VIEW POINTS

Biogas Plant Non-Typical. Fermentation with Solid Substrates

Planta de biogás no típica. Fermentación con sustratos sólidos

https://cu-id.com/2177/v33n3e10

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ABSTRACT: The work refers to the use of a plant of non-typical biogas in Germany. The first one leaves it refers to the exploitation of biogas plants that it doesn't use liquid substrates (pig or caw manure) in co-fermentation with agricultural materials in Germany to produce biogas. In this case, the principles and methods are described that are used in this country to exploit these facilities and their tendency toward the future. The second part of the part is about these same topics in the environment of Cuba. The third leave they discuss: if these systems are viable and would be possible to introduce in Cuba or in countries of the call "Third World"? This way, is the objective of the present work to disclose this type of technology of biogas production, which is carried out in this country and its feasibility of being introduced in the countries of the call "third world".

***Keywords*:** Liquid Substrates, Germany, Cuba, Third World.

RESUMEN: El trabajo se refiere a la utilización de una planta de biogás no tipicas en Alemania. La primera parte se refiere a la explotación de plantas de biogás que no utilizan sustratos líquidos (excretas porcinas o vacunas) en co-fermentación con materiales agrícolas en Alemania para producir biogás. En este caso, se describen los principios y métodos que se utilizan en este país para explotar estas instalaciones y su tendencia hacia el futuro. La segunda parte trata de estos mismo tópicos en el ambito de Cuba. La tercera parte se discuten: si estos sistemas son viables y serian posibles introducir en Cuba o en paises del llamado Tercer Mundo?. De esta forma, el objetivo del presente trabajo es divulgar este tipo de tecnología de producción de biogás, la cual se realiza en este país y su factibilidad de ser introducida en los paises del llamado tercer mundo.

***Palabras clave*:** sustratos líquidos, Alemania, Cuba, Tercer Mundo.

INTRODUCTION

Presently work, is carried out an approach to a type of biogas plant that uses the fermentation of solid substrates for the biogas production. This plant type is not typical in Germany and for this reason it seems important to carry out an approach to the same one. Of here the importance of knowing: What, How and Because? are these plants used in the German context.

On this base, the work intends as objective to give to know the technological characteristics of this installation type. This way the knowledge is potentializes in this address and the possibility could be analyzed to be extrapolated to countries with a smaller development (Third World).

DEVELOPMENT OF THE TOPIC

German case

In Germany big dedicated companies exist to the construction and exploitation of biogas plants inside which it is the Biogas Leinfelden-Echterdingen (Northdata, 2013). In this case this company was the in charge one of to build and to put in exploitation the plant that will be detailed later on. Which is in operation from 2013? This company possesses a website (www.northdata.com/ Biogas+Leinfelden-Echterdingen+GmbH+%26+Co.+KG,+ Leinfelden-Echterdingen/ Amtsgericht+Stuttgart+HRA+721484)

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Received: 24/11/2023
Accepted: 14/06/2024

The authors of this work declare no conflict of interests.

AUTHOR CONTRIBUTIONS: Conceptualization: C. Martínez. **Data curation:** C. Martínez. **Formal Analysis:** C. Martínez; H. Oechsner. **Investigation:** C. Martínez; H. Oechsner. **Methodology:** C. Martínez. **Supervision:** C. Martínez; H. Oechsner. **Writing - original draft:** C. Martínez. **Writing - review & editing:** C. Martínez; H. Oechsner.

where some productive data are offered, but emphasizing that these they are for their selective clients. It is a dossier (file) that details the record of the company, the nets, the financial development, the working indicators, the earnings and the losses etc. Also possess a series of charts excel where they report their productive indicators annually from 2013 until the present time.

In Germany, the Universities support the research and development of this type of facilities, at the same time that these companies support to the Universities with materials and financing to execute their investigation projects. This way, it closes and share the research-production and all win.

