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Performance of up-flow anaerobic fixed bed reactor of the treatment of sugar beet pulp lixiviation in a thermophilic range

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HIGHLIGHTS

- SBPL as substrate; high content of microorganisms in SBPL.
- Improve biogas productivity and the organic matter removal.
- Different OLRs and hydraulic retention times (HRTs) were carried out.
- The greatest efficiency; 90% COD removal for an OLR of 4.3 kg COD/m^3 d.
- OLR was directly correlated with active microbial biomass.

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ABSTRACT

The acclimatization and performance study of lixiviation of sugar beet pulp are carried out in upflow anaerobic fixed bed reactor in thermophilic range of temperature (55 °C). Several hydraulic retention time is conducted (11, 8, 6, 4, 2, and 1.5 days). The performance study showed that Chemical Oxygen Demand removal efficiency is 90% for 6 days-HRT. While COD removal efficiency was reduced within the range of 74.3% and 59.4% in others HRT. Organic loading rates greater than 10 kg COD/m^3 d in influent, (2 days-HRT), produces a destabilization of the process due to total acidity accumulation in reactors although is the HRT with highest methane production.

The results showed that an increase in OLR was directly correlated with active biomass inside reactor but not with the amount in microbial community. The bacterial concentration inside the reactor is strongly influenced by the content of microorganisms in the lixiviation of sugar beet pulp.

1. Introduction

The anaerobic digestion process provides a very efficient way to transform organic waste into an innocuous gas (methane) which is capable of providing energy. However the low settling velocity of anaerobic digestion in a conventional digester makes solid–liquid separation difficult, which results in a large reactor volume, poor effluent quality, and unstable anaerobic digestion. The immobilization technology which has been developed to increase productivity in the fermentation industry (Mozaffar et al., 1986) has been applied to anaerobic treatment in order to overcoming the demerits of the conventional process (Scherer et al., 1981). Regardless of their adhesiveness to biocarriers, almost all of the microorganisms contributing to anaerobic digestion can be held in the biosystem by using immobilization technology, which offers anaerobic bacteria protection from the effects of inhibitory substances (Speece, R.E., 1983) and gives a high ratio of SRT (solid retention time) to HRT. This high ratio is favorable since maximal SRT provides process stability and minimal sludge production, and minimal HRT minimizes the reactor volume.

Spain has approved several National Plans covering different waste categories and contaminated land over the past few years. The new National Integrated Waste Plan 2008–2015 (PNIR, Plan Nacional Integral de Residuos), approved by the Council of Ministers in December 2008, is intended to serve as a guide for the development of specific policies to improve waste management by reducing its generation and promoting its correct treatment.

This Plan establishes specific waste reduction, reuse, recycling, assessment and elimination targets and covers the treatment of household waste, specific waste, contaminated land and some non-hazardous agricultural and industrial waste. It also includes a Biodegradable Waste Discharge Reduction Strategy.

There already exists recent literature about applications and benefits of the anaerobic digestion process to produce renewable energy from various sources of biomass (Angelidaki et al., 2006). Furthermore, there also exist several works about continuous

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Notation

UAF	upflow anaerobic fixed bed (OR FILTER)	OLR_0	initial organic load rate
COD	chemical oxygen demand (soluble)	TSS	total suspended solids
HRT	hydraulic retention time	VSS	volatile suspended solids
OLRr	organic load rate removed	SBPL	sugar beet pulp lixiviation

anaerobic digestion of sugar beets for production of methane (Gallert and Winter, 1997; Jarrell and Kalmokoff, 1988).

Most renewable energies, and in particular, agricultural biomass waste, are energy sources scattered around a given country. The agro-industrial biomass waste generated is concentrated and its management in the same places from where it originates requires sufficient quantities of waste for energy recovery to be technically and economically viable.

Furthermore, production of the beet crop has risen in recent years, justified by its high energy productivity (3.5–4.5 t bioethanol/Ha). This crop generates high quantities of waste, such as sugar beet pulp, which has to be treated. In this regard, the anaerobic digestion of organic waste is a good choice.

Pretreatment with sugar dried pellets yields a homogeneous liquid effluent with high organic load, suitable for use in fixed bed reactor.

Section 2 shows the characteristics of the substrate that was used in terms of the organic matter content. Pellets were subjected to biological pretreatment before the co-digestion process in order to promote hydrolysis and solubilisation of the organic matter and therefore, improve anaerobic digestion in the generation of biogas and possible final residue agronomic valorisation.

