Anaerobic co-digestion of animal wastes (poultry litter and pig manure) with vegetable processing wastes

Pig produc

Beatriz Molinuevo , Mª Cruz Garcia , Mª Cristina León, Milagros Acítores.*
Agricultural Technological Institute of Castilla and Leon, Finca Zamadueñas, Valladolid, Castilla and Leon, Spain.
**E-mail address: gargonmi@itacyl.es*

Introduction

The increase in production and concentration of intensive livestock (pig and poultry farming) in a located area of Castilla y León is producing an important amount of organic wastes. An unsuitable use of these wastes could cause serious environmental and healthy problems so it is necessary to minimize the risks following the current legislation *(EC 96/61/1996, B.O.E (2002)*. In addition, vegetable processing industry, that generates a big amount of wastes (leeks, peas, carrots, maize) is also located in the same area and is producing a surplus of residues that is necessary to treat.

Anaerobic digestion has been found as a very good method to reduce organic matter and odours, destroy pathogens and produce energy (methane). It is an efficient biological alternative system to other conventional methods. Furthermore, anaerobic digestion is a good option that combines animal and vegetable wastes reduction, negative environmental impact reduction and cost-effectiveness (due to the new Spanish Royal Decree, *B.O.E. (2007)* that promotes renewable energy generation).

Anaerobic digestion of pig manure and poultry litter has been widely studied *(Bujoczek. et al., 2000; Magbauna et al., 2001; Campos et al., 2008)*. However, anaerobic digestion of pig manure alone produces low methane yield due to the high content of water and fibers of this material. In the case of poultry litter, the high total nitrogen concentration and the break down of the proteins during anaerobic digestion result in an ammonia inhibition of the process *(Angelidaki and Ahring, 1993).* Co-digestion with a carbon-rich substrate, like vegetable processing wastes, is an improvement of pig manure and poultry litter anaerobic digestion. The addition of this co-substrate increases carbon/nitrogen ratio, avoiding ammonia inhibition and enhancing the final methane yield.

The objective of this study was to evaluate co-digestion of different mixtures of animal and vegetable wastes. Two different batch experiments were carried out: 1) pig manure and vegetable processing wastes, and 2) poultry litter and vegetable processing wastes. The final aim of the study was to choose the best ratio between animal waste and vegetable processing wastes that produces the highest methane yield. The best mixture will be used to start up a 10L laboratory scale anaerobic digestion plant.

Materials and methods

Substrates and inoculum characteristics

Three different substrates were used: Pig manure (PM), poultry litter (PL) and vegetable processing wastes (VPW). Pig manure was obtained from a pig farm located in Avila (Spain), with 2600 finishing pigs with an annual manure production of 8750 m^3. Poultry litter was collected from a poultry farm located in Palencia (Spain) with 86000 laying hens and an annual manure production of 5850 m^3. Vegetable processing wastes were composed mainly by peas and their by-products and they were collected in a vegetable processing factory located in Segovia (Spain). They were ground to particles of about 1 mm in size in a mill fruit.

The anaerobic sludge (AS) used as inoculum was taken from an anaerobic digester in the municipal wastewater treatment plant (WWTP) of Valladolid, Spain. The composition of each waste and the sludge used is shown in Table 1.

All of the substrates were homogenised previously to use and stored at 4°C.

Table 1. Composition of the substrates. Poultry litter (PL), pig manure (PM), vegetable processing wastes (VPW) and anaerobic sludge (AS)

Parameter [1]	PL	PM	VPW	AS
TS (%)	30.55	4.21	14.30	3.11
VS (%)	18.60	3.45	13.35	1.40
Organic matter (%)	55.14	53.68	67.89	35.60
TKN (mg/g)	13.30	3.78	5.63	1.74
$N\text{-}NH_4^+$ (mg/g)	2.16	2.89	0.49	0.89

[1] TS: Total solids, VS: Volatile solids, TKN: Total Kjeldhal Nitrogen, $N\text{-}NH_4^+$:ammonia nitrogen

