COMPARISON BETWEEN THE PROCESS PERFORMANCE OF AN UASB-REACTOR AND AN UASB-FIXED FILM-COMBINATION WITH AN ACETIC ACID ENRICHMENT CULTURE

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SUMMARY

An Upflow Sludge Blanket-(USB)-reactor and an USB-Fixed Film-(UBFF)-combination were operated simultaneously, running as pH-auxostats with a synthetic wastewater containing acetic acid as the only carbon source. In the UBFF-reactor accelerated growth of the sludge blanket volume could be observed in addition to fast surface biofilm development and a granular bacterial sludge of high density. Hydraulic retention times (HRT) of 2.3 h, and gasproductivities of 100 v/v.d were achieved in the UBFF-reactor, compared to 3.5 h and 70 v/v.d respectively in the USB-reactor. At maximum loading rates the acetic acid conversion efficiency exeeded values of 90 % in both reactors.

INTRODUCTION

The idea of packing the settler compartment of the UASB-reactor with some proper support material in order to obtain a combined UASB-Anaerobic Filter-process was already realized by Lettinga et al. (1981) and by Guiot and van den Berg (1984). Lettinga et al. concluded that such a combination presumably would not be profitable. Guiot and van den Berg however showed that the biomass was fixed very effectively on a packing material of plastic rings, and that biomass was retained independently of the sludge blanket, which could be an inexpensive method to increase biomass accumulation in the process. Khan et al. (1983) worked with a two phase combination reactor for the conversion of cellulose to methane, combining a fully mixed phase for cellulose degradation and a fixed film phase with pre-immobilized bacteria for the conversion of fatty acids to methane in the upper part of the reactor.

We have chosen a support construction in our reactor combination and obtained an effective accumulation of biomass in the settler compartment, an improved separator efficiency and an acceleration of the sludge blanket development. This UASB-Fixed Film-combination, called UBFF-(Upflow Blanket Fixed Film) -reactor in comparison with an USB-(Upflow Sludge Blanket)-reactor without supporting inserts, were operated in parallel as pH-auxostats (Brune et al., 1982) using acetic acid as substrate. By this operation mode it was possible to compare these two process configurations without extern control directly.

MATERIALS AND METHODS

The UBFF-reactor (Fig. 1, Tab. 1) contained in its upper two thirds of the glass cylinder additionally a pile of 25 conical disks, made from red potters clay, which were stacked on a central rod with open distances of 5 mm from each other. Liquid volume was 0.8 l, compared to 1.05 l in the USB reactor without inserts.

Tab. 1: Physical characteristics and operational conditions of the UBFF-reactor.

Liquid volume (l)	0.80
Blanket space vol. (l)	0.28
Packing volume (l)	0.64
Pack.dead. vol. (l)	0.19
Specific surface area (m^2/m^3)	210
Recycling rate (ml/min)	15
Temperature (^oC)	37
pH-preset	6.8

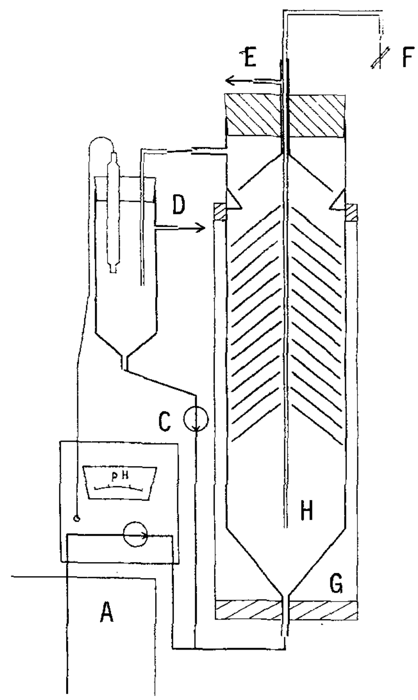

Fig. 1: Outline of the Upflow Blanket Fixed Film reactor A=feed tank, B=inlet, C=sludge recycling, D=effluent, E=gas exhaust, F=sampling port, G=water jacket, H=sludge blanket.

