



ANAEROBIC TREATMENT OF EFFLUENTS FROM SLAUGHTERHOUSE AND CATERING WASTES

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1. ABSTRACT

The purpose of the present research project was to develop a new concept to efficiently treat wastes from slaughterhouse and catering, and to test it at laboratory scale for 9 months and at pilot scale for 5 months. The treatment is based on the separation of the liquid and solid fractions of fresh wastes after sterilization. The liquid phase, heavily loaded in organic matter in suspension, was successfully treated by anaerobic digestion in hybrid bioreactors, whereas the solid residue was conditioned and tested as animal feed. Results obtained look very promising and should be a sound basis to design and implement an industrial scale process.

2. INTRODUCTION

Slaughterhouses, meat-processing industries and large catering services reject huge amounts of organic wastes and effluents (Tritt and Schuchardt, 1992; Cho et al., 1995). A major proportion of such wastes and wastewater are amenable to controlled biological treatments, yielding potentially useful and value added products like organic acids, fertilizers or animal feed, as well as energy (biogas). Over the last decades, efficient anaerobic digestors have been developed and tested successfully at different scales for the biological treatment of slaughterhouse wastewater (Sayed et al., 1987; Tritt, 1992; Borja et al., 1994, 1995). In contrast, no biological process seems able to treat satisfactorily and efficiently solid wastes and by-products from slaughterhouse (like carcasses, etc), which still contain large quantities of water and organic matter and are now considered as hazardous wastes (Banks, 1994). The rising costs of waste removal in the wake of current and future legislation are forcing the slaughterhouses to rethink their present concepts for waste disposal and find innovative, economical and ecological solutions, to reduce their impact on the environment and possibly to gain some ecological and economical benefits from them. It was precisely the aim of the present project, supported by the Swiss Federal Office for Energy, and developed in close co-operation with a poultry slaughterhouse and meat-processing industry, to test at laboratory and pilot scale a biological process based on the anaerobic digestion of the liquid fraction, operated under continuous conditions and mesophilic temperatures, whereas the solid residue could be used as animal feed.

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3. MATERIALS AND METHODS

The first step in the treatment was to sterilize fresh wastes and to squeeze them in an endless screw filter press (Figure 1). The solid residue, rich in protein and poor in fat, was then conditioned and tested as an animal feed, whereas the liquid phase, heavily loaded in organic matter in suspension (10 to 20%) and in fat (3% for catering, 20% for slaughterhouse wastes), was treated anaerobically. The liquid phase was thus pumped into an anaerobic hybrid reactor, operated in upflow mode (Figure 2). This type of bioreactor takes advantage of the properties of a conventional digester in its lower part with those of an anaerobic filter in the upper part, avoids their respective drawbacks (Borja et al., 1995; Cho et al., 1995; Cordoba et al., 1995), and is appropriate for effluents containing suspended solids. Therefore, two bioreactors were operated continuously for 9 months at laboratory-scale (17 litres) and one for 5 months at pilot scale (200 litres) on an industrial site (Figure 3). The upper part was filled with small cubes of polyurethane foam (laboratory bioreactors) or plastic rings (pilot bioreactor). Laboratory fermenters were inoculated with a mixture of bovine and pigs manure, operated in the upflow mode, at mesophilic temperatures (35-37 °C) and at controlled pH values. The pilot bioreactor was inoculated with strains present in the laboratory fermenters after 3 months of operation with slaughterhouse and catering wastes. In the perspective of a full scale plant, biogas could be used for heat and power generation. Biogas produced was thus measured quantitatively by volumetric flowmeters (Wohlgroth) and qualitatively by infrared CO₂/CH₄ analyzers (Ultramat, Siemens). Total chemical oxygen demand and ammonium were measured with the appropriate commercial tests.

