Swine Manure Treatment: status in Catalonia and process design

Marc Rul·lan Sabater

Biotechnology Degree

Introduction

Development of intense livestock farming in Catalonia, especially swine farming, is generating an environmental problem due to the waste produced. It is causing, among other consequences, nitrate accumulations on soil and underground water, which is reaching concentrations well beyond the ones dictated by national regulation. Near 20% of Catalonian soil is designated as nitrate vulnerable zone.

A way to tackle this problem is through the improvement of swine manure treatments. There are currently several methods for dealing with pig manure (Figure 2), the most promising one being anaerobic digestion, because of its environmental advantages and economic feasibility. This work is going to be centered on stating the current state of the technique on pig manure treatments, on seeing which are already implemented in Catalonia and in designing an anaerobic digestion system adapted to the Catalonian context.

Objectives

- Data recollection. Key aspects on swine manure biogas and its production process.
- Design of a treatment process for a model farm.
- Environmental, economic and legislative analysis of the proposed process

Methods

- Literature research on specialized scientific journals, monographs, government documentation, documentaries and interviews with experts of the field.
- Process Design performed with data extracted from the literature. Initial parameters were obtained from statistical data provided by Generalitat de Catalunya, and were picked to be representative of farms located in Catalonia.

BACKGROUND RESEARCH

Swine Manure

TABLE 1: CHARACTERISTICS OF BOTH RAW AND ANAEROBICALLY TREATED MANURE.

Characteristics	Environmental problems	Advantages of digested manure
• High water NH_4 P and K content, as well as presence of metals (Cu and Zn). • Low biogas potential. • Presence of fecal and pathogenic microorganisms.	• Water pollution: oxygen demanding materials and oxygen depletion., infectious agents. • Metal accumulation → crop land phytotoxicity. • Odor and emission of NH_3, SH_2, NO_x gases → acid rain and the greenhouse effect.	• Increased nitrogen availability. • Better short-term fertilization effect. • Decreased pathogen count. • Reduced risk of nitrogen losses to the atmosphere by ammonia emissions.

Biogas

Composed of CH_4 (65%), CO_2 (30%) and trace gases like H_2S.

Because of its combustion energy, it can be used both for heating and for electricity generation.

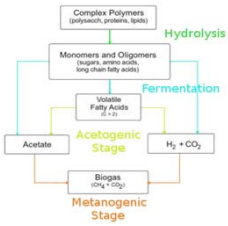

FIGURE 1: OVERVIEW OF BIOGAS METABOLISM

PROCESS DESIGN

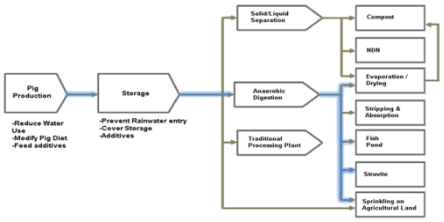

FIGURE 2: ALL PROCESS ALTERNATIVES. PROCESSES HIGHLIGHTED IN BLUE HAVE HAD THEIR ENVIRONMENTAL EFFECTS ANALYZED TO SE WHICH ONE WOULD BE MOST PROMISING TO IMPLEMENT AS FURTHER ADDITIONS TO THE ANAEROBIC DIGESTION.

Proposed Process

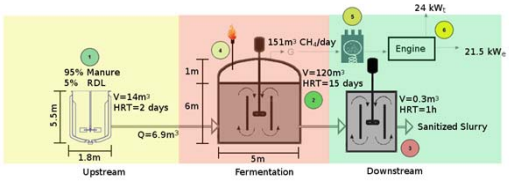

FIGURE 3: SCHEMATIC REPRESENTATION OF THE CHOSEN PROCESS DESIGN. IT CONSISTS OF:
-UPSTREAM: SWINE MANURE AND RESIDUAL DECOLORIZING LAND (LEFT-OVER FROM OLIVE OIL REFINEMENT) ARE MIXED. CODIGESTION HAS BEEN CHOSEN BECAUSE OF INCREASED BIOGAS YIELDS.
-FERMENTATION: IT TAKES PLACE IN A SINGLE MIXED REACTOR.
-DOWNSTREAM: REMOVING TRACE H_2S VIA WATER SCRUBBING AND POSTERIOR DEHYDRATATION. THIS IS NEEDED FOR THE BIOGAS TO BE SUITABLE FOR THE ENGINE.
SANITATION IS OPTIONAL, AND WILL ONLY BE DONE WHEN THE PRESENCE OF MICROORGANISMS IS AN ISSUE FOR THE SLURRY'S USE.

