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The effect of different inoculums on anaerobic digestion of swine wastewater

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ABSTRACT

Methane production from swine wastewater was evaluated by using three inoculums: rumen (I1), stabilized swine wastewater (I2) and sewage sludge (I3). Experimental design was based on four treatments by duplicate: T0: swine wastewater as substrate (S) without inoculum (I), T1: S + I1, T2: S + I2 and T3: S + I3 all with 90 (S)–10 (I) % vol with a ratio S/I approximately constant (1:0.05). ANOVA test was applied to evaluate the significance of treatments at 95% confidence. After a batch experiment of 140 days, results indicated that the addition of any inoculum improved methane production rate and shortened the start-up of methane exponential growth stage. I2 and I3 promoted the highest percentage of organic matter removal (close to 50% in terms of VS and COD) and, in relation to the control test, a higher methane production achieving 0.25 L CH_4/g VS. The use of rumen (I1) did not improve methane production to the same extent as the other inoculums while organic matter removal only achieved 15%. The evolution of VFA and alkalinity show that methanogenic phase could be considered as the rate-limiting step of the global methane production rate.

1. Introduction

One of the most important and current challenges is to find a solution to the pollution caused by waste and wastewater of industrial and agricultural activities and to satisfy the growing demand for energy [1]. During the last decades in Argentina it has been a gradual process of concentration of the primary activity with the emergence of large companies and the disappearance of many traditional producers of mid and small scale. Accompanying this phenomenon there was a wide diffusion of technologies of high-capital investment based on a technological concept of industrialization of rural production. The increase in the number of animals per establishment and the regionalization of the production has generated strong pressure on livestock, poultry and dairy sectors because if production operations are not properly handled, the discharge of nutrients, organic matter, pathogens and emission gases cause significant pollution on water, air and soil [2,3]. Anaerobic digestion (AD) tend to solve the problem of wastewater with a high content of organic matter through the availability of renewable energy source based on the use of the generated methane [4–6]. However, the estimation of net energy to be produced through this process is a complex task due to the wide range of factors that affect methane production [7].

AD of organic matter is carried out by a consortium of microorganisms in sequential stage resulting a synergic action [8–10]. The first stage corresponds to the hydrolysis of the complex organic compounds that are not directly available for microorganisms. The result is the production of more simple organic compounds as fatty acids, alcohols, and sugars. The second stage is the acidogenic phase, which involves the conversion of volatile acids and alcohols into simple substrates such as acetic acid and hydrogen that can be used by methane-forming bacteria. The third and last stage is the methanogenesis phase where methane and carbon dioxide are produced [11,12]. In the final steps of AD process, the dominant species are acidogenic and methanogenic bacteria. The first is characterized by fast growing and less sensitivity to the environmental changes while methanogens are of slow growing (from a few days to some weeks depending on environmental conditions) and they usually are inhibited to low pH values [7,12]. Veeken and Hamelers [13] have determined that

Abbreviations: AD, anaerobic digestion; AR, alkalinity ratio; I, inoculum; IA, intermediate alkalinity; PA, partial alkalinity; S, swine wastewater; T, treatment; TS, total solids; VFA, volatile fatty acids; VS, volatile solids.

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the accumulation of volatile fatty acids (VFA) as intermediates is a signal that the rate of the hydrolytic step is greater than the methanogenic stage. Any perturbation in the system can cause changes in the type of dominant species and in the population of microorganisms that will be reflected in the performance of the bioreactor [7]. From that, the production and consumption of VFA must be balanced to avoid overloads of the system and low degradation of waste.

Kinetic studies of AD models can provide useful information for the analysis, design and operation of a fermentation process [14–16]. Kinetics description of the complex organic matter is accomplished through the so-called rate-limiting step approach, which could be defined as the step that will cause failure under imposed conditions of kinetic stress [16]. The rate-limiting step is related to the nature of the substrate, process configuration, temperature, and loading rate. The type of waste digested dictates which step need to be considered [17]. According to Seghezzo [17] hydrolytic step is usually regarded as the controlling step for wastewater with a high content of particulate matter. Other authors such as Pavlostathis and Gossett [18], Pavlostathis and Giraldo-Gómez [16] pointed out that the methanogenesis or acidogenesis have been indicated as controlling stages even when the hydrolysis may affect the overall process kinetics.

