Case study: the characteristics of the biodegradable waste for the anaerobic digestion plant in Lisbon area

F. Vaz, A. Torres and C. Neiva Correia

ABSTRACT

Taking into account the physical-chemical characteristics of the SC-OFMSW processed at Valorsul's anaerobic digestion plant, the influence of seasonal effects was studied. The waste presents a good quality, with a putrescible content of around 90%. In terms of chemical characteristics, the waste composition is similar to the one referred in the literature. The results show that seasonal variations seem not to affect the SC-OFMSW characteristics. The waste is very soluble and for that reason the solids content in the digester is low (TS in the digestor is 2.8%). The production of biogas is higher than the one predicted in the design operational parameters. Consequently, smaller quantities of compost are produced.

Key words | anaerobic digestion, operational parameters, seasonal effects, solid waste physical-chemical characteristics, temperature

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INTRODUCTION

Valorsul, S.A. is the company responsible for the treatment of the Municipal Solid Waste (MSW) produced in Lisbon, approximately 800 thousand tons per year. It covers a population of 1,176,180 inhabitants, which represents 12% of the total inhabitants of Portugal.

In 1994, this multimunicipal system for processing and recovery of MSW from Lisbon (North) was created, including the municipalities of Amadora, Lisbon, Loures and Vila Franca de Xira.

This system consists of several operational facilities: a MSW Waste to Energy Plant (CTRSU); a Processing and Valorization of Bottom-Ash Plant (ITVE); an Anaerobic Digestion Plant (ETVO); a Materials Recovery Facility (CTE); a Collection Centre (EC); and a Sanitary Landfill (AS), to operate as a system fuse.

This paper aims to present the seasonal variation of the characteristics of the source collected organic fraction of municipal solid wastes (SC-OFMSW) processed at the anaerobic digestion plant, in terms of the parameters Total Solids (TS), Volatile Solids (VS), solubilization of the reactor feed (ratio between the soluble chemical oxygen demand–SCOD and the total chemical oxygen demand–TCOD) and the evolution of the Volatile fatty acids (VFA).

It also presents the influence of the substrate characteristics on the process behaviour. For that, several operational parameters were studied, like the biogas production, removal of VS and COD in the digester, methane content and others.

PROCESS DESCRIPTION

Biodegradable waste is selectively collected in restaurants, hotels, supply and retail markets, among other big producers of this kind of waste in the municipalities of Lisbon Area. A wet two-stage thermophilic anaerobic digestion process followed by a pre-composting stage in tunnel with forced aeration and a post-composting phase in a covered area is used.

The plant is dimensioned to treat 40 thousand Mg of biodegradable waste per year in a first stage and 60 thousand Mg per year in a second stage. In what concerns

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electric energy and compost produced, the plant is dimensioned, respectively, for 10 GWh and 14 Mg per year.

The plant receives waste 7 days per week, processing in 6 days, 14 hours per day, 302 days per year.

For this purpose Valorsul and the Municipalities selected big producers of Biodegradable Waste (BW) such as restaurants, canteens, hotels, supplying and retail markets. For that purpose a geographic information system (GIS) was implemented in order to optimise the collection circuits.

By the end of 2007, the Programme had 2,245 participant establishments and was able to collect 32,129 Mg of SC-OFMSW.

Figure 1 presents the process flow diagram.

The waste from different sources is discharged in two different lines, in accordance to their origin and quality. The "wet line" was design to receive waste with higher water content, and less contaminants, from canteen and markets, and the "dry line" was conceived to receive the waste from restaurants, hotels and supermarkets, with a lower water content.

The waste from the "wet line" passes through a sieve and hammer mill before entering the hydrolysis. The waste from the "dry line" has to suffer a pre-treatment that involves a manual sorting, shredding and sieving. Before going to hydrolysis it also passes through a pulper to promote size reduction and the contaminants removal.

After two days residence time in the hydrolysis tank, the suspension is sent to the two digesters of 3,500 m^3 each, where it stays about 21 days (project values) in complete mixture, promoted by the internal recirculation of biogas. In order to induce the inhibition of H_2S production, small quantities of air are added to the biogas that is recirculated into the digester.