The University of Hohenheim maintains narrow working relationships and investigation with companies of this type of regional, national or international character. In the scientific events, forum, fairs or promotion activities, these companies present their new productions and at the same time they help with the financing (sponsor) of the different events. The projects that are generated in the Universities have as objective the industry that is to say the production and generally these they are those that finance it. On the other hand, the users of the projects, in turn are the owners and this way it closes and overturned money. Since the capital that they contribute, they recover it and they obtain profit once the plants put on in exploitation. Previous to all this it stands out that the German Universities, have characterized the agricultural substrates regarding their potential for the generation of biogas. It had exists norms in this respect as the VDI-RICHTLINIEN-4630 (2006), which normalizes all the procedures to make to be able to determine the potential of any biomass that is wanted to investigate. Companies like the KTBL (2018), also exist that possesses a place web (https://www.ktbl.de), where you can determine the production of biogas that one can obtain in dependence ahead of time of: substrate type, percent of fresh matter, percent of organic matter, quantity of substrate to load, type of plant of biogas to use; cost of the substrate, annual production of biogas and yield of methane prospective etc. next will spend to describe the plant analysis object. This plant is formed by 5 digesters of concrete in form of silo tightly closed bunker with walls roofs and doors. Which allow the receipt and distribution of the material to ferment by means of special teams of transport (front loaders with diverse additions), which allow it: to evacuate the digested substrate or to introduce the fresh substrate. The plant operates for only three workers (the manager, the front loader's operator and an operator of the organic load). The load and the casting of the digesters is carried out with front loader that introduces inside these digesters the material to ferment (round pack of hays and material coming from the silage of the corn) in these containers for its fermentation. This technology is "Batch", this means that once ended the biodigestion cycle (35 days), the fermenter empties and it loads for a new cycle again. Inside these containers of concrete are located in their roof a skillful one, which each certain interval of time waters to all these substrates the liquid remainders of other previous digestions (grouts), as well as special inoculums to accelerate the process of fermentation with duration of 35 days. These digestion cameras have some approached dimensions of: 20 m x 4 m x 4 m (long wide, height). The same ones have a difference from the entrance until the end of 1,5º. This allows that the effluents (grouts) generated during the biodigestion of the substrate in each biodigestion camera (biodigester) they are picked up and correspondents to a common cistern where they are stored and they constantly recycle and that this form is guaranteed the quality and quantity of inoculum that it will activate the star of the new cycle of fermentation. The five cameras of fermentation can work simultaneously or in parallel. The normal thing is that they work in parallel, this way it becomes easier the work of loading (with substrate) and to discharge those (digested substrate) for the workers of the installation, due to the great workload of each camera of fermentation. In the second level of the cameras (it leaves superior of these cameras) it is installed the whole necessary equipment that: it allows the one dewed of the effluents on each camera, besides the system that captures the biogas, it sends him to the deposit for their storage and of here it is shipped to the internal combustion motors to generate electricity. At the same time that it generates electricity, they also generate vapor to heat the water that will be an employee in the heating. Finally, the roof of the installation, it is had in their entirety of photovoltaic panels. This way, they are used two renewable sources of energy simultaneously for the consumption of the installation and for the sale of the surpluses to a noted near community "Echterdingen" during the whole year, with which one has a contract to such goods. The objective of this plant is to produce biogas and to sell electricity and heat to the community of "Echterdingen" and the same time to obtain an organic biofertizers for the farmers that producing all the substrate to the plant need.

The authors of this work approach

this system presents as advantages: not to have to use excretes liquid swinish or bovine and this way it is not necessary to have an installation from this type to the biogas plant, that which mainly in the proximities of the cities, they are not very welcomed by the population.

On the other hand, once digested the substrates, these they are taken out to the exterior where they are loaded in means of transport and they move

toward the fields where they will be spread in form of organic biofertizers for the machine specialized in this activity. Closing the circle among the substrates cool air that are digested and those fermented that they are used in the bio fertilizing of the soil of the producers associated to the biogas plant. The fresh solid substrates' that are used are produced by a group of farmers (13) that in turn are the owners of this installation (shareholder). This way, they produce the material to ferment and they receive as ended product: electricity, heat and bio fertilizers. The difference between this plant and the typical biogas plants Germans is remarkable. The typical plants here are similar to those that are appreciated in the scale model of the experimental station of the University of Hohenheim (Fig.1). In this case, the biogas plants here use the co-fermentation of bovine or swinish manure with agricultural substrates, which are generally prepared for this end in silos type bunker, the most utilized agricultural substrates with these ends is corn, but other substrates and mixtures of these are also used. In the case of corn, the whole plant is harvested, cut it in small pieces, is placed in the silo bunker and later on once transformed into silaje, it feeds to the biogas plant like substrates. In the scale model they can be appreciated to reduced scale particulars of a German typical plant. Next it is exemplified with figures, which exposed with regard to this biogas plant of accustomed to residuals (Figures 1-10).

