Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 16, Issue 2, 2016
PRINT ISSN 2284-7995, E-ISSN 2285-3952

TECHNOLOGY TRANSFERS FOR DEVELOPMENT AND OPERATION OF MESOPHILIC BIODIGESTERS WITH MANUAL AGITATION

Carlos SABORÍO VÍQUEZ

University of Costa Rica, Postal Code 2060, San José, Costa Rica, Email:biocolibris@gmail.com

Corresponding author: biocolibris@gmail.com

Abstract

According to the needs of small farmers and indigenous population in their communities, a study was conducted to determine the best alternative applicable to this people; the study is based on the production of renewable energy in the form of biogas produced by mesophilic biodigesters. They were compared between different types of digesters used throughout the history of the production of biogas and determined to be the best choice in the field of biogas production to the areas mentioned above is that of innovation digesters having a system of manual agitation, which enables durability of the bacterial mass provided by the even greater biomass in a digester without agitation, which in turn increases the service life of the digester, and also takes into account the needs of the population of interest and resources.

Key words**:** *biodigester, biomass, indigenous population, manual shaking system, small farmers*

INTRODUCTION

The importance resides in creating a technology for the production of biogas as a renewable energy source through biodigesters in which to benefit indigenous people and small farmers in their communities where they do not have electricity to operating a digester with power agitation.
This is accomplished by creating a digester with shaking, which can be operated by a person in the community.
A digester about seizing all organic waste currently not utilized and otherwise represents a constant danger of environmental pollution.
In the vast majority of indigenous villages of our country, there are breeding farms and there is no means for the rational use of waste so that there are countless landfills where these wastes are dumped polluting the environment and wasting energy source It's very important.
It can be subjected to this waste as is the case of manure and other organic wastes, a process of anaerobic fermentation (without oxygen) as this process is available to any producer or organized community that wants do this, including indigenous communities.
The energy obtained is in the form of gas, which is called biogas or methane gas, since it is similar to swamp gas obtained by decomposition of all organic matter deposited therein.
This gas can be put into operation from kitchens and household lighting, motors to generate more electricity. (Kern and Siepenkothen, 2014) [8].
This type of bio-energy projects have a feasibility in various fields, as they are human, where diseases and pests are avoided, economic jobs, small and medium enterprises and development have been created, and socially not involve the transformation of foods from the basic food basket, this do not affect food security as well, the main objective of the research, which is that indigenous people and small farmers can use these tools to survive self-sufficiently, and the tools given are the most optimal. (Belhadj et al., 2013) [6].
Investigation's main objective: Develop mesophilic digesters with manual agitation, which can be used by both indigenous people as by small farmers, in the production of biogas as a renewable energy source.
Specific objectives: (i) To demonstrate the superiority of biodigesters with stirring over biodigesters without agitation.**(ii)**To demonstrate the efficiency of biogas production by having a stirring system either

mechanical or manual.**(iii)**To provide tools to small farmers and indigenous peoples to enable them to develop in the energy field as well as in humans.**(iv)**To discuss the different methods for the preparation of biodigesters so that they can transfer technologies for people with certain disadvantages.

MATERIALS AND METHODS

Procedure. The research was conducted in the Agricultural Experimental Station Baudrit Fabio Moreno (EEAFBM) in La Garita de Alajuela, Costa Rica.
The EEAFBM is located at 850 meters above sea level, has an area of 53.6 hectares; The average annual rainfall is 1,940 mm, distributed from May to November, while the annual average ambient temperature of 22 ° C.
The soil consists of sandy clay loam and sandy-clay loam. The region has a humid tropical climate, with rainfall ranging between 3,000 and 4,000 mm per year (Table 1, Fig. 1, 2 and 3).