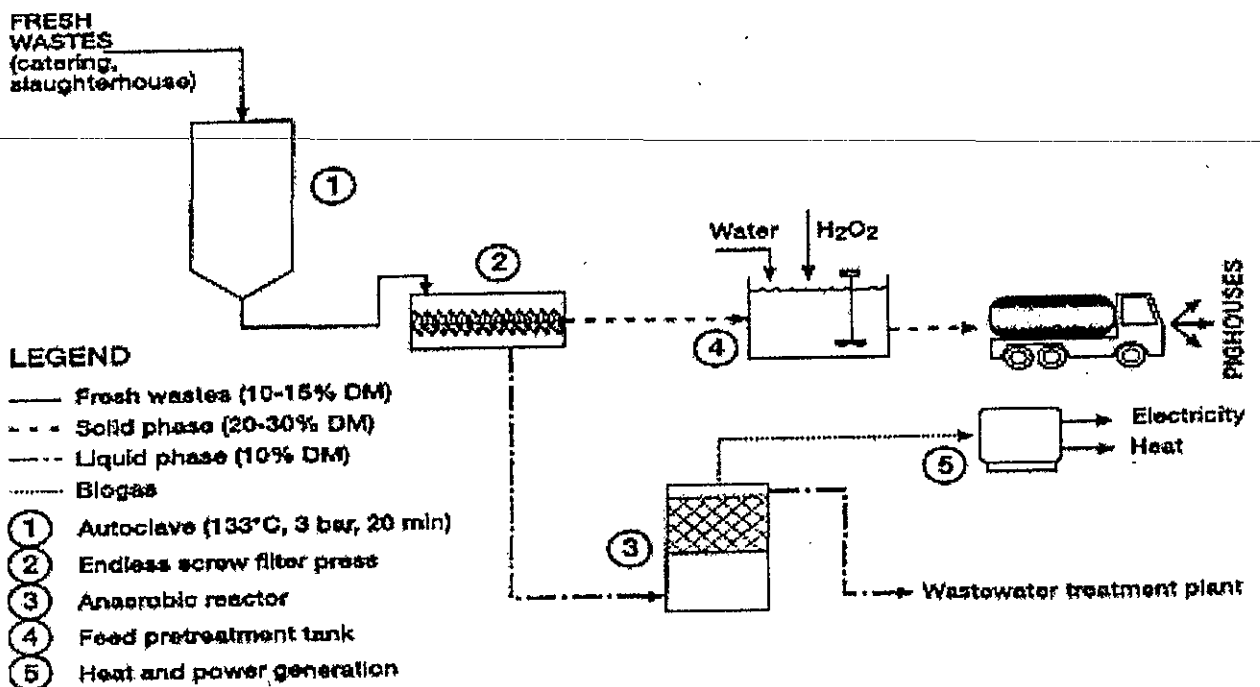


Figure 1. Process flow chart of the "Gazoporc" concept

LABORATORY REACTOR

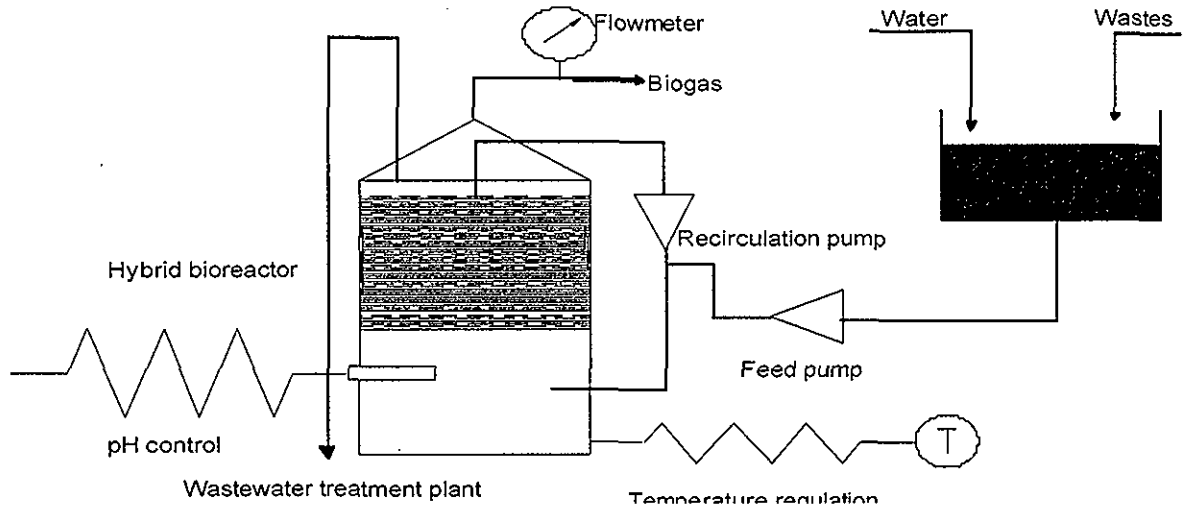


Figure 2. Process flow chart of the laboratory reactor

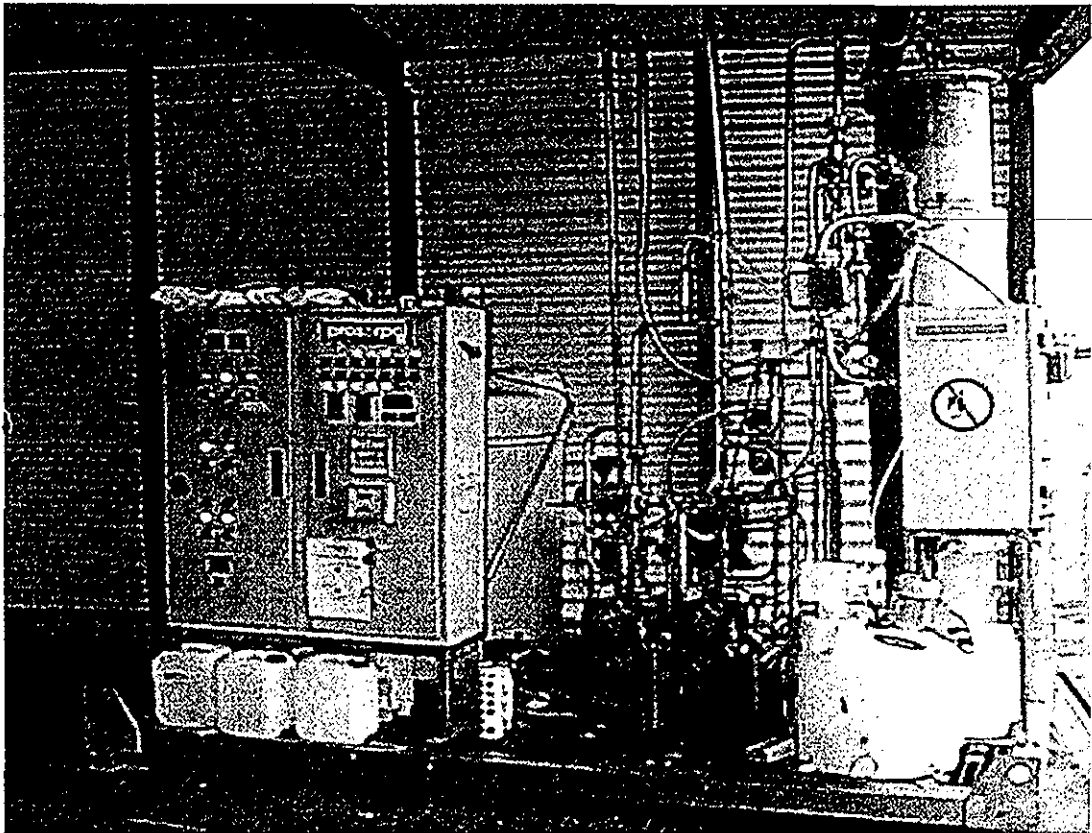


Figure 3. Reactor pilot plant

4. RESULTS AND DISCUSSION

4.1 Anaerobic digestion of liquid phase at laboratory scale

The aims of the experimentation at laboratory scale were to check the feasibility of the project before running the pilot bioreactor, prepare an appropriate inoculum and test several critical parameters, like the upper limits of loading for a stable operation, and estimate the ability of the system to recover after a shock of loading, temperature or pH.

The most significant results obtained are summarized on Table 1. Hybrid bioreactors seem appropriate to treat both types of substrates, since a very efficient COD removal was observed for loading rates around $15 \text{ kg COD m}^{-1} \text{ d}^{-1}$ and a hydraulic retention time of approximately one week. Furthermore, ammonium concentration never reached inhibitory values.

