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Anaerobic digestion of mechanically treated OFMSW: Experimental data on biogas/methane production and residues characterization

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ABSTRACT

One of the more promising processes for the energetic transformation of waste is the anaerobic digestion of the Organic Fraction of Municipal Solid Waste (OFMSW). An experimental campaign was carried out on three different samples of OFMSW from Waste Separation (WS), one as received and two obtained after mechanical treatment (squeezing): OFMSW slurry (liquid fraction) and OFMSW Waste (residual solid fraction). Anaerobic Biogasification Potential (ABP) and anaerobic digestion tests (AD) were carried out, investigating the effects of inoculum and pH. The OFMSW Waste was also examined to evaluate the possibility to dispose of it in a landfill. Results showed that OFMSW slurry must be diluted and inoculated and that pH control in the start up phase is essential, in order to have significant biogas productions. OFMSW as received did not show a significant biogas production, while OFMSW Waste showed suitable characteristics for landfill disposal, except for Dissolved Organic Carbon.

1. Introduction

The actual energy mix could be significantly diversified by an increase in the use of Renewable Energy Sources (RES), which have a lower environmental impact than Conventional ones. A significant contribution could be given by biomass and in particular by humid residues suitable for anaerobic digestion process, which are influenced by many chemical and physical parameters such as the Total Content of Solids (TS), the Total Content of Volatile Solids (TVS), the Carbon and Nitrogen Content and their ratio C/N, temperature and pH, the trace metals, such as nickel and cobalt (Kayhanian and Rich, 1995; Wilkie and Colleran, 1986). Temperature defines three different process conditions: thermophilic range (50–60 °C), mesophilic range (20–40 °C) and psychrophilic range (10–20 °C), while pH indicates the stability of the reaction media; the first phases (acidogenesis and acetogenesis) need acidic values of pH, in the 5–5.5 range (Battistoni et al., 1998, 2001a,b; Bolzonella et al., 2001; Pavan et al., 1994, 1996, 2000). The methanogenesis phase and the methanogenic bacteria activity are carried out in optimal conditions if pH is in the 6.5–7.5 range although the optimal value varies with substrate and digestion technique. For the digestion of the Organic Fraction of Municipal Solid Waste (OFMSW), optimal values of pH in the 7–7.5 range for thermophilic conditions were found; with lower pH values the methanogenic activity is reduced and for pH < 6 it is very inhibited (Liu et al., 2008).

OFMSW is one of the most employed substrates in anaerobic digestion processes. The Organic Fraction, when obtained from Waste Separation (WS), is particularly interesting for anaerobic digestion, due to the higher Total Content of Valatile Solids (TVS) than the Organic Fraction mechanically separated (Battistoni et al., 1998, 2001a,b; Bolzonella et al., 2001; Pavan et al., 1994, 1996, 2000). In the recent years co-digestion of OFMSW and sewage sludge or other substrates (i.e., agro-industrial by-products, such as dairy residues and olive oil industry residues) was developed, obtaining multiple waste treatment in a single plant and an increasing content of methane in the biogas.

In the literature data of co-digestion of OFMSW and sewage sludge (75% sludge and 25% OFMSW in volume) in thermophilic conditions are reported. Biogas production was doubled with respect to the sole sludge digestion while the methane content was about 60% (Sosnowski et al., 2003).

Other authors show the importance of the presence and characteristics of inoculum, in order to have a fast start up of the process and a right equilibrium of bacteria population. Cow and pig manure and digested sludge are often used as inocula (25% inoculum in mass, $T = 55$ °C and a TS content of 30%) showing a high removal of organic substance with digested sludge (Forster Carneiro et al., 2007). In full scale plants, the effluent of the same plant is often used as inoculum, to obtain a start up since the first days.

