SIMULTANEOUS DISPOSAL OF THE ORGANIC FRACTION OF MUNICIPAL SOLID WASTES AND WASTEWATER TREATMENT SLUDGES BY HYDROLYSIS AND THERMOPHILIC DIGESTION

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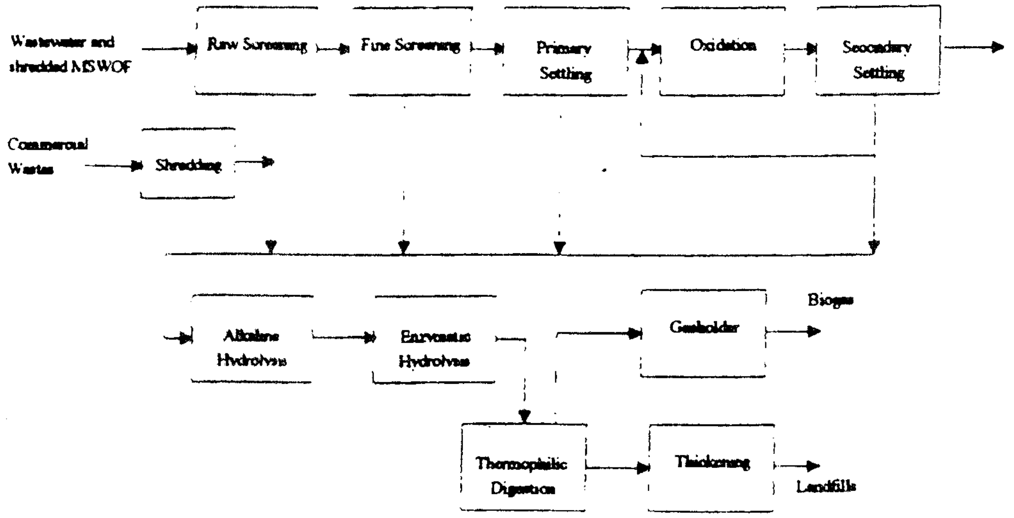
1 INTRODUCTION

Simultaneous anaerobic digestion of hydrolysed mixtures of sewage sludges and MSWOF (Organic Fraction of Municipal Solid Wastes) can be considered as a promising alternative to dumping, composting, incinerating of MSWOF or to simple fermentation processes. The proposed process addresses to both energy recovery and environmental protection.

The solid wastes and the sewages produced in urban areas are generally treated in different plants: the sludges from biological oxidation plants are anaerobically digested while MSW are dumped or incinerated. The technical feasibility of an alternative simultaneous treatment of the MSWOF together with municipal wastewater is considered in this study. This aim would be achieved conveying the MSWOF to the wastewater treatment plants: the consequent simultaneous anaerobic digestion of sewage sludges and MSWOF should be carried out under thermophilic conditions in order to make the use of the existent digesters possible (Figure 1).

FIGURE 1 - Schematic diagram of the process proposed for the simultaneous treatment of the organic fraction of municipal solid wastes and sewage sludges



The proposed methodology includes a preliminary domestic classification and shredding of MSWOF in the sinks, their discharge together with wastewater into the sewer system, subsequent screening, mixing with primary and secondary sludges and with previously shredded commercial wastes. Then the mixture should be submitted to a high temperature-alkaline pretreatment as well as to an enzymatic hydrolysis for the solubilization of the organic substances, before the thermophilic anaerobic digestion. Finally a biogas and a stabilized product, useful as organic soil amendant or directly disposable in landfills without risk of putrefaction, would be obtained.

2 MATERIALS AND METHODS

2.1 Experimental Set-up

Experimental tests were carried out using two 1-litre pyrex glass tanks as hydrolytic reactors, both filled with 50% (dry basis) of primary and secondary sludges from the municipal wastewater plant of Punta Vagno (Genoa) and with 50% of MSWOF, which were made up of fruits and vegetables adequately shredded and mixed to form an homogeneous slurry.

2.2 Feed Preparation

The average compositions of both materials listed in Table 1 were selected from the date available in the literature for municipal productions and compositions of MSW (Municipal Solid Wastes) and of primary and secondary sludges. Furthermore, it has been supposed that all the population served by the hypothetical plant should have the possibility to discharge the MSWOF directly into the sewer system.