The microorganisms originated from a local municipal sewage plant. The acetic acid converting methanogens were preselelcted in an 1-liter continuously stirred reactor, with 5 g/l acetic acid as carbon source, running as pH-auxostat (Brune et al., 1982) and used as inoculum for USB- and UBFF-reactors.

The medium contained mineral salts (Brune et al., 1982), vitamins and sodium sulphide (Hacker et al., 1982), and 15 g/l acetic acid as carbon source. According to Brune et al. (1982) a certain quantity of alkali was required to increase the pH over the preset value of the fermentation. The addition of 2.8 g/l sodium hydroxide proved to be sufficient for stable operation.

Acetic acid concentration, gas production and gas composition were analysed as previously described (Hacker et al., 1982). Bacterial dry weight was determined in 5 ml samples after centrifugation (25 000 g, 5 min) and washing twice. Samples for the determination of bacterial dry matter (d.m.) were taken from the effluents and the bottom of the digesters.

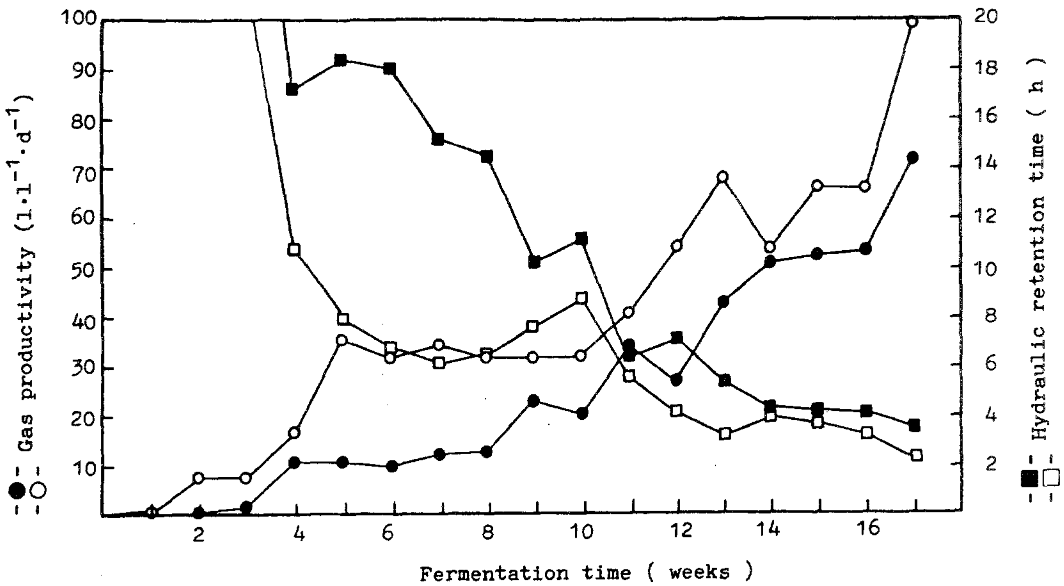

Fig. 2: Weekly average biogas productivities (CH_4-content 55-60%) and weekly average hydraulic retention times during pH-auxostatic digestion of acetic acid in the USB-(filled symbols) and UBFF-reactor (open symbols).

