BIOGAS PRODUCTION

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Abstract
This paper presents the recovery of energy from municipal solid waste through biological treatments like biogas production. The biogas production is an aerobic or anaerobic treatment of waste. The anaerobic digestion is a typical example of transfer at the industrial scale of a natural process. In fact, methanogenesis is a routine process occurring in some environments as the oceanic and lagoon sediments, or in animal's intestine.

Key words: biogas, waste, production, treatment.

INTRODUCTION

The high water content of VGF discourages the thermal treatment of these substrates. This technology would result economically disadvantageous. VGF or VGF nerve growth factor inducible is a protein and neuropeptide that may play a role in regulating energy homeostasis, metabolism and synaptic plasticity. (7) The protein was first discovered in 1985 by Lewi et al. in an experiment with PC12 cells and its name is non-acronymic. VGF treatment must take place close to the area where it has been produced for two main reasons:

1. Its specific volume makes the transportation quite expensive.
2. VGFs are good substrate for bacterial growth and, therefore, are easily attacked by microorganisms.

This latter property has to be carefully considered when planning the VGFs treatment procedure, as the action of some microorganisms may represent the most "natural" treatment technology. The conversion of VGF could in principle take place in the presence or absence of oxygen. The two processes are referred as "aerobic" and "anaerobic" treatment, respectively.

The microorganisms' respiration process, occurring in aerobic environments, leads to carbon dioxide (CO_2), water (H_2O) and biomass production (bacterial cells). This implies that an aerobic treatment may be suitable only for soluble materials and in non concentrated systems. In fact, the O_2 availability is a key point, often more important than the substrate composition. For a better result and a faster process, solid materials and suspended fine particulate are removed by biof1oculation or degradation.

Aerobic organisms can degrade solid organic substances, but the

kinetics is very slow and a proper air supply is needed.(4) A partial aerobic degradation of solids typically occurs during the "compost" making, when relatively dried organic solid wastes are converted by oxidation. The aerobic treatment, during the respiration phase, releases energy that is lost. Moreover, while the compost can be used as soil amend ant, the biomass produced in several other treatments (water, wastes) cannot be directly disposed in a landfill or used, because of the microbial content.

The *anaerobic metabolism* does not require oxygen and, therefore, is suitable for treating wet concentrated wastes or also some vegetal organic wastes. The main theoretical limits to the application of an anaerobic process are:

- Incomplete conversion of the substrate (often more than 50% of the organic material is not degraded).
- Medium- or long-retention time.
- Formation and persistence of some acids that may be polluting agents.
- Bacteria may need some nutrients that are not available in the original substrate. Their growth may be slow because of the scarce energy available.
- Permanence of ammonia (NH_3) and other N-compounds.

Some of these problems already found a solution at the industrial scale plant, others, like the persistence of N-compounds, need further studies and research.(5)

MATERIALS AND METHOD

The anaerobic digestion occurs under anaerobic conditions and is typical of both strict anaerobic bacteria and bacteria that growth either in anaerobic or aerobic conditions (facultative anaerobic). In this process, the organic substances are converted to methane and carbon dioxide. The process is driven by different bacteria in three phases. The first phase actually consists of two different steps driven by hydrolytic bacteria: the hydrolysis of polymeric organic compounds like carbohydrates, lipids, proteins, followed by the acidogenesis during which organic acids, alcohols, neutral compounds are produced. The hydrolysis and acidogenesis products are then converted into acetate, hydrogen and carbon dioxide by the "Obligate Hydrogen-Producing Acetogens" bacteria (OHPA). Acetate, hydrogen and carbon dioxide are ideal substrate for the "methanogenic" bacteria producing methane and carbon dioxide.

Acetate, the substrate that is mostly used by methanogens, is also produced by a fourth bacterial class called homoacetogenic bacteria that can ferment a wide spectrum of substrates. The methane yield of the anaerobic digestion mainly depends on the yield of the hydrolysis of the organic fraction. (8) Lignin, for instance, under anaerobic conditions is hardly

biodegraded. The difficulty is essentially due to the lack of specific hydrolytic enzymes in anaerobic bacteria, and the oxygen demand typical of hydrolytic enzymes. For this reason, it may be useful to treat the organic fraction with specific hydrolytic agents (fungi, other microorganisms) before the anaerobic digestion is started. This procedure may increase the methane yield and reduce the solid fraction.

Methane production also depends on the biodegradable organic fraction com- position: "reduced" compounds (like proteins and lipids) give better methane yield than "oxidised" compounds (sugars). Different processes regulate the methanation speed. If the substrate is rich of polymeric materials like cellulose, the rate determining step is the hydrolysis. If the substrate is soluble, it is the methanation to determine the overall rate.(5)

The parameters most commonly used are:

- Methane production.
- Methane volumetric rate (RV).
- Organic substance degradation rate (RD).
- Culture stability.
- Thermal efficiency.

The chemico-physical changes in the biodegradation of a substrate are typical of an exoergonic process. Two levels of biodegradation are usually distinguished:

- Primary, in which the reaction products are directly related to the original compounds (e.g. from cellulose to glucose).
- Final, in which the substrate is converted into CH_4 and CO_2 (e.g. from cellulose to methane).

