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New parameters to determine the optimum pretreatment for improving the biomethanization performance

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HIGHLIGHTS

- ▶ The biological pretreatment with mature compost improves the OFMSW anaerobic digestion.
- ▶ The total methane production is increased up to 37% over the control.
- ▶ The hydrolytic stage of the anaerobic digestion process is faster by means of application of pretreatments.
- ▶ New parameters (t_{MAX} and t_{OPT}) have been defined to select the optimum pretreatment.
- ▶ New parameters as new user-friendly tools have been used to characterize the biomethanization performance.

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ABSTRACT

Thermochemical and biological pretreatments have been applied to the organic fraction of the municipal solid wastes (OFMSW) coming from an industrial 30 mm-trommel placed in a full-scale mechanical–biological treatment (MBT) plant in order to study their effects on the organic matter solubilization yield and the biomethanization process.

To compare the effect of theses pre-treatments on anaerobic biodegradability of pretreated OFMSW, a series of batch experiments were carried out. The accumulated methane production and the temporary evolutions of the volatile fatty acids (VFA) have been used to define two new parameters (t_{MAX} and t_{OPT}) in order to compare the effect of the pre-treatments on anaerobic digestion of pretreated OFMSW.

From the point of view of the biomethanization, the results indicate that the optimum pretreatment is the "*Precomposting*", since it presents the lower t_{OPT} (12 days) and in only 15 days of operation (t_{MAX} = 15) the reactor achieves the maximum accumulated methane production, 37.5 l vs. 7 l of the control digester for the same operation time.

1. Introduction

The organic fraction of municipal solid waste (OFMSW) is a substrate that may contain many lignocellulosic and fatty materials. These difficulty biodegradable organic matters may involve limitations process on anaerobic digestion (AD) yield. The AD processes are usually developed through four main stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Generally, the hydrolysis is considered the rate-limiting step of anaerobic digestion of solid wastes [1]. Hence, the hydrolysis stage is decisive for the OFMSW biodegradation and it may determine the overall rate of the process.

To avoid the above aspects, in the literature have been reported many studies in which thermochemical and biological pre-treatments are applied in order to pre-hydrolyze the waste and improve the organic matter solubilization to the liquid phase during the hydrolysis stage of the AD [2–13].

However, the literature about the applications of pretreatments on industrial solid wastes with high particle size, as the organic fraction of municipal solid wastes (OFMSW) coming from a full-scale mechanical–biological treatment (MBT) plant used in this study, is very limited. In fact, only three papers have been found about this topic [14–16].

The above information indicates the relevance of studying different pretreatments in order to increase the biodegradation scope by enhancing the hydrolytic stage of complex solid wastes such as the industrial OFMSW used in this work.

For all the stated previously, the present paper has two main goals:

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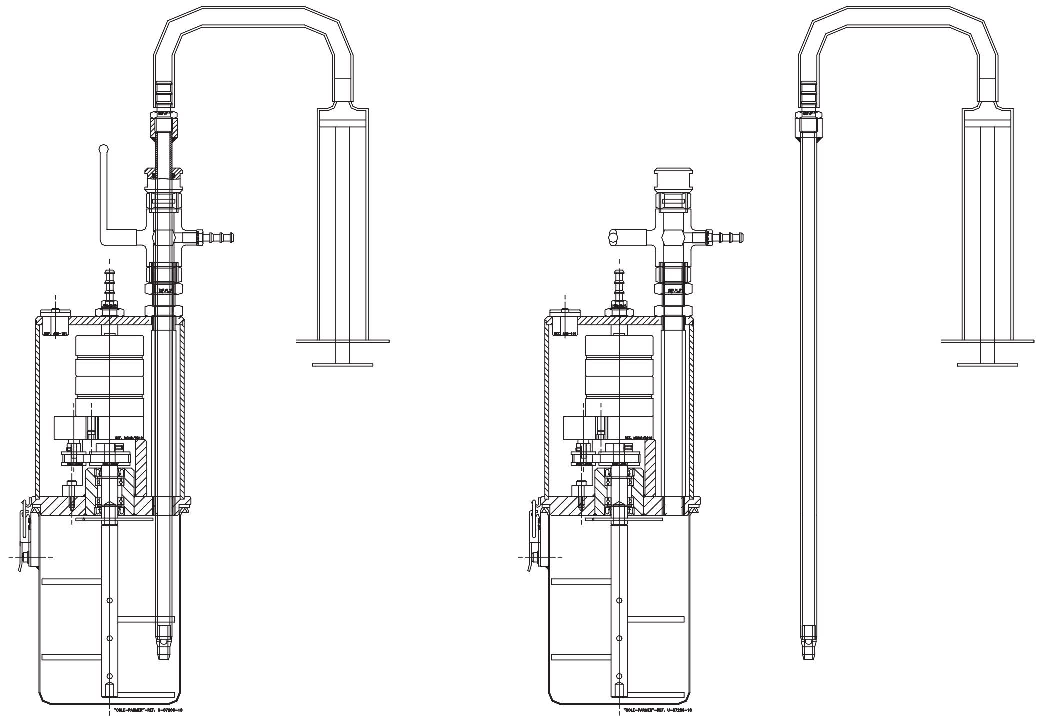