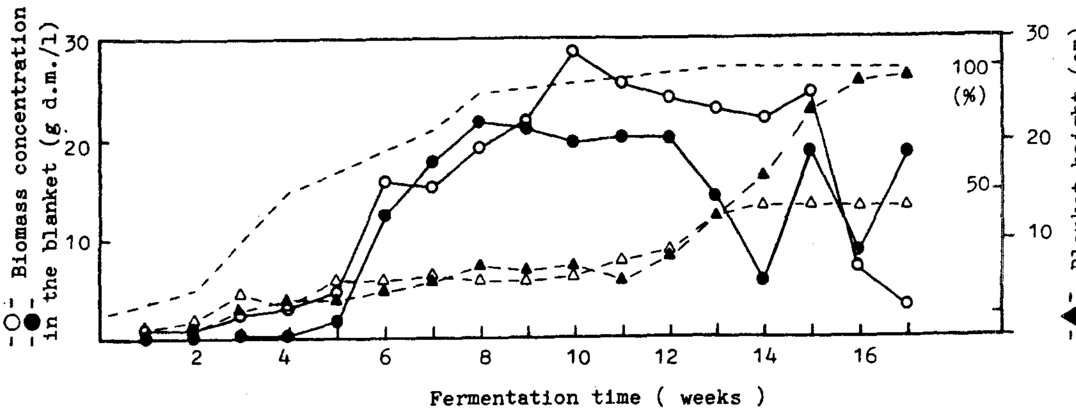

Fig. 3: Blanket height and biomass concentration in the USB-(filled symbols) and UBFF-reactor (open symbols); and the amount of biomass entrapped in the disk-space (---) of the UBFF-reactor.

RESULTS

Fermentation in both reactors started without lag. The synthetic wastewater was fed continuously according to the deviation from the preset pH value of 6.8, so that break-down of fermentation by high acetic acid or low pH could be avoided. The maximum acetic acid concentration in the sludge bed of both reactors was 4 g/l, the minimum pH was 6.0. After 5 weeks continuous operation HR-times of less than 20 hours in the USB-reactor and of less than 10 hours in the UBFF-reactor were obtained. Concidently increases in gas productivity to 10 v/v.d (USB-reactor) and to 35 v/v.d (UBFF-reactor) respectively were observed (Fig. 2). At this time a 3.5 fold amount of bacterial mass occured in the sludge bed of the UBFF-reactor as compared to the USB-reactor, while the space between the cones was half filled with biomass (Fig. 3).

The bacterial film on the clay disks mainly consisted of irregular granular flocks and increased in the course of the fermentation by sedimentation of rising flocks from the blanket. During the 5th week the bacterial mass in the sludge blanket of all reactors abruptly condensed and amounted to 22 g/l d.m. (USB-reactor) and 29 g/l d.m. (UBFF-reactor) respectively. The granular bacterial flocks of 1 - 3 mm diameter consisted of clusters of long shaped bacteria, probably belonging to the type Methanothrix soehngenii (Huser et al., 1982), interspersed with coccoid units of the Methanosarcina type, which became more frequent with higher dilution rates. After the 13th week the total blanket space of the UBFF-reactor was filled with sludge, composed of well pelletized bacterial flocks and the spaces between the cones were completely filled with biomass too. At this time the blanket height in the USB-reactor increasingly expanded together with considerable fluctuations in the local bacterial concentrations (Fig. 3), accompanied by a further rise of gasproduction. The increasing of biomass in the blanket of the UBFF-reactor was followed by an increased clogging of the disk spaces and by a significant reduced gasproductivity of the fixed biomass. From the 11th week on, when gasproductivity had attained values higher than 30 v/v.d in the USB-reactor and more than 40 v/v.d in the UBFF-reactor respectively, the biomass output in the effluent increased from 0.2-0.3 g/l to 0.4-1.0 g/l d.m. (Fig. 4).

Nevertheless gasproductivities of 70 v/v.d and HR-times of 3.5 h in the USB-reactor and of 100 v/v.d and 2.3 h in the UBFF-reactor respectively were finally observed, before the process had to be stopped owing to a technical defect. The charge loading of the UBFF-reactor was calculated at 156.5 g/l. d acetic acid or 166.9 g/l.d COD, and the acetic acid conversion efficiency was higher than 90 % (Fig. 4). These values were about 50 % higher than those obtained with the USB-reactor with a nearly identical conversion efficiency in the final fermentation period.

