ANAEROBIC DIGESTION OF A FISH PROCESSING INDUSTRY SLUDGE

*Carvalho, L., **Di Berardino, S. and *Duarte, E.
* ISA - Instituto Superior de Agronomia, Technical University of Lisbon.
** LNEG - Laboratório Nacional de Energia e Geologia.
Corresponding Author Tel. 00351 213653425, E-mail lopocarvalho@isa.utl.pt

Abstract

Due to the fact that all fish processing plants operating in Portugal send their sludge from the wastewater treatment process to landfill, and because it is a costly management policy, the aim of this work was to assess the potential use of this substrate for the production of biogas through the anaerobic process technology. Anaerobic digestion has long proven to be an efficient way for the production of a renewable fuel – Biogas - that can be used as a source of energy to produce electricity and heat. This renewable energy resource can be used to reduce the plant processing costs, reducing also the industry carbon footprint. So, the produced sludge becomes a valuable sub-product of the wastewater treatment process instead of being considered a waste, with disposal costs associated. In this study we performed mesophilic (35 ± 1°C) batch assays during 51 days. The inoculum used was from an anaerobic digester operating in a municipal WWTP, also at mesophilic conditions. The anaerobic digestion of the fish sludge produced 700 m^3 of CH_4/ton SV, which is a really promising result.

Keywords:

Anaerobic digestion, WWTP sludge, biogas, fish industry.

Introduction

Environment and energy production are two distinct areas that are getting closer as the world population grows and the fossil fuels become even more a national security and environmental concern. Climate change and petroleum dependence boosted the demand for new energy sources, cleaner and from affordable raw materials. The world growing population and the modern society habits lead to an increase in the generation of waste, which causes handling and environmental problems. To overcome these situations in a sustainable manner there is a worldwide growing concept which promotes the production of energy from different wastes (Waste – to – Energy), derived from agricultural, industrial and/or domestic sources (Kothari *et al.*, 2010).

Energy can be recovered from waste in distinct ways, depending on the technology used, being incineration currently the most popular, especially in countries with district heating coverage. However, there are other options available which use the biodegradable fraction of the waste to the production of bioethanol, biodiesel or biogas. These types of biofuels can be used not only to produce electricity and heat but also fuel for transportation. A study conducted by Münster and Lund (2010) comparing different technologies suggests that anaerobic digestion (AD) is one of the best alternative technologies to the energy production from the waste organic fraction.

AD process produces two distinct products, biogas and digestate. Biogas is mainly composed by methane (CH_4) and carbon dioxide (CO_2) and can be used in CHP engines, microgas turbines or in fuel cells. It can also be injected into the natural gas grid and be used in different gas applications, as for example vehicle fuel, although it needs to be cleaned before being injected to reach the quality standards defined by countries specific regulations. The digestate is the liquid fraction resulting from the AD process and it can be used as organic fertilizer (Weiland, 2010), saving not only the resources needed to produce chemical fertilizers as also the GHG emissions resulting from its production. This two products resulting from the AD process can be sell or used within the industrial process (biogas), reducing the overall plant processing costs and the plant carbon footprint, due to the utilization of a renewable fuel resource.

In Portugal few or any industrial wastewater treatment plants (IWWTP) are using AD as biological treatment, ending-up the process with a sludge rich in organic compounds that normally is sent to landfill. In this work we used a sludge from a fish canning industry, due to its potential use as AD substrate and also because among all the different food sectors fisheries are one of the fastest growing in the world, with a global total production continuously increasing and reaching approximately 142 million tonnes in 2008 (Figure 1). About 81% of total fishery production (115,1 million tonnes) was used for direct human consumption, with almost 15% (17,3 million tonnes) of it being processed by the canning industry. The non-food utilization of the fishery products is mainly for the manufacture of fishmeal and fish oil. World average per capita supply of fish grew from 9 kg in 1961 to 17,1 kg in 2007, with fish accounting for 16,1% of the global population's intake of animal proteins and 6,2% of all proteins consumed (FAO 2010). This worldwide growing industry is very attractive in terms of organic waste production and its potential utilization in the generation of renewable energy.