The substrate to inoculum ratio influence was investigated in the literature for different substrates (Chen and Hashimoto, 1996; González-Fernández and García-Encina, 2009; Gunaseelan, 1995; Neves et al., 2004; Raposo et al., 2009; Shujuan et al., 2010); for OFMSW the greatest values of the Specific Methane

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Nomenclature

ABP	anaerobic biogasification potential
ABP1, ABP2, ABP3	ABP test nos. 1, 2 and 3
AD	anaerobic digestion
AD1, AD2, AD3	anaerobic digestion test 1, 2 and 3
FA	fatty acids
OFMSW	organic fraction of municipal solid waste
RES	renewable energy sources
T	temperature (°C)
TFA	total fatty acid
TS	total content of solids (%)
TVS	total content of volatile solids (%)
VS	volatile solids (%)
VFA	volatile fatty acids
WS	waste separation

Productivity in the start up phase were found with the lowest values of the inoculum-substrate ratio (Fernandez et al., 2001). Other authors found that full scale plants to treat Source Sorted OFMSW can be started-up successfully and relatively fast provided that at least 10–15% of final inoculums volume is supplied, with a careful loading procedure based on a concept called "activated biomass" start-up (Angelidaki et al., 2006).

Good results were obtained in Charles et al. (2009) for OFMSW mixed to the effluent of the same plant in wet conditions; the effluent was preserved at ambient temperature in N_2 atmosphere and it was heated in a water bath until a $T = 55$ °C and maintained for three days before being loaded to the digester.

The pH control is also very important because Fatty Acids (FA) can accumulate and inhibit the methanization process. The Volatile Fatty Acids (VFA) are produced during acidogenesis and their concentration (expressed as CH_3COOH concentration per volume unit, mg/l) depends on the characteristics of the substrate and on the equilibrium between acidogenic and methanogenic bacteria. The stability parameter is expressed by the variations in acetate concentration: its rapid increasing indicates an evolution to the acidogenic phase with an increasing in the organic matter to be treated. In OFMSW digestion, the production, of VFA is high and fast, due to the substances easily biodegradable therefore an acidification of the substrate and an inhibition of the methanogenic phase are obtained (Battistoni et al., 1998, 2001a,b; Bolzonella et al., 2001; Pavan et al., 1994, 1996, 2000).

The pH value depends also on the alkalinity of the substrate, expressed as concentration of $CaCO_3$; a low alkalinity can cause an acidification of the substrate, therefore $CaCO_3$ is often introduced into the digester (Battistoni et al., 1998, 2001a,b; Bolzonella et al., 2001; Pavan et al., 1994, 1996, 2000).

In the literature alkaline pre-treatments of the OFMSW (by means of $Ca(OH)_2$) are used to break complex molecules into simple monomers, to increase solubilization of organic material and to improve the efficiency of the anaerobic treatment in the second step. With this technique an increasing methane yield of 172% with respect to a reference sample was found (Lopez Torres and Espinosa Llorens, 2008).

pH values can also be increased by introducing NaOH as in Forster Carneiro et al. (2007), where a shift from pH 4.5 to pH 8.5 yielded into the digester stability conditions and an optimal biological activity.

Other authors, in order to avoid the acidification of the substrate, suggest an aerobic treatment of the OFMSW for some days before the anaerobic digestion (Charles et al., 2009), reducing the quantity of organic compounds easy bio-degradable, however reducing also the potential biogas production (Charles et al., 2009).

The wet anaerobic digestion is particularly indicated for the OFMSW in batch processes. The substrate as received is diluted and added with effluent from an OFMSW anaerobic digestion plant, to obtain a TS content lower than 10% (Battistoni et al., 1998, 2001a,b; Bolzonella et al., 2001; Pavan et al., 1994, 1996, 2000).

2. Methods

The aim of the paper is to evaluate the performance of different portions of OFMSW mechanically treated by squeezing in anaerobic digestion without inoculum or with inoculum constituted by effluent from the same plant. Not using external inocula could simplify operational procedures during plant operation also from the legislative point of view.

Different samples of OFMSW were collected from a composting plant in Central Italy in July 2009. The OFMSW from WS was treated by a squeezing machine, which separates the OFMSW into two fractions:

- OFMSW slurry, the liquid fraction;
- OFMSW Waste, the residual one, constituted by materials such as plastics and wood.

Three different substrates were considered: OFMSW as received, OFMSW slurry and OFMSW Waste.

The experimental campaign was carried out at the Biomass Research Centre (CRB) Labs, University of Perugia, during the period July 2009–January 2010. Several tests were carried out on the considered substrates: chemical and physical analysis, in order to characterize the substrate; ABP and anaerobic digestion tests in a pilot plant, in order to evaluate the biogas production and the methane yield. The inoculum and pH effects were also investigated and results were compared to data from the literature. The anaerobic digestion tests were carried out in a batch pilot digestion plant designed and realized at the CRB Labs, where a research on anaerobic digestion is ongoing (Buratti et al., 2005; Fantozzi et al., 2008; Fantozzi and Buratti, 2009).

