Effects of Various Surfactants on Anaerobic Digestion of Water Hyacinth–Cattle Dung

Datta Madamwar, Anami Patel & Vikram Patel

Department of Biosciences, Sardar Patel University, Vallabh Vidyanagar – 388 120, Gujarat, India

(Received 25 August 1990; revised version received 23 September 1990; accepted 29 September 1990)

Abstract

In an effort to improve the anaerobic digestion process of water hyacinth–cattle dung, the effects of various doses of different surfactants: Tween 20, Tween 60, Tween 80, sodium lauryl sulphate, Tegoprens 42, Tegoprens 43, Tegoprens 47, Tegoprens 51, Tegoprens 52, Tegoprens 63, have been evaluated in bench-scale digesters. Increasing concentrations of surfactants produced maxima or minima in the various parameters measured. Amongst the surfactants tested, Tegoprens 43 showed a maximum of more than 114% increase in gas production with a 6.25% higher methane content.

Key words: Water hyacinth, cow dung, anaerobic digestion, methane, energy, surfactants, biogas.

INTRODUCTION

In India, a large number of water bodies have been damaged due to the excessive growth of aquatic weeds, particularly water hyacinth (*Eichhornia crassipes*), to the extent that they are of no further use. Today, utilization is considered an important part of weed management. Therefore, the anaerobic digestion of water hyacinth (WH), resulting in the production of biogas, a valuable source of energy, has recently attracted universal attention (Obeid, 1975; Gupta & Lamba, 1976; Wolverton & McDonald, 1976; Saraswat & Khanna, 1986; Annachhatre & Khanna, 1987). There is also a growing interest in maximizing the extraction of methane for energy recovery from water hyacinth. Unfortunately, operating experiences with anaerobic digesters and their cost effectiveness has not been consistently good. Digesters are susceptible to malfunctioning due to shock loading and a variety of toxic substances. Malfunctioning manifests itself in terms of reduced gas production, reduced degradation of organic materials and a simultaneous increase in acidity. Researchers have shown the need for pH control and the advantages of mixing. However, further process improvements are needed.

Surfactants are amongst the most versatile of the products of the chemical industry and are used in diverse forms. Of late, surfactants have become subjects of intense investigation in the field of chemical kinetics and biochemistry because of the unusual properties of the polymeric forms (micelles) of these materials. They show unusual catalysis of organic reactions (Fendler & Fendler, 1975) and show similar behaviour with biological reactions; for example, surfactants improve enzyme activity (Elworthy et al., 1968; Fendler & Fendler, 1975; Rosen, 1978; Naik & Rastogi, 1983). Surfactants are used in detergents and biocides and may adversely affect digesters. No study, however, seems to have been made so far on the effects of surfactants on the anaerobic digestion of water hyacinth and cattle dung with the objective of improving both the performance stability and the rate of decomposition, with improved gas production, by adding various surfactants.

METHODS

Resources

All chemicals used were of analytical grade. All Tegoprens were obtained from Gold Schmidt AG, Essen, FRG. Cattle dung and water hyacinth were obtained locally.

Anaerobic digestion

Several bench-scale anaerobic digesters were used. Each vessel consisted of a 10-litre glass reaction bottle, having a working volume of 6 litres and con-
taining 7% (w/v) of total solids (TS). The digesters were intermittently stirred with magnetic stirrers and maintained at 37 ± 1°C. Gas was collected and measured by displacement of acidified saturated salt solution, making due correction for atmospheric pressure and temperature. The digesters were fed on a semicontinuous basis once per day using a freshly prepared mixture of powdered WH (dried at 60°C and powdered to 50 mesh size) and cow dung (CD) in a ratio of 7:3 (w/w), with a RT of 8 days (where the loading rate was 8.75 g TS/litre digester/day). This was found to be most suitable for the initial study (Madamwar et al., 1990). Prior to feeding, an equal quantity of sludge was withdrawn from the bottom of the digester. Surfactants were mixed with feed sludge.

A fresh digester was always started by preparing a mixture of the powdered WH and CD in the ratio of 7:3 (w/w) to give a final total solid concentration of 7% (w/v) and using a 10% inoculum from the running biogas digester of the same type (containing only WH and CD in the ratio of 7:3 (w/w) and TS 7% (w/v) without surfactant). A steady-state condition was decided upon by a fairly constant mean gas production rate. Experiments were carried out in triplicate for each surfactant and for each concentration, and average data are presented.

Analysis

Gas composition was analysed with a CIC gas-liquid chromatogram with stainless steel chromosorb 2 column and thermal conductivity detector (Varel et al., 1980).