Table 1. Maximum and minimum temperature, precipitation and light hours per month in Costa Rica.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Max. Temp. (°C)	27	27	28	28	27	27	27	27	26	26	26	26
Min. Temp. (°C)	17	18	18	18	18	18	18	18	17	18	18	18
Precipitation (mm)	6,3	10,2	13,8	79,9	267,6	280,1	181,5	276,9	355,1	330,6	135,5	33,5
Light hours (%)	40	37	39	33	25	20	21	22	20	22	25	34

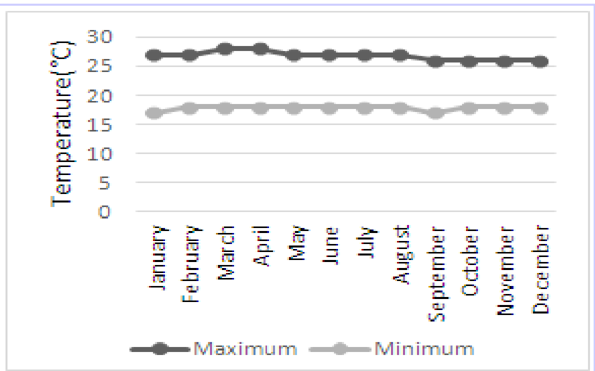

Fig. 1. Maximum and minimum temperatures per month in Costa Rica.

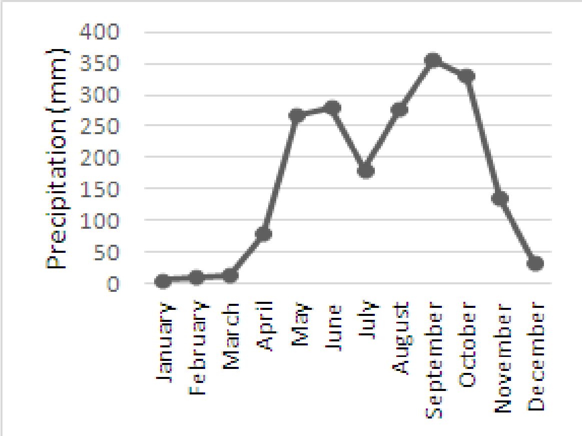

Fig. 2. Annual precipitation per month in Costa Rica.

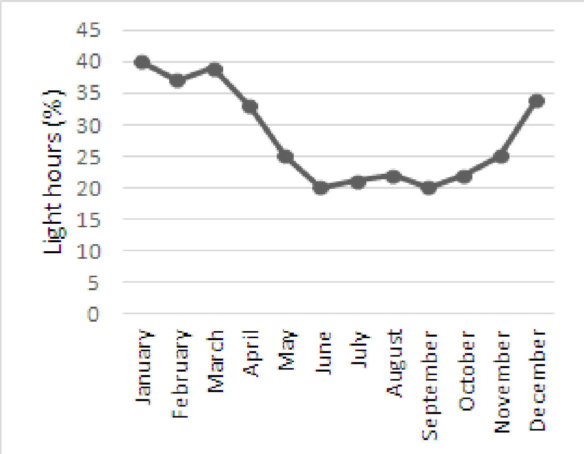

Fig. 3. Annual light hours received percentage in Costa Rica, per month.

History and origin of the biodigesters: It was in the eighteenth century when the presence of methane gas was detected in the decomposition of biogas, and later in the century XIX isolated experiments conducted by L. Pasteur demonstrated the feasibility of using the capacity of combustion of methane for energy purposes.(Coker, 2012) [7].
In the late nineteenth century and the first decades of this century in several cities in Europe, India and the US plants for sewage treatment, where sewage sludge were subjected to anaerobic digestion were installed. The gas produced is used for lighting public or as part of fuel needed to operate the plant. (Coker, 2012) [7].
During and immediately after World War II, the fuel crisis made the research in this area will increase, forcing the development to small and large scale, then in several European countries were developed and

disseminated plants for the production of biogas in the middle rural, in order to operate tractors and automobiles, due to the scarcity of fossil fuels such as oil.(Li, 2011) [9].

During the 1950s, in Asia and particularly in India, simple models proofers better known as digesters to produce biogas and appropriate for villagers homes and fed manure and plant waste fertilizers are developed.(Li, 2011) [9].

In China, India and South Africa, due to the shortage of funds these methods were spreading and developing so that today at present these countries have more than 30 million Biodigestores functioning properly, and developed techniques of gas generation small and large scale. (Moriarty, 2013) [10].

Types of digesters:

To conduct the investigation, were tested different types of biodigesters, which are detailed below.

