0273-2289/96/5601—0089$06.50

Tegoprens in Anaerobic Digestion of a Mixture of Cheese Whey, Poultry Waste, and Cattle Dung for Improved Biomethanation

CHIRAG PATEL, VISHWANADA SASTRY, AND DATTA MADAMWAR*

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

Received June 23, 1994; Accepted December 20, 1994

ABSTRACT

To obtain enriched methane content and improve the anaerobic digestion of a mixture of cattle dung, poultry waste, and cheese whey, the effect of various doses of Tegoprens: T-3012, T-3022, T-5842, T-5843, T-5851, T-5852 has been studied, in bench-scale digesters. Among them, Tegoprens 3022 showed more than a 45% increase in gas production with higher methane content.

Index Entries: Tegoprens; cheese whey; poultry waste; cattle dung; anaerobic digestion; biomethanation; energy.

INTRODUCTION

Cheese whey, a byproduct of cheese production, is generated at enormous quantities. It has a high organic strength with a chemical oxygen demand (COD) of about 70 g/L, which often causes disposal problems for the cheese manufacturers. In India, a large number of dairies dispose of their wastes, especially cheese whey, into the environment in enormous quantities. Anaerobic digestion of cheese whey offers an excellent approach for both energy production and pollution control considerations (*1–3*).

*Author to whom all correspondence and reprint requests should be addressed.

The whey contains about 4% lactose, 1% protein, 1% salts, and 0.8% lactic acid, and is not effectively utilized. Whey represents a potential energy source and poses several advantages if it is subjected to anaerobic digestion. During the past several years, there has been considerable interest in anaerobic digestion of cheese whey (*3–5*).

Previous work has shown that cheese whey contains a high level of carbohydrates, which promotes the growth of acid-forming bacteria, but has a negative effect on methane producing bacteria (*6*). However, addition of poultry waste increases the nitrogen content of the digester and supports the growth of methanogens (*3*). By itself, poultry waste is difficult to handle by anaerobic digestion owing to heavy ammonia toxification. Improved gas production with enriched methane content resulted when a mixture of cattle dung, poultry waste, and cheese whey in the ratio of 2:1:3 (w/w) on a dry weight basis was used as substrate (*3*).

There is a growing interest in maximizing the extraction of methane for energy recovery from cheese whey and poultry waste. However, despite the waste reduction and energy potential, anaerobic digestion is not a highly regarded process in the dairy industry, largely because of the problem of slow reaction. It has been reported that surfactants increase the productivity of anaerobic digesters (*7,8*). They show unusual catalysis of organic reactions (*9*) and show similar behavior to biological reactions. For example, surfactants improve enzyme activity (*10,11*). Tegoprens, a class of surfactants, have shown a tremendous potential in enhancing the rate of biological reactions and improving the performance of anaerobic digestion (*12*). No study, however, seems to have been made so far on the effects of surfactants, especially Tegoprens, on the anaerobic digestion of a mixture of cheese whey, poultry waste, and cattle dung. The purpose of our study was to elucidate the effect of different types of Tegoprens on the anaerobic digestion of a mixture of cattle dung, poultry waste, and cheese whey with the ultimate aim of improving gas production and methane content.

MATERIALS AND METHODS

Resources

All chemicals used were of analytical grade. All Tegoprens were obtained from Gold Schmidt AG, Essen, Germany. Poultry waste was collected from the Bakrol Poultry Farm, Bakrol, India. Cheese whey was collected from AMUL Dairy, Anand, India, and cattle dung was obtained locally.

