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Environmental treatment of slaughterhouse wastes in a continuously stirred anaerobic reactor: Effect of flow rate variation on biogas production

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ABSTRACT

The present study shows the treatment of slaughterhouse wastes of Badajoz municipal in Spain by an anaerobic codigestion process. The experimental device used was a completely mixed type (6-l capacity) continuous biodigester with recirculation of the methane produced in the anaerobic digestion. Under mesophilic conditions (37 °C), the biological anaerobic degradation, biogas production, and inhibition processes were analyzed for six flow rates; 200, 275, 350, 400, 537, and 672 ml/day. It was found that the environmental optimum flow rate is 350 ml/day for energy production.

1. Introduction

There are several methods for biological elimination of animal wastes and cattle. The principal thermal aim is getting a biogas rich in methane, in order to monetize the process. Among them is the fermentation of wastes from poultry slaughterhouses and cattle [1,2] with little production of biogas and that of anaerobic biodigestion can generate more amount of biogas [3].

Moreover, slaughterhouse wastes are among the most contaminating of meat industries. These generally contain organic matter, fats, suspended solids, phosphates, nitrates, nitrites, and sodium chloride. The sources of these contaminants are: from the stalls, excreta, and cleaning and disinfection water; from the slaughteryard, blood, hair, meat scraps, fat, bones, and belly contents; and, from the rendering rooms, hot water used in processing stomachs and intestines, and caustic solutions and detergents used in cleaning and disinfecting.

It is shown that the anaerobic biodigestion is a good process for the elimination of meat wastes and provides the necessary technology to eliminate fats and protein residues efficiently [4].

Since there exist plants for melting down the fats, processing the offal, and converting blood into animal feed or fertilizer, and the existence of a good market for these by-products, it is unfortunate that a large proportion of them end up in the public sewage network. This has led to ever stricter legislation aimed at impeding the discharge of meat industry wastes into the environment, and at insisting on the need to treat the wastewater before being released into the sewage system. In the case of Extremadura, without due measures being taken, the annual contamination from meat industries has been quantified as some 4.5 million EH [5,6].

As a contribution to solving this environmental problem, for several years now there has been an ongoing research program in the Alternative Sources and Renewable Energies Laboratory of the Industrial Engineering School of the University of Extremadura: The first results on the biodegradation of slaughterhouse solid and liquid wastes were obtained using a batch reactor [6]. They formed the basis for the design and construction of a continuous-flow stirred-tank reactor (CSTR) type continuous digester.

There are various tests and trials that have been carried out with co-digestion and anaerobic digestion, in order to obtain a biogas that makes the treatment profitable. Among them are the elevation of pressure and temperature in the process of digestion or in the pretreatment, that have not provided good results [7], or those that provide an increase in lipids or change the structure of the bacterial community of reactors [8], also with some discrete results.

With regard to the saponification of the lipids in slaughterhouse wastes during the process of pretreatment or the use of ethanol biodegradation, it has been shown that it improves biogas production and in some cases the reaction kinetics [9,10], but the results are not too bright for a definitive incorporation into the process.

Since the influent flow rate is a fundamental factor in the design of a real anaerobic waste treatment plant, one of the first tasks with the continuous digester was to determine the value of this parameter that optimized conjointly biogas production and biodegradation. There is work in the literature on the effect of varying the flow rate in batch anaerobic digesters [11], but references to continuous digesters are difficult to find and to be known its influence.

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Nomenclature

COD	chemical oxygen demand
BOD5	biological oxygen demand
SMA	specific methanogenic activity
EH	equivalent inhabitants
VS	volatile solids
WWTP	wastewater treatment plant

The principal objective of the present work was therefore to determine the effect of influent flow rate on the biogas production and the decontamination of solid and liquid wastes from the Badajoz municipal slaughterhouse using a continuous CSTR-type digester.