Experimental set-up

Different batch essays with 2% of volatile solids were prepared with different proportions of VPW and manure (PL and PM). Mixtures were the following: 100%PM-0%VPW, 75%PM-25%VPW, 50%PM-50%VPW, 25%PM-75%VPW, 100%PL-0%VPW, 75%PL-25%VPW, 50%PL-50%VPW, 25%PL-75%VPW. The essays were performed in triplicate. It was performed in vials with a total volume of 500 ml and a liquid volume of 200 ml (100 ml of inoculum and 100 ml of the correspondent mixture). Blanks were composed of 100 ml of inoculum and 100 ml of distilled water. The pH was fixed at 7.5 and a concentration of 20 g/l of $KHCO_3$ was added to each vial. Vials were closed with a septum and flushed with helium in order to remove the oxygen. Then they were incubated in a thermostatic shaker at 100 rpm and 35±2 º C for up to 68 days.

Analyses

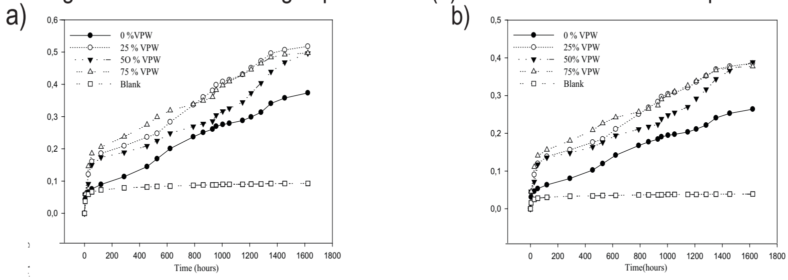
Analyses consisted of total solids (TS), volatile solids (VS), organic matter (OM), total Kjeldahl nitrogen (TKN) and ammonia nitrogen ($N\text{-}NH_4^+$). All the analyses were done according to *Standard Methods for the Examination of Water and Wastewater (APHA, 1998)*. TS were determined from the solids dried at 105°C *(Standard Method 2540 G)*. VS were determined from the subtraction of the solids dried at 505°C *(Standard Method 2540 G)*. Total TKN was determined using a Büchi K-435 digestion unit and a Büchi 324 Distilling unit. *(Standard Method 4500 N B)*. $N\text{-}NH_4^+$ was measured with a Büchi 324 Distilling unit *(Standard Method 4500-NH3 F)*. Organic matter (OM) was measured with the Walkey- Black method *(Walkley and Black, 1934).* The production of biogas was tracked by measuring the overpressure in the headspace with a time frequency depending of the biogas production *(Colleran et al., 1992).* Methane and carbon dioxide content were measure using a gas chromatograph (HP 5890) equipped with a TCD detector.

Results and Discussion

Co-digestion of pig manure (PM) and vegetable processing wastes (VPW)

The cumulative biogas production related with the percentage of VS removed for each mixture and for the blank is shown in figure 1a. The cumulative methane production related with the percentage of VS removed for each mixture and for the blank is shown in figure 1b. Although at the beginning of the assay, the mixture with 75% VPW produced a high amount of biogas, the 75% PM-25% VPW mixture produced the highest biogas yield (518 ml of biogas and 386 ml of methane) at the end of the assay. This demonstrated that a small amount of vegetables as co-substrate in the anaerobic digestion can highly increase the biogas and methane production compared with pig manure alone.

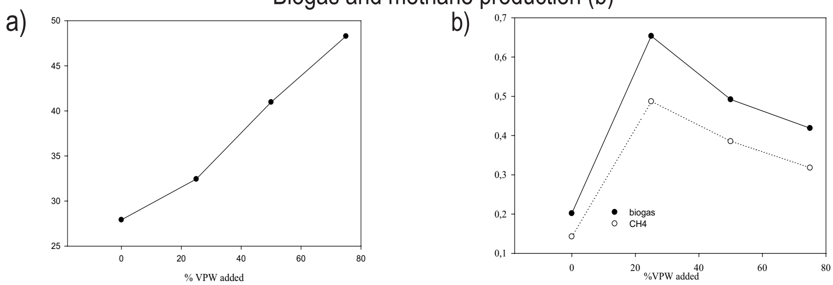
Figure 1. Cumulative biogas production (a) and cumulative methane production (b)



As shown in figure 2a, an increase in the vegetable waste added to the mixture resulted in an increase of the percentage of volatile solids removed, from 28% VS removed for pig manure without VPW to 58% VS removed for the 25% PM-75% VPW mixture .This was due to the fact that the more vegetable waste was added, the more biodegradable organic matter was available for the bacteria. *Callaghan et al, (1999),* reported that anaerobic co-digestion of fruit and vegetable wastes achieved a VS reduction between 45% and 55%. The results in the present study were in this range.