When the temperature was reduced to $20 \text{ }^{\circ}\text{C}$ or increased to $45 \text{ }^{\circ}\text{C}$, the efficiency of the treatment decreased markedly, but recovered rapidly when the initial temperature was re-established (not shown). Similarly, a decrease of pH to 6.5 or 6.0 caused a strong reduction of COD removal and biogas production, with a simultaneous accumulation of volatile fatty acids and ammonium, indicating an imbalance of the system. If the loading rate was suddenly increased to values around $20 \text{ kg COD m}^{-1} \text{ d}^{-1}$, the efficiency of the system markedly decreased. Therefore, the optimal loading rate appears to be around $15 \text{ kg COD m}^{-1} \text{ d}^{-1}$ for such hybrid bioreactors operated at laboratory scale.

Table 1. Summary of results obtained at laboratory scale

| Type of waste | Loading rate ($\text{kg COD m}^{-1} \text{ d}^{-1}$) | HRT (days) | Organic load (g COD l^{-1}) | COD removal (%) | Biogas produced ($\text{m}^3 \text{ kg}^{-1} \text{ COD}$) | NH_4 (mg l^{-1}) |
|-----------------------|---|---------------|---|--------------------|---|---|
| Catering in | 14.6 | 9 | 225.0 | | | 300 |
| Catering out | | | 43.4 | 81 | 0.33 | 1450-2150 |
| Catering in | 16.5-20.0 | 7 | 187.5 | | | 300 |
| Catering out | | | 61.5 | 65-70 | 0.15 | 2900 |
| Slaughterhouse in | 14.9 | 8 | 177.5 | | | 1500-2500 |
| Slaughterhouse out | | | 43.2 | 76 | 0.18 | 3700 |

4.2 Anaerobic digestion of liquid phase at pilot scale

The pilot bioreactor was operated with the liquid phase of catering wastes for 1 month and with slaughterhouse wastes for 4 months. The effects of organic loading rate and hydraulic retention time (HRT) on the efficiency of the treatment (reduction of total chemical oxygen demand, production of biogas and methane yield) were investigated.

The most important results obtained with the pilot digester operated at 37 °C and pH 7.5-8.0 are summarized on Table 2. The excellent performances of the system with catering wastes should be pointed out, since 85% of the total chemical oxygen demand was removed at a loading rate higher than 12 kg m⁻¹ d⁻¹ and a short hydraulic retention time of 2 days only.

Different loading rates and hydraulic retention times were tested for slaughterhouse wastes, indicating that the system could be efficiently operated at values higher than 12 kg total COD m⁻¹ d⁻¹ in 4 to 5 days. Suspended solids were in the range of 10-15 g/l in the slaughterhouse influent, but only 2.5-5.0 g/l in the effluent, indicating an excellent hydrolytic activity in the lower part of the reactor. Acetate concentration was constant in the digester (50 mmol/l) and other volatile fatty acids remained at a negligible level. Ammonium concentration in the effluent never exceeded 3.2 g/l, and no inhibition was observed. Biogas produced was quantitatively and qualitatively stable at values around 0.45 m³ kg⁻¹ COD removed and 75% CH₄ and 25% CO₂, respectively.

Table 2. Summary of results obtained at pilot scale

| Type of waste | Loading rate (kg COD m ⁻¹ d ⁻¹) | HRT (days) | Organic load (g COD l ⁻¹) | COD removal (%) | Biogas produced (m ³ kg ⁻¹ COD) | NH ₄ (mg l ⁻¹) |
|-----------------------|--|---------------|--|-----------------------|---|--|
| Catering in | 12.4 | 2.0 | 21.1 | | | 47 |
| Catering out | | | 2.8 | 87 | 0.40 | 122 |
| Slaughterhouse in | 5.0 | 3.5 | 18.1 | | | 555 |
| Slaughterhouse out | | | 1.7 | 91 | 0.30 | 913 |
| Slaughterhouse in | 11.0 | 4.0 | 42.0 | | | 1720 |
| Slaughterhouse out | | | 10.8 | 75 | 0.46 | 2300 |
| Slaughterhouse in | 12.5 | 5.0 | 48.0 | | | 2000 |
| Slaughterhouse out | | | 12.8 | 73 | 0.45 | 3200 |

4.3 Fattening pigs feeding trial with solid phase of poultry by-products

After separation, the solid phase (30% dry matter) represented approximately 10% of the initial poultry waste amount. The analyses revealed an interesting nutritional profile of the by-product, with high protein (58.3% of organic dry matter) and energy contents (13.8 MJ/kg of digestible energy), whereas lysin amounted to 4.5% of the protein. However, the most interesting effect of separating the solid from the liquid phase was the drastic reduction of the fat content in the solid part : from 20.2% of organic dry matter in the raw poultry waste to 9.3% in the final by-product. When given to fattening pigs, this would affect positively the carcass quality. In Switzerland, slaughterhouses actually control the amount of polyunsaturated fatty acids with severe commercial penalization for high values.