Other pretreatments have been studied in order to improve solubilize the substrate, substrate reduction or for the enhancement of biodegradability (Kavitha et al., 2013; Esakki et al., 2013; Rani et al., 2011, 2012).

Anaerobic processes operating under thermophilic conditions (55 °C) have attracted a great deal of attention in recent years due to their apparent advantages, which include high pathogen destruction, enhanced hydrolysis of complex organic/biological materials, and foaming reduction (Hartmann and Ahring, 2005).

Anaerobic digestion which is ultimately converted into methane and carbon dioxide, is carried out by the coordinated action of various groups of microorganisms and goes through several intermediate stages. The intermediary products are volatile fatty acids, acetic, propionic, and butyric acids. Two-thirds or more of the methane produced in anaerobic bioreactors is derived from acetate (Zinder, 1993). The conversion of acetate to methane by methanogenic populations becomes the rate-limiting step in biogas production, as methanogens are known for their slow growth, resulting in a relatively small population size (Zinder, 1993). The parameters normally employed in the control of anaerobic digestion, such as the percentage of COD removal, the concentration of volatile fatty acids and the amount and composition of biogas generated in the process, are not always representative of the composition and physiological state of biomass contained within the system. From a practical standpoint, given the importance of methanogens in anaerobic treatment processes, the ability to monitor methanogens and understand their ecology is essential to make effective controls of the start-up and operation of anaerobic bioreactors possible. Consequently, and in order to acquire more detailed information regarding of this biomass, other parameters have also been used in the characterization of the microorganisms responsible for the anaerobic processes. Direct counting procedures by microscopic methods reach the highest estimation of members of microorganisms and are occasionally used for indirect calculation of biomass. Epifluorescence microscopy with fluorometric stainings are widely used for direct counting of microorganisms, since it does not require culturing (Kepner and Pratt, 1994).

Molecular tools as fluorescence in situ hybridization (FISH), based on sequence comparison of small-subunit (SSU) ribosomal RNA (rRNA) molecules have made it possible to detect specific whole cells/organisms in biological samples as anaerobic reactors (McMahon et al., 2001; Montero et al., 2008, 2009; Zahedi et al., 2013).

Generally, the treatment capacity of an anaerobic digestion system is determined by the amount and activity of microorganisms, which in turn is influenced by wastewater composition, system configuration and operation of the anaerobic reactor. Unlike the conventional biofilm systems in which the growth support media are fixed in space either by gravity or by direct attachment to the reactor wall, the anaerobic fluidized bed system retains the growth support media in suspension by drag forces exerted by upflowing wastewater. Moreover, the distribution of biomass hold-up (in the form of a biofilm) is relatively uniform because of the completely mixed conditions maintained and the continuous biofilm sloughing process, which counterbalances the accumulation of biomass due to the growth. This is because of the biomass hold-up, which can be directly measured in terms of attached volatile solids using the techniques developed by Mulcahy and Shieh (1987).

A good design, starting and operation of these systems require knowledge of the mechanisms of absorption and fixation of microorganisms. It is necessary to establish the effects caused by the tensions generated between the effluent and the particles. The high complexity of all interactions leads to an unknown complete mechanisms of the colonization process.

The microbial biofilm can be developed on any surface where microorganisms can grow. This can be considered as the result of various physical, chemical and biological processes that constitute the following steps:

- Transport and absorption of organic molecules on the surface.
- Microbial movement of the cells to the surface.
- Surface adhesion of microorganisms and monocell formation.
- Development and accumulation of biofilm as a consequence of microbial activity and flora growth.
- Detachment of biofilm due to hydraulic fluid tensions.

When the surface of a solid particle or even reactor walls are in contact with an organic matter suspended in influent, a spontaneously initial absorption of nutrients and microorganisms occurs.

Physical, chemical and biological characteristics of biofilm depend on certain environmental conditions prevailing the base material for the attachment of the microorganisms. Factors such as temperature, pH, salts and nutrient levels affect the process.

Differents methanogenic species attached to support in an organized manner making easier the transfer of substrate (especially H2, important intermediate metabolite). Other chemical properties as the composition of the influent, the rate of biofilm development, cellular interactions are factors to take into account in the evolutive process of colonization of the support.