UASB TREATMENT OF TAPIOCA STARCH WASTEWATER

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ABSTRACT: Feasibility of the upflow anaerobic sludge blanket (UASB) process was investigated for the treatment of tapioca starch industry wastewater. After removal of suspended solids by simple gravity settling, starch wastewater was used as a feed. Start-up of a 21.5-L reactor with diluted feed of approximately 3,000 mg/L chemical oxygen demand (COD) was accomplished in about 6 weeks using seed sludge from an anaerobic pond treating tapioca starch wastewater. By the end of the start-up period, gas productivity of 4–5 $m^3/m_r^3 \cdot$day was obtained. Undiluted supernatant wastewater with a COD concentration of 12,000–24,000 mg/L was fed during steady-state reactor operation at an organic loading rate of 10–16 kg COD/$m_r^3 \cdot$day. The upflow velocity was maintained at 0.5 m/h with a recirculation ratio of 4:1. COD conversion efficiencies >95% and gas productivity of 5–8 $m^3/m_r^3 \cdot$day were obtained. These results indicated that removal of starch solids from wastewater by simple gravity settling was sufficient to obtain satisfactory performance of the UASB process.

INTRODUCTION

Tapioca starch is an important agro-based product found in many parts of the world (''18th Anniversary'' 1994). The starch extraction process involves preprocessing of tapioca roots, starch extraction, separation, and drying. It also generates large volumes of wastewater up to 20–60 m^3/t of starch produced (Economic 1982). Water pollution problems related to the tapioca starch industry are serious. The wastewater is highly organic and acidic by nature with chemical oxygen demand (COD) up to 25,000 mg/L and pH between 3.8 and 5.2 (Bengtsson and Triet 1994). It also contains biodegradable starch-suspended solids up to 4,000 mg/L. High-rate anaerobic processes offer an attractive alternative for treatment of starch industry wastewater (Lettinga and Hulshoff Pol 1986, 1991) as they employ a higher biomass concentration in the form of biofilms (Annachhatre and Khanna 1987, 1990) and can be operated at higher loading rates up to 15–20 kg COD/$m_r^3 \cdot$day. This is attributed to a close proximity between hydrogen producing and consuming bacteria, facilitating efficient interspecies hydrogen transfer (McCarty and Smith 1986; Schmidt and Ahring (1996).

Although high-rate treatment processes offer an attractive treatment alternative, process start-up is one of the hurdles that must be overcome before steady process operation can be achieved (Annachhatre and Bhamidimarri 1992). They are also sensitive to suspended solids (SS). SS inhibits sludge granulation in the UASB reactor or may even lead to sudden wash out of the sludge bed (Lettinga et al. 1980). A separate settling pretreatment system for SS removal has been recommended (Lettinga and Hulshoff Pol 1991). Other researchers have suggested restricting the SS level below 1,000 mg/L (Souza 1986) or preacidification of SS (Shin et al. 1992). Although no noticeable accumulation of SS in the UASB reactor is observed, its long-term effects are still unclear (Kwong and Fang 1996). Accordingly, this research addresses the feasibility of the UASB process for treatment of starch industry wastewater after SS removal by simple gravity settling.

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MATERIALS AND METHODOLOGY

Experimental Setup

The process was comprised of a feed storage tank, influent and recirculation pumps, UASB reactor with 21.5-L working volume, and a gas collection assembly (Fig. 1) (Amatya 1996). Wastewater was fed to the UASB reactor using a Masterflex (Cole Parmer Instrument Co.) peristaltic pump. Sufficient upflow velocity was maintained to achieve proper fluidization and mixing of sludge granules inside the reactor. Effluent was collected in a settling tank and the supernatant was partly recirculated back into the reactor. Biogas generated from the reactor was stored in a gas collection assembly that worked on the water displacement principle.

Reactor Operation

The combined starch wastewater from a tapioca starch factory in the central province of Thailand, was used as feed.