2. Experimental procedure

The experimental CSTR-type digester consisted of a 6-l tank mixed by means of forced convection of methane produced in the anaerobic digestion (Fig. 1). The digester was primed with a suitable volume of anaerobic sludge from the Badajoz sewage treatment plant. The components of the digester were the following:

(1) Primary digester/reactor (stirred tank)
(2) Secondary digester/degassifier
(3) Control system
(4) Pumping equipment
(5) Heating system
(6) Substrate tank
(7) Feed stream
(8) Gas stream
(9) Slurry stream
(10) Product slurry stream
(11) Sampling

2.1. Primary digester/reactor (stirred tank) (1)

The primary digester is of the CSTR type, heated and with complete mixing. Its volume is 6.2 l. Given the scale, and that the equipment is for indoor use, there is no problem in maintaining the temperature by means of ceramic resistances installed at the bottom of the digester, fed a security current at 24 V.

The influent flow rate to the digester is controlled by a peristaltic-type dosing pump at either a constant or a programmed rate. Mixing is by means of re-compressing the biogas that is produced in the digestion process. Two major advantages of this arrangement are the ease of cleaning the systems, it being unnecessary to halt or unmount the components of the digester, and the scalability of the system to digesters of different sizes.

The amount of biomass in the digester is maintained by means of an overflow. Surplus biomass can be led off to a secondary digester or to an appropriate deposit.

2.2. Secondary digester/degassifier (2)

The design of the secondary digester as a (6-l capacity) movable rigid bell jar presents the following advantages:

Ease of monitoring the volume of biogas produced the movable bell allows a visual reading of the accumulated biogas.

Safety the liquid content forms a barrier that is impermeable to the biogas. Surplus biogas or biogas produced within the bell jar is completely sealed off, and can be led of to a secure place (burner, a Tedlar gas sampling bag, or simply to the exterior). Fire risks and bad odours are thus totally obviated.

The possibility of secondary digestion the gasometer can operate as a secondary digester, with a second accumulation of the effluent (without temperature control). It can also operate without secondary digestion by being filled with clean water. In the secondary digester mode, it has a purging system for sampling the settled sludge, and an overflow system that is analogous to that of the primary digester for the control of the level.

2.3. Control system (3)

The control system comprises the elements that control the influent and digester temperature and mixing systems. It consists of a locker, a control element, and electrical elements.

2.4. Pumping equipment (4)

A peristaltic pump draws the gas off from the digester, and, under the control of a programmable automaton connected to electrical valves and a collector, recirculates the gas to mix the slurry in the tank or leads the surplus gas off to the secondary digester or to the bell jar for storage.

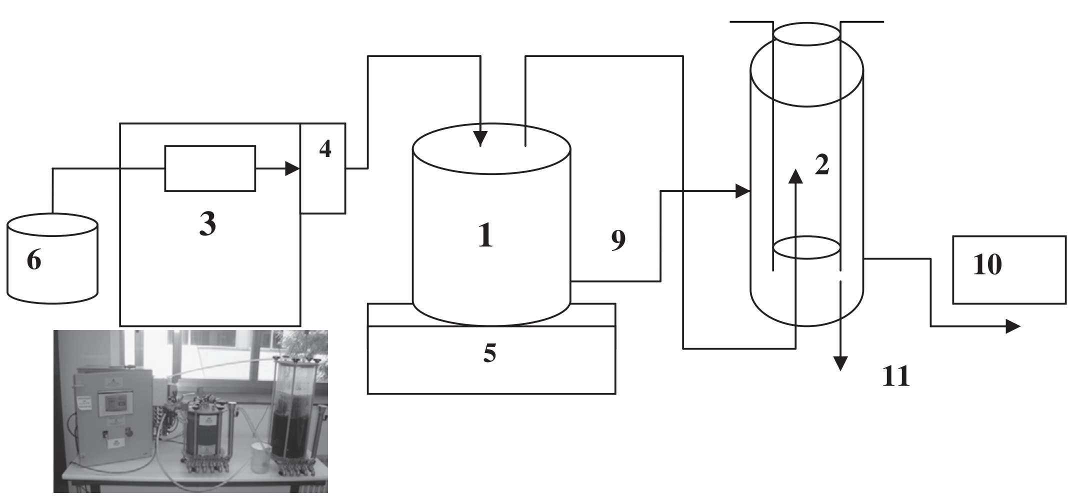

Fig. 1. Schematic diagram of a continuous anaerobic digestion pilot plant.