Diversification and overviews of anaerobic digestion of Cuban pig breeding

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This study shows the most recent advances of the "Centro de Promoción y Desarrollo de Biogás" (CPDB) about the use, diversification and perspectives of anaerobic digestion of Cuban pigs. Some of the reached results are the generation of electricity using biogas, the development of biodigesters of fixed domes and the tubular ones, the drying bed/biodigester system, and the characterization of biogas, produced in Cuba, not only with water wastes but also with residues of high content of animal fat. It is also stated the usage of new construction materials for repairing the biodigesters, and the experiences of the recycling of water. This study is also about the perspectives of the use of biogas in breeding pigs in Cuba. It can be concluded that the usage of biogas for cooking and generating electricity shows the development and diversification of this resource in Cuban agriculture. The results allowed characterizing the biogas and its more important indicators in the Cuban conditions. Besides, several plant systems of biogas have been evaluated and developed for small and medium pig productions. It is recommended to continue the researches and technology transfers in biogas plants that allow to accelerate, in short time, the use of these plants for the productions of cooperatives, small farms and state farms. It is suggested to continue the development of researches and technology transfers in prototypes of equipment for the use of biogas (lamps, refrigerators, electricity generators, among others). It is necessary to increase the training and organization as a way of increasing the number of specialists and technicians for working in plants and equipment design for the use of biogas, with the objective of carrying out constructions and installations in a short period.

Key words: biogas, pig breeding, environment, generation of electricity

Introduction

The anaerobic digestion is a biochemical process in which the residues of organic origin are transformed into a mixture of gases called biogas. Mud is also obtained and can be used as organic fertilizer.

It is important to highlight that the treatment of pig wastes is mandatory, according to the Cuban laws and regulations (Law 81 of the environment 1997, Cuban Rule CR 27 2012). The Technical Procedures for Breeding Pigs (López *et al*. 2001) are also regulated by the previously mentioned laws.

This process is recognized as one of the most effective process for the disposal of water wastes from the agroindustry, and other wastes. It is recommended to use it as a primary treatment.

For these reasons, before the need of protecting the environment, obtaining fertilizers, biogas and diversifying its use, the CPDB from the "Instituto de Investigaciones Porcinas" (IIP) has developed or adapted technologies for the treatment of agricultural water wastes, especially from pig breeding.

The fixed dome digesters were introduced for the first time in the dairy farm "Niña Bonita" and in pig farms. Besides, the tubular digesters of polyethylene and PVC were adapted with their own projects in small farms. The Cuban biogas was characterized and new construction materials were tested. Alternatives for decreasing the use of water have also been studied and some actions related to the adaptation of pig breeding to the effects of climate change have been presented.

There has also been a development in the diversification of the use of biogas, not only for cooking, where it is frequently wasted, but also to generate electricity with the possibility of being completely used.

Development

I. *Diversification of anaerobic digestion of Cuban pigs. 1.1. Electric energy generation using biogas*. During the 90´s, the IIP carried out the first tests of electricity generation with biogas in a polyethylene tubular digester of 21 m^3 in a pig farm of family scale, located in Punta Brava. At that moment, the available moto-generator worked with diesel, made in United States, like those commonly used by farmers for generating electricity before 1959.

The experiments lasted eight months and consisted on providing electricity to houses from the country during the night hours. This system worked properly during the period of crisis, known as the special period, because the blackouts were really frequent and it guaranteed the electricity every night.

Nowadays, there is a decision to make a scientific and economical evaluation to this activity. From this point of view, studies are carried out to replace the electric energy in the farms using the biogas they produce.

The biogas results from fixed dome digesters of medium capacity, from 48 to 90 m^3 although the studies will cover smaller digester of tubular or tunnel type.

This study was made in the pig farm "Julio Antonio

Mella", belonging to the IIP, located at carretera del Guatao, km 1 ½, in Punta Brava, Havana. The farm has a biodigester of 90 m^3 which is supplied with pig wastes.