Cuban case

In agreement Cuba with Suárez *et al.* (2021) a potential of production of upward biogas exists to 136 533 211 annual m^3, with an energy value of 75 289 tep/years and a potential of generation of electricity of 245 760 MWh/years. The biodigesters that are used in Cuba doesn't generally overcome the 90 m^3 of capacity. The main diffused technologies are those of fixed dome or Chinese model and the tubular plastics. Another technology that it has begun to introduce is the biodigesters of covered lagoon, appropriate for big masses of animal and for the electricity generation. Although they require a bigger initial investment, they have smaller investment cost for cubic meter of digestion capacity. These biodigesters that overcome the thousands of cubic meters, requires synthetic geo-membranes, electricity generators and other teams and cared auxiliary components. In an evaluation carried out by the Ministry of the Agriculture (MINAG) in the year 2020 that it embraced swinish 138 center, 4 198 swinish agreements, 1 999 dairies and 290 poultry farms, is a potential of electric generation of 807 552 MWh/years appreciated, equivalent to 241 782 t/years of fuel that avoids to emit 3,6 MM t of CO? eq/years. This potential allows producing

FIGURE 1. Small scale of a biogas plant associated to bovine facilities: I file of the author.

FIGURE 2. Detail of the fresh substrates dedicated to the fermentation (packed). It observes that in some cases they are covered with nylon. Source: author file.

FIGURE 3. Bunker silo for fermentation of the corn (silage) for their later bio fermentation. Observe the roof of the installation covered with photovoltaic panels. Source: author file.

FIGURE 4. Particulars of substrates without digesting (a) and digested (b) evacuated of the digester 1. The door digester 1 are observed open for extraction of digested material and their later one filled. Source: author file.

2 500 bio-fertilizer t/year, necessary to improve much degraded soil. 2 290 biodigesters was identified, they work 1 589. Of this figure 1 558 belong at the cooperative sector and peasant and 31 to the state sector; of the 6 625 cattle units (swinish 138 center, swinish 4 198 agreements, 1 999 dairies and 290 poultry farms), 34, 6% only possesses biodigesters and alone in 24% of them they are in operation. The main use of the biogas in Cuba is in kitchens from adapted GLP to biogas. There are experiences in kitchens, rice pots, refrigerators, illumination lamps and water heaters designed to use biogas, as well as small imported electricity generators, mainly through projects like Biomass-Cuba, but the use of the biogas doesn't overcome 10-20%.

Big biodigesters

In the municipality Martí, in the county of Matanzas, is two biodigesters of covered lagoon in operation. The adult has a capacity of 4 000 m^3 and it is located in a swinish center of Military Agriculture-forest company (AGROFAR). This team, supported by Biomass-Cuba, gives treatment to the residual of 11 000 pigs and it has a generator of 120 kW; the other biodigester in operation, with 1 700 m^3, is in a swinish center of Experimental Center of Development of the Cattle raising (GEGAN) and it has associate a generator of 80 kW; both give the electricity generated to the National Electric System (SEN). it is in construction another biodigester with this technology, with similar design and support of the projects Biomass and Bioenergie, led by the Experimental Station "Indian Hatuey" (EEIH), to 85% of execution of the work. The plants of biogas production in Cuba are using the mono-fermentation of excrete pig or caw. They are plants of small and medium format, which are always associated to swinish or bovine facilities with the objective of producing energy to small scale (cooking and electricity). on the other hand, the use of the effluents of the biodigesters like organic payment has been reported by several investigators among them Hernández *et al.* (2008); Utria *et al.* (2008); Negrin y Jiménez (2012); López *et al.* (2017); Martínez y Francesena (2018); Odales *et al.* (2020); Martínez *et al.* 2021; Martínez *et al.* (2021), highlighting its kindness and the possibility of using them as imports substitutes and soil boosters.

In this work, it has been able to appreciate that in the Cuban case, some few plants of great format exist, but anything similar to what is presented here. The installation type that discusses in this work is of great format and completely different in its construction technologies and operation with regard to the current Cuban plants. However, it would be interesting to be able to value this plant type in a small format in Cuba. For that a foreign investor is needed. Since the advantage of this plant type could be the non-association to any swinish or caw facility. Clear this, when depending totally on solid substrates; one would have to guarantee the whole infrastructure to produce them and to prepare them for the process of biodigestion of solid substrates. Of achieving the above-mentioned, it would be the knowledge of if it is possible or not, this technology type in the Cuban case. Finally, the great one questions to it will be: That the foreign investor obtains if he decides to carry out a project of this type in Cuba? To our approach:

FIGURE 5. External seen of the entrance to the 5 digesters. Source: author file.

