0273-2289/96/6002—0159$07.00

Biomethanation of a Mixture of Salty Cheese Whey and Poultry Waste or Cattle Dung

A Study of Effect of Temperature and Retention Time

CHIRAG PATEL AND DATTA MADAMWAR*

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

Received May 31, 1995; Accepted August 25, 1995

ABSTRACT

This paper describes the results of a study aimed at improving the efficiency of anaerobic digestion of salty cheese whey in combination with poultry waste or cattle dung. Best results were obtained when salty cheese whey was mixed with poultry waste in the ratio of 7:3, or cattle dung in the ratio of 1:1, both on dry weight basis giving maximum gas production of 1.2 L/L of digester/d with enriched methane content of 64% and 1.3 L/L of digester/d having methane content of 63% respectively. Various conditions such as temperature and retention time have been optimized for maximum process performance.

Index Entries: Biomethanation; energy; salty cheese whey; poultry waste; cattle dung; anaerobic digestion; temperature; retention time.

INTRODUCTION

A large number of dairies in India dispose of their waste, especially cheese whey, into the environment in enormous quantities. Cheese whey has a very high chemical oxygen demand (COD) of about 70 g/L, which often causes problems of disposal for the cheese manufacturers. Anaerobic digestion of cheese whey offers an excellent solution in terms of both

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

energy production and pollution control consideration (*1–3*). The application of this technique to the treatment of salty cheese whey is compounded by the presence of high salt (5–8% w/v NaCl), which can cause inhibition and toxicity problems in the biomethanation process (*4*). Whey, containing high sodium chloride content, is obtained from the manufacture of Domiati cheese, where sodium chloride is normally added to milk before renneting. The sodium concentration in such whey may reach a point that is above that of sea water, but the methanogenic activity was reported to cease at sodium concentration of 10–20 g/L (*5*). A satisfactory operation of high rate anaerobic reactors treating high saline waste has been reported (*6*). The major advantages of this process are low cost, high energy efficiency, and process simplicity as compared to other waste treatment methods. However, despite these advantages, anaerobic digestion is not widespread in the dairy industry for treatment of salty cheese whey largely due to the problem of high salt concentration and poor process stability. One of the methods used to overcome these problems is by adding poultry waste or cattle dung. This will dilute the level of sodium chloride and will make an environment favorable to methanogens and other anaerobes. Addition of poultry waste or cattle dung helps to maintain suitable C/N ratio in the digester (*7*). Cheese whey contains a high level of carbohydrates. This promotes the growth of acid forming bacteria, but has negative effects on methanogens (*8*). Poultry waste and cattle dung are responsible for increasing the nitrogen content, and support the growth of methanogen. Fermentation of mixed waste materials has proved to be more effective for methane generation than in case the material is treated individually (*7*).

No detail study seems to have been made so far on the effect of temperature and retention time on methane generation from salty cheese whey in combination with poultry waste or with cattle dung. This study was undertaken with the aim of maximizing the extraction of methane for energy recovery from salty cheese whey by mixing poultry waste, or cattle dung, and optimizing various conditions.

MATERIALS AND METHODS

Resources

All chemicals used were of AR grade. Poultry waste was collected from the Karamsad Poultry Farm, Karamsad (India). Salty cheese whey was collected from AMUL Dairy, Anand (India) and fresh cattle dung was obtained locally.

Anaerobic Digestion

Several bench-scale anaerobic digesters were used. Each digester consisted of a 5 L glass bottle, having a working volume of 3 L and containing 6% (w/v) total solids (TS) (mixture of salty cheese whey and poultry waste or cattle dung in different proportions). All digesters were maintained at a desired temperature of ±1°C in a thermostat. The digesters were fed on a semicontinuous basis (once/d) with freshly prepared mixture of cheese whey with poultry waste or cattle dung at desired ratio, with a retention time of 3, 5, 7, 9, 12, and 15 d for each temperature, where loading rate corresponds to 20, 12, 8.56, 6.66, 5, and 4 g TS/L of digester/d respectively. The temperature ranged from 30 to 60°C, with 5°C increments between fermenters. An equal quantity of slurry was withdrawn from the bottom of the digester prior to feeding. Fresh digesters were always started by preparing a mixture of the wastes in the specific ratio to give a total solid concentration of 6% (w/v), using 10% inoculum from the running digester of the same type.