The Tegoprens used are speciality surfactants based on polyether-polymethyl siloxane copolymers. They are labeled as T-3012, T-3022, T-5842, T-5843, T-5851, and T-5852. The molecular weights of T-5842, T-5843, T-5851, and T-5852 are 998, 3824, 4370, and 4740 g/mol, respectively. The molecular weights of Tegoprens T-3012 and T-3022 are not known. The solubility of all the surfactants was found to be <1 mg/L. However, the

hydrophilic liphophilic balance (HLB) values for the surfactants series T-5843, T-5851, and T-5852 were found to be 19, 18, and 11, respectively. The surfactant T-5852 has only hydrophilic moiety. The critical micelle concentration (CMC) of those surfactants was found to be 0.025, 0.035, 2.730, and 3.520 g/L (in water), respectively.

Anaerobic Digestion

Several anaerobic digesters were used. Each digester consisted of a 5-L glass bottle, having a working volume of 3 L and containing 6% total solids (TS) with mixtures of cattle dung, poultry waste, and cheese whey, in the ratio of 2:1:3 (w/w) on a dry-wt basis, which were maintained at 40 ± 1°C in a thermostat. Gas was collected and measured by displacement of an acidified saturated salt solution making due corrections for atmospheric pressure and temperature. The digesters were fed on a semicontinuous basis (once per day) with a freshly prepared mixture of cattle dung, poultry waste and cheese whey with a retention time (RT) of 10 d (where the loading rate was 6 g TS/L of digester/d). This was found to be most suitable from our previous study (*3*). The digesters were intermittently stirred with magnetic stirrers (total duration 4 h/d at 120 rpm). Prior to feeding, an equal quantity of sludge was withdrawn from the bottom of the digester. Tegoprens were incorporated with the feed. A steady-state condition was decided by a constant mean gas production rate and constant COD values. Digesters were run for at least 50 d, i.e., for five retention times after reaching steady-state conditions. Experiments were carried out in triplicate for each Tegopren and for each concentration.

Analysis

Gas composition was analyzed with a CIC-make gas-liquid chromatogram with stainless-steel Chromosorb 2 column and thermal conductivity detector (*13*). Feed and effluent slurry were routinely analyzed for pH, volatile acid, chemical oxygen demand, total solids, and volatile solids using standard procedures (*14*).

RESULTS AND DISCUSSION

The impact of Tegoprens, mainly Tegoprens 3012, 3022, 5842, 5843, 5851, and 5852, on the anaerobic digestion of a mixture of cheese whey, poultry waste, and cattle dung was investigated. Tegoprens is a class of nonionic surfactants. They have shown a tremendous potential to enhance the rate of biological reactions (*11*). Surfactants also increase the rate of enzymatic cellulose saccharification (*15*). Our previous study has shown that Tegoprens have an unusual ability to improve the performance of anaerobic digestion (*7*). Steady-state performance data using different types of Tegoprens are presented in Fig. 1. A trend of enhanced gas production with increasing amounts of Tegoprens 3022 was observed. The

