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Comparison of Treatment Methodologies to Improve Anaerobic Biodegradability of the Organic Fraction of Municipal Solid Waste

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Abstract

The correct disposal of the organic part of municipal solid waste is becoming a critical concern around the world. The consequences of inappropriate disposal include degradation of the environment, public health risks, and a scarcity of dumping ground. Anaerobic digestion can help with embodied energy recovery from organic waste, as well as waste reduction. Among the parameters affecting digestion efficiency and cumulative methane production, the chemical makeup of the substrate is critical. In recent years, there has been a growing interest in treating substrate to improve digestive performance. This paper examines several treatment procedures, such as mechanical, thermal, chemical and biological for increasing methane yield from anaerobic digestion of municipal solid waste's organic content. The correct disposal of the organic part of municipal solid waste is becoming a severe concern all over the world. To provide a proper understanding of the various processing methods, environmental pollution, treatment procedures, comparison of treatment methodology, and techno-economic assessment have all been presented.

Key Words: Municipal solid waste, Pollution, Energy recovery, Environment, Organic Waste

Introduction

Municipal solid waste (MSW) is a popular feedstock for anaerobic digestion (AD), which is considered a promising way to generate biogas. AD is a natural practice whereby feedstocks are broken down into renewable fuels (biogas in this case) and digested by a consortium of microorganisms in the absence of oxygen.Biogas from AD contains CH4 (50-70%), CO2 (30-50%) and small amounts of significant impurities such as NH3, H2S, siloxanes, halides and water vapor. Biogas from anaerobic digestion of OFMSW can be used directly in combined heat and power (CHP) units, cooking or purified for transport purposes.Anaerobic treatment of digested runoff can produce sustainable residues for use as soil amendments or to recondition certain types of soil. Another reason to use AD to treat waste is that the producers can earn emissions reductions (CER) credits through a clean development mechanism (CDM) defined in the Kyoto Protocol. The IPCC Guidelines (2006) recommend that cities should aim to reduce their emissions to below 1990 levels by the year 2050. This will require significant reductions in emissions from transportation, buildings, and other sectors.Besides the environmental benefits of waste treatment, government agencies and private companies have invested heavily in advanced AD technologies because of the increasing energy demand and environmental concerns such as global warming.

Since the substrates used in AD are relatively complex, hydrolysis has been reported to be the rate-limiting phase among the four phases that occur during AD namely hydrolysis, acidogenesis, acetogenesis, and methanogenesis.This observation was based on the description of individual biodegradation kinetics of carbohydrates, lipids and protein, and the hydrolysis step generates byproducts such as volatile fatty acids (VFAs) that are undesirable for the bioreactor in excessive amounts that inhibit methanotrophic bacteria. Many studies have been conducted using different treatment techniques to speed up the hydrolysis phase without producing harmful by-products. Several methods have been reported for recovering components such as nitrogen and phosphorus from waste and using them as soil amendments. Organic waste can make it harder for the methanogenesis process to occur. This complexity may be altered by different pretreatment (mechanical, thermal, biological, chemical, etc.). This technique involves breaking down the molecular barriers around the target. Thermal hydrolysis was attempted on various types of biological sludge, cow manure, grease waste, and spent grains before AD.Methane production increased by 1.5-fold when these materials were used. It was hypothesized that integrating thermal hydrolysis into a crop's production process may enhance up to 40% of the plant's income.

The purpose of this paper is to explore the complexity of the OFMSW and to consider various pretreatment methods that may help to overcome it. Environmental and technological aspects of pretreatment are discussed to see how pretreatment technique affects the environment. A comparison of pretreatment methods is provided to help readers understand pretreatment better.Now that we have covered the basics of biogas and its potential uses, we can discuss some of the challenges associated with its production and use.