On the basis of these encouraging analytical results, a fattening pigs feeding trial took place to check the palatability of the by-product and to measure the level of pigs performances. Water was added (50 l per 100 kg by-product) to get a dry matter of about 20%, thus allowing a liquid feeding. Hydrogen peroxide at 0.3% was added twice a week to prevent a possible fermentation of the liquid during the 5 weeks of the trial. Pigs were thus fed with a mixture of 85% of cereals containing minerals and vitamins and 15% of the poultry by-product.

Results presented on Table 3 show that such a poultry by-product fed to fattening pigs could be considered as a good source of protein and energy in complement to cereals. Pigs performances were equivalent to those of pigs fed with traditional protein compounds (soja and other vegetal proteins). However, the economical success would depend on the local ecological requirements and the respective prices of the raw materials.

Table 3 Feeding trials of fattening pigs

| | Control (100% cereals) | Trial |
|-----------------------------------|------------------------|-------|
| Number of pigs | 7 | 7 |
| Weight at the beginning (kg) | 36.5 | 35.5 |
| Weight after 5 weeks (kg) | 63.7 | 62.5 |
| Average daily weight increase (g) | 716 | 710 |
| Feed conversion (88% dry matter) | 2.37 | 2.39 |

5. CONCLUSIONS

On the basis of these promising results, the technical and economical feasibility of an industrial plant treating more than 6'200 t poultry wastes per year was estimated: biogas could be used to provide 15% of the electrical requirement and reduce by 40% fuel oil consumption by the poultry slaughterhouse and meat-processing industry. Even if effluents resulting from bioreactors still contain a significant amount of organic matter, they should be treated without problems in a classical wastewater treatment plant, since their volume is very small, as compared to the usual flow of wastewaters rejected by slaughterhouse (Johns, 1995). Furthermore, the solid phase of poultry by-product after pressing has been successfully used as feed for fattening pigs instead of usual protein ration. Finally, such a treatment could strongly reduce or even suppress the expenses presently required to transform these poultry by-products into meal and extract fats from them. Therefore, the economical and ecological interest of the proposed treatment concept seems sound and appropriate for industrial applications.

LIST OF REFERENCES

- Banks, C.J (1994). Anaerobic digestion of solid and high nitrogen content fractions of slaughterhouse wastes. *AIChE Symposium Serie*, 300, 48-55.
- Borja, R., Banks, C. J., Wang, Z. (1994). Stability and performance of an anaerobic downflow filter treating slaughterhouse wastewater under transient changes in process parameters. *Biotechnology and Applied Biochemistry*, 20, 371-383.
- Borja, R., Banks, C. J., Wang, Z. (1995). Performance of a hybrid anaerobic reactor, combining a sludge blanket and a filter, treating slaughterhouse wastewater. *Applied Microbiology and Biotechnology*, 43, 351-357.
- Cho, J. K., Park, S. C., Chang, H. N. (1995). Biochemical methane potential and solid state anaerobic digestion of Korean food wastes. *Bioresource Technology*, 52, 245-253.
- Cordoba, P. R., Francese, A. P., Sineriz, F. (1995). Improved performance of a hybrid design over an anaerobic filter for the treatment of dairy industry wastewater at laboratory scale. *Journal of Fermentation and Bioengineering*, 79, 270-272.
- Johns M. R. (1995) Developments in wastewater treatment in the meat processing industry : a review. *Bioresource Technology*, 54, 203-216.
- Sayed S., van Campen, L., Lettinga, G. (1987). Anaerobic treatment of slaughterhouse waste using a granular sludge UASB reactor. *Biological Wastes*, 21, 11-28.
- Tritt, W. P. (1992). The anaerobic treatment of slaughterhouse wastewater in fixed-bed reactors. *Bioresource Technology*, 41, 201-207.
- Tritt, W. P., Schuchardt, F. (1992). Materials flow and possibilities of treating liquid and solid wastes from slaughterhouses in Germany – a review. *Bioresource Technoogy*, 41, 235-245.