Analyses

Regular analyses were conducted of the effluent and feed slurry for pH, volatile fatty acid, total solids, volatile solids, and COD as per standard procedures (*9*). Gas was collected and measured by displacement of acidified saturated salt solution and results were corrected keeping in mind the atmospheric pressure and temperature. The gas composition was analyzed by Sigma-make gas liquid chromatography, with a stainless steel Chromosorb 2 column and a thermal conductivity detector (*10*). The steady-state condition was judged on the basis of constant gas production and the effluent COD values remaining constant.

RESULTS AND DISCUSSION

Effect of Poultry Waste and Cattle Dung

Different concentrations of poultry waste and cattle dung were used to study their effects on anaerobic digestion of salty cheese whey. Digestions were carried out at 40°C with a loading rate of 6.0 g TS/L of digester/d having a retention time of 10 d. Best results in terms of gas production and its methane content were obtained when cheese whey was combined with poultry waste in the ratio of 7:3 (w/w), and with cattle dung in the ratio of 1:1 (w/w) (Fig. 1A and B). This combination not only gave maximum gas production but also a higher methane content. Improved digestion was evident from the values of COD and volatile fatty acids. These combinations also resulted in higher COD removal indicating higher bacterial efficiency. Control experiments were also performed using individual wastes independently (Fig. 1A and B), and their combination gave better results.

Cheese whey promotes the growth of acid-forming bacteria due to its high content of carbohydrates. This in turn inhibits methane producing

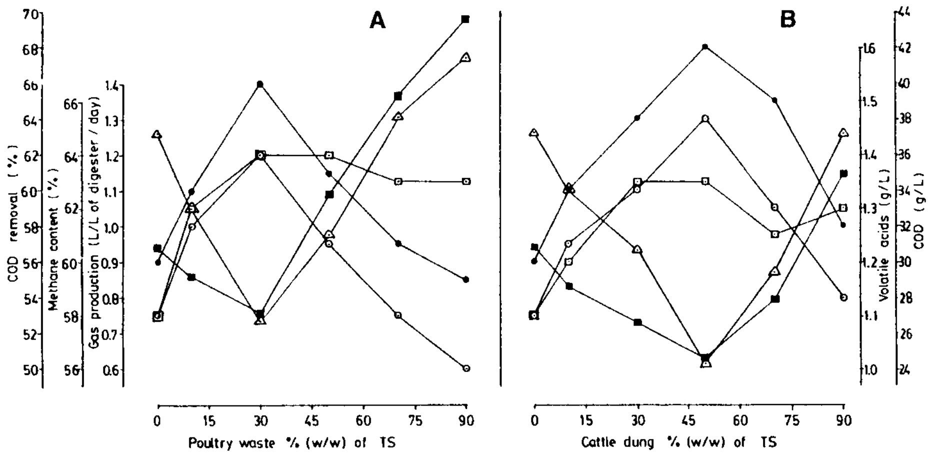

Fig. 1. Steady-state profile of anaerobic digestion of salty cheese whey and poultry waste (**A**), or cattle dung (**B**), under various combinations. Operational conditions: total solid concentration, 6% (w/v); retention time, 10 d with a loading rate of 6 g TS/L of digester/d; temperature 40°C. Symbols: ○, gas production; □, methane content; ●, COD removal; △, volatile acids; ■, COD.

bacteria (*8*). However, mixing it with poultry waste increases the concentration of nitrogen and reduces the inhibitory effect of acid formers on methane producing organisms, showing an overall positive effect. A similar effect was observed when dairy manure was mixed with cheese whey for biomethanation (*11*). Also, it has been noticed that addition of other waste such as poultry waste or cattle dung has a buffering effect. The rate of methanogenesis depends on the type and content of the organic matter undergoing digestion. Whey and poultry waste when combined has been found to be suitable for maintaining C/N ratio in the digester in such a way that the fermentation of mixed waste material has proved to be a more effective way of generating methane from the materials treated individually. Necessity of having proper C/N ratio for efficient digestion process has also been suggested by others (*12*).

