ANAEROBIC DIGESTION OF THE MSW ORGANIC FRACTION

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SUMMARY: in this study the biodegradability of the MSW organic fraction has been tested and in particular a comparison between the production of biogas from sewage sludge and from organic wastes in anaerobic conditions has been performed. The organic fraction used in this study was pre-treated with a particular mechanical procedure capable to squeeze the organic wastes coming from the separate collection of rubbish, against a grate in order to separate the organic fraction from the inorganic one (plastic bags, glass, metals, etc…). Pilot tests were executed both with sludge and with organic wastes, in batch conditions, controlling the temperature, pH and biogas composition with a biogas analyzer. Organic wastes have furnished the best results in terms of the biogas quantity and quality, but many problems have been encountered during tests because of the organic waste characteristics and pilot mixing system.

1. INTRODUCTION

The anaerobic digestion is a way to treat the MSW organic fraction in order to give a stabilized product and to have as a consequence the production of biogas, a gas rich in methane (50 - 70% v/v) with a high calorific power that can be used as a fuel. In this study, the experience gained in the anaerobic digestion of wastewater sludge was applied to the MSW organic fraction with the purpose of comparing the biogas production amount and quality coming out from these two organic matrices. The tests were performed in the Smat S.p.a. wastewater treatment plant near the city of Turin in the north-west of Italy; the tests equipment consisted of two pilot plants of 1 m^3 each and of the necessary equipment to perform and control the tests. Moreover, the temperature, pH and inner pressure were continuously monitored and in particular the temperature was maintained constant thanks to a thermostatic valve that controls the passage of hot water in a heating coil around the digesters. A mixing system with a grinding pump was used in order to treat the organic fraction of MSW before charging into the digesters. The peculiarity of this study is that the MSW organic fraction was preliminary treated with a particular machine capable to mechanically separate the organic fraction from the inorganic one made of plastic bags, glass, metals and other materials.

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This machine squeezes the wastes by means of a piston, against a grate with high pressure; this action has, as a result, the separation of most of the organic fraction that pass through the grate and is reduced into a kind of jam. The consequences of this pre-treatment are two, first of all the separation of the fraction of wastes that is not desired for the anaerobic digestion and that could give some problems to bacteria; secondly, the reduction of the organic particles dimension in order to increase the contact surface between matrix and bacteria into the digesters. The first two tests in pilot digesters were performed with the sludge because it was necessary to investigate the biogas production in order to have a term of comparison when the organic fraction of wastes would be tested. The other tests were performed with the organic fraction of wastes; many problems were encountered both because of the matrix characteristics (acid and difficult to mix in the digesters) and because of the pilot plants characteristics, in fact they were built to treat sludge and not organic wastes. Many variables performing these tests were considered, particularly the use or not of the inoculum as a starter for the reactions, the kind of inoculum and the kind of water usable to dilute the organic matrix from MSW; moreover, periodically during the tests, samples of the inner material were collected and analyzed in Smat laboratories in order to understand how the chemical characteristics change during the tests. The gathered results with organic wastes are encouraging and better than those ones obtained with the sludge both considering the biogas quantity and the biogas quality, but a lot of problems were encountered in many tests performed with organic wastes because of the very low pH values reached during the acidogenic phase. The best result obtained with organic wastes was a biogas production of 0,526 Nm^3/kg of volatile solids, while the biogas production from sludge was at most of 0,395 Nm^3/kg of volatile solids. Also the biogas composition was measured, values over the 70% in volume of methane were frequently achieved during the tests with organic wastes while the percentage of methane obtained with sludge was lower (60-65% in volume).

2. MATERIALS AND METODS

All the test were performed in the Smat S.p.a. wastewater treatment plant using sludge coming from this plant and organic waste coming from a plant near the town of Alessandria (Italy) were the machine used for the pre-treatment is located. Moreover, these tests were performed in batch conditions mainly because of pilot plant characteristics and a series of logistic problems linked to the material storage before charging.