- **Septic tanks:**

It is the oldest and simple anaerobic digester is known, normally used for the disposal of domestic sewage. It is believed that this derives from the potential of the gases produced by the anaerobic fermentation, for household use. For proper operation of these wells is a prerequisite to isolate sewage falling on it, from those containing soap or detergent. The effect of soaps and detergents especially inhibits the metabolic action of bacteria, and therefore clog the wells quickly and become inoperative, often necessitating uncover to restart the operation. When it is not possible to separate the soapy sewage, and urban sewage, it is necessary to make a chemical treatment with testers that this water in order to solve the problem before starting the anaerobic fermentation. (Ruiz, 2010) [14].

Photo 1. Installing biodigester septic tank.(Taken from Eternit.com)

- **Floating dome or Indian biodigester:**

This digester consists of a drum, originally made of steel but later replaced by fiberglass reinforced plastic to overcome the problem of corrosion. Normally the reactor wall and background are constructed of brick, although sometimes used reinforcing concrete. The gas produced under a floating cover that rises and falls in a central guide is trapped. The gas pressure available depends on the weight of the gas holder unit area and usually varies between 4-8 cm of water pressure. The reactor is fed semi-continuous manner through an inlet pipe.(Pandey and Soupir, 2012) [12].

Photo 2. Floating dome or Indian Biodigester fully operational.(Taken fromASOBIOGAS.com).

- **Fixed dome or Chinese biodigester:**

This reactor consists of a strong gas chamber constructed of bricks, stone or concrete. The top and the funds are hemispherical and are joined by straight sides. The inner surface is sealed by many thin layers of mortar to make it strong. The feed line is straight and flush ends. There is a cap inspection on top of the digester for easy cleaning. The gas produced during digestion is stored under the dome switches and some of the volumes site digester effluent in the chamber, the dome pressures between 1 and 1.5 m of water. This creates quite high structural strength and is the reason for hemispheric top and bottom. High quality materials and expensive human resources are needed to build this type of digester.

This installation has the advantage of its long service life (can reach on average 20 years), provided that a systematic maintenance is performed.(Rajendran et al., 2012) [13].

Photo 3. Fixed dome or Chinese biodigester fully operational. (Taken from AEBIG.com) .

- **Flexible structure biodigester:**

The high investment required to build the digester fixed structure was a limiting factor for the low income of small farmers. This motivated engineers in Taiwan Province in the sixties to do biodigesters with flexible and cheaper materials. Initially nylon and neoprene are used but they proved to be relatively expensive. Further development in the seventies was to combine PVC with the residue of aluminium refineries product called "red mud PVC."

This was later replaced by less expensive polyethylene which is now the most commonly used material in Latin America, Asia and Africa. Since 1986, the Centre for Research on Sustainable Agricultural Production Systems (CIPAV) has been recommending inexpensive plastic biodigesters as appropriate technology for making better use of livestock waste, lowering blood pressure and other natural resources.

In this digester gas accumulates at the top of the bag, partially filled with biomass during fermentation; the bag is inflated slowly with a low operating pressure, because they cannot exceed the pressure of it. (Ocaña, 2011) [11].

Advantages of plastic biodigesters economic:

i) This type of biodigester is very economical and easy to carry because of its low weight, especially in places with difficult access.

ii) Being sealed losses are reduced.

Biogas plants can provide several benefits to rural communities, including a reduction of physical labor, especially of women, reducing the pressure on natural resources such as fuel and charcoal, production of cheap energy, improves culture system recycling manure through biodigesters, production of cooking gas and fertilizer (manure once gone through a digester becomes an excellent organic fertilizer and reducing pollution, especially in urban areas. (Ocaña, 2011) [11].

Among the disadvantages of plastic biodigester is its low lifetime, making it necessary to set up a new facility every three years. It is also vulnerable to breakage due to adverse weather conditions, the actions of man and animals. (Ocaña, 2011) [11].

Photo 4. Flexible structure biodigester fully operational.(Taken from Carlos Saborio's investigation)

Biodigesters by type of bacteria involved in the decomposition of organic matter.

The proper management of organic waste is achieved through different treatments involving a recycling of these organic materials, transforming them into value-added products. The recycling of organic matter has received a major boost with the high cost of chemical fertilizers, the search for non-traditional energy alternatives, as well as the need for decontamination pathways and disposal. (Belhadj et al., 2013) [6].