After the digestion step the organic suspension is conducted to dewatering. The dewatered product is pre-composted in 5 tunnels, with forced aeration and post-composted in windrows in a covered area. The final compost is refined by passing it through a sieve and a densimetric table to remove contaminants.

The exhausted air extracted from the process areas and equipments is used as process air in the composting phase and is treated in two biofilters.

In respect to the liquid phase produced in the dewatering, part is used as process water and the excess is sent to a waste water treatment plant, which has a biological

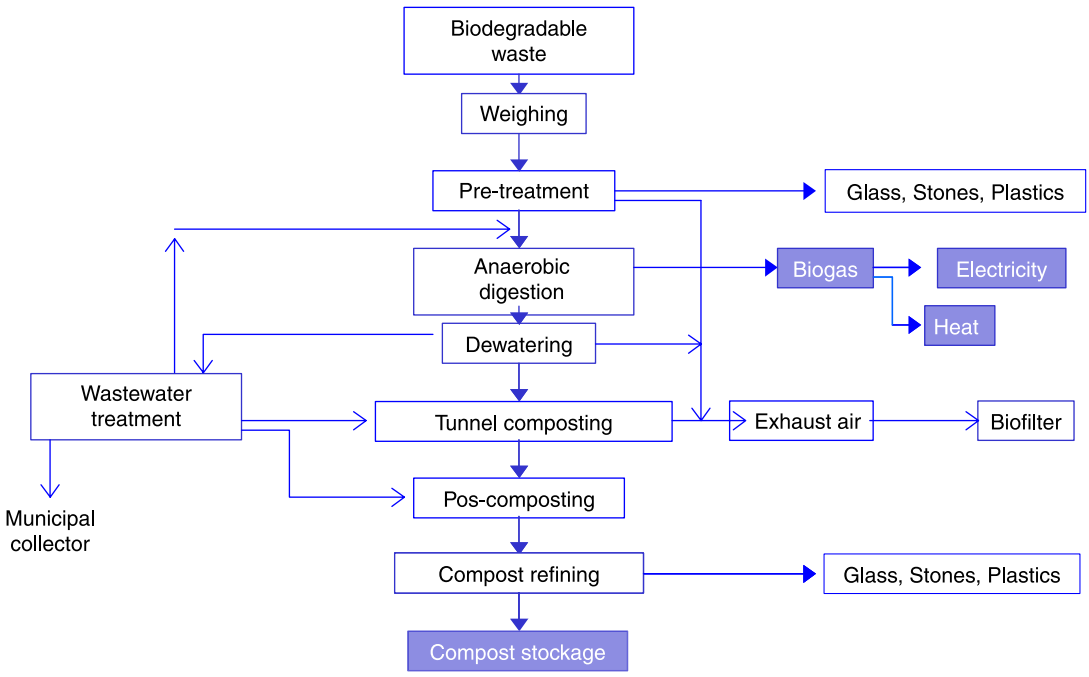

Figure 1 | Process flow diagram.

Table 1 | Waste characterization in 2006 and 1st semester 2007

Size of municipalities (nr inhabitants)		
Inhabitants	1,040,757	
Producers (no households included)	2,254	
Mg received (2006)	30,786	
Physical composition	**2006**	**2007 (Jan–Jun)**
Mg characterized (Mg)	83.7	63.2
Organics (%)	81.8	81.3
Paper and Carboard (%)	9.3	9.3
Contaminants (%)	8.9	9.5

treatment with a nitrification-denitrification process, followed by a membrane bioreactor for the solids removal. This pre-treated water can be used in the process and the excess is sent to the municipal collection system.

THE CHARACTERISTICS OF BIODEGRADABLE WASTE

In order to control the physical characteristics of SC-OFMSW delivered at the plant, Valorsul has implemented a reception control that involves a daily waste sampling.

These main characteristics are related to the physical waste characterized in 2006 and in the first semester of 2007, as presented in Table 1.

From these results it can be noted that the waste delivered at the plant, separately collected in markets, canteens, restaurants and others, has a content of organic material around 81%, a percentage of paper and cardboard of 9.3% and a variation of contaminants between 8.9% and 9.5%. Plastic materials (plastic bags and bottles) are the main contaminants.