Successful Implementation

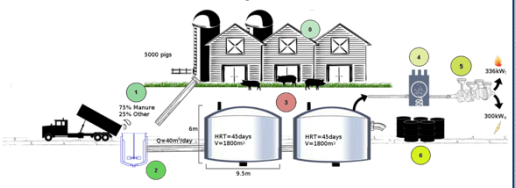

FIGURE 4: CONCEPTUAL REPRESENTATION A BIOGAS DIGESTION PROCESS OBSERVED IN CASSÀ DE SELVA, GIRONA. MAIN DIFFERENCES WITH THE PROPOSED PROCESS ARE:
-INCREASED MANURE PRODUCTION
-DIGESTION PROCESS DIVIDED INTO TWO DIGESTERS.
-LONGER HRT, BUT VERY SIMILAR GAS YIELDS.

RESULTS AND DISCUSSION

Economic Analysis

TABLE 2: PLANT COSTS AND COMPARISON OF THE PROCESS WITH SUBSIDIZED ELECTRICITY SALE PRICES (13.9C€/KWH) VS. NON-SUBSIDIZED PRICES (5C€/KWH).

Investment (€)	Yearly Maintenance (€)
115000	8300

	Subsidized	Non-subsidized
Income (€)	28100	12800
Net Income (€)	19800	4500

Variables that play big role on process economy:

- Economy of scale: high impact on initial investment. Price per unit of reactor volume is largely reduced, though maintenance is not influenced as much. Extra costs on storage and transportation.
- Generated electricity's sale price: subsidized project has IRR of 18%, while non-subsidized project is economically unfeasible.

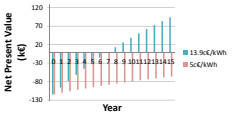

FIGURE 5: NPV EVOLUTION DURING THE 15 TERMS OF THE PLANT'S SERVICE LIFE. COMPARISON BETWEEN SUBSIDIZED (BLUE) AND NON-SUBSIDIZED (RED) ELECTRICITY SALE PRICES.

Environmental Analysis

TABLE 3: NEGATIVE ENVIRONMENTAL EFFECTS AND WEATHER THEY ARE SOLVED BY ANAEROBIC DIGESTION.

Harmful effect	Degree by which the problem is solved
Pollute water (oxygen demanding materials)	High
Pollute fields (N, metals)	None
Pathogenic microorganisms	High
Pollute surface water (N, P)	Medium
Odor	High
Greenhouse gasses	Medium

If implemented correctly, the digestion process improves the slurry's environmental properties. It also reduces the need for fossil fuels on the farm to heat up swine pens.

Additional operations to reduce environmental impact:

- Sprinkling on farmland: fertilizer, but high water content. Economic.
- Evaporation/ drying: easy transportation. Surplus heat used.
- Struvite precipitation: solid fertilizer. Great nitrogen reduction.
- Fish pond: complete biological cycle, need of extensive area of land.

Legal Framework

A country's development in anaerobic treatment systems is highly correlated with its legal framework. Examples of this fact are found in Germany, Denmark or China. All of this countries have different models of biogas production adapted to their own necessities. They have in common that their governments have made a strong bet in favor of this technology financially, subsidizing both plant construction investments and sale of biogas generated electricity.

Spain started creating favorable conditions for the implementation of such systems from 2007 to 2009 (RD 661/2007, RD 949/2009), by economically incentivizing both its construction and the sale of generated electricity. From 2007 to 2011, the Spanish biogas industry began develop, starting multiple projects and founding companies linked to implementing these project.

On 2012 though, RD 1/2012 was approved, decreasing net income by 64% (in the designed process), making unfeasible its implementation.

CONCLUSIONS

- Data recollection has been successful in allowing to choose the process design best suited for farms located in Catalonia, out of all available options.
- Economic analysis shows that this process by itself, with current legislation, is not feasible.
- The process has multiple environmental advantages compared to traditional manure sprinkling.
- Overview of biogas production around the world has allowed to see how important legislative framework is to promote biogas industry.

•Additional work that would be interesting to get done would be to further explore the different process alternatives mentioned on the environmental analysis, especially those that affect nitrate concentrations. Nitrate, the bottle neck in the amount of manure that can be sprinkled on farm land, is not reduced by anaerobic digestion. By implementing additional operations, it could be possible to improve the process' environmental effects or transform the slurry into an economically valuable good, like a transportable fertilizer.

REFERENCES

- Campos E (2001) "*Optimización de la digestión anaerobia de purines de cerdo mediante codigestión con residuos orgánicos de la industria agroalimentaria*". Phd Thesis. UdL.
- Campos E., Illa J., Palatsi J, Solé F, Magrí A (2004) "Guia dels tractaments de les dejeccions ramaderes". *Generalitat de Catalunya*. Lleida.
- Weiland P (2010) "Biogas production: current state and perspectives." *Applied Microbiology and Biotechnology* Vol 85 p.849-60.
- Cerrillo M (2012) "Obtenció d'estruvita a partir de la fracció líquida digerida de purins de vaca". Msc. Thesis. UVIC.