2.1 Sludge

As said before, the sludge used in these tests was taken directly from the Smat plant where the pilot plants are located. The employed sludge is a primary one, coming from the primary wastewater treatment with a low percentage of total suspended solids. The samples taken during the two tests executed with the sludge, have shown a TSS content varying between 1,2% and 1,7% with a VSS - TSS ratio of about 0,75.

2.2 MSW squeezed organic fraction

As said before, this matrix is the product of a mechanical selection of the organic wastes coming from separate collection. The result of this pre-treatment is a squeezed organic matrix with a very low percentage of undesired material and a jam-like consistence. Organic particles dimension is reduced and this has, as a consequence, an increase of the contact surface between bacteria and substrate. The measured TSS contents of this fraction are very variable both because of the season (organic fraction is different in every season and in particular the water content

Table 1. Measured TSS (%) content in the organic fraction of wastes after the mechanical pre-treatment

Month	*TSS %*
August	19
September	28,3
October	36
January	30

varies) and because of the percentage of grass and branch coming from trimming. Four tests were performed but the first of these failed (no biogas production). The measured TSS contents are reported in table 1.

As it can be noticed, the TSS content increases from summer to winter and this is an important fact that it's necessary to take in account when organic wastes are used because the required water amount to dilute varies. In this work the squeezed organic fraction has been diluted with water till a TSS content equal to the 3% w/w that has been maintained constant in all the performed tests. The measured solids content at the beginning of every test were always around the 2,7% for TSS and the 2,0% for VSS with a VSS/TSS ratio of about 0,8.

2.3 Inoculum

After that the first test with organic wastes failed because of the extremely acid conditions into the digesters and maybe because of the absence of inoculum, the use of inoculum was adopted. With the experience gained during the pilot digestion of sludge, the pre-treated organic wastes were also inoculated with digested sludge in the same percentage used to inoculate sludge: 67% of feed, 37% of inoculum. In one case (test W3) the digested organic wastes from test W2 were used as inoculum with good results in term of biogas quality and time of the reaction start up.

2.4 Dilution water

In order to dilute the pre-treated organic fraction of wastes until the desired TSS percentage (3% TSS), the water coming from the waste water treatment plant was used. In one case (test W2) the digestion was performed using the water coming from the dewatering system (pH = 11) with the aim of modifying input pH values. In all the other cases, the dilution water had a neutral pH of 7.

2.5 Pilot plant

As said before, the pilot plants consist of two digesters with a volume of $1 m^3$ everyone; these digesters where built to work with sludge, in fact they have only a system of biogas recirculation without any kind of recirculation of the inner material. Using the MSW organic fraction that is more heterogeneous both in dimension and in composition in comparison with the sludge, these pilot plants have shown all their limits. After the feed of the digesters, the MSW organic fraction quickly precipitates to the bottom without any possibility of being mixed; so, it was also very difficult to take representative samples of sludge from digesters. The two pilot plants are equipped with systems for the temperature control, the inner pressure is measured with a manometer while the biogas is collected in a gasometer and measured with a gas meter. Compressors are used to re-circulate biogas both to the bottom and to the top of every digester.

2.6 Squeezing machine

When the organic wastes arrive to the collection point it is necessary a phase of treatment in order to prepare the organic feed for digestion, in fact, plastic bags, metals, pieces of glass and other undesired things can be found in the organic fraction. In this case only one machine capable to select the organic phase was employed. The organic wastes arrive to the plant (in their plastic bags) and are charged into a hopper, than a piston pull the wastes against a grate at high pressure, squeezing the material. Only the organic material passes through the grate, while the inorganic one remains against the grate; after the squeezing process, a lateral piston pulls away the undesired material. The squeezed organic product represent about the 70-80% w/w of the initial quantity of treated wastes, the remaining 20-30% w/w contains the inorganic fraction, but also a certain quantity of organic matter that the machine is not able to squeeze (grass, branch, etc…).

2.7 Laboratory analysis

In order to characterize the organic matrix and to understand how its characteristics change during the anaerobic digestion, some analyses have been performed; so three samples have been taken and analyzed for every test. The samples are the feed to the digesters, the digested in output and a sample representative of matrix conditions into the digester after the start up of the biogas production. The analyzed parameters were: acidity-alkalinity ratio, BOD5, COD, organic carbon content (% w/w), total ammonium, pH, metals, total phosphorus, TSS, VSS and VSS/TSS.