The reported work on international literature about anaerobic digestion applied to the fisheries industry refers only to the treatment of wastewater, there is nothing previously done using the sludge from the wastewater treatment (Mendez *et al.* 1992; Puñal and Lema 1999; Palenzuela-Rollon *et al.* 2002 and Chowdhury *et al.* 2010). The main objective of the present work was to assess the methane yield obtained in the anaerobic digestion of sludge from an IWWTP, in batch experiments under mesophilic conditions, using as inoculum digested sludge from a mesophilic anaerobic digester operating in one municipal WWTP from Lisbon (Chelas).

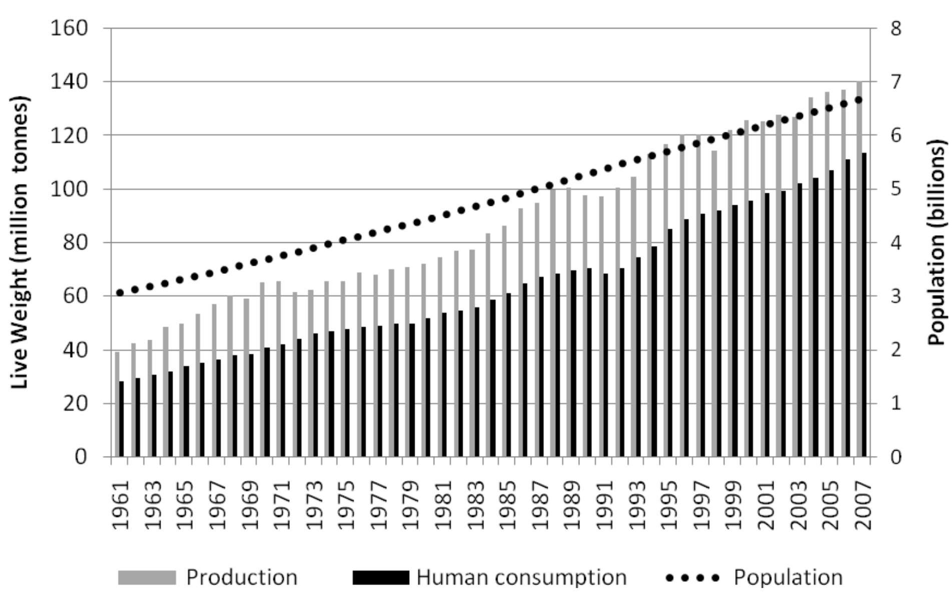

Figure 1 – World fisheries production, human fisheries consumption and population evolution from 1961 to 2007 (source: FAO 2010).

Material and Methods

Substrate and Inoculum

The sludge used in the batch assays (Figure 2) was collected from the WWTP of a fish canning industry, located in the Portuguese coastal city of Peniche. This industry produces canned fish conserved in olive oil and other vegetable oils. The main fish species used are Sardine and Atlantic mackerel. The inoculum used was collected from an anaerobic digester operating at mesophilic conditions in a municipal WWTP. The characteristics of the sludge and inoculum are presented on Table 1.

Table 1 – Sludge and inoculum characteristics. TS: Total Solids; VS: Volatile Solids; TSS: Total Suspended Solids; VSS: Volatile Suspended Solids; COD: Chemichal Oxigen Demand; TKN: Total Kjedahl Nitrogen.

	pH	TS (%)	VS (%)	TSS (%)	VSS (%)	COD (gO_2/l)	TKN (g/l)
Inoculum	7,56	2,2	1,6	2,2	1,7	14,2	1,05
Sludge	5,14	34,6	32,4	16,4	17,6	484,4	1,5