FIGURE 6. External of the plant, where the tank is appreciated to store the surplus of the generated hot water. Source: author file.

To promote this technology in countries of the "third world" and to demonstrate their economic feasibility to small scale. Because it to great scale in the case of the European Union this sufficiently demonstrated one.

DISCUSSION

Unfounded to doubts, the knowledge of what is wanted and one could make in the technologies of fermentation of solid residuals, it is a road to future of the study of this topic in Cuba. In the case of Germany that already this demonstrated today in day. In the Cuban case it is an option to value that it not could get it one day very distant, with the help of the foreign-owned investment. However, being realistic, a lot of road to travel him misses Cuba to be able to use with efficiency the diverse renewable sources of energy, but the first thing that should be clear, it is that without research and development it is not possible to end up paying the domestic energy problems. In this address, the use of the agricultural biomasses is one of the many alternatives that can be used, but the same as in other spheres of the domestic development, political and economic will is needed to take steps that take to the country to achieve it. To study and to analyze all the alternatives inside this type of technologies (biogas production), it can take us to know which would be feasible of introducing in the Cuban case. In these moments where the country crosses for a crisis with the exceptional fuels (knowing that approximately 60% of the electricity generation in Cuba is to leave of fossil fuels in (industries water heater energetics), it would be very hit upon to meditate in the form of leaving that painful situation once and for all and for all, with the support of the renewable sources of energy. That which is feasible, possible and necessary to achieve energy independence through our own internal resources.

CONCLUSIONS

The technology for the biogas production with solid substrates is broadly well-known and in constant development in Germany and Europe. The whole technological package meets norm with national and international norms of obligatory execution. In these moments, Germany is trying to export this technology to the developing countries. Some African countries are already interested in the topic. Cuba could be in the sphere of influence of these technologies with regard to Center and South America. It would not be anything disheveled to try to prove a station of this type of small format with the purpose of to win knowledge and to value their possible technician-economic viability. In all new projects, it will always be necessary to run risks. An important aspect will be to define the foreign partners and its interests in the holding in projects of this type in Cuba.

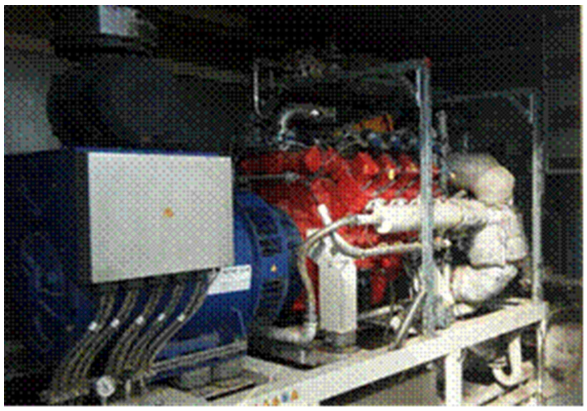

FIGURE 7. Detail of the internal combustion motors which transform the biogas into electricity. Source: author file.

FIGURE 8. Detail of the tank to store the biogas produced. Source: author file.

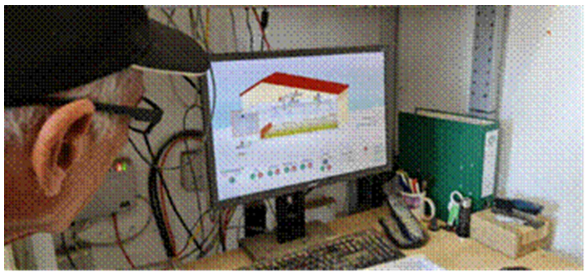

FIGURE 9. Detail of the program to control the operation of the biogas plant. Observe the showers for spread the inoculum and the pipes to capture the biogas. Source: author file.