2.8 Biogas Analyser

After the first two tests performed with sludge, where the quality of sludge was measured using Draeger vials, the biogas quality has been analyzed with a biogas analyzer, a *Biogas Check* by "GeoTechnical Instruments". This instrument furnishes the concentrations in volume of methane, oxygen, carbon dioxide.

3. RESULTS AND DISCUSSION

In this work the results of six pilot tests executed on two different matrices (sludge and pre-treated organic wastes fraction) are illustrated; the first two tests were performed with sludge, while the other four were performed with organic wastes. The purpose is that of comparing the biogas production of these two matrices both by the quantity and the quality point of view. Biogas productions have been normalized to standard conditions (273 K, 1 atm) and referred to the input quantity of volatile suspended solids; in this way, it has been possible to compare the biogas production of the two different matrices.

3.1 Sludge anaerobic digestion

The results obtained with these tests are reported in figures 1 and 2; on the x-axis there is the time, while on the y-axis there is the biogas production measured by the in field gas meter. These two tests have been developed at two different temperatures, 35°C and 40°C in order to understand if there was a different biogas production with temperature.

- **S1:** 1,7% w/w TSS - 1,3% VSS w/w - T = 45°C;
- 0,262 Nm^3_{biogas}/ kg TSS - **0,342 Nm^3_{biogas}/ kg VSS**
- **S2:** 1,2% w/w TSS - 0,8% VSS w/w - T = 35°C;
- 0,267 Nm^3_{biogas}/ kg TSS - **0,395 Nm^3_{biogas}/ kg VSS**

