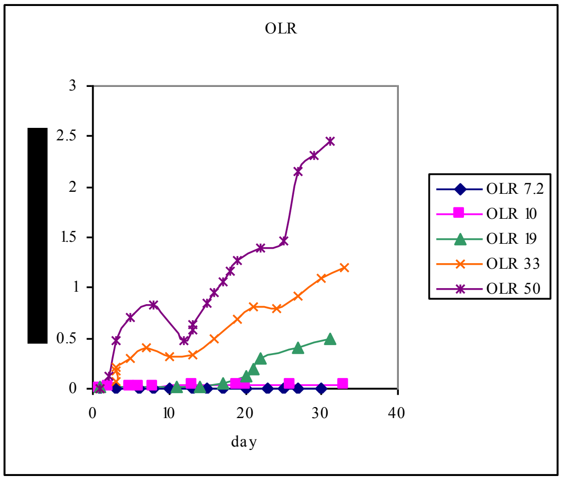

FIGURE 2 Organic loading rate variations in biogas production from biological cellulose recovery wastewater

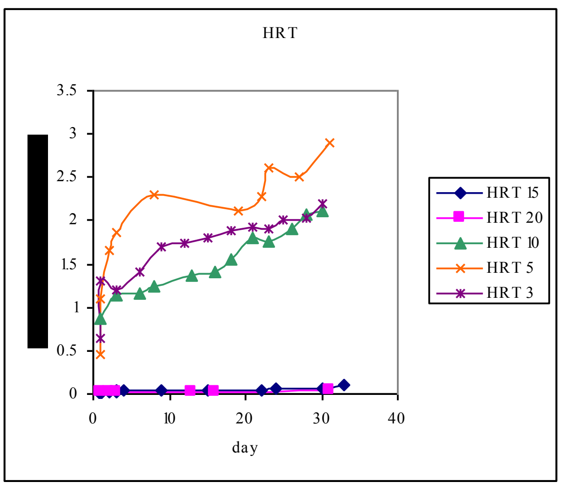

FIGURE 3 Hydraulic retention time variations in biogas production from biological cellulose recovery wastewater

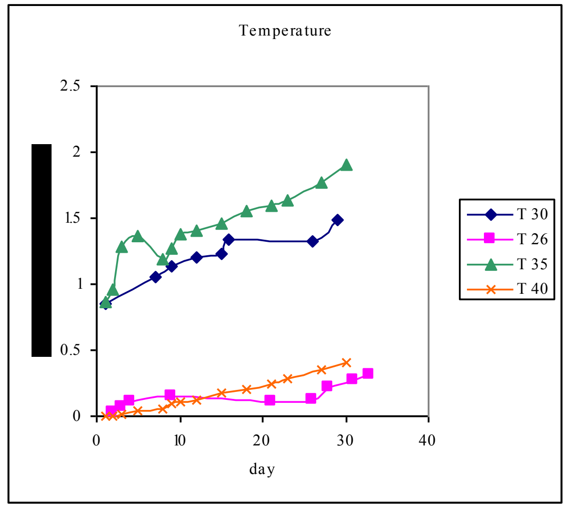

FIGURE 4 Temperature variations in biogas production from biological cellulose recovery wastewater

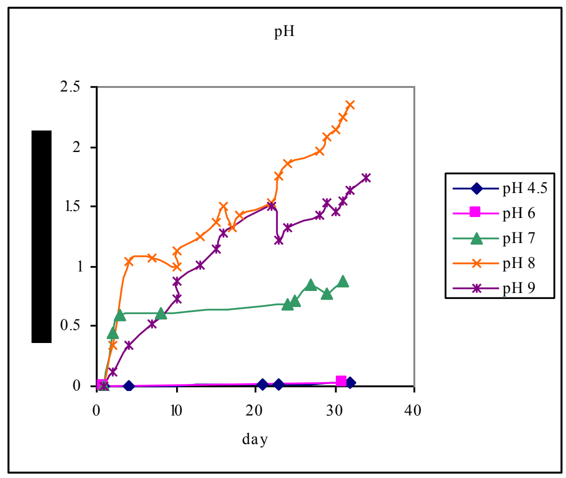

FIGURE 5 pH variations in biogas production from biological cellulose recovery wastewater