The microbial population plays an important role in the transformation of the organic soils especially if it is deemed to have a range of responses to the oxygen molecule, universal component of cells. This allows for processes based on the presence or absence of oxygen, in order to adequately treat various organic wastes. (Zhu and Kumar, 2013) [16].

- **Psychrophilicbiodigesters:**

It is also recognized that there bacteria growing in a range of 6.0 ° C to 20.0 ° C, referred psychrophile; but the degradation kinetics determined that this type of plant has no practical interest for the design of biodigesters. But for bacteria to work optimally, it is necessary to keep the temperature as constant as possible, that is to say, without sudden jumps in temperature during the day. Anaerobic fermentation process does not generate a significant amount of heat, thus the temperature above be achieved from outside. (Sathish and Vivekanandan, 2014) [15].

- **Mesophilicbiodigesters:**

A mesophilic digester in particular, operates at a temperature between 30 and 37 ° C, therefore the temperature of the melt is more important to control and monitor, with the inflow of daily broth and the flow of gas generated parameter. (Aremu and Agarry, 2012) [4].

In addition to measuring the aforementioned parameters, the system must control different devices vital for optimum performance and safety as the pump inlet, the engine produces stirring the broth, closed circuit pump water through the heat exchanger heats broth, gas compressor and all necessary measures to maintain the dynamics of the system valves. Another vital function to be performed by the system is to ensure the safety of both people and mechanical and electrical elements that are part of the biodigester, monitoring and controlling all necessary variables. (BaniHani et al., 2015) [5].

- **Thermophilicbiodigesters:**

It is a digester operating at a temperature above ambient, operating between 60 ° C and 80 ° C. The main disadvantage of this type of digester is that the raw material is required at high temperature. For this, the use of it is lower than conventional digesters, operating at lower temperatures. However, this type of digester is used for example in the tributaries of the production of alcohol from sugar cane.

For a given volume of a digester, it produces ten times more biogas, while a digester operating at room temperature. Also, the construction cost is lower. Given that the thermal insulation is of higher cost, this type of digester is cheaper to build, since methane production and digestion are equal.

Conventional digesters do require a large mechanical type, such as agitation of the dispensing system of the digester and a great job for this natural convection mechanical agitation, in this type of digester completely replaces mechanical agitation. (Anisiji, et al., 2014) [3].

Biomass sources:

Biomass sources that can be used for energy production cover a wide range of materials and sources waste forestry and aquaculture, urban waste and energy plantations, they are generally used for modern processes of conversion involving power generation on a large scale, focused on replacing fossil fuels. (Al-Rousan and Zyadin, 2014) [2].

Agricultural residues such as firewood and charcoal have been used in traditional processes in developing country and primary uses small-scale, for example, cooking food or small productive activities such as bakeries, boilers, drying grains, etc. (Al-Rousan and Zyadin, 2014) [2].

Energy plantations: these are large plantations of trees or plants grown specifically to produce energy. To do trees or fast growing plants are selected and low maintenance, which usually are grown on land with low production value.(Al-Rousan and Zyadin, 2014) [2].

Forest waste: wastes from forestry processes are a major source of biomass that is currently under-exploited. It is considered that each tree removed for timber production, only commercially advantage from a nearly 20% share. It is estimated that 40% is left in him, in the branches and roots, even though the energy potential is far and another 40% in the sawmilling process, in the form of chips, bark and sawdust.(Aguayo and Ojeda, 2009) [1].

Agricultural waste: agriculture generates significant quantities of waste, is estimated that, in terms of debris field, the percentage is over 60%, and process waste, between 20% and 40%. On the other hand, the farms produce a high volume of wet waste in the form of animal manure. The common way to treat this waste is scattering in the fields, with double interest to dispose of them and benefit from their nutritional value.(Al-Rousan and Zyadin, 2014) [2].

Industrial waste: the food industry generates a lot of waste and by-products, which can be used as sources of energy, from all kinds of meat (poultry, beef, pork), and vegetables (peel, pulp) whose treatment as wastes represent considerable cost to the industry. These residues are solids and liquids with a high content of sugars and carbohydrates, which can be converted to gaseous fuels.(Aguayo and Ojeda, 2009) [1].