In terms of variation of the chemical parameters, Table 2 presents the characteristics of the waste, analyzed during two periods, between November 2006 to February 2007 and October 2007.

In terms of chemical characteristics, we verified that the solids content, TS and TVS, and the TKN (%, dry matter) of the waste received at the plant are in the range of the characteristics of the organic fraction of MSW (SC-OFMSW) separately collected in canteens and in fruit and vegetables markets (Cecchi *et al.* 2003).

INFLUENCE OF SEASONAL VARIATIONS ON THE SUBSTRATE CHARACTERISTICS

In order to study the influence of seasonal variations on the substrate characteristics, the data presented in Table 3 shows the results of the chemical-physical characteristics of SC-OFMSW monitored during one year, between 2006 and 2007. This variations are also represented in the Figure 1, where these data are disposed according with the increasing of the temperature.

As reported by Zorzi (1997) (Cecchi *et al.* 2003), the results obtained at the anaerobic digestion plant of Valorsul support the conclusions made by this author that the seasonal variations seem not to affect the SC-OFMSW characteristics. As also according to the study referred above, the content of VFA, measured in the hydrolysis tank before entering the digester, was registered in order to evaluate the putrescibility of these materials in relation to the temperature evolution. The Mg of waste processed was also taken into account because it can interfere in the parameter variation. The graphics with this evolution are shown in Figure 2.

In respect to the racio SCOD/TCOD, as indicative parameter of the hydrolysed organic fraction, with an

Table 2 | Chemical characteristics between November 2006 and February 2007 and October 2007

Parameter	Unit	Average values	Percentile 75	Percentile 25	Nr. Of samples	Std. Dev.
TS	[% original sample]	27.6	31.4	24.1	55	5.0
TVS	%, TS	86.9	91.4	81.9	15	6.0
TOC	[g/kg]	422.0	461.0	389.0	55	6.4
Total nitrogen (TKN)	[g/kg]	34.8	37.5	23.5	55	2.0
P	[g/kg]	4.5	4.1	2.5	55	4.4

Table 3 | Chemical characteristics of SC-OFMSW between 2006 and 2007

	2006			2007										
Parameters	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air temperature	23.00	19.10	14.30	13.80	15.80	17.90	20.40	22.10	24.20	28.10	28.30	27.40	23.90	19.10	14.30
TS %	29.98	26.69	28.36	26.10	26.63	28.04	28.95	27.26	25.63	22.58	27.20	24.65	26.85	26.98	26.13
TVS, % TS	60.97	63.76	77.22	81.99	83.66	74.10	68.22	77.78	81.27	71.29	80.93	81.24	74.24	82.59	76.47
TCOD	112.84	121.58	119.17	127.86	118.00	123.39	101.17	113.06	121.33	117.08	114.73	106.42	110.17	107.59	102.00
SCOD	50.16	53.22	67.70	66.13	61.47	61.78	50.42	54.27	55.75	57.42	55.20	51.08	48.79	46.23	50.19
SCOD/TCOD	0.44	0.44	0.57	0.52	0.52	0.50	0.50	0.48	0.46	0.49	0.48	0.48	0.44	0.43	0.49
VFA (g/L Ac)	16.59	21.26	20.96	20.71	20.98	19.09	18.08	20.57	20.83	21.03	18.59	19.84	17.86	16.64	15.16
Mg processed	544.82	995.60	1799.06	1821.91	2321.76	3151.24	1834.68	2864.60	2379.91	2251.46	2483.44	2179.58	2487.67	1788.54	2188.94

average value of 50% was found to be greater than the values reported in the literature (Pavan *et al.* 2000). This indicates that a high amount of VS is hydrolysed in a very short time as a result of the high putrescibility of the delivered waste (Neiva Correia *et al.* 2007).

WASTE CHARACTERISTICS AND OPERATIONAL PARAMETERS

Relating the substrate physical chemical characteristics with the operational parameters of the process, the scheme represented in Figure 3 shows the variation of the average values registered in 2007, in terms of the parameters TS and VS, along the several steps of the biological treatment. These values were compared with the design assumptions, in order to be possible to see the main differences.