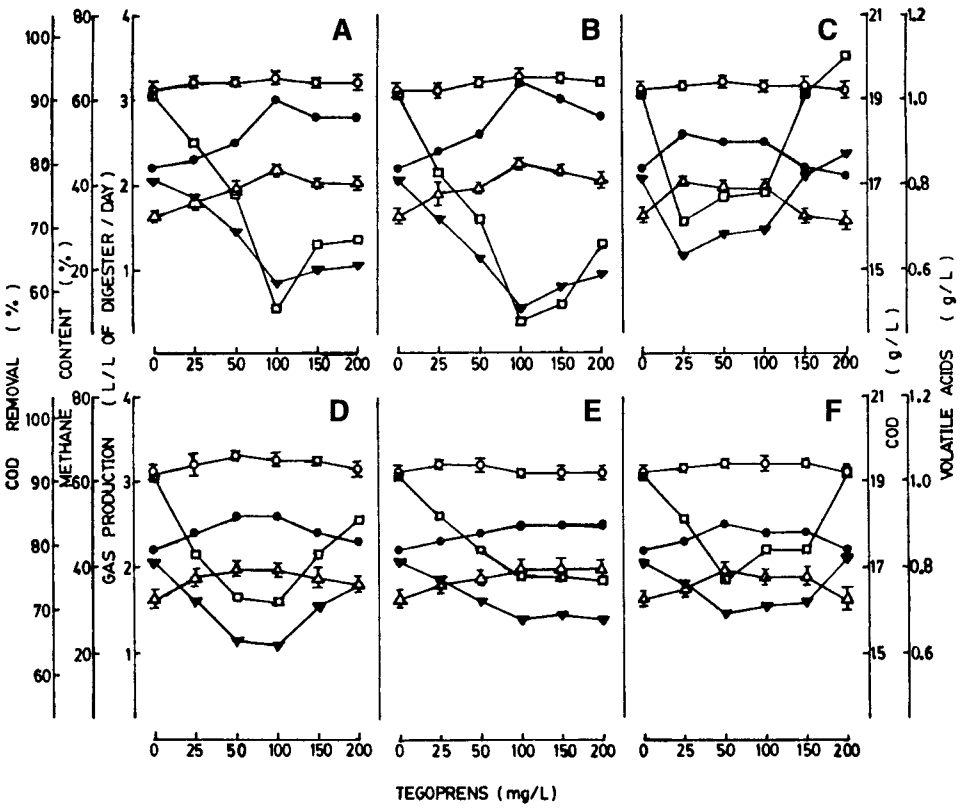

Fig. 1. Anaerobic digestion profile of a mixture of cheese whey, poultry waste, and cattle dung in the presence of Tegoprens: (**A**) T-3012; (**B**) T-3022; (**C**)T-5842; (**D**) T-5843; (**E**) T-5851; (**F**) T-5852. Operational conditions: temperature 40 ± 1°C; retention time 10 d; loading rate 6 g TS/L digester/d (CD:PW:CW, 2:1:3, w/w). Symbols: ●, gas production; ○, methane content; □, COD; ▼, volatile acids; △, % COD removal.

maximum improvement in gas production, over 45%, was obtained with the addition of Tegoprens 3022 at a concentration of 100 mg/L, and gas production declined thereafter (Fig. 1B). The gas was also higher in methane content in a Tegoprens 3022 dosed digester. Maximum enhancement of methane content from 62% in control digester to 65% in Tegoprens 3022 (100 mg/L) dosed digester has been achieved (Fig. 1B), thus improving the fuel value.

The concentration of volatile fatty acids in a digester is a sensitive parameter used to determine process stability (*13*). Figure 1 indicates the levels of total volatile fatty acids (equivalent acetate units) present in the digesters stabilized with different doses of Tegoprens. Average volatile fatty acids concentration ranged from 0.81 g/L in the digester with no Tegoprens to 0.51 g/L in Tegoprens (100 mg/L) dosed digester. It appears that at certain concentrations, Tegoprens 3022 did enhance the methane-forming step of the digestion process. The volatile fatty acids were consumed at a faster rate in Tegoprens dosed digester than in the control digester. The rate-limiting step in methane fermentation often involves the degra-

dation of fatty acids, which is related to the efficiency of H_2 utilization by methanogenic bacteria (*16,17*). Methanogenic bacteria catabolize mainly acetate, carbon dioxide, and hydrogen to the terminal products. The maintenance of a very low concentration of hydrogen in the digester by methanogens is essential for efficient fermentation, because it maintains low production of propionate and other reduced products (*17*). Addition of Tegoprens helps the digester to maintain a low level of hydrogen by enhancing the methane-forming step. Thus, addition of Tegoprens 3022 helped the digester, which otherwise was stressed by accumulation of fatty acids.

The organic removal efficiencies increased with increasing concentration of Tegoprens 3022, reaching a maximum at concentration of 100 mg/L as indicated by %COD removal (Fig. 1B).