Admixing cheese whey with poultry waste or cattle dung reduces the inhibitory level of sodium chloride, and is thus responsible for creating a favorable environment for efficient biomethanation process.

Effect of Temperature and Retention Time

Temperature and retention time are the primary operating variables that can be employed to control the growth of organisms and, therefore, the rate of formation of microbial metabolic products. Our aim was to optimize the temperature and retention time for efficient anaerobic digestion process.

A summary of the steady-state profile of anaerobic digestion of cheese whey with poultry waste or with cattle dung at different temperatures under varying retention times, is presented in Figs. 2 and 3. As the temperature was increased, there was a gradual increase in gas production

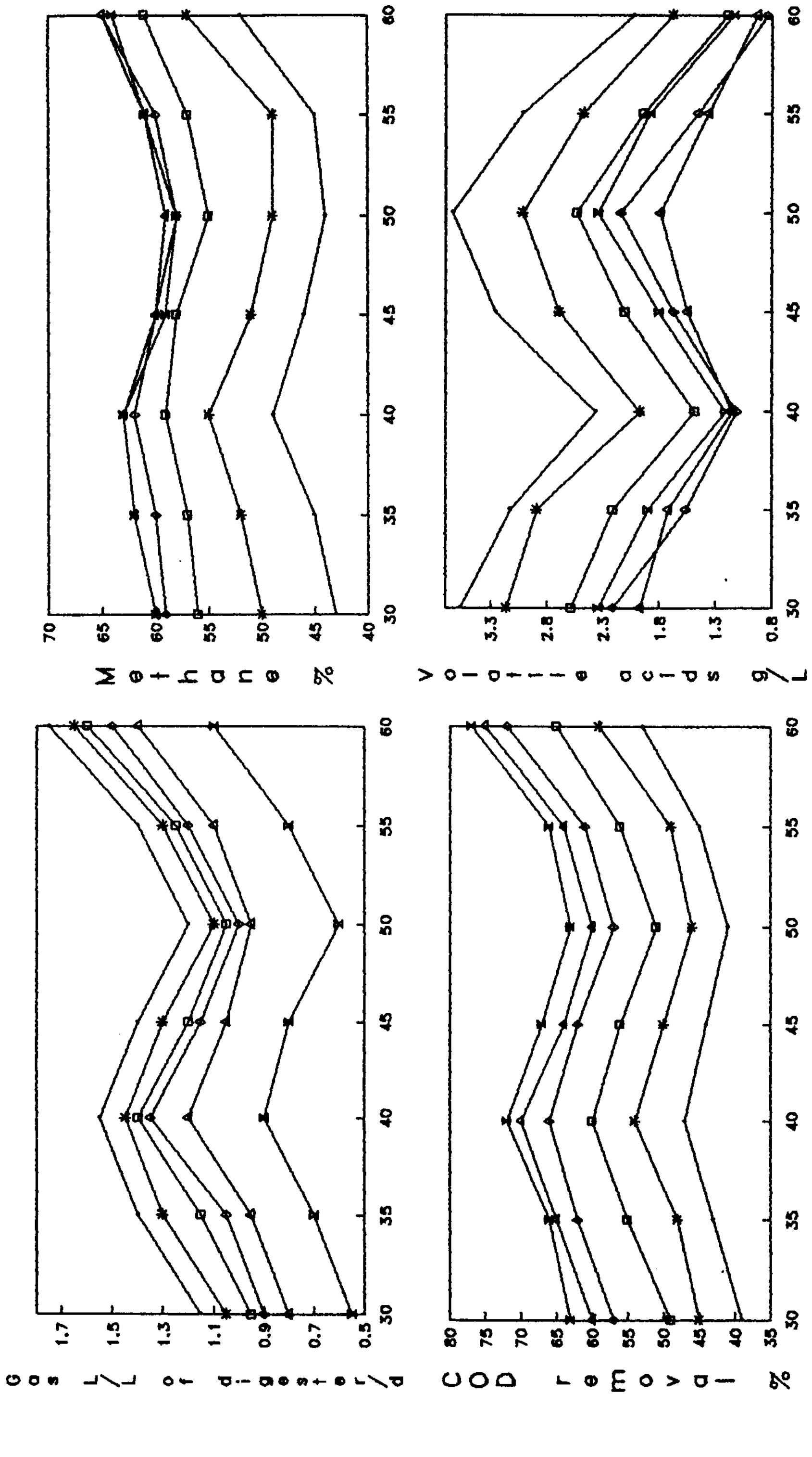

Fig. 2. Steady-state profile of anaerobic digestion of salty cheese whey and poultry waste in the ratio of 7:3 (w/w) (TS 6% w/v) at different retention times for various temperatures. Symbols: Retention time (in d): —●— 3; —*— 5; —□— 7; —◇— 9; —△— 12; —⧗— 15.