Fig. 1. Batch stirred tank reactor (Patent no. WO2006/111598A1-World Intellectual Property Organization).

Table 1
Configuration and operational conditions in batch pretreatment tests.

Reactor	Pretreatment	Conditions
1	Control	–
2	Biological – mature compost	2.5% (v/v)
3	Biological – sludge (WWTP)	2.5% (v/v)
4	Biological – *Aspergillus awamori*	2.5% (v/v)
5	Thermochemical	180 °C - 5 bar - 3 g/L of NaOH (*inert atmosphere with* N_2)
6	Thermochemical	180 °C - 5 bar - 3 g/L of NaOH (*oxidizing atmosphere with synthetic air*)

- To examine different pretreatments applied to OFMSW to enhance the hydrolysis stage, in a previous stage to the dry-thermophilic AD process, in order to increase the methane production and the organic matter (expressed in terms of volatile fatty acids) removal rate.
- To define new parameters in order to determine the optimum pretreatment among the tested in this work.

About the second goal, in many cases classical operational and control parameters to check the performance of biomethanization process as the specific methane production, accumulated methane production or kinetic parameters not provide unambiguous information to determine the optimum pretreatment.

For these reasons, two new parameters (as new user-friendly tools) to evaluate the performance/efficiency of pretreatments on the biomethanization, without resorting to the kinetic characterization of the process, are defined in this work. Below, these new parameters are presented to the scientific community:

1. "t_{MAX}" is defined as the operation time necessary to reach the accumulated methane production value from which the accumulated methane production is increased by less than 5%. Thus, if t_{MAX} is low, it represents that the substrate biodegradation and, hence, the biomethanization process occurs rapidly. In this case the effect of the pretreatment will be better compared to the opposite cases (high t_{MAX}).
2. Kinetics of batch anaerobic processes is well established. In general, in any microbiological process, the microorganisms require a lag phase to adapt to substrate and subsequently, both the acceleration phase and the exponential growth phase take place. However, in anaerobic processes the complexity of microbiota leads to a concatenation of the phases for the different microorganism groups and hence, in most of the cases, a spontaneous separation of stages can be observed. Taking into account the above mentioned, VFA evolution in the system shows an initial increase as consequence of the hydrolysis and acidogenesis phases, followed of a stationary stage in which the microorganisms are adapting to these new conditions. Later, acetoclastic population degrades the VFA to methane causing a continuous decreasing in VFA concentration.
   Simultaneously, the methane production is related initially to the hydrogenotrophic microorganisms in the hydrolysis and acidogenesis phases and, later, to the VFA degradation in the methanogenic phase by means of acetoclastic microorganisms. In this sense, VFA degradation is considered the main route for methane production.
   As a consequence, the maximum removal rate of VFA and the maximum rate for methane production are located in the methanogenic phase of the process developed by acetoclastic microorganisms. The operation time necessary for both maximum rates (maximum values of the slopes) match, it is a specific parameter that can be denominated "t_{OPT}".
   Obviously, lower t_{OPT} values imply that the system reaches the methanogenic phase faster and, hence, the pre-treatment is more effective.

The value of both parameters (t_{MAX} and t_{OPT}) must be determined graphically from the normalized curves of cumulative methane production and temporal evolution of VFA.