The effect of Total Solids, Particle Size Distribution and hydrodynamics in anaerobic digestion of carrots and rice straw

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1.Introduction

Research in the last twenty year demonstrated that biogas yield and production rate were at least as high in anaerobic digesters where the wastes were treated in their original solid state, i.e. not diluted with water (Spendlin and Stegmann, 1988; Oleszkiewicz and Poggi-Varaldo, 1997). In dry systems, the fermenting mass within the reactor is kept at a solids content in the range 20–40% Total Solids (TS). Three designs have been demonstrated effective for the adequate mixing of organic waste at industrial scale, Dranco, Valorga and Kompogas (Lissens et al., 2001). The specific objective of the present research is to develop a mathematical model able to simulate the hydrodynamic and bio-chemical processes in dry and semi-dry anaerobic digestion plug flow reactors. In order to optimize and calibrate the model, a series of Bio-Methanation Tests (BMT) were performed. In particular the objectives of BMT were:

- to define the rate limiting step of the anaerobic digestion process as a function of the particle size distribution (PSD) of the carrots and rice straw separately fed to the reactor;

- to define the effect of TS concentration (in the range wet and semidry digestion) on the process performances and the specific methane potential.

2. Hydrodynamic Tests.

A laboratory scale reactor was set up with the aim to obtain a plug flow configuration similar to the Kompogas reactor configuration. The designed anaerobic digester (Fig.1.1) consists of 4.6 l plexiglas horizontal reactor with an internal diameter of 10 cm and a length of 60 cm. The reactor is equipped with a water jacket for temperature control and 4 sampling point. Experiments with laboratory scale reactor were carried out in order to study reactor flow patterns at selecting HRT(in the range of 20-46 min) values. Tracer tests (Teefy, 1998), using a conservative tracer (KCl), were performed to study reactor hydrodynamics. In each experiment the tracer was introduced to the reactor at selected concentration with pulse input feeding. As a result, tracer concentration through-out the reactor decreased as time elapsed. For each selected HRT Residence Time Distribution Curves (RTD) and the dispersion number were obtained. Direct correlation between HRT and the dispersion number was found. In particular with the highest tested HRT (in the range of 20-30 min) the highest dispersion value (in the range of 27-46) was found. This means that complete mixing conditions can be assumed. This behavior demonstrates that molecular diffusion has a greater impact on the flow pattern than advection. Whereas with smaller HRT (10-12 min) dispersion values in the range of 9-11 were found, which means that the flow pattern is closer to plug flow conditions.

3.1 Effect of PSD on Methane Production

Two sets of Bio-Methanation tests (BMT) (Esposito et al., 2012) were performed using buffalo manure (BM) as inoculum and two selected substrates: carrots and rice straw.

For each organic substrate the following selected sizes were investigated: <1 mm, 4 mm, 9 mm, 1,5 cm and 2 cm. For each bottle the methane production was monitored throughout the test duration (50 days). With regard to carrots, the results showed that methane production rate was influenced by particle size. In particular an inverse correlation between PSD and the methane production rate was found. From these results it is possible to gather that the disintegration step is the rate limiting process of carrots anaerobic digestion. On the contrary in the case of rice straw, it was not possible to see any correlation between methane production rate and PSD. In fact a small difference in methane production (8%) between 9 mm and 15 mm was observed. Additionally for 9 mm and 15 mm the average methane production was in the range of 90-95 ml/d while for < 1 mm a value of 70 ml/d was found. This behavior could be caused by poor inoculum acclimation at rice straw, in fact a second test was performed using inoculum acclimated to rice straw and the preliminary results seem to indicate an inverse correlation between methane production rate and PSD.

3.2 Effect of TS on Methane Production

Two sets of BMT were performed using carrots as substrate and two different inoculums: buffalo manure (TS = 4,1%) and digestate of semi-dry anaerobic reactor (TS = 16%). To guarantee mixing conditions inside the bottles magnetic agitation was operated. The buffalo manure was first concentrated through centrifugation in order to obtain the following TS values: 13%, 6,5%, 4%, 1%.

The BMT with carrots and concentrated buffalo manure gave as results an inverse correlation between TS content and methane production rate. This result was confirmed also with a second set of experiments operated with carrots and digestate of semi-dry anaerobic reactor diluted with water in order to obtain the same TS value used in the previous tests.

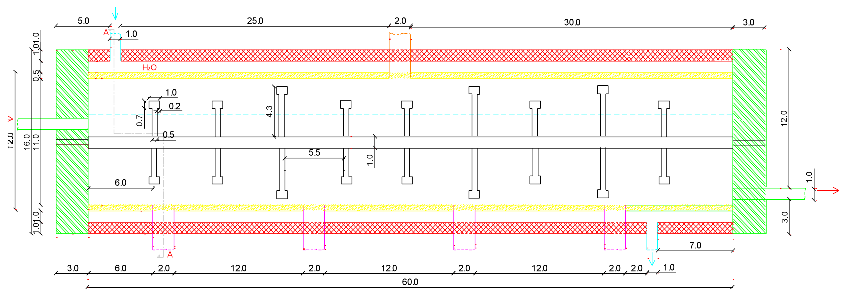

Figure 1.1. Laboratory scale plug flow reactor.

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