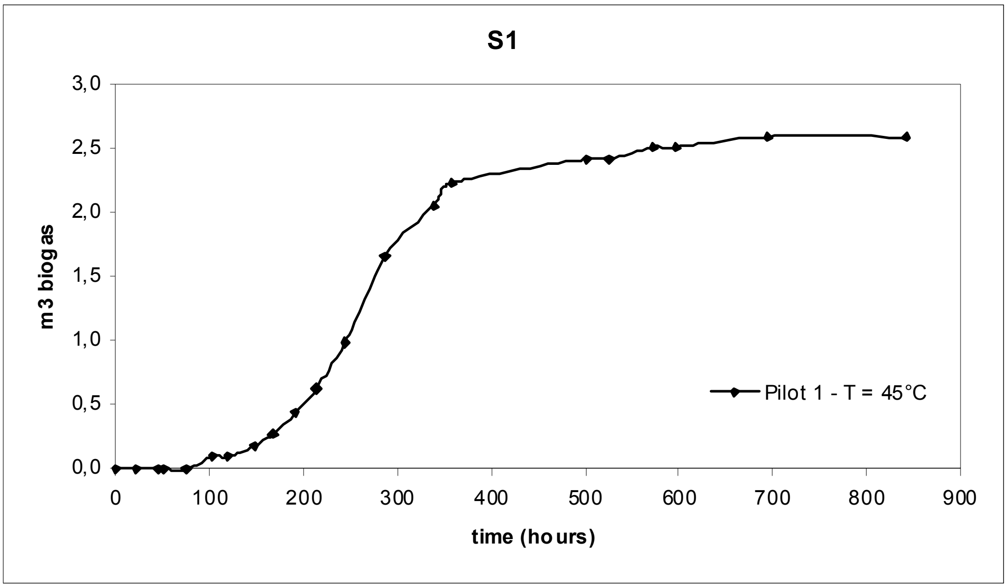

Figure 1. Biogas production from sludge - pilot 1

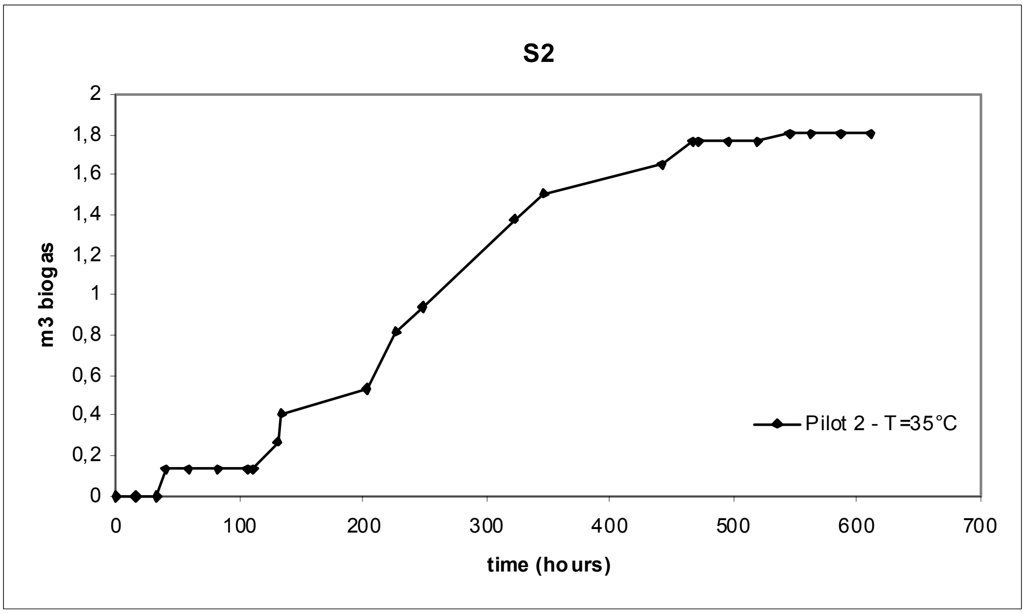

Figure 2. Biogas production from sludge - pilot 2

Biogas productions perfectly agree with literature data; the difference of production with temperature is very low but the digester at lower temperature show the higher production. As said before, measures of the biogas quality for sludge where performed using Draeger vials, this is not an accurate measuring method as the biogas analyser, but in every case, the obtained results agree with those ones measured every day in Smat real scale digesters. The biogas quality measures show a methane content about equal to the 60% in volume and never over the 65%.

3.2 Anaerobic digestion of the pre-treated organic fraction

Four tests have been performed with this treated fraction, the first test (W1) was without inoculum and it was a failure as there was no biogas production also because of the extremely acid substrate conditions. In the second test (W2), inoculum (digested sludge) and different dilution water coming from the dewatering treatment of the digested sludge with high pH values, were used. A high biogas production was measured, but a long time was required to start reactions and to produce biogas.

The digested organic fraction was used in the third test (W3) as inoculum for a new charge of organic wastes, the starting time was reduced, the biogas production was lower than in the previous test, but the biogas quality was excellent from the beginning of the production to the end. In the fourth test (W4) an organic waste treated in a different way was tested because a grate with smaller holes was employed: 8 mm instead of 13 mm adopted in the previous tests. This test gave the highest biogas production, but the starting time was also extremely long.