Until this moment, the biogas has been used for cooking the food of 350 people, teachers and students, from a near school, and for heating meals, make coffee and other uses of the farm workers. Table 1 shows the characteristics of a biogas moto-generator used in the study.

The farm, where the experiments were developed, has 80 reproducers and their litter up to the pre-fattening category. When they reach around 25 kg, they are used for the production of medicine.

The farm has twelve workers. When making a record of the electric equipment, there are lighting circuits among the ones of low power that include a washing machine, a refrigerator and a computer. There are also water pumps with three-phase system, but they cannot be fed because the moto-generator works with single-phase electric power.

Table 1. Characteristics of a biogas moto-generator used in the pig farm "Julio Antonio Mella"

Model	B4T-500 Bio
Power, CV	10.0
N, cylinders	Monocylinder, of four times with air cooling and OHV
Cylinder capacity, cc	389.0
Ignition	CDI
Intake, m^3/h of work	2
Expense, L/h	-
Maximum height, mca	-
Oil in the crankshaft, L	1.1
Maximum power, kw	4.0
Nominal power, kw	3.6
Voltage, V	110/220
Frequency, HZ	60.0
Charge voltage, V	12.0
Charge electric current, A	8.3
Compression, mm	695.0
Long, mm	555.0
Height, mm	580.0
Weight, kg	84.0
Type	Single-phase electric power
Manufacturer	Branco
Country	Brazil

The following actions were carried out for implementing the experiment:

- Translation into Spanish of the technical manual of exploitation and maintenance of the equipment.
- Training of the technical staff and the workers of the farm that operate the Biodigester-Moto-generator System.
- Charge and implementation of the battery with 12 V-CC for the electrical starting.
- Revision and attachment of the top of the filter and expansion chamber of biogas.
- Production of a electric circuit for fulfilling the demand of monophasic charge from the farm.
- Selection and preparation of the place for the location of the moto-generator in the farm.
- Inspection and tightening of the moto-generator.
- Testing of the system without charge.

The connection of an electric heater of 1250 W and an air-conditioning of 1500 w were rejected during the first part of the tests. In the first stage, the replacement of the energy from the electric lighting and the office is expected that includes a refrigerator for the conservation of medicines and vaccines for treating the animals.

Every motor can be adapted to biogas, but the most commonly used are the gas-Otto and the gas-Diesel motors (Dohne 1998). This means that a cubic meter of biogas can be compared to 0.4 kg of diesel oil, 0.6 kg of oil or 0.8 kg of coal.

The pressure exerted to the biogas defines the distance for transporting it through pipes. Calculations (Borda, quoted by Hesse 1983) state that at 0.8 kN/m^2 of pressure (8 cm of water column) 1 m^3 of biogas can be transported per hour through a pipe of 1.27 cm (1/2"), of 20 m of distance, as well as through pipes of 1.91 cm (3/4") of 150 m. Within a diameter of 2.54 cm (1"), 500 m could be transported. If 2 m^3 per hour are needed the distance should be reduced.

These are some advantages of using biogas for generating electricity:

- Diversification the use of this combustible, not only for cooking, which is typical in less developed areas, but also for transforming it into electric energy, makes more efficient system for treating wastes. This way, the biogas is completely used, avoiding the pollution of the atmosphere and its negative consequences for the environment. In this study the biogas is totally used, unlike its usage for cooking, for which it is not frequently used completely. This is typical of farms in which the number of animals and the biogas production is very superior to the requirements of a small group of workers.

- It encourages the development of the industry of equipment that consumes biogas, and improves the training of the technical staff of maintenance and repair, with new and appealing jobs.

- There is no more need of fossil combustible which are becoming more and more expensive in the international market.

- The electric energy is locally generated, therefore, it is not centralized

1.2. Fixed dome digesters created by the "Centro de Promoción y Desarrollo de Biogás" (CPDB). The CPDB has created a group of executive projects of fixed dome digesters, from 6 m^3 to 90 m^3.