Between livestock waste, swine wastewater has characteristics that make it able to be a favorable substrate for AD due to its higher levels of water content and buffer capacity. Furthermore, swine wastewater is a complex substrate that contains undissolved and dissolved organic matter such as polysaccharides, lipids, proteins and VFA in addition to a wide variety of nutrients which are favorable for the growing of anaerobic microorganisms [14,19]. All these compounds interact during the anaerobic process in a complex system that should be analyzed to assure its stability when the use of energy is a goal. Previous studies [20] demonstrated that the use of fresh liquid swine manure a substrate in AD did not achieve a good and steady performance for methane production without the application of inoculums (I). Quality and quantity of inoculums are key factors that determine the length of the start-up and operation in a steady state of the reactor [12].

Forster-Carneiro et al. [21] reported that inoculum source is a very important operational parameter. Different types of inoculums have been used in mesophilic anaerobic digestion, such as swine wastewater, rumen, and sewage sludge that have demonstrated good quality due to its content in methanogenic bacteria [1,7]. Furthermore, these inoculums are waste from several sectors such as meat and other food productions (slaughterhouses, pig and cattle breeding, dairy sector) that highly impact the environment. Liquid swine manure have been used as inoculums in AD of urban solid waste [21], and in poultry manure [22]. Meanwhile Lopes et al. [23] and Budiyono et al. [1] analyzed the influence of bovine rumen fluid as inoculum during anaerobic treatment of the organic fraction of municipal solid waste and cattle manure respectively. González-Fernández and García-Encina [24] analyzed the influence of sewage sludge on AD of liquid swine manure. Neves et al. [25] used two types of sewage sludge as inoculum (granular and suspended) in the AD of kitchen waste finding that the first one (granular) was better in terms of methane production than the second one. Digested sludge resulted the best inoculums between six types (corn silage, restaurant waste digested mixed with rice hulls, cattle excrement, swine excrement, digested sludge, and swine mixed with sludge) in anaerobic thermophilic digestion of organic fraction of municipal solid waste [21]. Taken into account that not all substrate can be utilized by all methane-forming bacteria [12], the performances of the process is strongly dependent on the characteristics of the substrate as well as the inoculum and the whole mixed system. In this sense, no comparative studies were found relative to the influence of different inoculum on the DA of swine wastewater.

The objective of this study was to analyze the effect of three different inoculums-highly available in the region of this study- on the AD of fresh swine wastewater and evaluate the performance of the process regarding the methane production and identifying those factors that affect the start-up and stability of the process.

2. Materials and methods

2.1. Experimental design

Four treatments in duplicate were carried out in a batch laboratory-scale experiment. Reactors of 1 L capacity were filled with mixtures of substrate and inoculums. They were hermetically closed in order to assure anaerobic conditions and were manually agitated at least once a day to avoid stratification. Bioreactors were maintained in a water bath a constant temperature (35 ± 1 °C) corresponding to mesophilic conditions (Fig. 1). Experiment were conducted for 140 days until, methane production declined in all treatments.

2.2. Substrates and inoculums

The substrate used was liquid fresh swine wastewater collected from a piggery the same day that was produced and previous to the discharge in a covered lagoon.

Three inoculums (I) were used: rumen (I1), swine liquid manure previously digested (I2) and sewage sludge (I3). I1 was provided by the local slaughterhouse the same day that was collected to avoid degradation and death of anaerobic bacteria. I2 was obtained from the Bioenergy Lab (College of Engineering, UNCPBA) from a previously conditioned material under mesophilic conditions and used when methane percentage achieved its higher and constant value (67.61 ± 3.39%) in order to assure the methanogenic activity [12]. I3 was obtained from the wastewater

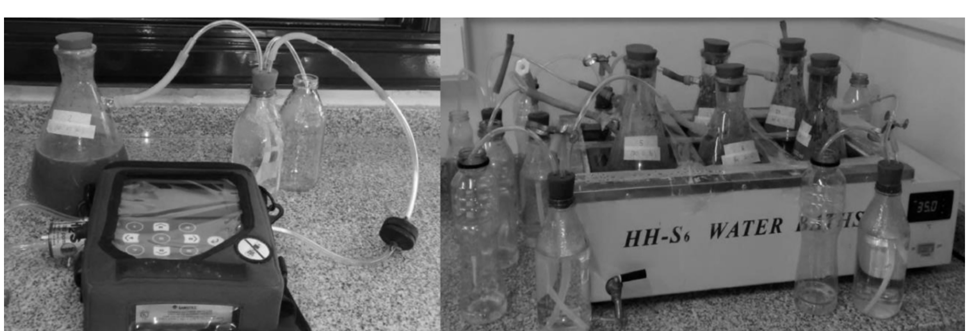

Fig. 1. Experimental arrangement; biogas and methane measurement.