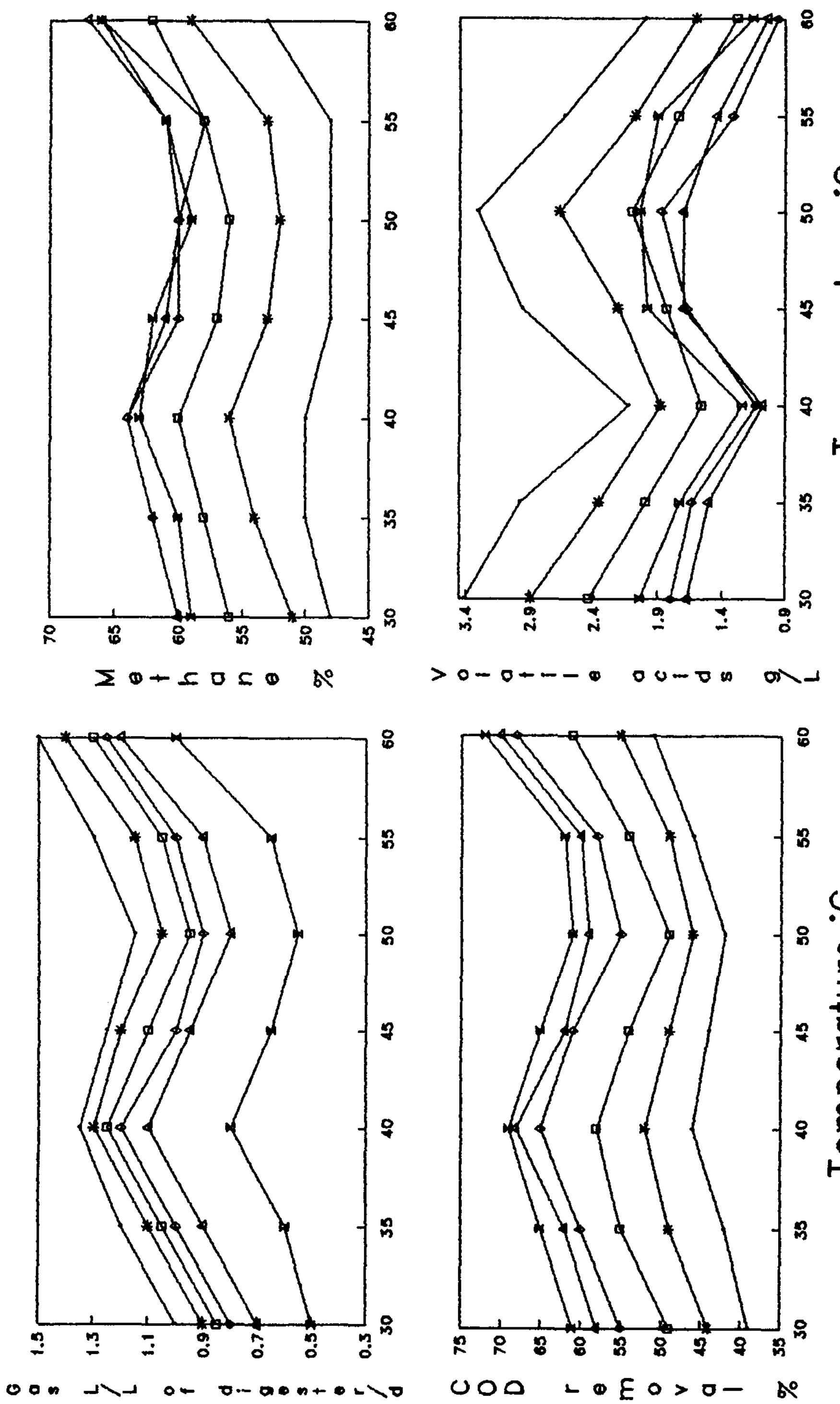

Fig. 3. Steady-state profile of anaerobic digestion of salty cheese whey and cattle dung in the ratio of 1:1 (w/w) (TS 6% w/v) at different retention time for various temperatures. Symbols: Retention time (in d): —●— 3; —*— 5; —□— 7; —◇— 9; —△— 12; —⧗— 15.

with a higher methane content reaching its maximum at 40°C. This was followed by a decrease in gas production and a further increase giving second maxima at 60°C, indicating the two temperature optimas, one at 40°C and the other at 60°C for maximum gas production. A similar trend has also been observed in case of municipal refuse (*13*) and in our earlier work (*7,14*). On the whole, thermophilic operation in this system performed better than mesophilic operation.

Buhr and Andrews have reviewed the results of various studies on the effect of temperature and retention time on anaerobic fermentation (*15*), and suggested several advantages for thermophilic temperature. Though there are advantages in converting organic waste into methane at a high temperature, such as 60°C, even at a short retention time in terms of gas production, this would be only at the cost of a higher energy input in order to maintain the fermenter temperature.

In general, as the retention time decreased, a gradual increase in gas production was noticed at all temperatures (Figs. 2 and 3). Effect was more conspicuous with the increase in temperature from 30 to 40°C. Process stability is in evidence due to the lower volatile acids (*16*). Volatile acids contents were decreased as the temperature was increased from 20 to 40°C and with increased retention time giving maximum process stability at 40°C, with a retention time of 9 d and at 60°C, with a retention time of 7 d, indicating a faster washout rate of volatile