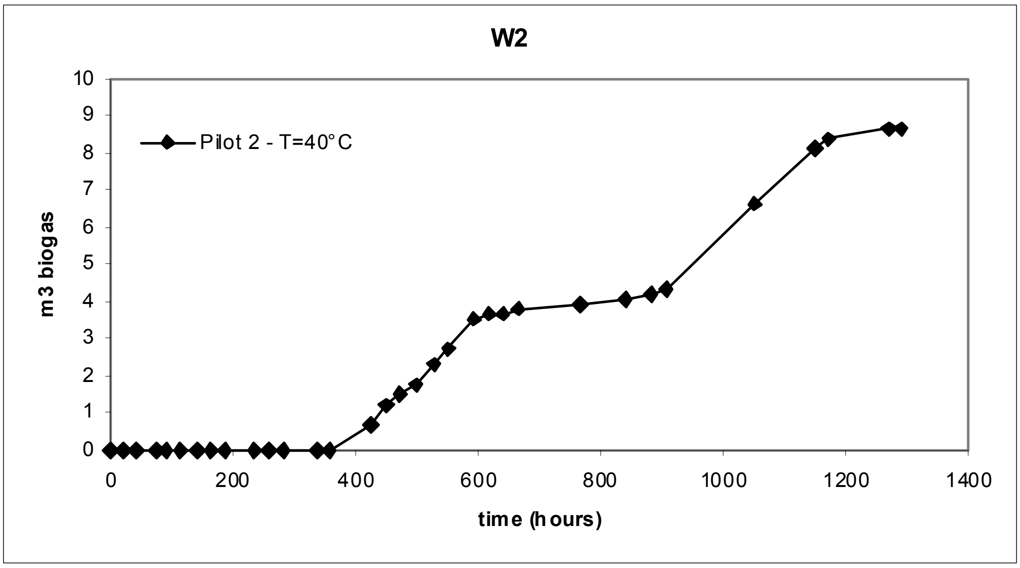

Figure 3. Test W2: biogas production from organic wastes - pilot 2

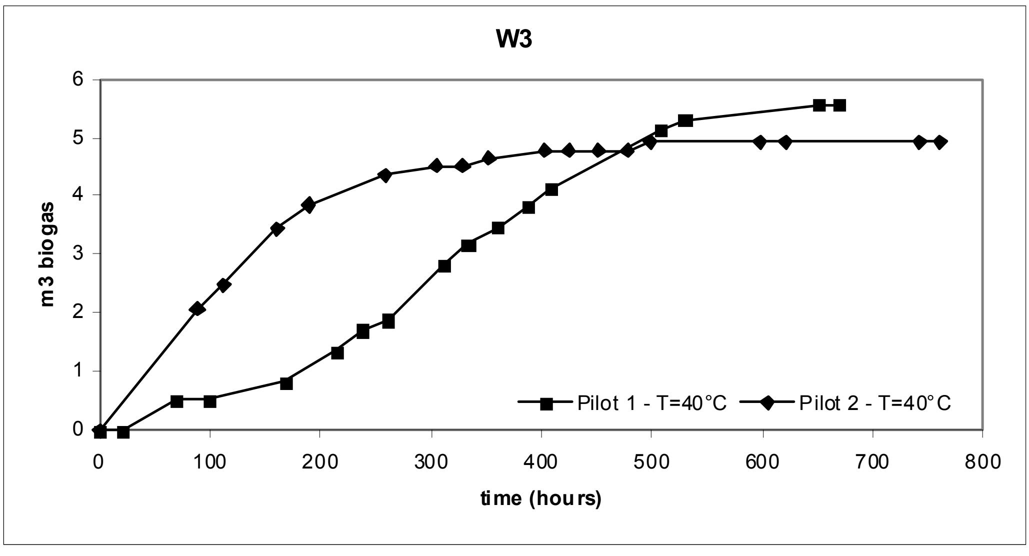

Figure 4. Test W3: biogas production from organic wastes – pilot 1 and 2

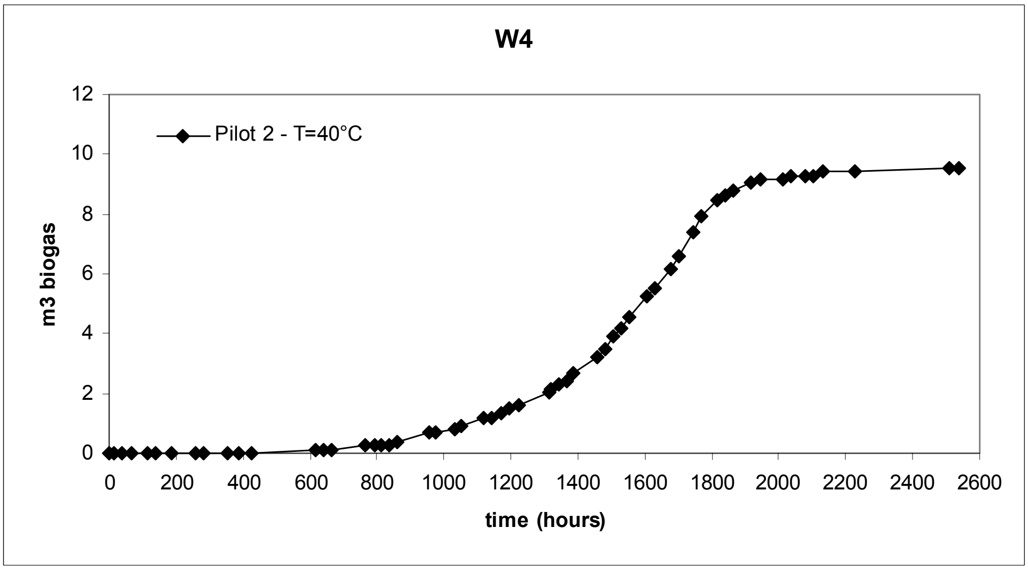

Figure 5. Test W4: biogas production from organic wastes – pilot 2

The general feed characteristics and the biogas production rate are reported below.

- **W2**: 2,7% w/w of TSS - 2,0% w/w of VSS
  0,349 Nm^3 biogas/ kg TSS - **0,448 Nm^3 biogas/ kg VSS**
- **W3**: *pilot 1*; 2,9% w/w of TSS - 2,5% w/w of VSS
  0,186 Nm^3 biogas/ kg TSS **- 0,216 Nm^3 biogas/ kg VSS**
- **W3**: *pilot 2*; 3,2% w/w of TSS - 2,1% w/w of VSS
  0,149 Nm^3 biogas/ kg TSS - **0,227 Nm^3 biogas/ kg VSS**
- **W4**: 2,7% w/w of TSS - 2,1% w/w of VSS
  0,409 Nm^3 biogas/ kg TSS - **0,526 Nm^3 biogas/ kg VSS**Temperature was maintained constant in all these tests and equal to 40°C. The biogas production was monitored using the biogas analyzer; the methane percentage in biogas grew up during the anaerobic digestion till values that were over the 65% in volume, with a maximum value in W2 test equal to the 74,4%. Test W3 – pilot 2 gave a low biogas production, but the production started immediately with constant and high values of methane, included between 62,8% and 70,1% in volume.

4. CONCLUSIONS

In this work the results of a part of a complex research about the anaerobic digestion of organic wastes are reported with the main purpose to optimize this process. A particular pre-treatment concerning the use of a machine capable to separate the MSW organic fraction from the undesired fraction was tasted thus obtaining a material directly employable in digesters. In order to understand the real advantages gathered by means of this machine, in the future other tests will be performed using other treatment system. Now, from the performed tests it is possible to say that the biogas production is similar to the one reported in literature; next table reports some tipical values of biogas production from organic wastes and wastewater sludge, as it can be noticed, the in situ achieved data agree with literature data.