OFMSW as received was characterized by chemical–physical analysis and ABP tests, in order to compare its behavior to the one of OFMSW slurry.

OFMSW Waste was finally characterized in order to verify the possibility to dispose of it in a landfill.

2.1. Samples

Samples of Organic Fraction of Municipal Solid Waste (OFMSW) were collected in a composting plant in July 2009, according to CEN/TS 15442. Samples of OFMSW as received, slurry and waste were collected; slurry was produced just before sampling, by a squeezing machine for OFMSW treatment, model Tiger DSP 25. The following measurements were carried out in the period July 2009–January 2010:

(1) OFMSW as received:
  (a) Total and volatile solids,
  (b) ABP tests,
(2) OFMSW slurry:
  (a) Total and volatile solids,

(b) ABP tests,
(c) Anaerobic digestion tests in pilot plant.

(3) OFMSW Waste:
(a) Total and volatile solids,
(b) BOD e COD,
(c) O_2 hourly consumption for the biochemical oxidation of the organic matter easily bio-degradable (IRD),
(d) Putrescibility index,
(e) Leaching tests.

2.2. Instrumentations

2.2.1. Chemical–physical properties

The chemical–physical properties were measured at the Analysis Lab of the Biomass Research Centre described in previous works (Buratti et al., 2005; Fantozzi et al., 2008; Fantozzi and Buratti, 2009), by means of TGA 701 LECO for Proximate Analysis and Truspec CHN LECO for Ultimate Analysis.

Moisture, Ash and Total and Volatile Solids Content, according to CEN/TS 14774; CEN/TS 14775 and CEN/TS 15148 were determined. The samples were prepared in compliance with CEN/TS 14780 while Ultimate Analysis was carried out in compliance with CEN/TS 15104.

2.2.2. ABP tests

The ABP (Anaerobic Biogasification Potential) evaluation was carried out by means of particular vessels (Fig. 1) of 1 l capacity realized in boro-silicated glass. They are equipped with probes for pressure, temperature and pH (Hanna Instruments HI9124, double junction electrode, resolution 0.01) measurement and for biogas sampling, in order to analyze its composition. The screw plugs guarantee the anaerobic conditions during the test. The vessels are maintained at a constant temperature in a climatic chamber.

The biogas production is evaluated by measuring the pressure variations. Excess biogas is vented or sampled and its volume is measured by an air tight syringe HAMILTON 1025 SL; biogas samples are analyzed by gas-chromatography (GC Varian 3800 with TCD and FID detectors).

The bottles for ABP tests are simply to use and some of them could be contemporary filled with different mixtures, in order to maximize the biogas production and methane yields and to choose the best one to test in the pilot scale digester (see Section 2.2.3). It differs from bottles, being more similar to a full plant in the heating system, the possibility of stirring (although not used in this test), the biogas storage and the possibility of continuous monitoring and variations of operating conditions.

Fig. 1. Glass vessel for ABP tests.

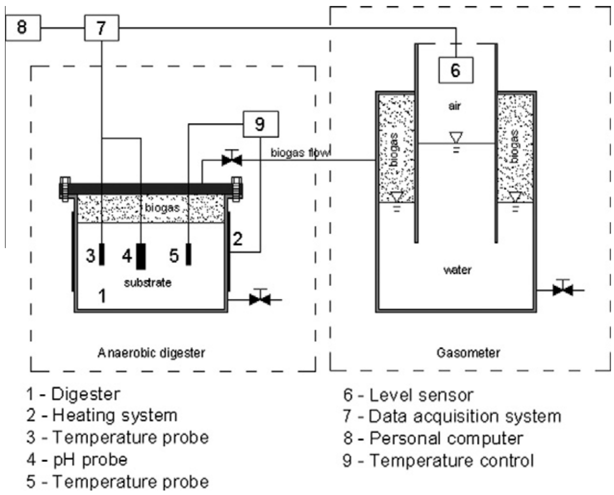

Fig. 2. Sketch of the anaerobic digestion pilot plant.