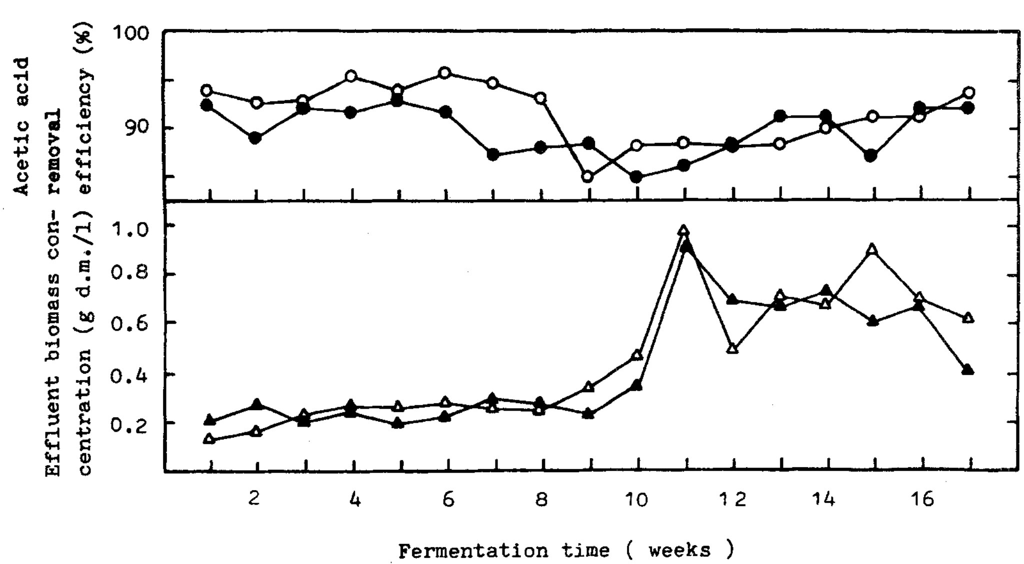

Fig. 4: Weekly average effluent biomass concentration (-△-) and acetic acid removal efficiency (-O-) in the USB- (closed symbols) and the UBFF-reactor (open symbols).

DISCUSSION

As shown, a pH-auxostatic operation of feeding resulted in an optimal substrate supply for the growing biomass and a quick development of granular bacterial flocks. According to Hulshof Pol et al. (1982) this principle should fulfill an essential criterion for the cultivation of a well adapted pelletized bacterial sludge with a complex wastewater. A pH-auxostatic operation meets the requirement that pH-changes clearly reflect concentration changes of the degradable substrates (Follmann und Märkl, 1979). So there are until now only few practical applications (Follmann und Märkl, 1979; Brune et al., 1982).

An UASB-reactor fitted out with additional stapled conical disks resulted in an accelerated development of granular bacterial sludge of higher density in the blanket, and a fast development of biofilm on the disks in the settler compartment of the reactor. Guiot and van den Berg (1984) reported that the filter in the upper part of a hybrid-reactor "Upflow Blanket Filter" also effectively retained biomass independently of the sludge blanket. When the disks spaces in the UBFF-reactor were nearly completely filled with biomass, the function of the support as separator ceased, followed by an increased wash-out of biomass. On the other hand a comparable loss of biomass occured in the USB-reactor, related to the strong liquid flow agitation due to increasing gasproduction. The final biomass wash-out in both fermenters was higher than the growth of biomass calculated from the substrate input. According to Wandrey and Aivasidis (1983) and to Roels (1980) a maximum yield of 2.16 biomass d.m. per mol acetic acid consumption can be expected. The maximum substrate input and the respective bacterial growth of 4 g biomass d.m. per day is comparatively lower than the loss of 5 g biomass d.m. per day, which was measured in the UBFF-reactor.

Further improvement of this separator construction can be expected from expanding the space between the disks and from increasing the distance between separator and sludge blanket in order to prevent a clogging of the support material as far as possible.

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