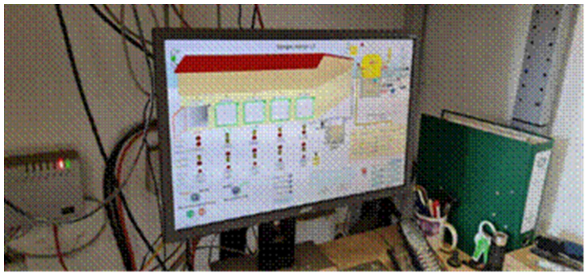

FIGURE 10. Detail of the pursuit of the process in each digester by means of the room control. Source: author file.

GRATEFULNESS

To the University of Hohenheim, specifically to the State Institute of Agricultural Engineering and Bioenergy.

REFERENCES

HERNÁNDEZ, M.F.; PRIETO, H.C.R.; SONIA, C.; GONZÁLEZ, J.; SANCHEZ, J.V.: *Los biodigestores como aportadores de energía y mejoradores del suelo*, *[en línea]*, 2008, *Disponible en: Recovered from* https://docplayer.es/45125012-Los-biodigestores-como-aportadores-de-energia-ymejoradores-del-suelo.html.

KTBL: "KTBL-Feldarbeitsrechner", 2018.

LÓPEZ, D.E.; CALERO, H.A.; GÓMEZ LEÓN, L.Y.; GIL, U.C.Z.; HENDERSON, D.C.; JIMENEZ, J.C.: "Agronomic effect of the biosolid in tomato cultivation (Solanum lycopersicum): biological control of Rhizoctonia solani.", *Cultivos Tropicales*, 38(1): 13-23, 2017, ISSN: 0258-5936.

MARTÍNEZ, H.C.; FRANCESENA LÓPEZ, Y. (2018) 'Tratamiento y utilización de efluentes instalaciones de biogás como abonos orgánicos, revisión y análisis', *Centro Agrícola*, 45(2): 83-92. ISSN: 0253-5785.

MARTÍNEZ, H.C.; SÁNCHEZ, J.J.A.; REINOSO, P.M.; RODRÍGUEZ-URRUTIA, U.A.; MARTÍNEZ, F.N.R. (2021) 'Uso de efluentes de lagunas de oxidación del complejo "Carlos Baliño" como fertilizantes orgánicos', *Revista Ciencias Técnicas Agropecuarias*, 30(1). ISSN: 2071-0054.

MARTÍNEZ, H.C.; GARCÍA, L.Y.; OECHSNER, H. (2021) 'Biogas Plants in Germany: Revision and Analysis', *Revista Ciencias Técnicas Agropecuarias*, 30(4): 88-100. ISSN: 1010-2760.

NEGRIN, B.A.; JIMÉNEZ, P.Y.: "Evaluación del efecto agronómico del biosólido procedente de una planta de tratamiento por digestión anaerobia de residuales pecuarios en el cultivo del frijol (Phaseolus vulgaris L)", *Cultivos tropicales*, 33(2): 13-19, 2012, ISSN: 0258-5936.

NORTHDATA: *BioGas Leinfelden-Echterdingen*, *[en línea]*, Northdata, 2013, *Disponible en: por www.northdata.com/ Biogas+Leinfelden-Echterdi ngen+GmbH+%26+Co.+KG,+Leinfelden-Echterdingen/Amtsgericht+Stuttgart+HRA+721484* .

ODALES, B.L.; LÓPEZ, D.E.; LÓPEZ, G.L.; JIMÉNEZ, H.J.; BARRERA, C.E.L.: "Biofertilizer potential of digestates from small-scale biogas plants in the Cuban context", *Revista de Ciencias Agrícolas*, 37(2): 14-26, 2020, ISSN: 0120-0135.

SUÁREZ, J.; GUARDADO, J.; CEPERO, L.: "El estado del biogás en Cuba", *CUBAENERGÍA*, 7, Boletín informativo renovable.cu. Centro de Gestión de la Información y Desarrollo de la Energía (CUBAENERGÍA), CITMA, La Habana, Cuba, 2021, ISSN: 2219-6919.

UTRIA, E.; CABRERA, J.; ESCOBAR, I.; MORALES, D.; FERNÁNDEZ, A.; TOLEDO, E.: "Utilización agraria de los biosólidos y su influencia en la planta de tomate", *Revista Chapingo. México. Horticultura*, 14: 38-39, 2008.

VDI-RICHTLINIEN-4630: *Fermentation of organic material characterization of substrate, sampling collection of material data, fermentation tests*, Inst. VDI-RICHTLINIEN, Dusseldorf, 2006.

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