Urban waste: urban centers generate a large amount of biomass in many forms, e.g. food waste, paper, cardboard, wood and sewage.

The lack of adequate systems for processing the waste generated great problems of contamination of soils and watersheds, particularly by improper waste disposal and collection and treatment systems with high operating costs.(Al-Rousan and Zyadin, 2014) [2].

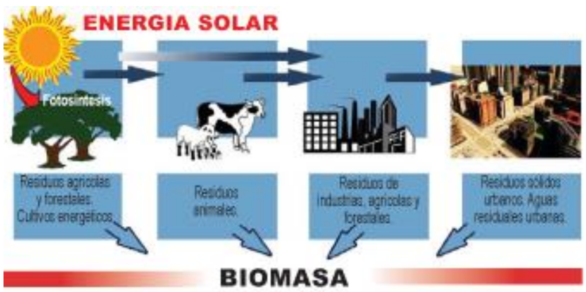

Fig. 4. Various sources of biomass that can feed a digester.(Taken from Elpais.com.).

Preparation of biomass:

As part of the work in order to obtain a better biodigestate efficiency from the point of view of the growth of bacteria, it is recommended and essential, that there is adequate anaerobic fermentation; besides the stirring process, the biomass of agricultural origin must be previously subjected to a hydrolysis process (fermentation), by which over the course of about 15 days, the biomass of plant origin below the decomposition process, which in turn advance the anaerobic fermentation process once introduced into the digester, which in turn, produce biogas more quickly and efficiently.

Methodology:

To conduct research experiments with different types of digesters were performed, as well as modifications to these to analyze the optimal potential that can offer in terms of biogas production and ease of handling.

Variables such as building materials and design of the digester, reaching more favorable results with mesophilic digester model, sustained by external membrane structure were analyzed with stirring.

It is noteworthy that the agitation system, can be hybrid, in areas that do not have electricity, it can start with a manual stirring, which will be mentioned later; and when it begins production of biogas, this may be used in transforming the biogas produced from electricity and thus can power an engine that was later responsible for the agitation, so the digester may be placed on up either manually or by means of a motor that works with the same biogas produced by the digester.

The stirring system is carried by a horizontal bar moved by a motor (motoreductior), which is explained in Figure 6.

Photo 5. Geared motor for mesophilic digester agitation in the form of horizontal bar. (Taken from Carlos Saborio’s investigation).

RESULTS AND DISCUSSIONS

Mesophilic biodigesters with manual stirring:

Construction:

The sizes of these digesters may vary depending on the needs of both the available biomass and the energy requirements fully flexible type of manual stirring. It performs better in both digesters with concrete base structure as a structure in which the agitation system comes not affect the membrane of the digester, can cause damage to its which can cause poor digestion of organic material or even a leak of biogas. The following figure shows the design that arises based on a flexible structure with a stirring system shown manually built.

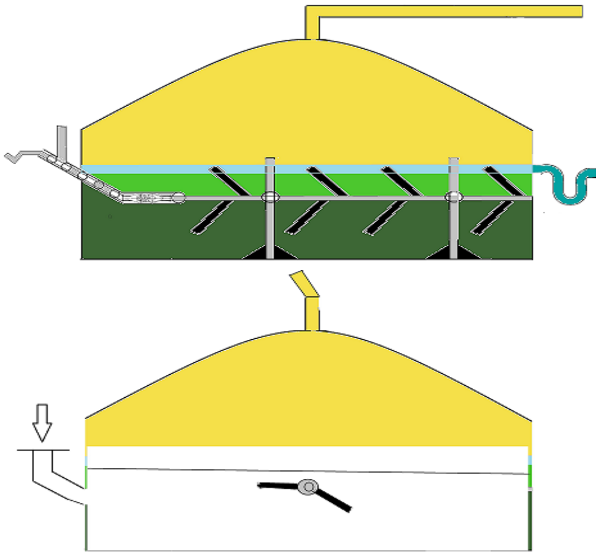

Fig. 5. Proposed model for the mesophilic digester with manual stirring up in a front view, side view in down. (Taken from Carlos Saborio's investigation)

Biomass inside the digester is compacted in the absence of agitation, resulting in the deterioration of the biodigestate and digester life is shortened. Here the importance of the turmoil in the implementation of a mesophilic digester. This is especially relevant when the digester is in a remote or difficult to access area in which the support from trained personnel may be zero or at distant periods, such as in indigenous areas or rural areas.