Feed and effluent slurry were routinely analysed for pH, volatile acids, biological oxygen demand (BOD), chemical oxygen demand (COD), total solids (TS), volatile solids (VS), lignin, cellulose and hemicellulose as standard procedures (Updegraffe, 1969; APHA, 1976; Deschatelets & Yu, 1986).

RESULTS AND DISCUSSION

In the present work the effects of Tween 20, Tween 60, Tween 80, sodium lauryl sulphate (SLS), Tegoprens 42, Tegoprens 43, Tegoprens 47, Tegoprens 51, Tegoprens 52, Tegoprens 63 on anaerobic digestion of WH–CD mixture were investigated. Increasing concentrations of surfactants produced maxima or minima in the various parameters measured (Fig. 1). Tegoprens 43 showed the greatest effect with a maximum gas production at 50 mg litre⁻¹. Maximum enhancement (of over 114%) was achieved with the addition of 50 mg litre⁻¹ Tegoprens 43 and gas production declined thereafter. The gas was also higher in methane content in a Tegoprens 43-dosed digester.

Process stability, as evidenced by lower volatile acids (Fraser, 1977; Varel et al., 1980; Madamwar & Mithal, 1986), increased with 50 mg litre⁻¹ loads of Tegoprens 43. It appears that at certain concentrations Tegoprens 43 did enhance the methane forming step of the digestion process. The rate limiting step in methane fermentation often involves the degradation of fatty acids, which is related to the efficiency of H₂ utilization by methanogenic bacteria (McInerney et al., 1979; Boone & Bryant, 1980; McInerney & Bryant, 1981).

Tegoprens 43 at a concentration of 50 mg litre⁻¹ gave a minimum value of BOD and COD, indicating greater biodegradation with high process performance. Values of BOD and COD were 11.6 g litre⁻¹, 22.7 g litre⁻¹ respectively in Tegoprens 43-dosed digester, in comparison to values of BOD (17.3 g litre⁻¹) and COD (27.2 g litre⁻¹) in controls without surfactant. This also indicated that microbial degradation of organic matter was at a much higher rate in the Tegoprens 43 dosed digester than in the control. Figure 1 also gives the data on COD removal. This parameter is important because the values suggest the bacterial efficiency (Hills & Roberts, 1981), and shows that presence of Tegoprens 43 improves the bacterial efficiency, thereby increasing biodegradation.

The other surfactants tested also showed increased gas production with enriched methane content, indicating that surfactants in general enhance the conversion efficiency. Nonionic surfactants like Tegoprens have exceptionally great effects on anaerobic digestion. Addition of these surfactants results in high performance stability, as shown by the lower values of volatile acids and increased rates of decomposition, giving reduced values of effluent BOD and COD.

It is known that surfactants have unusual properties of polymeric form (micelles) and they show catalysis of organic reactions (Madamwar & Mithal, 1987). Surfactants also increase the rate of enzymatic cellulose saccharification (Castanon & Wilke, 1981). From studies presented here it seems that contact of substrate with the bacteria or with the enzymes released by bacteria is enhanced. Adsorption and orientation of the surfactant molecules at the solid-liquid interface could render the substrate readily wettable by the enzymes produced by the bacteria, thereby pro-
Fig. 1. Anaerobic digestion profiles of water hyacinth–cattle dung in the presence of surfactants: (a) Tween 60 (Polyoxyethylene sorbitan monostearate); (b) Tween 80 (Polyoxyethylene sorbitan monooleate); (c) Tween 20 (Polyoxyethylene sorbitan monolaurate); (d) sodium lauryl sulphate (SLS); (e) polydimethyl siloxane–polymers (Tegoprens 42); (f) polydimethyl siloxane–polymers (Tegoprens 43); (g) polydimethyl siloxane–polymers (Tegoprens 47); (h) polydimethyl siloxane–polymers (Tegoprens 51); (i) polydimethyl siloxane–polymers (Tegoprens 52); (j) polydimethyl siloxane–polymers (Tegoprens 63). Operating conditions: temperature = 37 ± 1°C; retention time = 8 days; loading rate = 8.75 g TS/litre digester/day. (WH–CD, 7:3, w/w). ⊗, Gas production; ▼, CH₄ %; △, BOD; ▽, COD; ◻, volatile acids; ◦, % COD removal.
viding a highly localized substrate concentration. This may thus provide a more favourable environment for the bacteria (enzymes)-substrate systems and so improve the digester performance.

ACKNOWLEDGEMENT

Thanks are due to the DNES, New Delhi, India for financial support.

REFERENCES