TABLE 1 - Characterization of sludge and MSWOF

Parameters	Sludge	MSWOF
TS (Total Solids) $(g \cdot l^{-1})$	49.25	145.9
SS (Suspended Solids) $(g \cdot l^{-1})$	43.47	113.8
VS (Volatile Solids) $(g \cdot l^{-1})$	38.97	132
COD (Chemical Oxygen Demand) $(g_{COD}/g_{dry\ solids})$	2.75	10.2

MSWOF and sludge mixture was fed into the reactors after preparing suspensions with average total solid concentrations of 2% and 6%. The first quite low TS concentration was supposed to ensure the maximum yield of hydrolysis of the organic mixtures. The second one is the usual solid concentration fed into the sewage sludge digesters.
The average compositions of both feeds are reported in Table 2.

TABLE 2 - Average compositions of the digesters feeds

Parameters	2% mixture	6% mixture
TS $(g \cdot l^{-1})$	21	62.42
SS $(g \cdot l^{-1})$	18.23	54.87
VS $(g \cdot l^{-1})$	16.8	47.82
VSS $(g \cdot l^{-1})$	14.03	46.27
COD_S (Soluble COD) $(g \cdot l^{-1})$	6	15

2.3 Feed Pretreatment

Batch enzymatic hydrolysis tests were carried out after different thermo-chemical pretreatment procedures in order to evaluate the efficiency of the global pretreatment on the performance of the following digestion step. The tests carried out were the following:

A. Enzymatic hydrolysis
B. Chemical hydrolysis, heat treatment and enzymatic hydrolysis
C. Heat treatment and enzymatic hydrolysis
D. Chemical hydrolysis and enzymatic hydrolysis.

Heat treatment has been performed autoclaving the mixtures at 110°C for 20 minutes, chemical hydrolysis[1] by adding NaOH to a concentration of $4 g \cdot l^{-1}$, while the enzymatic hydrolysis has been carried out at 25°C and pH=7 inoculating the mixtures with $1 g \cdot l^{-1}$ of selected hydrolytic bacteria. Samples were collected before and after each physical or chemical pretreatment and at regular time intervals.
Standard methods[2] were used for COD, TS, VS, SS and VSS (Volatile Suspended Solids) determinations. These parameters were followed to evaluate the effectiveness of the hydrolysis of the organic polymeric materials contained in the tested mixture.

2.4 Anaerobic Digestion Tests

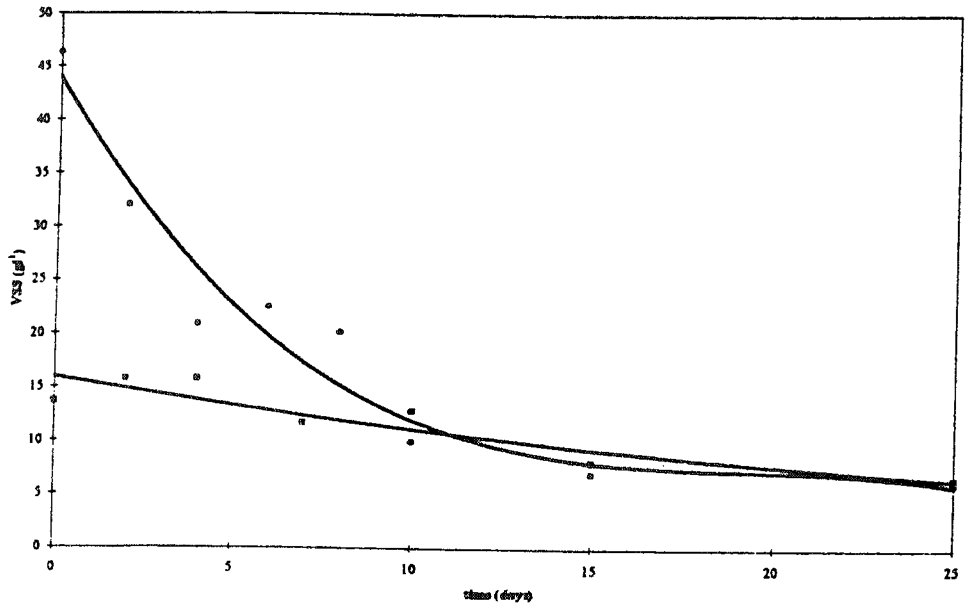
To evaluate biogas production and substrate stabilization for fed-batch thermophilic anaerobic digestion of hydrolysed feeds, a set of anaerobic digestion tests was carried out by feeding the digestor with the 6% hydrolysed mixture.
A similar thermophilic anaerobic digestion was successfully carried out by feeding the digester with a 6% mixture without any pretreatment (blank test).
The fed-batch tests were carried out sampling every 24h and substituting the sampled volume with an equivalent amount of fresh feed.
The organic loading rate has been varied between 0.56 to $5 g_{COD} \cdot l^{-1} \cdot day^{-1}$ by feeding the digesters with fixed volumes of solutions with increasing starting COD values.
The start-up phase of each selected organic load was followed by daily measurements of methane, carbon dioxide and total biogas production. Mixed liquor was analysed after reaching steady state conditions.