Table 2. Comparison between the literature biogas production data (CRPA – Centro ricerche produzioni animali, 2007) and the pilot tests measured values.

Organic matrix	Biogas [Nm^3/t VSS] literature data	Biogas [Nm^3/t VSS] measured data
Waste water sludge	250 - 350	342 - 395
MSW organic fraction	400 - 600	216 - 526

Moreover, the biogas production from wastes is good in comparison with the biogas production obtained with sludge, both for quantity and quality (65-70% of methane in volume). On the other hand, many problems were encountered performing these tests; in particular it's necessary to take into account the possibility of a different mixing system to move diluted wastes in pilot plants, because they quickly precipitate to the bottom of the digesters creating many problems. A particular attention must be given to the pH problem because wastes strongly acidify the solution till pH values lower than 4 that disturb and slow down the bacteria activity. So, in the future, a new couple of pilot plants will be built with an adequate mixing system that will work in semi-continuous conditions, instead of batch conditions. In this way, it will be possible to start the digestion process using sludge and then completely substitute it with organic wastes, day by day, measuring the differences in the biogas production and quality. The anaerobic digestion of the organic fraction of wastes is doubtless an important solution in order to solve many problems linked to the MSW treatment and stabilisation; moreover this process has, as a consequence, the production of biogas, an important renewable fuel, employable to produce electric and thermal energy.

5. REFERENCES

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