2.2.3. Anaerobic digestion tests

The anaerobic digestion tests were carried out in a laboratory batch pilot plant (Fantozzi et al., 2008; Fantozzi and Buratti, 2009) (Fig. 2). It is a cylindrical vessel equipped with an airtight lid. Flexible silicon rubber heaters are fitted on its external surface of the vessel to maintain the feedstock at the required temperature, measured by a thermocouple connected to a PID controller; pH is also measured by a probe in a hole of the lid (Hanna Instruments HI 9124, double junction electrode, resolution 0.01). The vessel has an helix electrical mixer, however tests were carried out in non stirred conditions. A tap allows to collect the biogas produced, sent to a dedicated gas storage system made of two cylindrical coaxial chambers. Data are acquired by a digital system and a purposely-developed software. Biogas is characterized by an infrared gas analyzer, which measures the volume percentages of CO_2, CH_4, O_2, H_2S and CO in the mixture (Geotech GA 2000 Plus, IR and electro-chemical detectors).

2.3. Methodology

2.3.1. Samples preparation

The OFMSW sample was extracted in compliance with CEN/TS 15442 from a 5 m^3 pile of OFMSW, constituted by market wastes which contained also undesired materials, such as plastics and packages.

Slurry was obtained by squeezing OFMSW on site in a machine model Tiger DSP 25; it was collected by discontinuous sampling, in order to be statistically representative and it was put into 3 plastic airtight vessels of 30 l capacity.

OFMSW Waste is the dry fraction output of the squeezing machine. The sampling procedure was carried out in compliance with CEN/TS 15442.

Samples were frozen, in order to avoid the early fermentation of the Organic Substance.

2.3.2. ABP tests

One ABP test was carried out on OFMSW as received; 400 g of sample were grinded to a maximum size of 2 cm before the ABP test and were put into the glass vessel without inoculum; the vessel was maintained at 55 °C for 30 days.

Three ABP tests were carried out on OFMSW slurry:

ABP1. 400 g of OFMWS slurry without inoculum and dilution were put into a vessel and maintained at 55 °C for 30 days;

ABP2. 200 g of OFMWS slurry diluted with 200 g of water were put into a vessel; 200 g of inoculum constituted by piggery manure anaerobically digested from an existing plant were added, on the basis of the same ratios employed in previous anaerobic digestion tests (Fantozzi and Buratti, 2009) in mesophilic conditions (see the characteristics of the mixture and of its components in Table 1); in Fernández et al. (2008), Montero et al. (2008) and Ortega et al. (2008) it was in fact found that some mesophilic bacteria could be re-activated in thermophilic conditions;

ABP3. OFMSW slurry was diluted and inoculated with effluent from an anaerobic digestion plant of OFMSW: three vessels were contemporary tested, maintained at a temperature of 55 °C. The quantities of substrate, inoculum and dilution water and the related substrate-inoculum ratios are reported in Table 2, together with the characteristics of the mixtures.

2.3.3. Anaerobic digestion tests

Three anaerobic digestion tests were carried out on OFMSW slurry:

AD1. 7 kg of OFMWS slurry not diluted and without pH control were put into the digester, in the same conditions (temperature 55 °C) and during the same period of the ABP1 test, in order to compare the results of the different methodologies;

AD2. OFMWS slurry was diluted with water and inoculated with effluent from a plant of OFMSW anaerobic digestion in thermophilic conditions; 8 kg of mixture were put into the anaerobic digester: 1.4 kg of slurry, 0.6 kg of inoculum and 6 kg of water. The test was carried out in thermophilic conditions (55 °C) for 40 days and the pH values were monitored;

AD3. OFMWS slurry was diluted with water and inoculated with effluent from an anaerobic digestion plant of OFMSW, similar to the inoculum of AD2 test; also in this case, 8 kg of mixture were put into the reactor: 1.4 kg of slurry, 0.6 kg of inoculum and 6 kg of water. The temperature during the test was 55 °C and the pH values were monitored.

Table 1
ABP2 test: characteristics of the mixture slurry + inoculum (piggery manure anaerobically digested from a plant).