As it can be seen, despite the average values of TS of the two reception lines in the waste input are in the range defined in the tender documents (27–39%), the real values obtained in the hydrolysis are lower than the ones predicted in the project. This fact is probably related with the high solubility of the waste, shown by the high ratio of SCOD/TCOD referred above. Consequently, the values of TS inside the digester have a lower value of TS (2.75%). These results were also verified in another plant with the same technology where a solid content of 2.7% for the digested material was achieved (Gatto *et al.* 2007).

In terms of the performance of the digester, in the Table 4 are shown several operational parameters, related with the solids and COD removal efficiency in the digester and the biogas production per Mg VS (SGP). In the same table the design values are indicated. The process is considered stable since the beginning of January of 2007, where the nominal capacity to one of the two existing digesters was achieved.

Face to these results, we verified that due to the high biodegradability of the substrate in respect to the design values, where the operational parameters like SGP and removal of VS are much higher than the design values. In fact, in respect to the SGP (m3/Mg SV), in 2007 it was registered a median value of 650 m^3/Mg SV while the project predicted 400 m^3/Mg SV. As for the removal of VS,

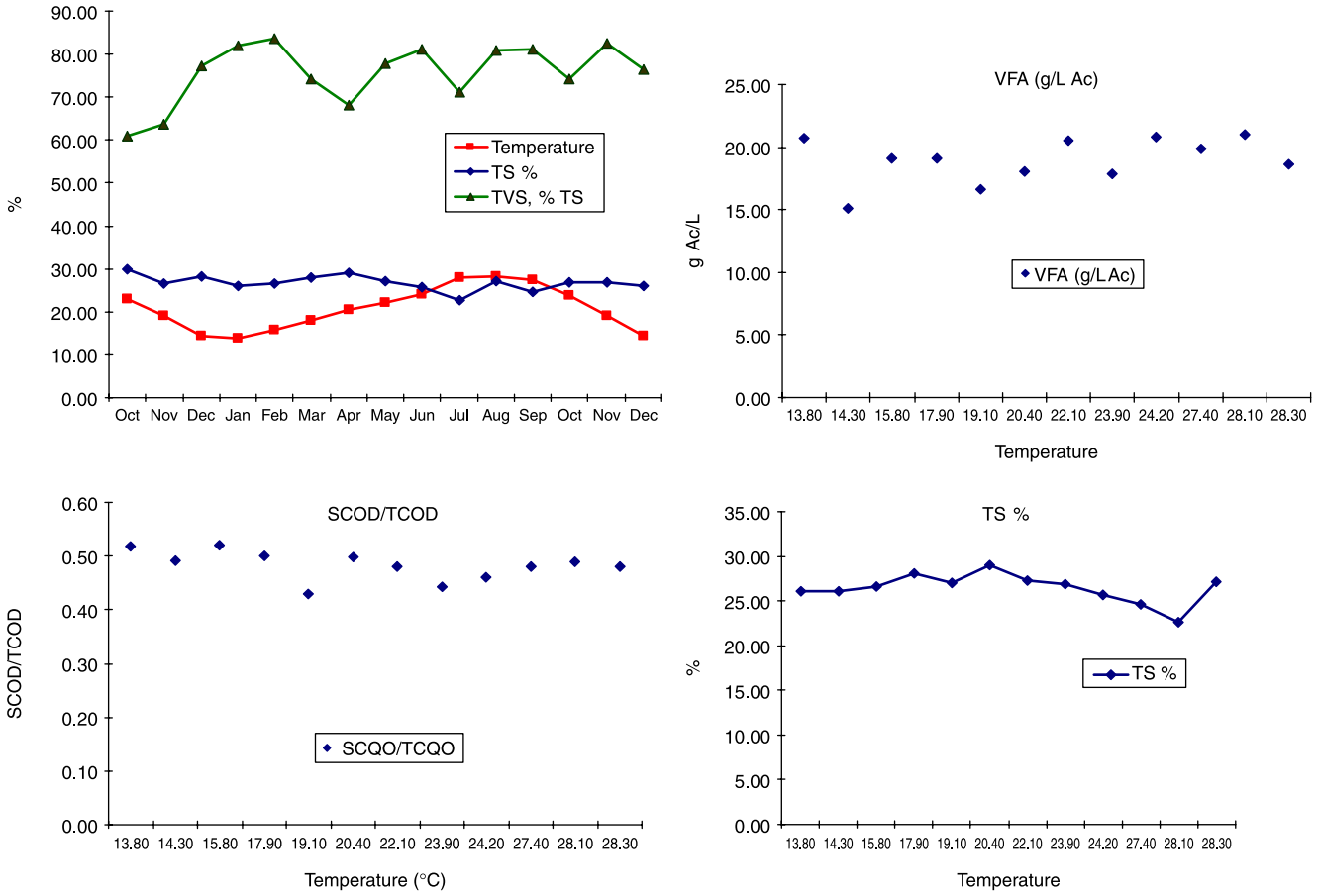

Figure 2 | Comparison between substrate characteristics and temperature.

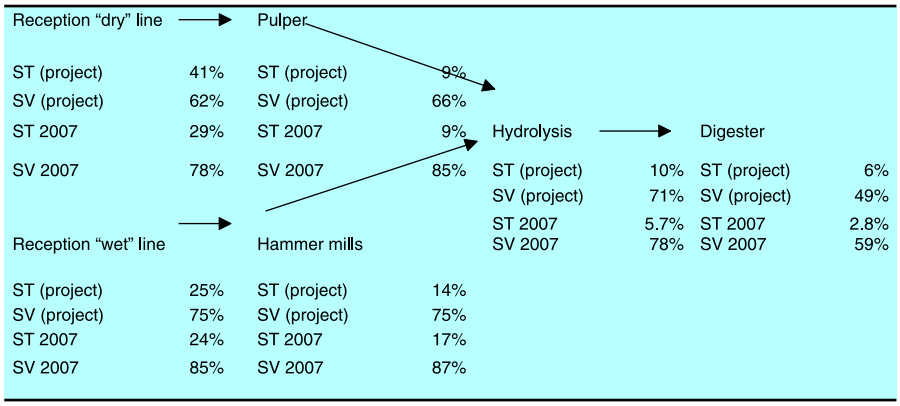

Figure 3 | Solids Balance.

Table 4 | performance parameters in digestion

Parameters	Values (Jan–Dec 2007)
Total waste income in 2007 (Mg)	27,754
OLR (kg SV/m^3)	2.1
OLR (kg VS/m^3) design	5.6
OLR (kg COD/m^3)	5.0
Biogas (Nm^3)	3,898,496
SGP (m^3/Mg SV)	650
SGP (m^3/Mg SV) design	400
m^3 biogas/Mg SC-OFMSW	137
VS rem %	76
VS rem design %	57
COD rem %	2.05
$CH_{4\%}$	63
$CH_{4\%}$ design	57

it can be observed the same evolution with the real value of 76% versus a design value of 57%.