If the case of biodigesters based in concrete and sustained external membrane structure, have the advantage that the membrane can expand or contract according to the volume of filling the same need, if the membrane is sufficiently full, thanks their support tubes, this will be able to move up in order to not be broken, even if in a situation where the volume down on the membrane.

Through a system of vertical rail, the structure that supports the membrane can move according to the increase that has biogas within the digester. Being umbrella type this structure outside the membrane, it has the advantage that without opening the membrane and thus lose biogas; you can do any work from the outside of this membrane. The automatic coupling of the membrane shown in Photo 6.

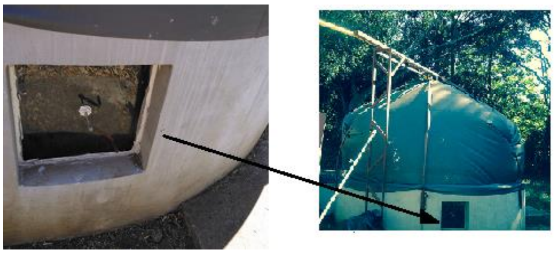

Photo 6. System coupling membrane with slide rail.(Taken from Carlos Saborio's investigation).

Mesophilic biodigester model with manual agitation also has a window system which allows visually monitor the biomass into the digester. This system external window incorporated in the wall of the digester can observe the inside biodigestate. In order to maintain the cleanliness of the window, has a built-type windshield washer system, which through a simple and inexpensive construction, allows optimum cleaning by clearly see the biodigestate inside. This system shown in Photo 7.

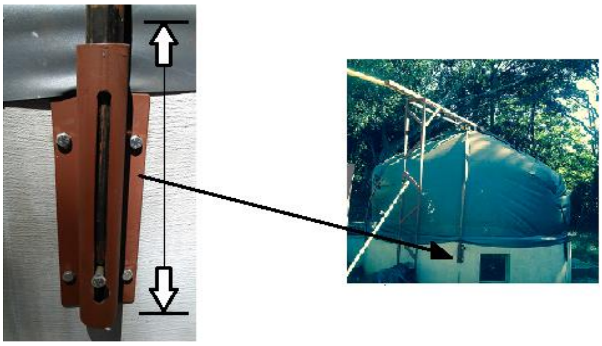

Photo 7. System window wiper to visualize the inside of the digester. (Taken from Carlos Saborio's investigation)

There are different ways to set the gas outlet of the membrane that covers the digester, however, so far the best results have been placing it at the top of the digester. This system is shown in Phot 10.

Photo 8. System output of the biogas produced.(Taken from Carlos Saborio's investigation)

PRINT ISSN 2284-7995, E-ISSN 2285-3952

The most important aspects regarding the mesophilic digester shaking, it is precisely the presence of this type of agitation to allow the biomass in the digester constant mixing, avoiding accumulations which may potentially damage the digestate and digester.
Yet another aspect is the ease of assembly and disassembly of the membrane of the digester.
The installation of the membrane is the most important highlights, it has a system of coupling of the membrane to the concrete at the bottom of the digester, which uses an inflated hose is placed in a small canal at the end higher but at its other end adapted to accommodate the hose and inflated; the membrane is introduced into this channel and is pressed so that there is no escape of biogas. This system is shown in Fig.6.

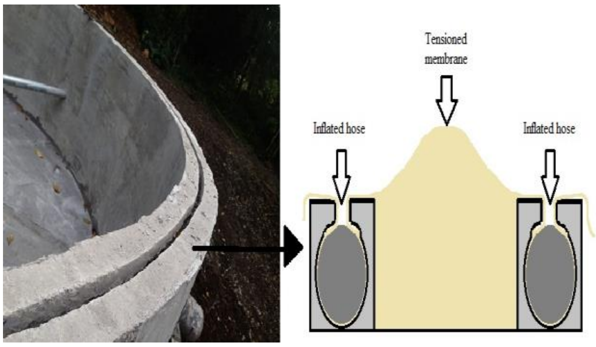

Fig.6. System coupling membrane on the concrete digester through a hose. (Taken from Carlos Saborio's investigation)