Substance	Moisture (%)	Total volatile solids (%)	Ash (%)	Fixed carbon (%)
Slurry	86.74	11.7	1.10	0.46
Inoculum	98.90	0.6	0.44	0.06
Mixture (slurry + inoculum)	92.83	6.15	0.78	0.24

Table 2
ABP3 test: characteristics of the mixtures OFMSW slurry + inoculum (effluent from an anaerobic digestion plant of OFMSW).

Vessel	Composition		Moisture (%)	Total volatile solids	Starting pH
1 (70–30% in mass)	Substrate Inoculum Water	0.0561 kg 0.0225 kg 0.2250 kg	95%	0.012 kg	4.98
2 (70–30% in VS)	Substrate Inoculum Water	0.0670 kg 0.0937 kg 0.1500 kg	92%	0.017 kg	n.a.
3 (70–30% in mass, control of pH with NaOH)	Substrate Inoculum Water NaOH	0.0561 kg 0.0225 kg 0.2250 kg 60 ml	96%	0.08 kg	5.46

Table 3
OFMSW as received and slurry: chemical–physical properties.

Sample	Moisture (%)	Total solids (%)	Total volatile solids	
			Wet bases (%)	Dry bases (%)
OFMSW as received				
1	81.02	18.98	15.76	83.03
2	81.16	18.84	15.79	83.83
Mean value	**81.09**	**18.91**	**15.77**	**83.43**
OFMSW slurry				
1	87.06	12.94	11.39	88.05
2	86.42	13.58	11.93	87.83
Mean value	**86.74**	**13.26**	**11.66**	**87.94**

2.3.4. Chemical physical properties

The samples were characterized before the tests in moisture, total solids (TS) and total content of volatile solids (TVS) (see Tables 1 and 3).

Other chemical–physical properties of interest were determined on OFMSW Waste, in compliance with UNI EN 14039/2005 and EPA 6010C/2007. Leaching tests were also carried out, in order to verify the possibility of a landfill disposal. Data were compared to Italian Legislation limits (DM 3 August 2005) and UNI 10802.

3. Results and discussion

3.1. OFMSW as received

3.1.1. ABP tests

Test on OFMSW as received did not produce significant quantities of biogas and the analysis did not reveal the presence of methane. The methanogenic phase did not start possibly because of the absence of dilution and of pH control, that generated an acidic ambient in which the bacteria formation was inhibited (Battistoni et al., 1998, 2001a,b; Bolzonella et al., 2001; Charles et al., 2009; Fernández et al., 2008; Lopez Torres and Espinosa Llorens, 2008; Pavan et al., 1994, 1996, 2000).

3.2. OFMSW slurry

3.2.1. ABP tests

The ABP1 test yielded a poor quantity of biogas which was not sufficient for gas–chromatographic analysis.

This is coherent with the literature, that shows how the substrate doesn't produce significant biogas quantities if not diluted (Fernández et al., 2008) and does not start the anaerobic digestion process in absence of inoculum (Charles et al., 2009; Fernández et al., 2008) while being influenced by the substrate-inoculum ratio (Fernández et al., 2008; Forster Carneiro et al., 2007; Zhang et al., 2007). Moreover, as previously stated, the absence of pH control generates an acidic ambient in which the bacteria formation is inhibited.

The ABP2 test lasted after 17 days. The biogas production curve is reported in Fig. 3, which shows an immediate start up and a continuous production. A correct balance between bacteria and organic matter allowed a regular and continuous degradation of the substrate. The peak of the production was on the seventh day. The biogas composition during the test was determined; data are reported in Table 4. The maximum methane percentage (68.5%)