Table 2 shows the behavior of a fixed dome digester of 90 m3 for treating the residues of pigs from three fattening buildings

The value of the total solids of the wastes from the entrance to the digester (1.96) is relatively low and typical under the conditions of this experiment. This happens because the Cuban cleaning system is carried out using a hosepipe with a great stream of water for removing those wastes.

The removal of volatile solids (85 %) and of CDO (72 %) is good for this type of systems. Likewise, the pH of the exit of the digester (7.69 %) has a normal value, as part of the anaerobic digestion. It is located in the range referred by other authors (Schullz and Miherleitner 1990 and Marchaim 1992).

A handbook about the construction of fixed dome digesters (Sosa *et al*. 2009) has been published and distributed all over the country. These designs already contain constructive improvements regarding experiences and researches carried out on similar projects introduced in Cuba.

1.3 Tubular biodigesters. The polyethylene tubular digesters, and later those of PVC, have been studied and used until this moment for small pig productions up to 200 pigs. The first ones started to be studied in Cuba at the beginning of the 90´s, after they were applied in the rural areas of Colombia by the Center for the Research in Sustainable Systems of Agricultural Production (CIPAV, initials in Spanish). They are considerable, mainly, due to their low costs of construction and maintenance and to their simple and fast installation (Sosa 1998, Sosa *et al*.1998 and Sosa 1999).

This system, thanks to its low cost and easy installation, perfectly complements the pig productions at familiar scale, with around 70 pigs, which is getting stronger within the Cuban agriculture.

Table 2 Performance of a fixed dome digester of 90 m^3 created in the IIP (Chao *et al*, 2002).

	Totals Solids,%	Volatile Solids, %	CDO, mg/L	pH
Entrance to the digester	1.96 ± 0.62[1]	1.57 ± 0.49	2310.0 ± 882.0	6.95 ± 0.51
Exit of the digester	0.38 ± 0.08	0.23 ± 0.05	657.0 ± 296.0	7.69 ± 0.24
Removal %	81.0	85.0	72.0	------

Mean and standard deviation (n=80)

Tabla 3. Characterization of the functioning of a biodigester with piston flux for treating bovine and pig waste-waters (Sosa 1999).

Indicators	Residues from bovine	Residues from pigs and bovine
TRH (days)	65.12 ± 7.5	25.45 ± 2.9
Organic Charge (kgDM/m^3 digester/day)	0.33 ± 0.1	2.16 ± 0.3
Organic Charge (kgVS/m^3 digester/day)	0.28 ± 0.1	1.713 ± 0.2
Specific yield of biogas (L/m^3 digester/day)	123.5 ± 24	314.09 ± 65.7
Removal efficiency CDO (%)	73.43 ± 14.4	56.77 ± 20
Removal efficiency DM (%)	71.77 ± 0.1	59.2 ± 20
Removal efficiency VS (%)	71.07 ± 18.3	63.89 ± 15.8

Studies on this type of biodigesters shows similar results of functioning to those of fixed dome (table 3).

Although several of these systems are still functioning, the main disadvantage is the durability of polyethylene with 500 mm thick, and the lack of knowledge of the Cuban producers about the use of them.

The second types, those of PVC, function mainly in central provinces of Cuba and have functioning characteristics similar to those of polyethylene. However, they are more resistant than the first ones. Nowadays, there is a work on the design of versions that will be produced by the Cuban industry.

1.4 Drying bed/Biodigester system. An acceptable reduction of the indicators of environmental pollution (CDO, BOD5, TS, TVS, fecal and total coliforms, and worm eggs) is obtained with the use of anaerobic biodigesters for treating pig wastes. Thanks to these characteristics, they can be used for fertilization and irrigation of several crops, according to the guidelines of WHO (1989).

However, when superior values of decontamination are needed, mainly for water bodies (category I), category applied to rivers and other water deposits for population and tourism, it is then recommended to use a drying bed/biodigester system.

Table 4 shows the results obtained with this system for treating the water wastes of the pig farm from the IIP. Ten reproducers were used with this purpose.