Categorization of the OFMSW

AD has been inclusive in its handling of the OFMSW for the past few decades. Modern trends focus on the link between anaerobic and aerobic processes , gaining net energy gain from methane and production of soil conditioners from substrates. Depending on the composition, source, and biological structure of OFMSW, and therefore the source, significant changes have been observed in its particular content. Categorization of waste should take into account regional, seasonal, and socio-economic impacts. OFMSW includes food waste, kitchen waste, leaf, grass clippings, flower trimmings, and yard waste. Wasted food is a significant part of organic material. Restaurants' leftovers are also a large part of the OFMSW. Yard waste includes materials like grass clippings and straw, leaves, weeds, and that from trees like leaves and branches.

Different Methods Used to Treat OFMSW

Improvement of AD process depends on the treatment that is a fundamental step and alters the substrate features. The biogas yield of OFMSW from AD is strongly affected by the substrate availability and mass transfer . Treatment techniques aim to break the barrier between microbes and nutrients, which will speed up the chemical reaction.Researchers who use OFMSW treatments have mostly opted for thermal, chemical, and mechanical processes, accounting for 24%, 21%, and 33% of treatments, respectively. The hydrolysis phase is the most important step in the overall performance of a biogas digester, during which complex compounds are converted into oligomeric and monomeric units.

Thermal Treatment

Thermal treatment is often used as a molding procedure for raw or processed waste, because it enhances the dewater ability properties of the waste. The study looked at the effects of different temperatures on kitchen waste breakdown. Higher temperatures were found to speed up the hydrolysis process. Treatment at 60 °C showed the best results, achieving a hydrolysis capacity of 27.3% and a fat removal rate of 37.7% compared to the untreated sample. Thermal treatment can help expel pathogenic bacteria, improve dewatering and reduce the thickness of the digestate. A wide range of temperatures (50–250 °C) have been established for AD refresh of the diverse organic fraction of solid waste by different groups of researchers. The primary effect of heat treatment is to disrupt the cell wall and aid in the dissolution of organic matter (Marin et al., 2010; Protot et al., 2011). The solubilization of CO2 and temperature have a direct impact on the yield of biogas. Higher solubilization may also be achieved at lower temperatures, but the treatment time required is longer. Motets etc.(2009) studied various heat treatment techniques and reported no significant distinction between steam and electric heating, while microwave heating was observed to melt more biopolymers.

The better charge of solubilization with microwave remedy become because of the phenomenon of polarization of macromolecules gift withinside the feedstock (Toreci et al., 2009; Marin et al., 2010). Thermal remedy at extensively excessive temperatures (>170°C) might also additionally end result into formation of bonds and agglomeration of the particles. Maillard response is stated to provide complicated recalcitrant substrates from starch and amino acids, while subjected to excessive thermal remedy (150°C) or longer remedy time at lesser temperature (<100°C) .

The influences of thermal remedy at the chemical and bodily houses of kitchen waste, vegetable waste and waste activated sludge have been explored through Liu et al. (2012). Outcomes discovered that thermal remedy (175°C, 60 min) faded the viscosity and accelerated COD, dissolvable sugar and proteins. A discount of 7.nine and 11.7% of methane turned into discovered for kitchen and vegetable waste respectively. The authors ascribed this phenomenon to the association of an intractable copolymer and melanoidin (Maillard response products). Under associated running conditions (170°C, 1 h), Qiao et al. (2011) discovered that each biogas and methane technology from anaerobically dealt with FW and cow manure have been faded through 3.four and 7.5% respectively because of decrease pH and better VFAs. Ma et al. (2011) said a 24% enhancement in CH4 manufacturing whilst FW turned into dealt with at 120°C.

Chemical Treatment

A variety of chemical compounds viz. acids, base, and oxidants (e.g., ozone, peroxide) had been efficiently hired to interrupt down herbal constituents (Carrere et al., 2010). Chemical remedy is applied to breakdown the linkages in plant mobileular wall through using sturdy acids, alkali or oxidants. Alkali remedy is taken into consideration as the popular chemical remedy whilst as compared to different remedy methods (Li et al., 2012). During alkali remedy, the number one responses that take place to the substrate are solvation and saponification, which instigates the swelling of solids (Carlsson et al., 2012). Subsequently, the floor place is expanded, and the substrates are efficiently to be had to anaerobes.

