Available online at www.sciencedirect.com

SCIENCE DIRECT®

Bioresource Technology 96 (2005) 721–730

BIORESOURCE TECHNOLOGY

Effect of aeration rate and waste load on evolution of volatile fatty acids and waste stabilization during thermophilic aerobic digestion of a model high strength agricultural waste

J. Obeta Ugwuanyi *, L.M. Harvey, B. McNeil

Strathclyde Fermentation Centre, Department of Bioscience and Biotechnology, University of Strathclyde, Glasgow G1 1XW, UK

Received 3 September 2002; received in revised form 13 May 2004; accepted 20 June 2004
Available online 11 September 2004

Abstract

Thermophilic aerobic digestion (TAD) is a relatively new, dynamic and versatile low technology for the economic processing of high strength waste slurries. Waste so treated may be safely disposed of or reused. In this work a model high strength agricultural waste, potato peel, was subjected to TAD to study the effects of oxygen supply at 0.1, 0.25, 0.5 and 1.0 vvm (volume air per volume slurry per minute) under batch conditions at 55 °C for 156 h on the process. Process pH was controlled at 7.0 or left unregulated. Effects of waste load, as soluble chemical oxygen demand (COD), on TAD were studied at 4.0, 8.0, 12.0 and 16.0 $g l^{-1}$ (soluble COD) at pH 7.0, 0.5 vvm and 55 °C. Efficiency of treatment, as degradation of total solids, total suspended solids and soluble solid, as well as soluble COD significantly increased with aeration rate, while acetate production increased as the aeration rate decreased or waste load increased, signifying deterioration in treatment. Negligible acetate, and no other acids were produced at 1.0 vvm. Production of propionate and other acids increased after acetate concentration had started to decrease and, during unregulated reactions coincided with the drop in the pH of the slurry. Acetate production was more closely associated with periods of oxygen limitation than were other acids. Reduction in oxygen availability led to deterioration in treatment efficiency as did increase in waste load. These variables may be manipulated to control treated waste quality.

Keywords: Thermophilic aerobic digestion; (TAD); Volatile fatty acids; Acetate; Soluble chemical oxygen demand; Agricultural waste; Air flow

1. Introduction

Production of volatile fatty acids (VFA) during thermophilic aerobic digestion (TAD) of waste has several possible consequences. It may be encouraged if TAD is used as the first or acidification stage of a dual (TAD-anaerobic) digestion process, since acids accumulated in the first, aerobic stage, encourages rapid establishment of methanogens in the second, anaerobic stage (Messenger et al., 1993; Henry and Thomson, 1993; Hawash et al., 1994), or if it is needed to enhance waste pasteurisation (Williams et al., 1989; Kelly et al., 1993; Ugwuanyi et al., 1999). Conversely, their production may be undesirable if TAD is used as a stand-alone treatment process (Murray et al., 1990; Haner et al., 1994; Ponti et al., 1995a,b). Concentration of VFAs in effluent is related to the efficiency of the treatment process in this case, and conditions that lead to the least accumulation of VFAs are considered most efficient. Some studies describing acidification and the production of VFA in TAD have been reported (Mason et al., 1987, 1992; Chu et al., 1994). Malladi and Ingham (1993) reported rapid acidification during TAD of potato process

* Corresponding author. Present address: Department of Microbiology, University of Nigeria, Nsukka, Nigeria. Tel.: +234 0804 318 4850; fax: +234 042 256 831/+44 0141 553 4124.
E-mail address: jerryugwuanyi@yahoo.com (J.O. Ugwuanyi).

0960-8524/$ - see front matter
doi:10.1016/j.biortech.2004.06.028

waste but did not analyze the waste for the types of acids involved. However, other workers have reported that acetate is the major VFA produced during TAD of a variety of wastes (Haner et al., 1994; Chu et al., 1996, 1997).

Oxygen concentration is often limiting in full-scale TAD processes. This is due to high demand for oxygen by the rapidly growing thermophilic populations (Ugwuanyi, 1999), limited solubility of oxygen at high temperatures and solids contents, limitations in equipment capability, high cost of aeration and the need to prevent evaporative cooling of self-heating TAD processes which would occur at high aeration rates (Messenger et al., 1993). At any given aeration rate and waste loading, these variables should relate constantly in such a manner as to lead to reproducible effluent quality. Oxygen limitation, which in TAD processes may produce an effect on effluent quality similar to shock loading in otherwise well aerated systems, is believed to result in the accumulation of products of fermentative metabolism (VFAs), in a manner akin to the pockets of facultative and anaerobic metabolism that occur during composting (Tiquia et al., 1996).