The Tegoprens 3022 dosed digester had lower values of COD, as shown in Fig. 1B, indicating greater biodegradation and better process performance. The COD was 13.80 g/L in the Tegoprens 3022 dosed digester (100 mg/L) in comparison to 19.11 g/L in the control without Tegoprens. This indicates that the microbial degradation of organic matter is at a much higher rate in the Tegoprens 3022 dosed digester than in a control digester.

The other Tegoprens tested also showed increased gas production with enriched methane content, indicating that surfactants in general enhance the substrate conversion efficiency. Addition of Tegoprens results in a high-performance stability, as shown by the lower values of volatile acids and increased rates of decomposition, giving reduced values of effluent COD.

Nonionic surfactants have shown exceptionally great effects on anaerobic digestion (*7*). Surfactants are especially noted for their solubilizing qualities, and they show catalysis of organic reactions (*18*). The addition of surfactants like Tegoprens may lead to the formation of favorable active sites that enhance the coupling of sequential reactions for conversion of polymeric substances into soluble substances, fatty acids, and finally into gases. Tegoprens molecules at the solid–liquid interface could render the substances readily wettable by the enzymes produced by bacteria and, therefore, the presence of surfactants may provide a more favorable environment for the bacteria (enzyme)-substrate system. This will improve the digester performance and quality of gas, giving a higher fuel value.

CONCLUSIONS

Thus, our study proves that anaerobic digestion of a mixture of cattle dung, poultry waste, and cheese whey can be improved by adding Tegoprens, especially Tegoprens 3022, which results in more than a 45% increase in gas production with higher methane content and better process performance.

REFERENCES

1. Lo, K. V., Liao, P.H., and Chiu, C. (1988), *Biomass* **15,** 45–53.
2. Lo, K. V., Liao, P. H. and Bulley, N. R. (1986), *Agric. Wastes* **17,** 279–291.
3. Desai, M., Patel, V., and Madamwar, D. (1994), *Environ. Pollut.* **83,** 311–315.
4. Barford, J. P., Cail, R. G., Callander, I. J., and Fioyd, E. J. (1986), *Biotechnol. Bioeng.* **28,** 1601–1607.
5. Boeing, P. H. and Larson, V. F. (1982), *Biotechnol. Bioeng.* **24,** 2539–2556.
6. Hanson, G. (1982), *Process Biochem.* **17,** 45–49.
7. Madamwar, D., Patel, A., and Patel, V. (1991), *Bioresource Technol.* **37,** 157–160.
8. Desai, M. and Madamwar, D. (1994), *Transactions of the ASAE* **37,** 959–962.
9. Fendler, J. and Fendler, E. (1975), *Catalysis in Micellar and Macromolecular Systems.* Academic, New York.
10. Rosen, M. J. (1978), *Surfactants and Interfacial Phenomena.* Wiley, New York.
11. Naik, B. N. and Rastogi, S. C. (1983), *Adv. Biosci.* **2,** 157–163.
12. Madamwar, D., Patel, A., Patel, V., and Shastri N. V. (1992), *Appl. Biochem. Biotechnol.* **36,** 163–169.
13. Varel, V. H., Hashimoto, A. G., and Chen, Y. R. (1980), *Appl. Environ. Microbiol.* **46,** 217–222.
14. APHA (1976), *Standard Methods for Examination of Water and Waste Water,* 14th ed. American Public Health Association, Washington, D.C.
15. Castanan, M. and Chavles, W. R. (1981), *Biotechnol. Bioeng.* **23,** 1365–1372.
16. Boone, D. K. and Bryant, M. P. (1980), *Appl. Environ. Microbiol.* **40,** 626–632.
17. McInerney, M. J. and Bryant, M. P. (1981), in *Biomass Conversion Process for Energy and Fuels,* Sofer, S. S. and Zaborsky, O. R., eds., Plenum, New York, pp. 277–296.
18. Madamwar, D. B. and Mithal, B. M. (1987), *Ind. J. Microbiol.* **27,** 81-84.