acids at the longer retention time (7 and 9 at temperature of 60°C and 40°C, respectively) and maintaining balance between acidifying bacteria and methanogenic bacteria. Under these conditions pH of the digester remained around 7.0. Even though gas production is high at shorter retention time, the digester is under stressed conditions as indicated by high volatile acids. Propionic acid has been found to be accumulated under such stressed conditions (data not given). Similar observations have been recorded by others (*10*).

The rate of biodegradation is also judged by COD value of effluent. It was found that at long retention times, COD values were low, indicating greater biodegradation. However, the decrease in COD values was more significant as the retention time was increased from 3 to 12 d (depending on temperature) but further increase in retention time did not reduce COD value markedly (Figs. 2 and 3).

Figures 2 and 3 provide the data of percent COD removal and has been found to show a function of retention time. With the increase in temperature and with increase in retention time, a trend of COD reduction was evident. The maximum percent COD removal of 65 occurred at 40 and 60°C with a retention time of 9 and 7 d, respectively. This parameter is highly important as it indicates bacterial efficiency.

Our studies indicate that cheese whey in combination with poultry waste in the ratio of 7:3 on dry weight basis, or in combination with cattle dung in the ratio of 1:1 also on dry weight basis is found to ideal for running anaerobic digester efficiency at 40°C with a retention time of 9 d for the generation of methane.

ACKNOWLEDGMENTS

Thanks are due to Gujarat Energy Development Agency, Baroda (India) for financial help.

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