Ozonation is a way with the aid of using which biogas upgradation can be executed in conjunction with greater hydrolysis rate. However, chemical remedy is assumed to be much less suitable for without problems biodegradable or much less recalcitrant substrates. Feedstocks encompassing excessive quantities of starch, confirmed improved biodegradation ensuing in get admission to VFA, which might also additionally inhibit methanogenesis step (Wang L. et al., 2011). However, it is able to have useful results on lignin wealthy substrates that has complex community of lignin carbohydrate complicated linkages (Fernandes et al., 2009). López Torres and Espinosa Lloréns Mdel (2008) pronounced an multiplied OFMSW AD efficacy after a number one remedy with Ca(OH)2. The addition of 62.zero mEq Ca(OH)2/L in conjunction with stirring for six h led to 11.5% increment withinside the soluble COD (sCOD) out of the combination COD.

Other downside related to acidic remedy consists of lack of fermentable sugars due to the continuing degradation of complicated substrates, the excessive price of acids. Additional price related to base this is had to neutralize dealt with substrate earlier than the AD manner has been suggested to be a depend of concern (López Torres and Espinosa Lloréns Mdel, 2008; Kumar and Murthy, 2011). In few cases, including acids may be powerful for the anaerobic absorption of protein-wealthy substrates through era of ammonia. However, this could prevent the biogas production (Hansen et al., 1998) because of the truth that microbes get inhibited withinside the presence of ammonia. In spite of the thrilling outcomes from anaerobic trials of chemically dealt with waste, lots of room is to be had for development in pH healing at some stage in pilot scale programs for financial viability in addition to sustainability of the manner.

Biological and Biochemical Treatment

Promoting microbial increase on biomass ought to considerably beautify hydrolysis of the substrate. This may be carried out through the utility of commercially to be had enzymes in addition to developing microbes on it (Yin et al., 2016). Fdéz-Güelfo et al. (2011a) stated that the addition of compost (crafted from manure) to business OFMSW facilitates in lowering the dissolved natural compound (DOC) through 61% and VS through 35% in comparison to control. As a result, the biogas and methane technology expanded as much as 60 and 73%, respectively. While evaluating the usage of manure compost, organic remedy (the usage of fungus Aspergillus awamori) confirmed higher hydrolysis results (Fdéz-Güelfo et al., 2011b). Several different research concluded the prevalence of using organic remedy in comparison to thermochemical-handled substrates for expanded AD rate.

Impact of pH value on two-level AD turned into studied through Zhang et al. (2005). The studies institution endorsed retaining the pH at 7 whilst hydrolysis is being finished withinside the reactor. This could beautify the general natural strong intake and assist to beautify the biogas production. White rot fungi, regarded to devour lignin, leaving in the back of cellulose can be efficaciously carried out for organic remedy. Group of researchers have already said the excessive de-lignification productiveness of numerous white rot fungi on exclusive lignocellulosic biomass (Keller et al., 2003; Shi et al., 2009; Kumar and Wyman, 2010). Keller et al. (2003) concluded that treating lignocellulosic residues the usage of fungi should convey numerous blessings such as (i) green procedure, (ii) no chemical requirement, (iii) reduced power input, (iii) working at ambient conditions, (iv) less expensive unit operations, (v) much less spinoff generation, (vi) no washing step and (vii) negligible inhibiting agent production. However, Shi et al. (2009) pondered that most effective disadvantage of fungal remedy is that it is time-ingesting manner and require tremendous quantity of area and further infrastructure to keep the substrate for a length of 20–30 days. Pasteurization of substrate previous to fungal mycelium inoculation will upload extra fee to the manner.