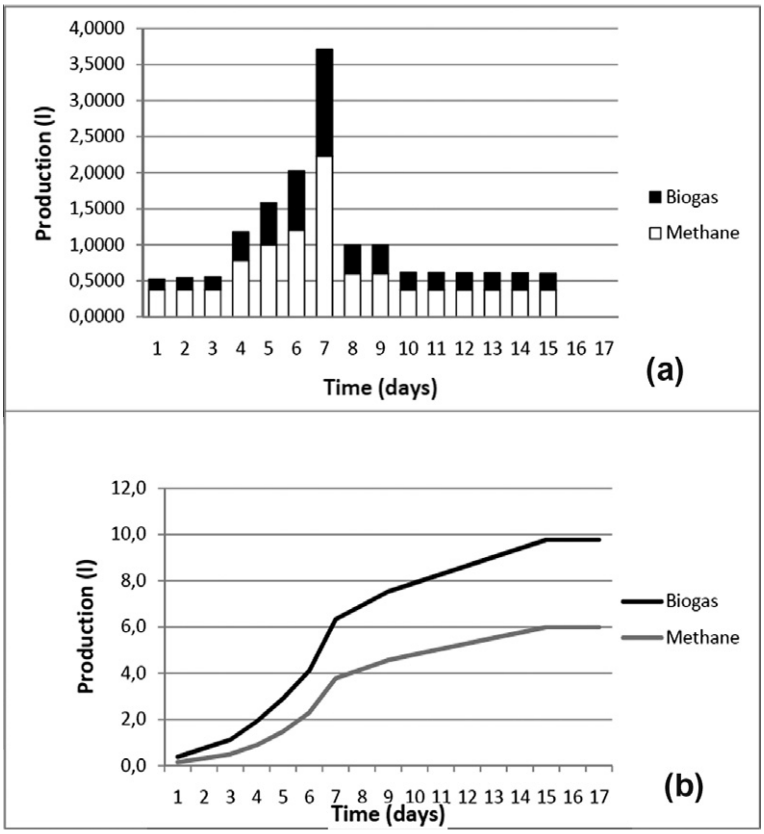

Fig. 3. Daily biogas and methane production (a) and cumulative curves (b) of ABP2 test.

Table 4
ABP2 test, mixture slurry + inoculum (piggery manure from an anaerobic digestion plant): produced biogas composition.

Gas	Samples						
	1	2	3[a]	4	5	6	7
H_2 (%)	1.370	0.008	0.000	0.008	0.040	0.031	0.001
CH_4 (%)	40.0	50.8	58.6	68.5	66.3	65.9	62.3
CO_2 (%)	58.7	49.2	26.5	31.5	33.7	34.1	37.7
O_2 (%)	0	0	1.0	0	0	0	0
N_2 (%)	0	0	13.9	0	0	0	0

[a] There was probably an air infiltration in the syringe after the sampling.

coincided with the maximum biogas production (sample 4 in Table 4); the produced biogas, with a mean value of methane content of 59.7%, has optimal energetic characteristics. The cumulative curve shows a rapid increase in the first days and a lower increase after the production peak both for biogas and methane. The biogas and methane yields resulted in 0.398 N m^3/kg SV and 0.238 N m^3/kg SV, in agreement with data from literature, however showing slightly lower values for biogas and slightly higher for methane (Chynoweth et al., 2001; Zhang et al., 2007).

In the ABP3 test the maximum methane percentage was obtained for vessel no. 2 (52.9%), although biogas and methane yields were very low: 0.08 N m^3/kg SV and 0.042 N m^3/kg SV respectively. They are lower than data from the literature (Sosnowski et al., 2003) for biogas production, while the methane percentages are in good agreement.

3.2.2. Anaerobic digestion tests

Results of AD1 test showed a discontinuous and poor production of biogas, with yields of 0.051 N m^3/kg SV for biogas and of 0.002 N m^3/kg SV for methane. Data from literature show variable values from 0.435 N m^3/kg SV for refectory waste (Zhang et al., 2007) and 0.11 N m^3/kgSV for OFMSW (Fernández et al., 2008); however literature results are always referred to tests with inoculum.

In the AD2 test pH was substantially low (below 5) during the test, resulting in a relatively high biogas production during the first days, with a peak during the second day, while methane percentage was very low, with a maximum value of 27.7% during the fifth day (Fig. 4a). The biogas cumulative production was 0.258 N m^3/kg VS, but the methane cumulative production was very low and equal to 0.035 N m^3/kg VS (Fig. 4b). Data from the literature show high potential in methane production from OFMSW (De Baere, 2000; Edelmann et al., 2000), in the range 0.2–0.4 N m^3/kg VS, with high percentages in the 40–60% range. Nevertheless, even if the mixture was biologically active, the test showed a too low methane production, probably due to the low value of pH. At the end of the test, the digested matter was analyzed. It was separated by centrifugation at different speeds (3000, 5000 and 10000 rpm); liquid percentages of 53.6%, 55.7% and 59.8% were obtained respectively at 3000, 5000 and 10,000 rpm. Moisture and total volatile solids are reported in Table 5. The starting value of the Total Volatile Solids was 0.29 kg, the ending value was 0.13 kg; a reduction of 55% was obtained. It is an index of the substrate degradation and of the process efficiency; the biogas production is about 0.75–1.10 m^3 per kg of destroyed volatile solids. In the literature (Forster Carneiro et al., 2007; Zhang et al., 2007) values of 77–78% of Volatile Solids removed after 10–25 days were found. The lower value found in this study is probably due to the acidification of the mixture. The liquid fraction of the digested matter was also characterized by measuring, at the different centrifugation speeds, NH_4^+ (<0.4 mg/l), biochemical oxygen demand (BOD_5) (in the range 34,000–43,000 mg/l O_2), chemical oxygen demand (COD) (in the range 60,000–63,000 mg/l O_2) and total fatty acids (TFA), the last