Bath Assays

The assays were performed in triplicate in 1L batch reactors placed inside a water basin with controlled temperature (35 ± 1°C). The reactors were mixed manually twice a day and the biogas produced was measured by liquid displacement in a column filled with a saline solution, to minimize the biogas dissolution. The reactors were filled with 480 mL of inoculum which will add 8,2 g VSS/l, value little superior to the one recommended by Field *et al.* (1988) for sludge used as inoculum. For the substrate was added 10g, which will introduce 3,2 g VS/l. The final volume was adjusted to 700 ml by adding distilled water and the solution pH was fit to values between 7 and 7,5 through the addition of NaOH 10M. Reactors only with inoculum and distilled water were used as controls, to assess the biogas produced by the inoculum, in order to discount that volume on the final volume of the sludge under study. Anaerobic conditions were created by flushing nitrogen gas during 2/3 minutes before closing the reactors.

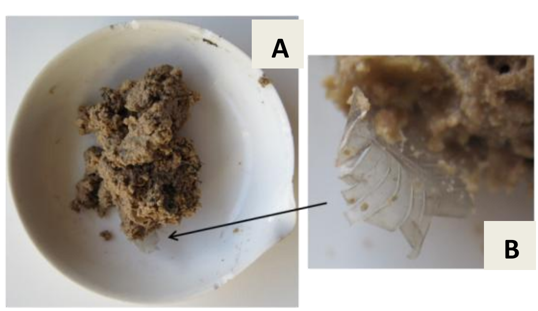

Figure 2 – A: fish processing sludge aspect; B: small scam detail.

Analytical Methods

Total, volatile and total and volatile suspended solids, pH, COD and total kjeldahl nitrogen were measured as described in Standard Methods 20th edition (1998). Methane and carbon dioxide concentration in the biogas were measured with a Varian-3800 chromatograph fitted with a Porapack S column (3m x $^1/_8$ inches) and a thermal conductivity detector. Operating conditions were: oven 50ºC; detector 150ºC and injector 60ºC. The biogas was analyzed once a week, during the 7 week assay. The specific methane yield was measures as m^3 $CH_4.t^{-1}$ VS with methane from inoculum (control) subtracted.

RESULTS AND DISCUSSION

Throughout the batch phase the biogas produced was recorded every day (Figure 3).The evolution of the daily biogas production during that period shows that the adaptation phase (lag-phase) was almost inexistent, since on the 2nd day of the assay there was already biogas generated. The first two weeks were those on which more biogas was produced, and then the daily production started to decrease slowly. After the first 10 days 81% of the total biogas was formed and by the 20th day 92% of it was already produced. This short adaptation period is probably due to the good quality of the inoculum, being from a municipal WWTP digester normally used to digest different types of organic wastes, and also to the low organic loading rate (3.2g SV/l) applied to the batch reactors.

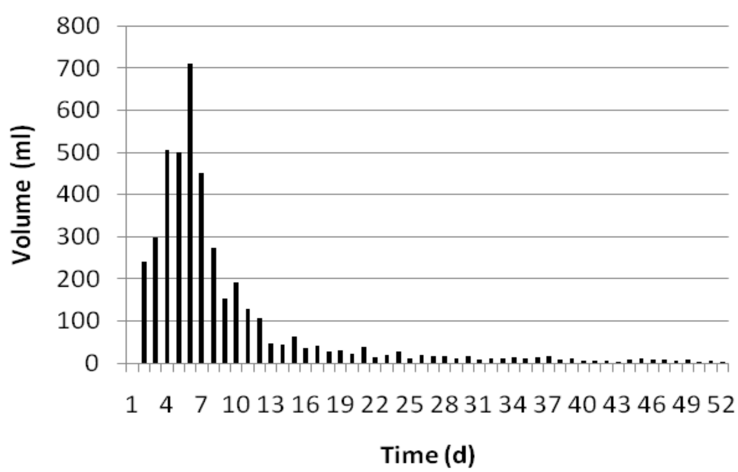

Figure 3 – Daily biogas production from fish sludge substrate, during the batch assay.