On the other hand there is an internal piping system that keeps the temperature of the digester, it is essential that the mesophilic digester with manual stirring is maintained at temperatures between 30 and 36 ° C, this system allows that in the event of a decrease, thanks to provides heat water that is incorporated into the pipes and is heated previously with the same energy produced by the digester, the temperature matches the required, and thus the process of biogas production is not reduced. This system is shown in Photo 9.
The system manual stirring, unlike conventional digesters is performed horizontally, through a bar along the inner diameter of the digester with at least three mixer turbines take charge of moving the biomass into the digester.

Photo 9. Internal cooling system of the digester.(Taken from Carlos Saborio's investigation).

The system described above is shown in Photo 10.

Photo 10. Stirring system using bar horizontally. (Taken from Carlos Saborio's investigation).

Results:

It has been found that the durability of a bacterial mass is less in a conventional digester without stirring, because the decomposition of organic matter is not uniform and is consumed rapidly. This sets a disadvantage to this type of digester, because it requires more biomass to feed, consuming a large amount of organic matter, and in turn, producing fewer biogas. This problem is solved by incorporating into the digester a stirrer, which increases the service life thereof and at last the organic matter a longer period of decomposing time, will produce a greater amount of energy is being sought, as is the case biogas.

Photo 11. Stirring system used in conventional digesters and Germany. (TakenfromAEBIG.com).

Ascan be found through a comparison of photos 10 and 11, the system proposed in this research consists of an agitator easier and cheaper suitable for developing country; This system also allows horizontal bar optimum agitation of biomass for this is beaten uniformly and constantly, achieving efficient production of biogas.

If it is true, given the results obtained in the investigation, biodigesters with stirring of the biomass are more effective, because of its durability and lifespan, in indigenous areas is hard to find facilities that are in an urban area, such in the case of electricity, many of these places are in reserve area and do not have electric power, therefore, cannot operate a digester with stirring, and would be wasting the benefits they bring. Same case is the small entrepreneurs who want to start with the implementation of systems for biogas production and clean energy, but do not have a lot of resources to invest in an electric stirrer.

The solution to these problems is presented to the system manual stirring in biodigesters. A digester with manual stirring can be easily manipulated by a person responsible for handling an external lever in the digester internally mix the organic matter in it, this without the need for an electricity system or an electric motor having to perform agitation.

Inaddition to simplifying the cost of the operation, the system can reduce hand shaking costs, because energy that would be spent with an electric stirring save, and secondly, the profit margin in terms of biogas produced is greater.

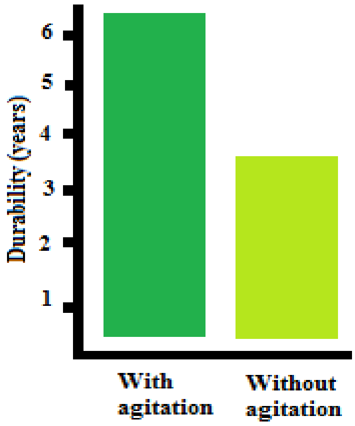

Fig.7. The lifespan of a biodigester with stirring and one without stirring. (Taken from Carlos Saborio's investigation).

CONCLUSIONS

In conclusion in this research it may include the important and innovative technology that represents the creation of mesophilic digesters with manual stirring for alleged inaccessible areas where it does not have any power as areas with indigenous populations ... This will provide an opportunity to venture to the aforementioned population in which the economic and logistical investments will be lower, and also in which can implement projects of clean energy production with the best choice of environmental conservation and a increased energy production, this added to the unnecessary expense in the future of electric power to stir the digesters, due to the implementation of the system of hand shaking.

Sources of biomass can be obtained directly from the debris of their communities and can be incorporated into the biodigesters by the same people who handle it, then undertake a process of shaking, which will allow small farmers to produce more biogas, and do for a longer period of time due to the increase in the life of the digester.

It will also allow use certain wastes which feeds the digester and thus not polluting the environment.