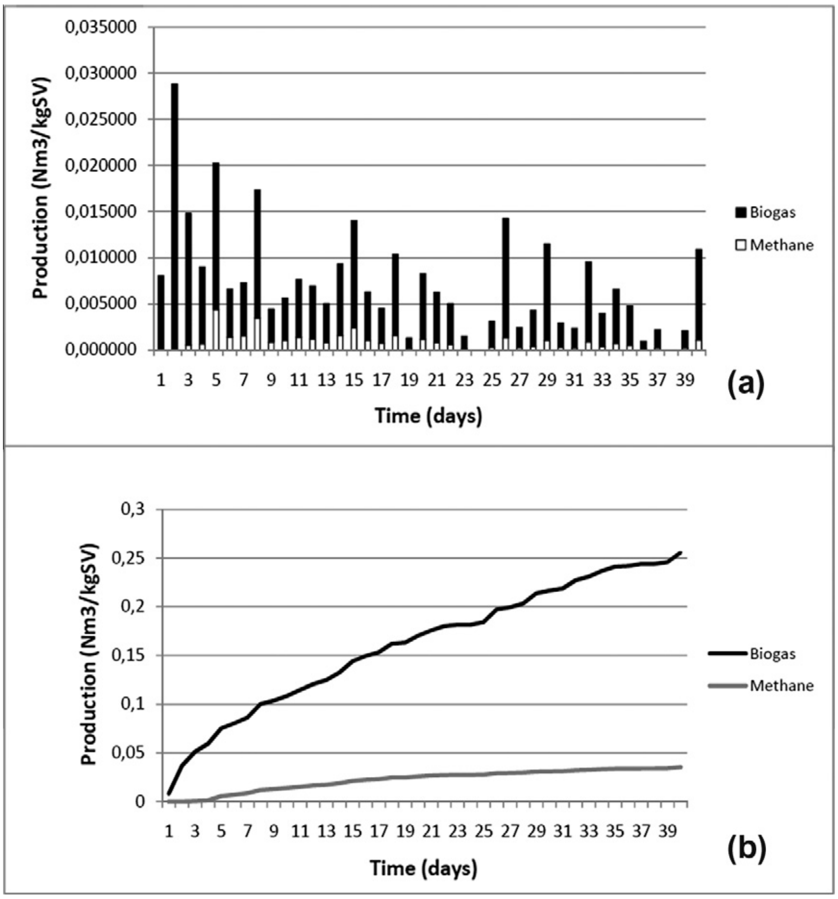

Fig. 4. Daily biogas and methane production (a) and cumulative curves (b) of AD2 test.

Table 5
AD2 test: characteristics of the components, of the mixture and of the digested matter.

Substance	Samples	Moisture (%)	Total volatile solids (wet basis) (%)	Starting pH
Slurry	1	77.25	18.23	4.53
	2	76.01	19.68	
	3	77.19	18.68	
	Mean value	**76.82**	**18.86**	
Inoculum	1	91.50	5.93	7.21
	2	91.46	5.97	
	3	91.58	5.91	
	Mean value	**91.51**	**5.94**	
Mixture	–	**95.0**	**3.6**	**4.82**
Digested matter as received	1	97.77	1.65	–
	2	97.92	1.51	
	3	97.90	1.69	
	Mean value	**97.86**	**1.62**	
Digested matter – liquid fraction	1	98.22	1.50	–
	2	98.27	1.33	
	Mean value	**98.25**	**1.42**	
Digested matter – solid fraction	1	74.91	19.97	–
	2	73.81	20.94	
	Mean value	**74.36**	**20.45**	

in the range 0.15 0.55 g/l; the total fatty acids were also identified and the maximum percentages were found for C18:0 + C18:1 cis9 (49–53%), C18:2 cis9,12 (29–30%) and C18:1 trans9 (11–13%). The high values of BOD_5 and COD, together with the presence of TFAs, confirm a low degradation of the substrate. NH_4^+ concentration is too low to employ the digested liquid as a fertilizer.