The biogas cumulative production is represented on Figure 4 for both the fish sludge and the inoculum. The first two weeks were the most representative in terms of biogas production, with the great part of it being produced in this period. This situation shows that the fish sludge has a high biodegradability degree, even without any kind of pre-treatment applied.

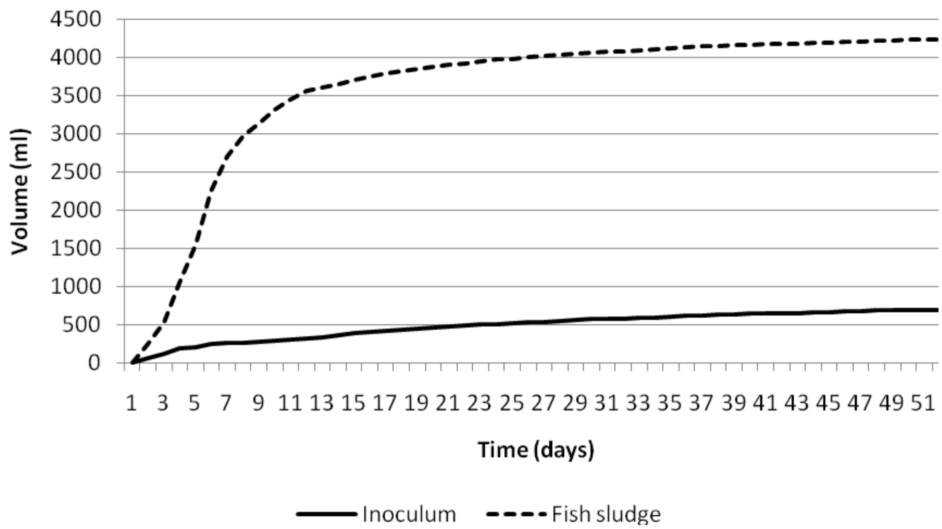

Figure 4 – Cumulative biogas production during batch assay period.

The biogas production yield is not the only factor with influence on the final calculations of the methane potential yield of a given substrate, its qualitative composition is also an important aspect. The biogas quality varies according to the substrates used in the anaerobic digestion process (Rasi *et al.*, 2007). Throughout the batch assays the methane content of the biogas produced by the fish sludge evolved and stabilized after some days (data not shown). For the calculation of the methane potential yield (Table 2) the average values determined on the last week measurements were used, which resulted on 67% methane (CH_4) content on the biogas produced from the fish sludge. These are quite good results, since the value normally defined as fine for the methane concentration on biogas ranges between 65 to 70%.

Table 2 - Potential biogas and CH_4 yield from the anaerobic digestion of the fish sludge (inoculum subtracted).

Biogas (m^3/t VS)	1069
CH_4 (m^3/t VS)	712

From the reported results on the international literature about the assessment of the potential CH_4 yield of different types of organic biomasses (Table 3) one can conclude that the sludge studied within this work has a good biogas potential yield. The landfilling of these quality substrates is probably the worst environmental and economical management policy. The results of this study can be used to change the actual policy follow by the Portuguese fish industry and all the others all over the world that follow the same policy.

Table 3 – Literature references to the CH_4 yield of different organic wastes. Refs - 1: Angelidaki and Ellegard, 2003; 2 - Weiland, P. 2010).

Substrate	m^3 CH_4 /t VS	Substrate	m^3 CH_4 /t VS
Cattle Manure	210[1]	**Sugar beet**	730–770[2]

Pig Manure	290[1]	**Fodder beet**	750–800[2]
Chicken manure	300[1]	**Maize**	560–650[2]
Molasse	310[1]	**Corn cob mix**	660–680[2]
Vinasse	150[1]	**Wheat**	650–700[2]
Meat and bone flour	570[1]	**Triticale**	590–620[2]
Household waste	400 - 500[1]	**Sorghum**	520–580[2]

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