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Review

Characteristics of the organic fraction of municipal solid waste and methane production: A review

Rosalinda Campuzano *, Simón González-Martínez

Environmental Engineering Department, Institute of Engineering, National University of Mexico (Universidad Nacional Autónoma de México), 04510 Mexico DF, Mexico

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ABSTRACT

Anaerobic digestion of the organic fraction of municipal solid waste (OFMSW) is a viable alternative for waste stabilization and energy recovery. Biogas production mainly depends on the type and amount of organic macromolecules. Based on results from different authors analysing OFMSW from different cities, this paper presents the importance of knowing the OFMSW composition to understand how anaerobic digestion can be used to produce methane. This analysis describes and discusses physical, chemical and bromatological characteristics of OFMSW reported by several authors from different countries and cities and their relationship to methane production. The main conclusion is that the differences are country and not city dependant. Cultural habits and OFMSW management systems do not allow a generalisation but the individual analysis for specific cities allow understanding the general characteristics for a better methane production. Not only are the OFMSW characteristics important but also the conditions under which the methane production tests were performed.

Contents

1. Introduction

The definition of organic fraction of municipal solid waste (OFMSW) varies regionally and nationally; in the United States of America, OFMSW is considered a mixture of food, garden wastes and paper (Palmisano and Barlaz, 1996). In the European Union is considered a mixture of wastes from parks, gardens and kitchens (Al Seadi et al., 2013). Production and composition of OFMSW

Abbreviations: OFMSW, organic fraction of municipal solid waste; TS, total solids; VS, volatile solids; COD, chemical oxygen demand; TP, total phosphorus; KN, Kjeldahl nitrogen; FOG, fat oil and grease; NL, normalised litres; MSW, municipal solid waste; STP, standard temperature and pressure; BPM, biochemical methane potential.

* Corresponding author.
E-mail addresses: rcampuzanoa@iingen.unam.mx, rcampuzano.a@gmail.com (R. Campuzano).

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depends on geographic region, number of inhabitants and their social condition, predominant economic activities, regional food habits, season and recollection system (VALORGAS, 2010; Hansen et al., 2007b; Palmisano and Barlaz, 1996).

The world municipal solid waste production is approximately 1300 million tons per year (Hoornweg and Bhada-Tata, 2012; Al Seadi et al., 2013) and it is estimated that, in 2025, the production will rise to 2200 million tons per year with approximately 46% organic contents (Al Seadi et al., 2013). During many years municipal waste was disposed in landfills but, because of its environmental impact, regulations are now strict and allow landfilling only under special considerations (Browne and Murphy, 2013; Fdez.-Güelfo et al., 2011). Anaerobic OFMSW degradation takes place naturally in landfills and the produced biogas is generally released to the atmosphere or used for energy production (Palmisano and Barlaz, 1996). In Landfills, a system of wells and pipes collects the biogas and conveys it a boiler or turbine where it is combusted to generate heat or electricity, or simply flared (Themelis and Ulloa, 2007). Li et al. (2015) describe largely the environmental and economic benefits from using landfill methane for energy production. The actual tendency is to decrease the amount of wastes disposed in landfills and to use the landfills only for disposing of the remaining wastes (CEPA, 2008). The tendency is to avoid, reduce, reuse, recycle, recover, and treat and, if nothing else is possible, to dispose of the remaining wastes (Al Seadi et al., 2013). At the end of the 90s, European legislation ordered closing several landfills to start avoiding this practice and to promote the domestic separation of waste fractions (Mata-Alvarez et al., 2000).