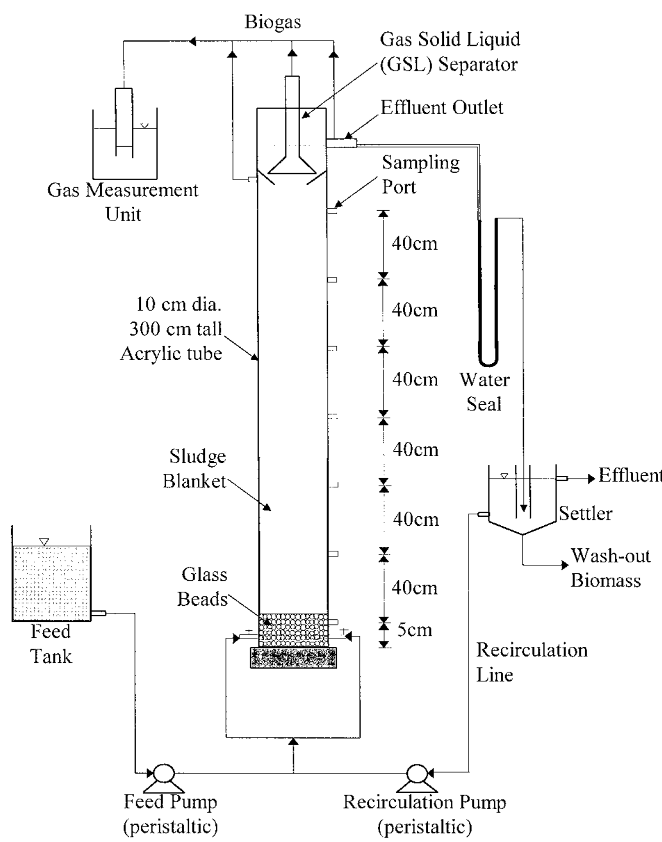

FIG. 1. Detailed Schematic Process Flowchart with Experimental Setup

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Sludge from wastewater anaerobic lagoons treating the starch wastewater was used as seed. All experiments were performed at an ambient temperature between 30–35°C. Initially, about 50% reactor volume was filled with active sludge from an anaerobic lagoon to yield average volatile suspended solids (VSS) concentration of 15,000 mg/L in the entire reactor. The supernatant wastewater after simple gravity was diluted to desired COD concentrations using tap water and was neutralized by NaOH to a pH of 7. A COD:N:P ratio of 300:5:1 was maintained during start-up using urea and KH_2PO_4.

The process operation lasted from Days 44 to 115, during which the reactor was fed with undiluted supernatant wastewater. During this period COD:N:P was maintained at 600:5:1 with a pH of approximately 7.0 and an organic loading rate (OLR) of 10–16 kg COD/$m_r^3 \cdot$day. Synthetic feed with glucose as its carbon source was fed to the reactor whenever starch wastewater was not available. All analyses such as COD and volatile fatty acids (VFA) were carried out according to *Standard Methods for Examination of Water and Wastewater* (American 1992). The specific methanogenic activity (SMA) of the sludge was measured as reported by Sørensen and Ahring (1993). Biogas composition was determined by a gas chromatograph (Shimadazu 14-A, Japan) analysis with a thermal conductivity detector.

RESULTS AND DISCUSSION

Wastewater Characteristics and Seed Sludge

Starch industry combined wastewater has low pH, high suspended solids, and high total COD (COD_t) (Table 1). The supernatant of the combined wastewater after the gravity settling used in the investigation, had lower total SS (TSS), as approximately 70–75% of the solids were removed. The seed sludge had a VSS content of about 30,000 mg/L, a VSS/TSS ratio of approximately 0.43 (Table 2), and SMA of 0.03 kg CH_4-COD/kg VSS$\cdot$day.

Reactor Startup

Feed concentration and upflow velocity maintained during the start-up stage are presented in Fig. 2. Since the sludge activity was initially low, feed concentration of <3,000 mg COD/L was maintained. The COD conversion obtained during the first three weeks was low, at about 15–50% (Fig. 3). During Days 9–20, a higher upflow velocity of 0.40 m/h was tried (Fig. 2), resulting in an OLR of more than 10 kg COD/$m_r^3 \cdot$day (Fig. 3). This made the process operation unstable as evidenced by a higher effluent VFA concentration of 2,000–3,500 mg/L (Fig. 2). Hence the upflow velocity was reduced to 0.24 m/h after Day 24. The biogas production up to Day 23 was low, less than approximately 30 L/d (Fig. 3). Beyond Day 25, however, when the VFA concentration was controlled to <1,500 mg/L, the gas production, as well as COD

TABLE 1. Tapioca Starch Wastewater Characteristics

Parameter (1)	Combined wastewater (2)	Supernatant wastewater (3)
COD_t (mg/L)	13,500–25,000	12,500–24,550
COD_f (mg/L)	10,440–24,500	9,000–22,000
TSS (mg/L)	2,200–4,000	540–1,280
TDS[a] (mg/L)	6,000–8,000	5,500–7,800
pH	3.8–4.5	3.8–4.5
Acidity [as $CaCO_3$ (mg/L)]	1,800	—
Orthophosphate [as P (mg/L)]	—	25–48
TKN[b] (mg/L)	—	85–250
Turbidity (NTU)	280	32

[a]TDS = Total dissolved solids.
[b]TKN = Total Kjeldahl nitrogen.