The no-addition of VPW produced the lowest biogas and methane production (202 ml biogas/g VS removed and 143 ml methane /g VS removed). These values are higher than the study carried out by *Magbanua et al., (2001),* that reported that anaerobic digestion of hog manure alone produced a biogas yield of 140 ml biogas/g VS removed. The best yield obtained in our study (654 ml biogas/g VS removed and 487 ml methane/g VS removed) was produced by the mixture composed of 75% of PM and 25% of VPW (figure 2b). This value was much higher than the value achieved by *Callaghan et al., (1999)* for co-digestion of fruit and vegetable wastes (FVW) and cattle manure, which obtained a yield of 225 ml methane/g VS removed. The reason for this high difference in both methane yields is not clear because the VS load was the same in both experiments, so it might be due to some differences in volatile solids composition. It has been demonstrated that methane yield depends on the composition of solids digested *(Neves et al, 2008.*

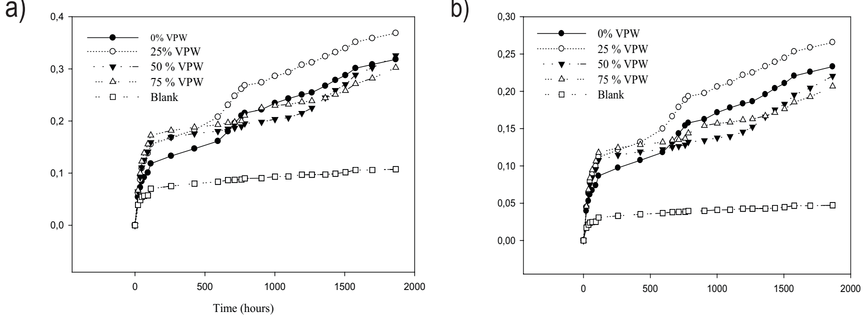
Figure 2. Percentage of VS removed in the different mixtures (a).
Biogas and methane production (b)



Co-digestion of poultry litter (PL) and vegetable processing wastes (VPW)

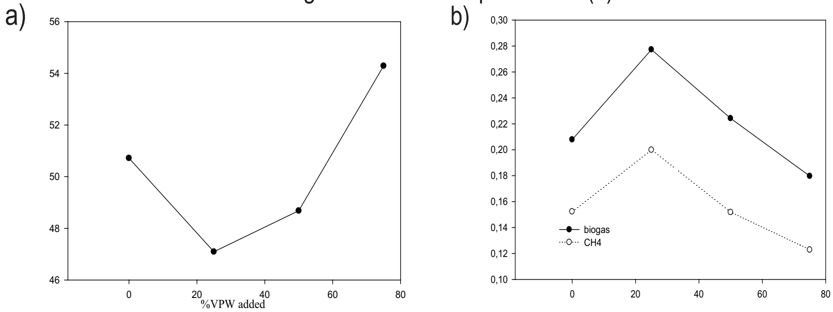
The cumulative biogas production related with the percentage of VS removed for each mixture and for the blank is shown in figure 3a. The cumulative methane production related with the percentage of VS removed for each mixture and for the blank is shown in figure 3b. Poultry litter produced 318 ml biogas/kg SV added and 233 ml methane/kg VS added. The addition of VPW (25%) resulted in an increase of biogas and methane production. However, more than 25% VPW added resulted in an inhibition of the biogas production probably due to pH decrease because of an excessive VFA accumulation (data not shown). Another explanation for this behaviour could be that more than 25% of VPW added to the poultry litter resulted in a lag phase in the beginning of methane production (figure 3b), similar to an organic overload in a continuous system *(Campos., 2001)*.