The decrease of the system according to the TS, TVS and CDO is higher than the one of the biodigesters. Therefore, the liquid residues have more possibilities of fulfilling the health rules for being poured in water bodies or being applied to different crops. Besides, the solid wastes are more feasible for vermiculture.

1.5 Characterization of the Cuban biogas. This study was carried out through random sampling of biodigesters of fixed dome, of floating bell and of tubular of polyethylene in small and medium agricultural farms with pigs and bovines. Measurements were performed at the Lab of the Empresa de Gases de La Habana, from the Ministry of Basic Industry. Table 5 shows the results of these experiments.

1.6 Biogas production with residues of high content of animal fat. This kind of study is performed in Cuba for the first time. It consisted on evaluating the biogas production from excretions of pigs fed with processed residues from the slaughterhouse. This material contains 14.88 % of fat, which increased the production of biogas up to 155 % (Díaz 2012). This result is similar to the data referred in the available international bibliography. It also has an environmental and economical importance because it demonstrates that feed for pigs can be obtained when applying the treatment of organic residues from the slaughterhouse which contain fat, and the biogas results from their excretions and it is used as combustible.

1.7 Study and usage of new construction materials for repairing the biodigesters and the floors of pig pens with Concrete Patch and Hydraulic Cement. A proportion of 1:1:1 of Hydraulic Cement, Concrete Patch and water was initially used as painting for repairing and waterproofing the dome of a fixed dome biodigester of 70 m^3. This painting was applied on several occasions in order to create a sheet of painting

Table 4. Characteristics of pig wastes at the entrance and exit of the biodigester and of the drying bed (Chao *et al.* 2000).

Indicators	Total solids (TS) %	Total volatile solids (TVS) %	COD mg/L	pH
Entrance to the digester	6.08 ± 1.941	5.15 ± 1.70	65107.0 ± 20231	6.69 ±0.25
Exit of the digester	1.77 ± 0.42	1.40 ± 0.59	18092.0 ± 5733	7.18 ±0.12
Reduction, %	70.9	72.8	72.2	
Liquid	0.60 + 0.10	-	3215.0 ± 691	
Reduction of the liquid fraction, %			82.1	
Total reduction of the system	-	-	95.1	

Mean and standard deviation (n = 72)

Table 5. Chemical composition of biogas and the studied biodigesters

Name of the component	Formula	Concentration %		
		$\overline{X}$	SE ±	VC
Methane	CH_4	56.10	6.6	11.77
Carbon dioxide	$C0_2$	42.11	6.7	15.85
Propylene	C3=	1.77	0.8	46.57
Hydrogen sulfate	H_2S	1.66	0.28	17.67

of 2.4 mm thick.

The biodigesters have a good technical condition. When they start functioning, the pressure and exploitation of their ability to storage biogas elevates gradually (Sosa, unpublished data).

1.8 Recycling water. Nowadays, there are studies on the recycling of water for cleaning the pig pens and on the usage of rainwater in these facilities. These studies include the *in situ* measurements of cleaning water and rainwater obtained during the production, as well as its microbiological evaluation. The objective of these researches is to diminish the volume of drinkable water currently used for cleaning the pig pens, to make a good use of the water that comes from the biodigester system (drying bed), and to collect rainwater from the roof of pens.

The reduction of the expenses on water for cleaning the pig pens has a direct effect on the volume decrease of the system of water wastes treatment, including the biodigesters, and guarantees the reduction of the investment expenses.

1.9 Overview of biogas for Cuban pig breeding. Current situation of biogas plants from the cooperative pig sector. According to estimated data from 2013 of the Group of Porcine Production from the Ministry of Agriculture, there are 14,000 producers or farmers with mutual understanding.

The physical amount of pigs varies from 30 to 2000, in some cases. Nevertheless, the majority ranges as average between 100 and 120 pigs.

Only the 5.5 % (Sosa *et al*. 2012) uses biodigesters, but this percent is still low, which evidences the great potential of the cooperative sector. This not includes the state sector, where the animal concentrations are superior.

