Chemical Engineering Journal 240 (2014) 24–37

Contents lists available at ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Review

Pretreatment methods to improve anaerobic biodegradability of organic municipal solid waste fractions

Alessandra Cesaro *, Vincenzo Belgiorno

SEED – Sanitary Environmental Engineering Division, Department of Civil Engineering, University of Salerno, via Giovanni Paolo II, 84084 Fisciano, SA, Italy

HIGHLIGHTS

- As anaerobic digestion is well-established, process optimisation raises interest.
- Substrate pretreatment is a valuable option.
- Main kinds of OFMSW pretreatments were reviewed.
- Advantages and drawbacks for each technology were discussed.
- Likely future research areas were identified.

ARTICLE INFO

Article history:
Received 10 July 2013
Received in revised form 8 November 2013
Accepted 24 November 2013
Available online 28 November 2013

Keywords:
Anaerobic digestion
Organic fraction of MSW
Pretreatment
Process
Technology

ABSTRACT

In the last decades, anaerobic digestion facilities for the treatment of organic solid waste have become widespread throughout Europe, since anaerobic process provides a suitable treatment for this kind of waste as well as the possibility to recover energy from the produced biogas, which is mainly composed of methane. Recently anaerobic processes of organic residues are also being studied for bio-hydrogen production.

Among the factors affecting the mass transfer in each biological step of anaerobic digestion, both the composition and the quality of the substrate play a fundamental role. According to the kind of substrate, pretreatments can be used in order to optimise biological process yields.

Aim of this work is to review the major classes of chemical, physical and biological pretreatments of organic solid residues, with particular reference to the ones applied to the organic fraction of municipal solid waste (OFMSW) and its prevailing constituents.

Therefore, main characteristics of OFMSW are provided, experimental results are compared and technologies are reported in order to identify the state of art of organic solid waste pretreatments, at both research and industrial level, as well as to point out the likely areas of future research in this field.

Contents

* Corresponding author. Tel.: +39 089 96 4181; fax: +39 089 96 9620.
E-mail addresses: acesaro@unisa.it (A. Cesaro), v.belgiorno@unisa.it (V. Belgiorno).

1385-8947/$ - see front matter
http://dx.doi.org/10.1016/j.cej.2013.11.055

1. Introduction

Anaerobic processes represent one of the most attractive treatment methods for organic solid waste and, in particular, for the organic fraction of municipal solid waste (OFMSW).

The implementation of anaerobic digestion for the treatment of this kind of waste has been the major development in the field of waste treatment facilities in Europe during the last decades. Since 1990, many waste treatment plants have been constructed and a significant part of the organic solid waste has been treated by means of anaerobic digestion. In most of these plants, the anaerobic process is followed by an aerobic phase [1].

The interest in this technology is related to the possibility of producing methane gas that can be used as a renewable energy in order to obtain certified emission reduction (CER) credits by clean development mechanism (CDM) under the Kyoto Protocol [2]. Besides helping to reduce carbon emission to the environment, CDM has the advantage of offering to developing countries the chance to attract foreign investments, in order to sustain renewable energy projects [3]. Moreover, the aerobic treatment of digestion effluent can produce a stabilized residue which can be employed as soil amendment or for environmental restorations [4].

More recent research trends are directed towards the study of the fermentative anaerobic digestion phase to produce hydrogen from organic waste: the so called "dark fermentation", which allows energy recovery from the hydrogen production process, represents the first stage of organic matter degradation. In this stage, complex molecules are converted to soluble compounds that can be further transformed to methane by anaerobic microorganisms [5].

As anaerobic digestion represents a well-established technology, the technical and scientific interest is mainly directed towards the process optimisation, with the aim to maximise process yields, both in terms of hydrogen and/or methane generation from the anaerobic treatment of organic matter.

To this end, different systems can be implemented depending on the specific purpose, which can be the process stabilization or the promotion of the hydrolysis.

In the former case, optimising anaerobic digestion reactions separately in different stages or reactors may lead to a larger overall reaction rate and biogas yield. Typically, the separation of the hydrolytic stage from the methanogenic one allows a more stable development of each biochemical reaction, thus promoting organic matter degradation and biogas production as well.

Nevertheless, in Europe, more than 90% of the digestion capacity is provided by single-phase digesters, which can use wet or dry technologies [6], according to the solid content in the reactor. The number of wet systems slightly increased when some plants were put into operation in Netherland and Spain in 2003 and 2004, but in 2005 more dry fermentation plants were built. Since 2008, several studies [7,8] have been reporting that the overall capacity provided by wet and dry anaerobic fermentation systems was almost the same.

Anaerobic process yields can be also improved by treating simultaneously different substrates with complementary characteristics in terms of nutrients, total and volatile solid contents. This process, known as anaerobic co-digestion, promotes the balance of the mixture parameters, with several advantages for the proper development of the process itself.

Anaerobic digestion yields can, otherwise, be enhanced by favouring the hydrolysis step, which is recognized as the rate-limiting one. To this end, several pretreatments can be applied.

This work aims to review the major classes of chemical, physical and biological pretreatments of organic solid waste, with particular reference to the ones applied to OFMSW and its basic components, thus evaluating their likely future for anaerobic digestion improvement. To this end, OFMSW characteristics are pointed out and main experimental results are compared. Moreover design solutions and technologies are reported in order to identify the state of art of organic solid waste pretreatments, at both research and industrial level.

2. Characterisation of the organic fraction of municipal solid waste

The European Council Directive on the Landfill of Wastes 1999/31/EC provides, within 2016, the reduction of landfilled biowaste to 35% of the amount produced in 1995. Therefore, waste management policies are mainly focused on the recovery of organic waste streams [9]. To this end, biological treatments are the main solution for the organic fraction of municipal solid waste [10].

In the last decades anaerobic digestion has been widespread for the treatment of the organic fraction of municipal solid waste [11]. The most recent trend is directed towards the coupling of anaerobic and aerobic processes [12], in order to obtain a net energy gain by methane and the production of a fertilizer from the residuals.

The organic fraction of municipal solid waste (OFMSW) is heterogeneous based on composition, source and structure [13], so that its specific content in different countries is extremely unpredictable.

Typically, the organic fraction of MSW includes food waste, leaf and yard waste. Food waste represents a significant proportion of organic material: it can originate from residential and commercial kitchens (i.e., restaurants and hospitals) or come from distribution and retail agents. Left and yard waste consists of lignocellulosic based materials, such as green grass clippings and thatch, leaves, weeds, brush, and tree prunings, whose production varies widely through the year. A further, although minor, contribution to lignocellulosic content of organic MSW is provided by soiled paper [14].

With reference to Europe, in Nordic countries for a large part of the year there is no fresh garden waste in the biowaste, which mainly consists of food waste [15].

On the other hand, Izawa et al. [16] reported that the main fraction of raw garbage consisted of vegetables (53.6%); De Gioannis et al. [17] assessed that OFMSW could be modelled as composed by 10 wt% meat, 65 wt% fruit and vegetables, 10 wt% bread and 15 wt% pasta and rice.

Table 1
Hydrolysis rate constant for basic substrates [18].

Substrate	K (d^{-1})
Carbohydrates	0.5–2
Lipids	0.1–0.7
Proteins	0.25–0.8