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Research article

The effect of feed composition on anaerobic co-digestion of animal-processing by-products

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ABSTRACT

Four streams and their mixtures have been considered for anaerobic co-digestion, all of them generated during pig carcasses processing or in related industrial activities: meat flour (MF), process water (PW), pig manure (PM) and glycerin (GL). Biochemical methane potential assays were conducted at 37 °C to evaluate the effects of the substrate mix ratio on methane generation and process behavior.

The results show that the co-digestion of these products favors the anaerobic fermentation process when limiting the amount of meat flour in the mixture to co-digest, which should not exceed 10%. The ratio of other tested substrates is less critical, because different mixtures reach similar values of methane generation. The presence in the mixture of process water contributes to a quick start of the digester, something very interesting when operating an industrial reactor. The analysis of the fraction digested reveals that the four analyzed streams can be, a priori, suitable for agronomic valorization once digested.

1. Introduction

The production of pork is a significant part of meat production in Spain and Europe. More than 251 million head of pigs were slaughtered in 2014 in Europe (EUROSTAT, 2016), of which 43 million came from Spain (MAGRAMA, 2016). It is a clear fact that the demand for meat has increased over time and, as a consequence, the amount of organic by-products from slaughterhouses also did it. About 30% of the total weight of slaughtered pigs is not intended for human consumption. It is estimated that, annually, remains of pigs corpses (carcasses) in Europe and Spain are 5.4 and 0.9 million tons, respectively. Over the past 60 years, these remains of slaughterhouse, rich in proteins and lipids, have been treated and used for feed production. However, due to legal restrictions and consumers being increasingly more aware with the environment, treatment of waste and animal by-products has become a major concern not only in the industry of pork, but also in the meat industry in general. For example, the outbreak of diseases, such as bovine spongiform encephalopathy (BSE) in cattle and the dangerous Creutzfeldt-Jacob in humans in 2001, has resulted in an increased general awareness of the need for standards for the management of these products, greater control of processes, and the prohibition of the use of certain animal by-products.

According to current legislation (EC, 2009; EC, 2011), slaughterhouse waste must be treated by different methods depending on the category of the animal by-product. Two Community regulations categorize animal by-products into three categories based on the risk: Category 1 is high-risk material (parts of infected animals, international catering, etc.) and it is not allowed to be composted or treated in biogas plants under no circumstance; Category 2 is by-products of animal origin medium risk (sick animals, manure, digestive tract content, etc.) that cannot be used as raw material in composting and biogas plants unless they first have been sterilized at least at 133 °C and 300 kPa for 20 min; and finally Category 3 or low risk material (catering waste, meat, ready meals, etc.) approved for human consumption, to be treated at least at 70 °C for 1 h in a closed system.

Anaerobic digestion is disclosed as a possible method for the treatment of animal subproducts, which in turn allows the production of energy as methane and the use of effluents of digestion as fertilizer for agricultural application (nutrients recovery) (Salminen and Rintala, 2001).

However, slaughterhouse wastes are generally considered as difficult substrates for anaerobic digestion, mainly because of their typically high protein and lipid content (Banks and Wang, 1999). Protein degradation releases ammonia, which at high

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concentrations is an inhibitory compound for anaerobes (Angelidaki and Ahring, 1992; Khalid et al., 2011; Palatsi et al., 2011; Rajagopal et al., 2013). It is generally considered that the unionized form of ammonia causes inhibition and concentrations of 0.1–1.1 kg m^{-3} turn out the process inhibitory (Yenigün and Demirel, 2013). Furthermore, the lipids can also cause problems in the anaerobic digestion because of its tendency to promote the presence of supernatants phases in the digesters and the possible accumulation of intermediate by-products, as long chain fatty acids (LCFA) (Bayr et al., 2012; Palatsi et al., 2011; Rajagopal et al., 2013; Yenigün and Demirel, 2013). LCFA degradation can be the limiting step in the overall process of complex substrates (such as animal fats) degradation, requiring a gradual adaptation of the microorganisms to these substances and a careful dosing of lipid rich waste streams to avoid accumulation of LCFA. Even at very low concentrations (around 0.5 g L^{-1}), LCFA, especially unsaturated, are inhibitory for syntrophic acetogenic and methanogenic bacteria (Cirne et al., 2005).

The relatively high nitrogen and total solids (TS) content of the animal subproducts cause they are rarely treated in their original state, i.e., undiluted. For this reason, the dilution is usually necessary. In this regard, a very attractive option is the co-digestion of these animal subproducts with other less concentrated organic waste, such as manure or wastewater generated in rendering processes. The presence of more dilute streams provides stability to the whole process and serves as a dilution medium while the residual stream itself is also treated (Hejnfelt and Angelidaki, 2009).