The perspectives of the production and use of biogas for Cuban pig breeding are stated in the Plan of Investments from the Group of Porcine Production (GRUPOR, initials in Spanish), belonging to the Ministry of Agriculture from 2013 to 2020.

These investments expect:

- 1000 biodigesters of 22 m^3 for 100- 120 pigs from the cooperative sector.
- 36 biogas plants of medium ability for the state units.
- Use of biogas for generating electricity.
- Usage of other renewable sources of energy, for instance the installation of 300 solar water heaters in the state farms.

New integrated projects are also presented for the food production for humans and animals, and for the production of renewable energies, including the biodigesters as main element for the treatment of agricultural residues and for the protection of the environment.

The CPDB also works on projects about the adaptation of the pig production to climate change. Technologies are developed for developing and maintaining a sustainable pig breeding.

Conclusions

It can be concluded that the use of biogas for cooking and generating electricity demonstrates the development and diversification of biogas in Cuban agriculture. The results allowed to characterize the biogas and its more important indicators in the Cuban conditions. Several plant systems of biogas have been evaluated and developed for small and medium pig productions.

References

Chao, R., Del Río, J. & Sosa R.2000. Evaluación de un sistema biodigester/lecho de secado en el tratamiento de residuales porcinos. Rev. Comp. de Produc. Porcina. 7(3): 15

Díaz, Y.M. 2012. Influencia de la adición de residuos de matadero procesados a dietas porcinas en la producción y calidad del biogás y los biofertilizantes en biodigestores de cúpula fija La Habana, Master Thesis. Universidad Agraria de La Habana.

Cuban Rule 27. 2012. Vertimiento de aguas residuales a las aguas terrestres y al alcantarillado Especificaciones. Vigentes desde 1999. 11pp.

Dohne, E. 1998. Biogas for motors and Engines. Biogas Forum II. (73):7-8

Hesse, P.R. 1983. Project Field Document No.23. Storage and Transport of Biogas. p. 2

Ley No. 81 del Medio Ambiente. Gaceta Oficial de la República de Cuba. Edición Extraordinaria, La Habana, 1997: 39 p.

López, O., Valdivia, J.M., García A., Leal M., Diéguez, F., Sosa, R., Acosta, M., Cervantes, A., Cárdenas, A., Mendoza, M, Arias, T, Perdigón, R, Morales, G., Santana, I., Mederos, C., Martínez, V., Naranjo, R., Piloto, J., Chao, R. & León, E. 2001. Tratamientos de residuales porcinos. In: Procedimientos Técnicos para la Crianza Porcina. p. 115-120

Marchain, U. 1992. Biogas Processes for Sustainable Development. Bull.FAO Agric. Services, Rome, 95. 165-193.

Schullz, H. & Miherleitner, H. 1990. Agricultural biogas plants and the use of slurry a fertilizer in the Federal Republic of Germany. Report of the International Conference on Biogas Technologies and Implementation Strategies. Bremen. pp. 541 561

Sosa, R. 1998. Construcción y evaluación de un biodigestor de flujo pistón. Ciudad de La Habana. Tesis de Maestría en Ciencias del Agua. Centro Nacional de Investigaciones Científicas

Sosa, R. 1999. Tratamiento y uso de Recursos producidos por excretas Porcinas.. V Encuentro sobre Nutrición y Producción de Animales Monogástricos. Universidad Central de Venezuela. Maracay- Venezuela. p. 82

Sosa, R., Díaz, Y.M. & Cruz, T. 2012. Biogás, seguridad alimentaria y medio ambiente en el contexto del desarrollo local. Ponencia: Situación actual, tendencias y perspectivas del biogás en la porcinocultura cubana. CIBA/UNICA. Ciego de Ávila. CD-ROM

Sosa, R., Del Río, J., Chao, R. & Pérez, A. 1998. Una nota sobre la construcción y desarrollo de digestores de bolsa plástica en la montaña. Rev. Comp. de Produc. Porcina (5) No.2. p. 59

WHO. 1989. Directrices recomendadas sobre la calidad microbiológica de las aguas residuales empleadas para el riego de cultivos

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