TABLE 2. Characterization of Seed Sludge and Reactor Granules

Day (1)	Sludge blanket height (cm) (2)	VSS (mg/L) (3)	TSS (mg/L) (4)	VSS/TSS (5)	SMA (kg CH_4-COD/kg VSS$\cdot$day) (6)
0	Seed sludge	30,054	69,791	0.43	0.06
2	220	15,005	34,895	0.43	0.60
38	85	13,332	17,915	0.74	0.58
84	90	17,599	24,328	0.72	0.77
115	106	21,292	25,198	0.84	0.66

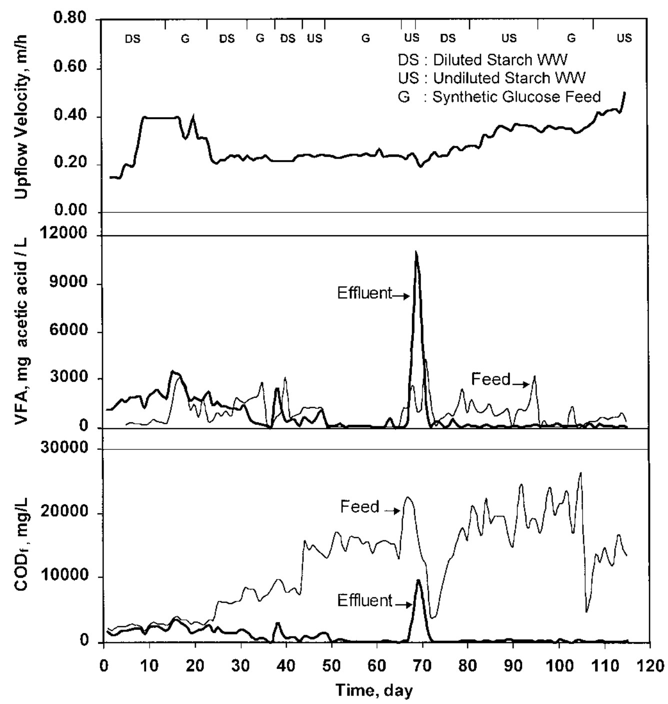

FIG. 2. COD_f and VFA Concentrations in Feed and Effluent, and Upflow Velocity during Reactor Operation Period

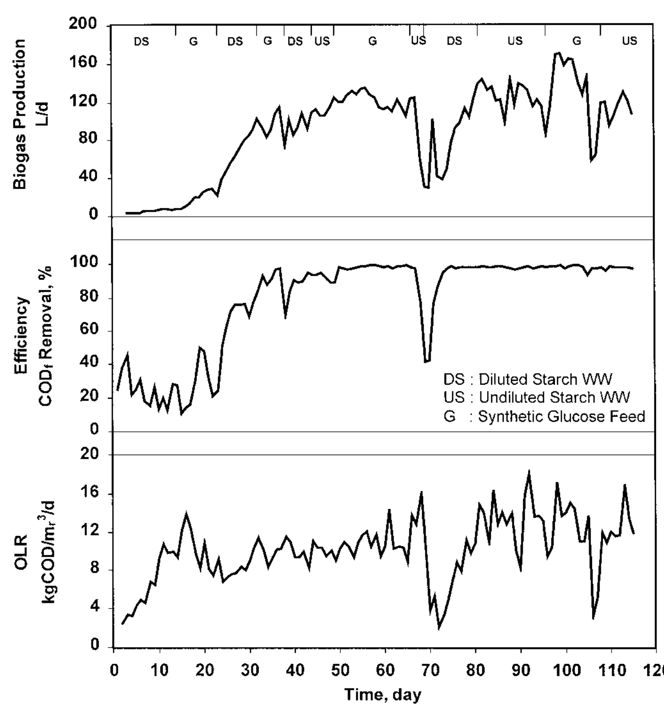

FIG. 3. OLR, COD Removal Efficiency, and Biogas Production during Reactor Operation Period

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