Innovation aimed at population either way are marginalized small farmers or indigenous people, should be present more and more, with the intention to provide them with tools enabling them to function equally in terms of technologies and search of new knowledge.

This study opens the door to research in indigenous areas and in turn, calls for future research will continue to take into account this population, which has been sidelined for most of the time.

REFERENCES

[1]Aguayo, D., Velázquez, L., Ojeda, S., 2009, Desarrollo de un sistema de calentamiento solar y acoplamiento a un digestor anaeróbico. Instituto de Ingeniería. Universidad Autónoma de Baja California. Mexicali, B.C., México

[2]Al-Rousan, A., Zyadin, A., 2014, A Technical Experiment on BiogasProduction from Small-Scale Dairy Farm. Journal of Sustainable Bioenergy Systems, 2014, 4, 10-18. United States

[3]Anisiji, O., Chukwuneke, J. L., Achebe, C., Okolie, P., 2014, Integrated Process Modelling of a Thermophilic Biogas Plant. International Journal of Scientific & Technology Research, volume 3, issue 7. Nigeria

[4]Aremu, M., Agarry, S., 2012, Comparison of Biogas production from Cow dung and Pig dung under Mesophilic condition. International Refereed Journal of Engineering and Science (IRJES), Volume 1, Issue 4 (PP.16-21). Department of Chemical Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

[5]BaniHani, F., Qasaimeh, A., Abdallah/Qasaime, M., 2015, Biogas Production Enhancement from Mixed Animal Wastes at Mesophilic Anaerobic Digestion. Int. Journal of Engineering Research and Applications. Vol. 5, Issue 10, (Part-3), pp.167-173. Jordan.

[6]Belhadj, S., Karouach, F., El Bari, H., Joute, Y., 2013, The biogas production from mesophilic anaerobic digestion of vinasse. IOSR Journal of Environmental Science, Toxicology and Food Technology. Volume 5, Issue 6, PP 72-77. Tofail University, Kenitra, Morocco.

[7]Coker, C., 2012, Anaerobic Digestion. MEHA 2012 Annual Meeting. Coker Composting & Consulting. United States.

[8]Kern, M., Siepenkothen, J., 2014, Bio waste potential in household waste. Modelling of collection increase of bio waste from household waste. Müll und Abfall 7/2014, pp. 356. Germany.

[9]Li, Z., 2011, Sanitation aspects & acceptance issues in Chaoyang and Shenyang Municipalities, Liaoning Province On behalf of China node for sustainable sanitation (CNSS). Centre for Sustainable Environmental Sanitation, University of Science and Technology Beijing, China.

[10]Moriarty, K., 2013, A Study Prepared in Partnership with the Environmental Protection Agency for the RE-Powering America's Land Initiative: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites. Feasibility Study of Anaerobic Digestion of Food Wastein St. Bernard, Louisiana. Produced under direction of the U.S. Environmental Protection Agency (EPA)by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-08-0719and Task No WFD3.1001. United States

[11]Ocaña, F., 2011, Biodigestor an aerobio de laboratorio. Departamento de Ciencia e Ingeniería de Materiales eIngeniería Química, Universidad Carlos III de Madrid, España

[12]Pandey, P., Soupir, M., 2012, Impacts of Temperatures on Biogas Production in Dairy Manure Anaerobic Digestion. IACSIT International Journal of Engineering and Technology, Vol. 4, No. 5. Singapore

[13]Rajendran, K., Aslanzadeh, S., Taherzadeh, M., 2012, Household Biogas Digesters—A Review. School of Engineering, University of Borås, Borås 50190, Sweden

[14]Ruiz, F., 2010, Diseño, construcción y puesta en marcha de un biodigestor tubular de polietileno de bajo costo. Escuela de Ingeniería Mecánica, Universidad de Talca, Chile

[15]Sathish, S., Vivekanandan, S., 2014, Effect of Mesosphilic and Thermophilic Temperature on Floating drum an aerobic bio-digester. International Journal of Mechanical & Mechatronics Engineering, IJMME – IJENS. Vol:14 No:06.Rawalpindi, Pakistan.

[16]Zhu, G., Kumar, A., 2013, Psychrophilic dry anaerobic digestion of cow dung for methane production: Effect of inoculum. Science Asia 39, Number 5. (500-510), Thailand