In the AD3 test the pH was always acidic during the first nine days; a correction was tried by adding 720 ml of NaOH 1 M, that increased pH from 3.30 to 6.20, but after one day it decreased again. Therefore the test was stopped after 15 days. The biogas production was very low and the methane production was practically zero (maximum value 0.02% after eight days).

Table 6
OFMSW Waste: results of the leaching test.

Parameter	Unit	Samples		Limits
		1	2	
Arsenic As	mg/l	<0.0085	<0.0085	0.2
Barium Ba		<0.0001	<0.0001	10
Cadmium Cd		<0.0005	<0.0005	0.02
Total chromium Cr		<0.0003	<0.0003	1
Copper Cu		0.0028	0.0052	5
Mercury Hg		0.00022	0.00017	0.005
Molybdenum Mo		<0.0008	<0.0008	1
Nickel Ni		<0.0017	<0.0017	1
Lead Pb		<0.0042	<0.0042	1
Antimony Sb		<0.0066	<0.0066	0.07
Selenium Se		<0.0076	<0.0076	0.05
Zinc Zn		0.2	0.34	5
Chlorides		366.6	268.1	1 500
Fluorides		<0.2	<0.2	15
Cyanides		0.03	0.05	0.5
Sulphates		51.7	49.7	2 000
Dissolved organic carbon (DOC)		695.5	478.5	80
Total dissolved solids (TDS)		3 740	2 640	6 000

The digested matter was analyzed: a liquid percentage of 93% was found at 5000 rpm. The liquid fraction had a concentration of NH_4^+ of 634 mg/l, a COD value of 17,810 mg/l O_2 and a BOD5 value of 1135 mg/l O_2. The latest values are lower than the ones of the digested liquid of AD2 test, therefore a higher substrate degradation was obtained; finally the NH_4^+ concentration is higher and therefore showing the possibility to employ the liquid as a fertilizer.

3.3. OFMSW Waste

3.3.1. Chemical–physical properties

The characterization of OFMSW Waste shows that moisture was about 33% and total solids about 67%. BOD_5 and COD were respectively 370 and 1150 mg/l O_2. COD, if compared to data for untreated waste (1500–3000 mg/l, such as in Jutta Laine et al., 2004), is low; nevertheless, the BOD_5/COD ratio is higher than 0.2, considered as upper limit to have a stabilized waste (Binner et al., 1999). The Putrescibility Index is related to the environmental impact of the waste; it was 108, in agreement with data from the literature for bio-stabilized Municipal Solid Waste (Scaglia and Adani, 2008). The O_2 hourly consumption for the biochemical oxidation of the organic matter easily bio-degradable (IRD) was about 890 mg/kg h dry basis and 1360 mg/kg h of Volatile Solids. No limits are imposed by the Italian Legislation for IRD; nevertheless some Regional Guidelines suggest a maximum value of 1000 mg/kg h of Volatile Solids, lower than the one found in this study.

Results of leaching tests are showed in Table 6; they are lower than the limits according to Italian Legislation (DM 3 August 2005) and UNI 10802, with the exception of Dissolved Organic Carbon (DOC).

4. Conclusions

Experimental data on mechanically treated OFMSW fractions in anaerobic digestion are reported.

The liquid fraction (slurry) showed good biogas and methane productions if inoculated with piggery manure, lower values with effluent from OFMSW digestion (ABP tests). AD tests in batch reactor showed low biogas productions without inoculums, higher values if inoculated with effluent from OFMSW digestion, but very low methane yields. It may be concluded that OFMSW slurry is suitable for AD only when inoculated, therefore procedures for different wastes handling are required.

The solid fraction (Waste) could be disposed of in a landfill provided that Dissolved Organic Carbon is reduced.

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