Comparison of Treatment Methods

Efficiencies, monetary attainability and ecological impacts are criteria for the selection of required treatment strategy prior to AD of OFMSW. There are different types of treatment technologies available based on the origin and variety of biomass. These technologies may be physical, mechanical, chemical, biochemical, thermal as well as combination of the treatment methods for disrupting the cell walls. Every technology has their own pros and cons and it may not be possible to recommend the treatment technology, which is suitable for all types of biomass, as every biomass is unique in terms of its chemical composition and hence a specific treatment method may be required for its disruption and obtain maximum energy. The effectiveness of any treatment strategy can be assessed through the increased methane yield and VS reduction.

Environmental Impacts of Treatment

Besides the energy balance and techno-economic investigation, environmental aspects i.e., pathogen expulsion, utilization of chemicals, the likelihood for a manageable utilization of the deposits and impacts on human health has to be considered while opting a treatment process (Stabnikova et al., 2008; Thorin et al., 2012; Di Matteo et al., 2017). The solids that are generated after AD process has the potential to be used as soil amendments, which is good for the environment. Life cycle assessments (LCA) will help to assess the efficiency and environmental impact of AD process. Only few researchers have assessed the environmental impacts of using treatment technologies before AD of solid wastes. Carballa et al. (2011) have performed the LCA to evaluate environmental attributes associated with the use of seven treatment technologies (alkaline, acid, thermal, thermal acid, freeze-thaw, pressurize-depressurize, and ozonation) for kitchen waste and sewage sludge. Impacts were analyzed with respect to the potential of abiotic resource depletion, eutrophication, global warming, human toxicity and terrestrial ecotoxicity. The researchers suggested that pressurize-depressurize and chemical treatment techniques outstripped ozonation, freeze–thaw and thermal strategies by having a minimum adverse environmental impact. Nwaneshiudu et al. (2016) assessed the environmental impact of mild bi-sulphite treatment of forest residues. The study reported less eutrophication impact of forest residues as compared to the effects from traditional beet and cane sugars, while the global warming impact falls within the range of conventional processes. However, the scarcity of literature regarding the evaluation of environmental impacts of treatment methodologies is inevitable. Adding environmental impact assessment in addition to technical and economic evaluation of treatment will help biogas production environmentally sustainable.

Conclusion and Future Aspects

The demand for renewable energy and rise in global warming due to greenhouse gas emission has motivated many government agencies to identify new methods to sustainably produce biogas using AD system. Most treatment techniques have been assessed at batch scale to evaluate the biogas potential from treated OFMSW. However, very limited reports are available that demonstrate biomethanation process at pilot scale using newly developed methods and technologies. Several scientific modifications have to be encountered when the lab scale experiments are translated to large/industrial scale operations. Also, anaerobic biomethanation plants should be operated 24 × 7 in contrast to the one under the controlled lab-scale conditions. Generating energy from OFMSW using anaerobic assimilation research is mainly in two areas, (i) understanding the fundamental of treatment systems and (ii) assessment of the technical and monetary attainability of the joined treatment/anaerobic processing framework. Promising treatment method that is developed in lab scale should be further scaled-up in order to evaluate the overall cost of processing and sustainability. Different treatment procedures viz. physical, thermal, combined, organic or chemical have extensively been attempted at lab scale under defined conditions. Other processes that have been demonstrated at large scale include mechanical, thermal and thermochemical techniques. Anaerobic digestion offers benefits compared to the other disposal procedures for OFMSW considering a fundamental sensibility assessment. Treatment technologies still require advancements at different faces viz. higher biogas yield, efficient management of pathogen, reduction of digestate and reducing the hydraulic retention time as well as the techno-economic viability. The OFMSW offers huge biogas potential and promising opportunity for renewable energy generation, nutrient recovery as well as future research avenues in the area of sustainable waste management and treatment.

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