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Application of a geophysical tool to monitor liquid repartition during agricultural wastes degradation for biogas production

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1 Introduction

Anaerobic digestion is a method engineered to decompose organic matter by a microbial consortium under oxygen-free conditions, into biogas (60–70% methane) and an organic residue with excellent agronomic qualities. This technology has been successfully implemented in the treatment of agricultural wastes, food wastes, and municipal waste in order to produce renewable energy [1]. Solid-state digestion generally occurs at solid contents higher than 15% in the reactor. During this process, wastes are placed in hermetic reactors and a liquid phase (inoculum) is recirculated to accelerate anaerobic digestion. A number of studies have pointed out the important role of liquid recirculation to optimize the waste degradation [2]. In dry process, a linear relationship between water content and methanogen activity has been established [3]. Liquid phase enhances biogas production by implementing distribution and spreading of microorganisms performing the methanogenesis, temperature favoring microorganism development, nutrients and moisture essential to microorganism growth. Liquid recirculation presents advantage to decrease lag time of biogas production, increasing both carbon conversion rate and cumulative biogas production [4].

Major topics of dry anaerobic digestion are characterization and management of water flow and hydrodynamic behavior of wastes subjected to degradation. Several methods exist to quantify and to determine water localization in landfills such as neutron probe, time domain reflectometry probe, gravimetric method, capacitive probe, optic fiber, gas tracer and electrical resistivity tomography (ERT) [5]. Most of these methods are intrusive, their measurements are localized and implying an important probe number. ERT was chosen because it is a non-intrusive method, and data acquiring and treatment are fast.

Several works have used this method mainly in municipal solid waste [6]. They established a relationship between resistivity and water content according to Archie's law. In the majority of cases ERT method is implemented on long profile in landfill. In dry anaerobic digestion, no data were found concerning the implementation of these techniques to detect and quantify liquid content. Commonly, gravimetric method is used to get total solid content.

The aim of this study was to implement ERT method for a 30 m³ container reactor using an Isman and Ducellier-like dry process. Agricultural waste was loaded and a liquid phase was recirculated to accelerate waste degradation under mesophilic conditions. Liquid content distribution is essential to get an optimal methane production. Three ERT campaigns were achieved to define optimal conditions for ERT method in order to map resistivity values and consequently the distribution of liquid content in the container. Samplings were also performed to characterize physico-chemical parameters (total solid (TS), volatile solid (VS), pH, and conductivity), fiber content and methane potential, aiming to establish relationships between resistivity, liquid content, degraded waste and methane potential zones.

2 Methods

An experimental set-up was performed on a dry batch anaerobic digestion reactor to investigate liquid repartition in process and to map spatial distribution of inoculum, using electrical resistivity tomography (ERT) method. The reactor was 6 m long, 2.5 m height and 2.5 m width, around 30 m³ working volume. Anaerobic digestion was carried out on about 20 tons of agricultural waste (mainly cattle manure, straw, silage of corn). Waste was inoculated with 6 m³ of liquid phase called inoculum coming from a previous anaerobic digestion cycle. The reactor was closed with roof and temperature was maintained at 37°C to have optimal mesophilic anaerobic conditions. Leachate was re-circulated 500 L per hour during the batch process. Methane content of biogas was measured by a gas sensor (Dynament, UK) and biogas production was recorded by a gas meter (Gallus G4, Itron, USA). A technical adaptation of ERT method was necessary. Two array electrodes were used: pole–dipole (PDP) and gradient arrays (GRD). Measured resistivity data were inverted and modeled by RES2DINV software to get resistivity sections. Continuous calibration along resistivity section was necessary to understand data involving sampling and physicochemical analysis.

3 Results

The first results permitted to technically adapt ERT method, using one electrode introduced at the bottom of the container before loading waste, to validate PDP array in a full-scale dry batch process. Both second and third campaigns provided useful information to establish correlation between resistivity values, liquid content, methane potential and fiber content in the reactor, representing liquid repartition, high methane potential zones and degradations zones. High TS content were associated with low resistivity values, while low TS content gave higher resistivity values. Samples with high TS content produced more methane. A positive correlation was established between the cumulative methane production and TS content of samples (Pearson correlation: 0.86; R²: 0.74) establishing a conflict with the anaerobic digestion knowledge. Typically, methane production increases with the increasing of water content in the substrate. However, low TS content samples, above 19%, were composed of more than 6% of cellulose. A positive correlation was found between TS content and cellulose content. Resistivity values were correlated with two important parameters: cellulose content and methane potential. To summarize, before the waste inoculation, low resistivity (1.5–3 ohm m) values corresponded to substrates with high TS content (>19% TS), high methane potential values and high cellulose content (>6% of cellulose), representing high methane potential zones. The same measurements were performed after 30 and 60 days of anaerobic digestion. The reactor seemed saturated during anaerobic digestion, but after liquid pumping, resistivity was correlated with total solid content, methane potential and lignin content, showing a heterogeneous degradation. ERT conditions gave a good description of degradation zones, showing liquid repartition and locating high methane potential zones in dry AD. However ERT needs a calibration by continuous sampling. ERT method showed a strong relevance to monitor and to optimize the dry batch anaerobic digestion process.

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