During the last years, anaerobic digestion of OFMSW and other organic wastes has been used widely as a form to recover energy in the form of biogas (methane) and many researchers, companies and governmental agencies are actively working to improve the processes (Wang et al., 2014; Guendouz et al., 2010; Mata-Alvarez et al., 2000). In comparison with incineration or landfilling, anaerobic digestion does not represent a potentially polluting process when the produced biogas is adequately used (Wang et al., 2014; Dong et al., 2010; Guendouz et al., 2010) and the costs are relatively lower than aerobic treatment (Mata-Alvarez et al., 2000). Actually, anaerobic digestion is the most promising and sustainable process for the treatment of organic wastes because it produces energy and fertilizer complements such as compost rich in nitrogen (Walter et al., 2016; Fisgativa et al., 2016; Suwannarat and Ritchie, 2015). When processing the biogas properly it helps reducing the methane discharges to the atmosphere decreasing greenhouse emissions, smells and the sanitary disadvantages of landfills (Nielfa et al., 2015; Agyeman and Tao, 2014). On the other side there are disadvantages like the complexity of starting-up of the reactors (Angelidaki et al., 2006), increasing stabilisation time (Fernández et al., 2010) and the presence of toxic and inhibiting compounds when OFMSW is not properly separated from non-organic wastes (CEPA, 2008). Also, process control needs complex analysis because it is sensible to different waste composition affecting kinetics: instability of the process is common (Fisgativa et al., 2016). Kitchen wastes containing fat tend to affect negatively reaction kinetics (Suwannarat and Ritchie, 2015). These installations need a complex and complete waste management in order to become profitable (Walter et al., 2016).

Knowing the OFMSW characteristics and composition are essential when recovering energy through biological processes; these characteristics also affect the quality of digestate (Al Seadi and Lukehurst, 2012). Physical and chemical heterogeneity makes the characterisation difficult (Al Seadi and Lukehurst, 2012; Hartmann and Ahring, 2006; Buffiere et al., 2006; Jansen et al., 2004). Because of the possible presence of unwanted substances, European legislation does not allow the use of digestate as fertilizer when the separation is mechanical (Browne and Murphy, 2013; Hansen et al., 2007a).

Several investigations have concentrated their efforts to study the relationship between biogas production and OFMSW physical characteristics such as particle size and type of components after mechanical separation; others analyse chemical characteristics like molecule types and elementary composition, and bromatological properties such as macromolecules (Melts et al., 2014; Xu et al., 2014; Browne and Murphy, 2013; Bernstad et al., 2013; Bernstad and Jansen, 2012; Banks et al., 2011; Labatut et al., 2011; Izumi et al., 2010; Forster-Carneiro et al., 2008a; Hansen et al., 2007a; Davidsson et al., 2007; Zhang et al., 2007; Gunaseelan, 2004). Other researchers studied variations in physical, chemical and bromatological characteristics according to geographical region, population number and socioeconomic development, climate and seasonal conditions, and recollection systems to know the advantages and disadvantages to use OFMSW for biogas production (Al Seadi et al., 2013; Bernstad and Jansen, 2012; Hansen et al., 2007b; Jansen et al., 2004).

The main objective of this work is to make an analysis of the OFMSW characteristics of cities from different countries and compare them with their corresponding methane production.

2. Method

Information about methane production found in articles is often reported without considering commonly accepted units. This work is an effort to extract the information from articles and to homogenise the units it in order to make a comparison possible. Into account were taken characteristics such as solids, humidity, cellulosic compounds, nutrients contents, type of reactor the authors used and methane production. Knowledge of the similarities and differences allow researchers and practitioners compare their experimental results with other investigations.

2.1. Literature selection

All articles reported belong to indexed journals in English. For this purpose the online data bases Scopus, Science Direct and Scholar Google were used. The selection criteria for the search was: (a) Less than 15 years (2001–2016); (b) source-separated and mechanically-separated OFMSW (without metal, glass, stones and plastic); (c) the articles used OFMSW for different biological treatment processes; (d) no combined OFMSW with other organic materials was considered; (e) only the reference with the most complete information from every city was taken into account.

2.2. Data extraction

The OFMSW characteristics were classified as physical, chemical and bromatological. Most of the authors report only few characteristics with different units, according to the objectives of their work. The information summarised in this paper is homogeneous (as far as possible) for comparison purposes. In order to homogenise the information it was necessary to transform units and calculate concentrations and contents from every article presented. In several cases the methane production reported did not comply with standard conditions. From the countries with the highest number of reports, only one report from every city was considered.

3. Physical characteristics

There are different criteria to categorize solid municipal wastes and OFMSW. VALORGAS Project (valorisation of food waste to