3 RESULTS AND DISCUSSION

3.1 Hydrolysis

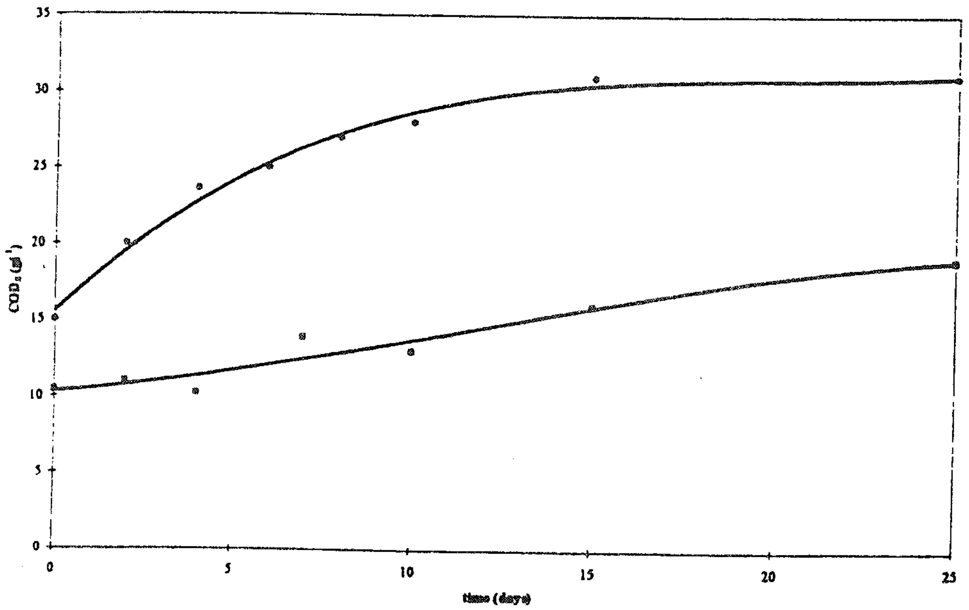
The comparative examination of the pretreatments of MSWOF and sludges mixtures, previously called A, B, C and D, shows that high temperature, chemical pretreatment using alkaline hydrolysis and enzymatic hydrolysis ensure the most significant benefits. The comparisons has been made considering VSS as substrate and COD_S as product.
VSS decreased quickly during thermal and chemical pretreatments of 2% mixture and varied from 16 to $6.5 g \cdot l^{-1}$ during the enzymatic hydrolysis (Figure 2).

FIGURE 2 - Effect of enzymatic hydrolysis on VSS concentration of 2%(■) and 6%(•) mixtures



On the contrary, after a sharp increase due to thermal and chemical treatment, the COD_S increased from 10 up to $19 g \cdot l^{-1}$ during the enzymatic hydrolysis of 2% mixture (Figure 3).

FIGURE 3 - Effect of enzymatic hydrolysis on COD_S concentration of 2% (■) and 6%(•) mixtures



As regards 6% mixture, similar results have been obtained in terms of percentages of VSS removal and COD_S increase. TS and total COD are practically constant during the enzymatic hydrolysis probably because there was only a slow growth of the bacteria that partially offset the liquefaction of polymeric solids.

3.2 Anaerobic Digestion

The start-up phase, preceding the pseudo-steady state achievement, was followed in terms of methane, carbon dioxide and total biogas production.
A performance comparison between digestion processes of various substrates and the proposed processes is presented in Table 4. The selected digestion processes are the following:
A. mesophilic digestion of waste water sludges[3];
B. thermophilic digestion of waste water sludges[3];
C. mesophilic digestion of organic fraction of source-sorted municipal solid wastes[4];
D. mesophilic digestion of MSWOF (50%) and sludge (50%)[4];
E. mesophilic of pre-hydrolysed agricultural waste and wastewater sludge[5];
F. thermophilic digestion of MSWOF (50%) and wastewater sludge (50%) (this work);
G. thermophilic digestion of pre-hydrolysed MSWOF (50%) and wastewater sludge (50%) (this work).