In this context, the VALPORC project arises as a sustainable alternative to pig carcasses and slurry management. It addresses the environmental problem associated with current management and seeks to recover these wastes by converting them into biofuels (biogas and biodiesel) and organic fertilizers, with all the corresponding environmental and socioeconomic benefits that this will afford. This sustainable model (Fig. 1) includes, as an initial step, the stage of rendering of category 2 pig by-products. This stage includes strict hygienization treatment.

The system is designed to optimize, from the energy point of view, the meat flour and fat production process and to encourage the recovery of these products. The fats generated in the previous stage enter a biodiesel generation process while meat flour (with traces of fat), process water and glycerin generated during biodiesel production are co-digested with pig manure in an anaerobic digestion plant. The organic fraction in the digestate, along with the nutrients not transformed in the process and other byproducts of the overall process, will be used as fertilizer in areas close to the plant, which will result in important savings in chemical fertilizers.

As a part of this VALPORC project, in the present study, methanogenic yields in batch digesters of various subproducts proceeding from a rendering plant of pig carcasses, which operate in the mesophilic temperature range (37 °C), are analyzed when they are co-digested, in different proportions, with liquid manure, water process and glycerin generated as a by-product during the production of biodiesel from pig fat. The aim of this work is to set the ideal composition of the feeding to optimize the behavior of the industrial anaerobic digester operating with these streams.

2. Materials and methods

2.1. Substrates

Four streams generated in the pork industry have been the base of this study: meat flour (MF) and process water (PW), both including traces of animal fat, from a rendering plant in Soria (Spain); pig manure (PM) from a centralized livestock effluents treatment plant, also in Soria; and glycerin (GL), generated as a byproduct during the production of biodiesel from fat pig in the laboratory. As inoculum for the mesophilic anaerobic digestion assays, sludge from an anaerobic reactor operating in a sugar factory was used.

Characterization analysis and experimental tests were performed immediately after samples arrival at the laboratory.

2.2. Analytical methods

In the case of fats used in the biodiesel production process, entering directly, although in small proportion, in the anaerobic digester as a part of the meat flour and process water, the characterization analysis includes: acid index (expressed as a percentage of oleic acid and using the reference method Regulation (EC) No

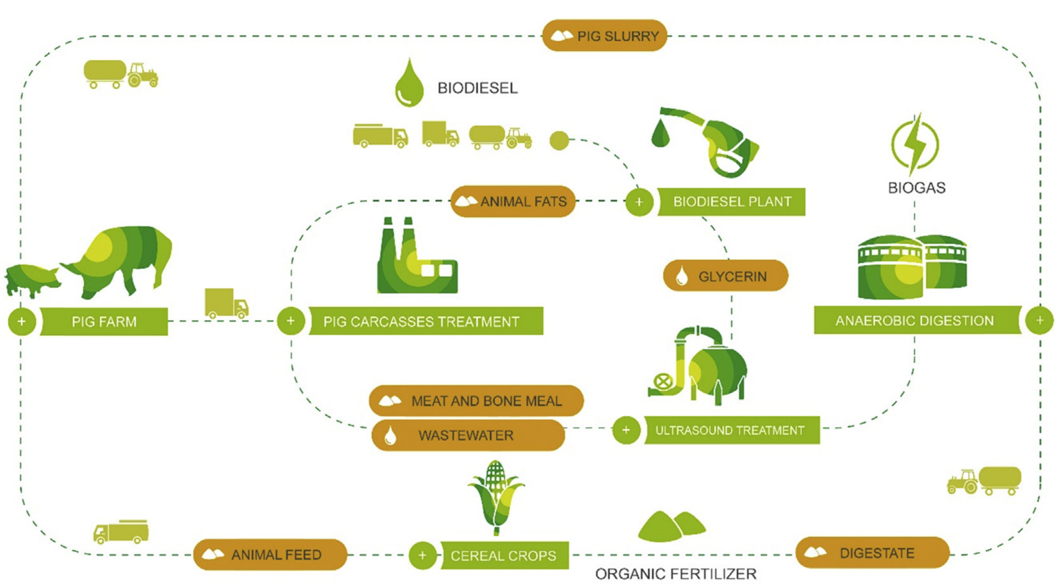

Fig. 1. VALPORC model for valorization of pig carcasses.

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