Biogas production efficiency

The performance of the reactor was tested under the conditions of various temperatures (26ºC-40ºC), organic loading rates (OLR) (7.2 kgSS/m^3 day-50 kgSS/m^3 day), hydraulic retention times (HRT) (3 days-20 days) and pH (4.5 to 9). Five experimental runs were completed for each parameter. The general trend showed gradually increasing biogas yield with lowering of HRT (Figure 3) and increasing of OLR. COD is the major pollution control parameter stimulated in the environmental quality regulations currently enforced in Malaysia. The biogas yield was pronounced in terms of COD. The maximum biogas yield obtained at HRT of 5 days which is 3 l biogas/g COD. The optimum temperature to produce biogas is 35ºC since temperature more than 35ºC did not improve biogas yield (Figure 4). Nagamani and Ramasamy (1991) also observed that though there was higher production of biogas at 55ºC, the process was unstable due to higher production of volatile fatty acids and that specific microbial consortia was needed for biomethanation of cattle waste at 55ºC. In order to increased biogas yield a pH of 8 is optimum (Figure 5), though the biogas production was satisfactory at pH 7 as well. Sahota and Ajit (1996) reported that the biogas production was significantly affected when the pH of the slurry decreased to 5. They observed decreased methanogenic activity due to lower pH. The effect of OLR concentration on the biogas production is given in Figure 2. The maximum biogas yield was observed to be around 2.5 l biogas/g COD corresponding to OLR of 50 kgSS/m^3 day. It was appeared that the system was able to tolerate high organic loading rate.

Biogas yield

Animal wastes were generally used as feedstock in biogas plants and their potential for biogas production. But, the availability of these substrates is one of the major problems hindering the successful operation of biogas digesters. Many researchers have explored various substrates for biogas production (Dalis *et al*. 1996; Lata *et al*., 2002; Perez *et al*., 1999; Kalyuzhnyi *et al*., 1998; Sammaiah *et al*., 1991; Gangagni Rao *et al*., 2004). For biogas production the two most important parameters in the selection of particular plant feedstock are the economic considerations and the yield of methane for fermentation of that specific feedstock (Smith *et al*., 1992). Biological cellulose recovery was using banana stem waste as substrate. The high non-structural carbohydrates in biological cellulose recovery wastewater make it a good feedstock for biogas production. Biological cellulose recovery wastewater was selected as the substrate in this study. The maximum biogas yield obtained in this study was 3 l biogas/g COD. The optimum conditions for biogas production were as follows; temperature of 35ºC, OLR of 50 kgSS/m^3 day, HRT of 5 days and pH 8. Martin *et al*. (1991) reported biogas yield of 1.74 l biogas/ g COD using olive mill wastewater as substrate at pH 7.5. In the case of fruit and vegetables wastes, at mesophilic conditions (30ºC) Dinsdale *et al*. (2000) and Viswanath *et al*. (1992) observed yields of 0.5 l biogas/g COD and 2.8 l biogas/g COD respectively. Martin *et al*. (1994) investigated the optimum HRT for the production of biogas from olive mill wastewater and reported that 5 days HRT was the best for maximum production of biogas (1 l biogas/g COD). Hashimoto (1983) and Polat *et al*. (1993) also applying low HRT in their research (8 days). Hashimoto (1983) was using straw plus manure as substrate and obtained biogas yield of 2.2 l biogas/g COD while Polat *et al*. (1993) reported 0.78 l biogas/g COD from sunflower head.

Conclusions

Preliminary studies were conducted to assess the biogas yield using biological cellulose recovery wastewater as feedstock. Anaerobic batch reactor (volume 10 l) was used in this study. The performance of the reactor was tested under the conditions of various temperatures (26ºC-40ºC), organic loading rates (OLR) (7.2 kgSS/m^3 day-50 kgSS/m^3 day), hydraulic retention times (HRT) (3 days-20 days) and pH (4.5 to 9). After about 30 days, biogas yield from preliminary studies reached maximum values of 3 l biogas/g COD. Biogas yield increased with increased OLR. The best conditions for biogas production from banana stem were as follows; temperature of 35ºC, OLR of 50 kgSS/m^3 day, HRT of 5 days and pH 8. The biogas yield is comparable to others reported in literature.

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