Figure 3. Cumulative biogas production (a) and cumulative methane production (b)



VS decreased in all the mixtures tested, as shown in figure 4a. Biogas yields improved with the addition of VPW (277 ml biogas/g VS removed and 200 ml methane/g VS removed) compared with PL alone (208 ml biogas/g VS removed and 152 ml methane/g VS removed). As expected, as more VPW added, biogas and methane yields decreased due to acid inhibition (figure 4b). Previous studies reported this inhibition. According to *Callaghan et al, (2002)*, co-digestion with 30% or more of fruit and vegetable wastes resulted in high concentrations of volatile fatty acids and thus inhibition occurred.

Figure 4. Percentage of VS removed in the different mixtures (a).
Biogas and methane production (b)



These essays were the previous work to a more important study in a 10L laboratory scale anaerobic reactor, so it will be necessary to implement these preliminary essays.

Conclusions

Results show that addition of VPW to pig manure and poultry litter for anaerobic co-digestion is a very good method to enhance methane yield and VS reduction. In the case of pig manure, the 75% PM-25% VPW was the best mixture because it produced the best methane yield. The buffer capacity of pig manure contributed to avoid VFA inhibition.

However, for poultry litter and VPW co-digestion it should be necessary an exhaustive control of the amount of VPW added in order to avoid VFA accumulation and therefore inhibition.

References

Angelidaki, I., Ahring, B.K. 1993. Thermophilic anaerobic digestion of livestock waste: the effect of ammonia. Appl. Microbiol. Biotechnol. 38, 560±564.

APHA 1998. Standard Methods for the Examination of Water and Wastewater. 20th ed. Washington, D.C.: American Public Health Association, American Water Works Association, and Water Environment Federation.

B.O.E. (2002). Ley 16/2002, de 1 de julio, de prevención y control integrados de la contaminación (IPPC Spanish Directive).

B.O.E. (2007). Real Decreto 661/2007, de 25 de mayo, por el que se regula la actividad de producción de energía eléctrica en régimen especial.

Bujoczek, G.; Oleszkiewicz, J; Sparling, R and S. Cenkowski. 2000. High Solid Anaerobic Digestion of Chicken Manure. J. agric. Engng Res. 76, 51-60

Callaghan, F.J., Wase, D.A.J., Thayanithy,K. and C.F. Forster. 1999. Co-digestion of waste organic solids: batch studies. Bioresource Technology 67, 117-122.

Callaghan, F.J., Wase, D.A.J , Thayanithy, K. and C.F. Forsterb. 2002. Continuous co-digestion of cattle slurry with fruit and vegetable wastes and chicken manure. Biomass and Bioenergy 27, 71–77

Campos, E. 2001. Optimización de la digestión Anaerobia de purines de cerdo mediante codigestión con residuos orgánicos de la industria agroalimentaria. Escola tècnica superior d'Enginyeria Agrària. Universitat de Lleida. Spain.

Campos, E., Almirall, M., Mtnez-Almela J., Palatsi J. and X. Flotats. 2008. Feasibility study of the anaerobic digestion of dewatered pig slurry by means of polyacrylamide, Bioresour. Technol. 99, 387-395

Colleran, E., Concannon, F., Golde, T., Geoghegan, F., Crumlish, B., Killile, E., Henry, M., Coates, J. 1992. Use of methanogenic activity tests to characterize anaerobic sludges, screen for anaerobic biodegradability and determine toxicity thresholds against individual anaerobic trophic groups and species. Wat. Sci. Technol. 25,31–40.

E.C. (1996). Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control.

Magbanua Jr. B., Adams, T.T , Johnston, P. 2001. Anaerobic co-digestion of hog and poultry waste. Bioresource Technology B 76, 165-168.

Neves,L. ,Gonçalo, E. , Oliveira, R. M.M.Alves. 2008. Influence of composition on the biomethanation potential of restaurant waste at mesophilic temperatures. Waste Management 28 :965–972

Walkley, A. and I. A. Black. 1934. An Examination of Degtjareff Method for Determining Soil Organic Matter and a Proposed Modification of the Chromic Acid Titration Method. Soil Sci. 37:29-37.