Waste loading is often an important factor in TAD design considerations since, as in most waste treatment processes, shock loading can occur. When this happens, it can cause increased oxygen demand in treatment processes, thereby exerting metabolic pressures on the thermophilic populations at the given, often low aeration rates employed in TAD (EPA, 1990; Messenger et al., 1993). Although oxygen deficiency is believed to lead to accumulation of VFAs in TAD (as does shock loading), the relationship between aeration rate/waste load in TAD and acidification (in terms of the extent and types of VFAs) is not clear. It is important to understand these relationships since the nature and concentration of residual dissolved organic matter in treated waste streams is more a function of process variables, than of the nature of influent waste (Grady et al., 1984).

Air supply and waste loading are, for economic reasons, the usually controlled variables in waste treatment, because control of dissolved oxygen tension is often too sophisticated and expensive to be attractive for use in waste treatment (Messenger et al., 1993). This investigation therefore, was carried out to understand the effect of different aeration rates, at a given waste load, on the physical and chemical parameters of slurry and, in particular on the concentration and types of volatile fatty acids produced during the TAD of model waste slurry under conditions that may be obtained in full-scale treatment. To enable an understanding of the effect of waste loading on this indicator parameter, different loading rates were also studied at one aeration rate considered economical, efficient and representative of full-scale aeration rate regime. Batch processes have been selected for this study because the need for waste pasteurisation in TAD requires that the process be operated in batch or draw and feed modes (EPA, 1990; Messenger et al., 1990; Ugwuanyi et al., 1999). The (suspended) solid component of waste slurry employed in this study is considered potentially reusable (in animal nutrition) as high quality wastes, perhaps after protein enrichment, hence it is not monitored additively as volatiles along with the liquid effluent intended for immediate disposal.

2. Methods

2.1. Preparation of model waste for digestion

Peel waste was manually generated in large batches from the same type of locally procured white potatoes (Pentlands variety) for batch digestion. The potatoes were washed in lukewarm tap water and air dried before peeling. Peel was stored in batches of 2.0 kg at −20 °C until required. Peel was defrosted in a water bath at 40 °C immediately prior to use, and blended to a fine paste capable of passing through a 250 μm mesh, using a commercial blender (Waring Co. MA). The blended peel was digested without any further treatment unless otherwise specified. The total solids content was determined by reference to the dry weight of peel and is as shown in Table 1 (which includes both suspended and total solids of slurry). Minimal mineral supplement was added to help in stabilizing thermophilic enzymes in the slurry. The composition of the mineral solution used to make up

Table 1
Effect of digestion at different aeration rates and pH 7.0 on some properties of the model agricultural waste (potato peel) during thermophilic aerobic digestion

Aeration rate (vvm)	Total Suspended Solids (TSS) (% w/v)			Soluble Solids (SS) (% w/v)			TS (TSS + SS) (% w/v)			Soluble COD ($g l^{-1}$)		
	Initial	Final	Rem.	Initial	Final	Rem.	Initial	Final	Rem.	Initial	Final	% Rem.
0.1	2.26 (0.09)[a]	1.31 (0.02)	42.0	1.12 (0.02)	1.46 (0.00)	−30.36	3.38 (0.06)	2.77 (0.01)	18.05	8.7 (0.27)	4.1 (0.27)	53.3
0.25	2.51 (0.10)	1.28 (0.08)	49.0	1.01 (0.00)	1.30 (0.00)	−28.70	3.52 (0.07)	2.58 (0.04)	26.71	8.4 (0.27)	1.8 (0.27)	79.0
0.5	2.56 (0.09)	1.25 (0.02)	51.2	0.97 (0.02)	1.11 (0.01)	−14.43	3.53 (0.06)	2.36 (0.04)	33.14	8.0 (0.18)	2.8 (0.13)	65.0
1.0	2.46 (0.09)	1.18 (0.02)	52.0	0.95 (0.03)	1.13 (0.02)	−18.95	3.41 (0.07)	2.31 (0.03)	32.26	8.4 (0.0)	3.1 (0.0)	63.6

[a] Figures in parentheses are the SD of three determinations.