TABLE 4 - Comparison between digestion processes of various substrates

Parameter	A	B	C	D	E	F	G
Volatile solids load ($g \cdot l^{-1} \cdot day^{-1}$)	1.6	4.8	4.2	2.8	3.4	4	1.73
Total COD load ($g \cdot l^{-1} \cdot day^{-1}$)	-	-	-	-	-	5	3.75
Temperature (°C)	37	55.5	35	35	35	55	55
Residence time (days)	14.4	11.6	13.6	14.5	20	12	12
TS ($g \cdot l^{-1}$)	31	84.4	64.8	57	151	62.4	42.4
VS ($g \cdot l^{-1}$)	21	55	57.1	40	125	47.8	21
VS/TS in the feed	0.68	0.65	-	0.7	0.85	0.76	0.49
VS/TS in the digested sludge	0.51	0.56	-	0.47	0.81	0.67	0.57
VS removal (%)	26.6	-	67	57	-	64	63
VS in reactor ($g \cdot l^{-1}$)	18.6	36.6	-	17.4	-	17	7.7
Specific biogas production rate ($l \cdot g_{VS}^{-1}$)	0.3	0.19	0.62	0.6	0.12	0.36	0.87
CH_4 content (%)	62	65.4	62.5	60	45	50	46

As it can be expected, the residence times of thermophilic processes can be quite lower than those of mesophilic ones. At the same time, the increase in temperature allows to work at loads of both COD and VS remarkably higher than those usually employed in traditional mesophilic digestion.
The specific biogas production, that strictly depends on the organic loading rate, is generally higher for MSWOF and sludge mixtures than for sludge. The unsatisfactory value observed for process E were ascribed to some extent to a relevant fraction of suspended non digestible ligninic particles not completely hydrolysed by the caustic treatment. Other possible inhibition was recognized in the formation of furfural from cellulose hydrolysis and phenolic compounds released by lignin hydrolysis. This phenomenon has not been evidenced in process G, that is characterized by both chemical and enzymatic pre-hydrolysis, so the specific production of biogas has been particularly high, also due to the low VS/COD ratio of the feed, as a consequence of liquefaction of great part of solid organic matter.
The lower methane content suggests, on the other hand, some biogas loss during the hydrolysis.
Even though, the total volatile solids reduction in the digester is comparable for all processes used for MSWOF digestion. If one takes into account the complete process (digestion and hydrolysis), the yield of VS reduction observed by process G is much higher (83.7%) than by the others.
The volatile solids amount in the digester is very low in comparison with the other digestion processes and the final amount of sludge to be disposed of is about one half that of the same process without hydrolysis.

4 SIMULATION BY "BIOPROCESS SIMULATOR"

The proposed process has been simulated by means of software Aspen Plus and BPS, its application to biotechnological processes. BPS software is not planned to simulate biological purification processes, so that several hypothesis have been assumed to take into account the specific parameters COD, SS, VS and so on:

1. process feed has been characterized by its elementary dry composition (C, H, O, N) and water;
2. chemical and thermal hydrolysis has been realised in a simple RYELD reactor where the feed has partially transformed in soluble organic matter (COD_S), expressed as dextrose;
3. the reaction products have been biologically hydrolysed into two CFERM reactors where they became dextrose (hydrolysis) and where dextrose became acetic acid (acidogenesis);
4. in a third CFERM reactor, acetic acid is converted into biogas (CO_2 and CH_4).

The results of the simulation are in very good accordance with the experimental ones.

5 CONCLUSIONS

After a preliminary shredding, the organic fraction of municipal solid wastes, has been mixed with sludges from municipal wastewater treatment plant, in proportion simulating the disposal of MSWOF through the sinks and the sewer system. Successively this mixture has been hydrolysed by thermal, chemical and biological treatment. During this treatments, the content of volatile suspended solids decreased from 16 to $6.5\,g \cdot l^{-1}$, while the soluble COD, that represents the organic fraction which can actually be solubilized, increased from 10 up to $19\,g \cdot l^{-1}$.

A thermophilic digester was fed with the hydrolysed mixture. In order to establish how much this hydrolytic pre-treatment could make the digestion easier, a mixture of MSWOF (50%) and sludge (50%) was also tested.

The most important result which can be ascribed to hydrolysis of the feed is the very low total and volatile solids concentrations in the digester, which could allow us to convert the mesophilic reactors employed to digest the waste water sludges into thermophilic ones capable to digest mixtures of MSWOF and sludges without considerable plant changes. In this circumstance, the MSWOF could be sorted directly at the source simplifying the problem of urban solids wastes treatment.

6 REFERENCES

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