While the biodegradability of a waste, that is the fraction that can be converted into biogas, depends on the degradation thermodynamics, the biogas daily yield depends on the kinetics of the process. A compound that is not biodegradable or requires a long induction time for biodegradation is defined "refractory".(6)

RESULTS AND DISSCUSION

The first reaction occurring in a digester is the depolymerisation of substrates with a high molecular mass, as homopolysaccharides (cellulose, starch), heteropolysaccharides (hemicellulose), pectins, lignins, proteins, lipids. The anaerobic degradation of these polymers requires the action of different enzymes able to at- tack their terminal- or internal-functional groups.

Hydrolytic reactions are followed by acidogenesis leading to the formation of soluble extracellular intermediates. They are produced at low concentration but with a high turn-over. (10) However, the methane

production is not influenced by the eventual loss of acids through the effluent. In fact, the high acid production rate leads to a quick re-establishment of the equilibrium conditions. Table 1 lists some of the hydrolytic bacteria. It is worth to note that none of the listed bacteria is able to hydrolyse lignin that is, thus, considered as not degradable through an anaerobic process. As cellulose, hemicellulose and lignin are bound together to form the lignocellulose matrix, the relative percentage of lignin will make the matrix more or less degradable.(3)

Table 1

Bacteria involved in the hydrolysis-acidogenesis phase

	C	**H**	**Lg**	**Pc**	**s**	**Lp**	**Pr**
Anaerovibrio						X	
Bacteroides amylophilus					X		X
Bacteroides fibrisolvens	X	X		X		X	
Bacteroides succinogens		X		X	X		X
Butyrivibrio fibrisolvens	X	X					
Clostridium multifermentans				X			X
Clostridium thermocellum	X						X
Ruminococcus albus	X	X					
Ruminococcus flavefaciens	X	X					
Succinomonas amylotica					X		

C = Cellulose; **H** = Heminocellulose; **Lg** = Lignin; **Pc** = Pectin; **S** = Starch; **Lp** = Lipids; **Pr** = Proteins

It is now clear that growing bacteria on a single- or multi-substrate produces different products both from a quantitative and a qualitative point of view. Such change is due to many factors, as growth rate variation, pH value, and concentration of the substrate used as energy source. These parameters affect the bacterial flora composition and the extracellular enzymes concentration.

The energy used by bacteria during the anaerobic fermentation derives essentially from oxidation reactions in which molecules other than oxygen are used as electron acceptor. A narrow class of bacteria uses nitrates and sulphates as electron acceptors, but the greater part reduces the compounds derived from the hydrolysis-acidogenesis phase, or form gaseous-H_2 in combination with a hydrogenase enzyme.(12)

Fatty acids are the substrate employed by methanogens, as demonstrated by the fact that they do not accumulate in the digesters where are produced during the hydrolysis, acidogenesis, and acetogenesis phases.

Table 2 shows the set of methanogenesis reactions. About 7/10 of the methane produced derives from acetate, whereas the remaining 3/10 results essentially from the hydrogenation of carbon dioxide.

Table 2

Methanogenesis reactions

$$4\,H_2 + CO_2 \Rightarrow CH_4 + 2\,H_2$$
$$4\,HCOOH \Rightarrow CH_4 + 3\,CO_2 + 2\,H_2O$$
$$CH_3COOH \Rightarrow CH_4 + CO_2$$
$$C_2H_5COOH + 2\,H_2O \Rightarrow CH_4 + 2\,CO_2 + 2\,H_2$$
$$C_3H_7COOH + 2\,H_2O \Rightarrow 2\,CH_4 + 2\,CO_2 + 2\,H_2$$
$$C_4H_9COOH + 4\,H_2O \Rightarrow 2CH_4 + 3\,CO_2 + 5\,H_2$$

These data allow estimating the biogas potential composition. Would biogas derive from acetate, the composition should be 50% methane and 50% carbon dioxide. If 30% of methane derives from the direct reaction of carbon dioxide with hydrogen, the final potential composition is 65% methane and 35% carbon dioxide.

CONCLUSIONS

Differences in biogas real composition depend on the process control and the capacity to optimize the various reaction steps. Experiments with labeled carbon have shown that in the acetate molecule the methyl group gives rise to methane, whereas the carboxylate group produces carbon dioxide.(11)

Methanogenic bacteria can be categorised into two groups:

- "Acetoclasts" (or methylotrophic) which are able to metabolise methanol, methylammine and, above all, acetate. Only two genera belong to this group: *Methanosarcina* and *Methanotrix.*
- "Hydrogenophils" (or non-methylotrophic) which employ H_2 and CO_2 as substrates for methanogenesis (some may use formate).

Several schemes have been proposed to explain the metabolic path leading to methane. Barker (2) proposed that intermediates are bound to carriers (generally marked with X)**.** One of these carriers has been isolated by McBride & Wolfe (8) and shown to be 2- mercaptoethanol sulphonic acid ($HS\text{-}CH_2CH_2SO_3$), named **Coenzyme M.**

The methane production from the coenzyme M adduct requires the intervention of the F430 coenzyme which has been proposed to have a nichel-tetrapyrrolic active centre. The enzymes involved into the methane synthesis from CO_2 and H_2 are matter of investigation by several research groups as their knowledge can bring to the development of new interesting biotechnological applications.

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