These results also affect the processes that occur after the digestion step, namely the solids removal efficiency of the dewatering phase, because the organic suspension is very diluted and has implications on the quantity of material to be composted, as well as in the treatment in the waste water treatment plant of the centrifugate, due to the presence of a high solids content.

In terms of the quantities of compost produced, in 2007 was verified a compost production of 471 Mg, when was expected a production of compost of around 7,300 Mg. This means, that the good quality of substrate implicates a higher production of biogas and lesser quantities of compost. These also means that, probably, with the same waste characteristics and process technology the compost areas of this kind of facilities could be smaller and more simplified, instead of two stages, as implemented at Valorsul's plant (forced aeration tunnels followed by windrow composting). Consequently, taking into account the economic aspects, eventually the investment cost could be reduced, but more studies have to be done to verify these suppositions.

CONCLUSIONS

The SC-OFMSW processed at Valosul's anaerobic digestion plant reveals a good biodegradability, according to the literature, and its quality is better than the one predicted in the project phase. The waste is very soluble and for that reason the solids content in the digester is low (TS in the digestor is 2.8%). These results have implications in the process performance where a higher production of biogas is achieved and consequently smaller quantities of compost are produced.

As reported by previous studies, the seasonal variations seem not to affect the SC-OFMSW characteristics.

More studies have to be done to verify if similar plants, with the same collection schemes or waste characteristics and similar climacteric conditions, have this kind of process behaviour. Maybe this hypothesis could be expanded to the national territory of Portugal or to the Mediterranean Countries.

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