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Biogas production with the use of animal manure: a practice for obtaining socioeconomic and environmental benefits

Produção de biogás com o uso de esterco animal: uma prática para a obtenção de benefícios socioeconômicos e ambientais

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ABSTRACT

Currently, there is a large production of animal waste / manure that is erroneously discarded and often promotes environmental impacts such as pollution of watercourses, which has contributed to the promotion of waterborne diseases. Thus, it has been objectified to use animal manures in an efficient way in the promotion of biogas, which has contributed to provide socio-environmental improvements. Therefore, the present study aimed to analyze the social, economic and environmental benefits of biogas production through the use of biodigesters and how this technology can contribute to the improvement of the lives of rural low-income families. For this, a qualitative research was carried out where, through theoretical and methodological foundations, exploratory and participatory studies were carried out with the rural families in the municipality of Pedra Lavrada-PB, in the semi-arid region of Paraíba. With the studies, it was possible to conclude that the biodigestors: 1) they assemble simple techniques and of easy construction; 2) are low-cost implementation/construction technologies; 3) produces biogas for food cooking, which inhibits costs with the purchase of cooking gas; 4) enables environmental benefits with the use of animal manure - which is renewable - for heat generation, in addition to the use of digestate for soil fertilization; and 5) that biodigestors are a socially disseminable, economically viable, and environmentally sound technology.

Keywords: Rural families, Digesters, Socioeconomic and environmental benefits, Biogas, Animal manure.

RESUMO

Atualmente, existe uma grande produção de dejetos/esterco animal que são descartados de forma errônea e, muitas vezes, promove impactos ambientais como a poluição de cursos de água, o que tem contribuido para promoção de doenças por veiculação hídrica. Assim, muitos projetos estão sendo relizados objetivando utilizar os estercos animais de forma eficiente na promoção de biogás, o que tem contribuído para prover melhorias socioambientais. Diante disso, o presente estudo objetivou analisar quais os benefícios sociais, econômicos e ambientais advindo da produção de biogás através do uso de biodigestores e como esta tecnologia pode contribuir para melhoria de vida de famílias rurais de baixa renda. Para tanto, foi realizado uma pesquisa qualitativa onde, através de fundamentos teórico-metodológicos, realizou-se estudos exploratórios e participativos junto às famílias rurais no município de Pedra Lavrada-PB, no semiárido paraibano. Com os estudos, pôde-se concluir que os biodigestores: 1) reúnem técnicas simples e de fácil construção; 2) são tecnologias de baixo custo de implementação/construção; 3) produz biogás para cozimento de alimentos, o que inibe custos com a compra de gás de cozinha; 4) possibilita benefícios ambientais com o uso de esterco animal – que é renovável – para geração de calor, além do uso do digestado para fertilização do solo; e 5) os biodigestores são uma tecnologia socialmente disseminável, economicamente viável e ambientalmente correta.

Palavras-chave: Famílias rurais, Digestor, Benefícios socioeconômicos e ambientais, Biogás, Esterco animal.

1. INTRODUCTION

At the same time, livestock farming has grown in Brazil and with this there is a potential increase in the production of animal waste/manure, which can be used for several purposes: nutrient recycling, biofertilizer production; natural fertilization of agricultural and garden soils; generation of electric energy or production of biogas (ARAÚJO, 2017, p.25).

In relation to the use of animal waste for the production of biogas, it is stated that this practice has been very efficient, and has conditioned the advent of social, economic and environmental benefits, namely: 1) it combines simple and easy techniques construction; 2) are low-cost implementation techniques; 3) enables the generation of electric energy for homes; 4) produces biogas for food cooking, which inhibits costs with the purchase of cooking gas; and 5) provides environmental benefits from the use of animal manure - renewable - to replace the use of liquefied petroleum gas (LPG - non-renewable), which contributes to atmospheric pollution.

Given the above and considering that the use of biogas is an important alternative to improve the living conditions of rural families, besides contributing to mitigate the environmental problems related to the emission of pollutants, the present study aimed to analyze the social, economic and environmental benefits derived from the use of biodigesters (ALCÓCER *et al*., 2020, p. 801).

In order to reach the proposed objective, an exploratory and qualitative research was carried out with the rural families in the municipality of Pedra Lavrada-PB, in the semiarid region of Paraíba State, seeking to identify some aspects: i) biodigestor model; (ii) modes of construction and use; iii) relevance of the biodigester for quality of life and iv) the socioeconomic and environmental improvements resulting from the use of biodigesters. Considering that the production of feces is abundant in animal husbandry and that such an abundance of waste can generate a large amount of biogas; biodigestors becomes an extremely important technique (ALMEIDA; BRUNO, 2016, p.4).

In addition to the above, Khalil *et al*. (2019, p. 323) emphasize that the production of biogas from animal waste was considered one of the best ways to achieve sustainable energy development goals in many developing countries. It is essential to remember that the implementation of biodigesters is reduced due to technical problems, or the lack of government incentives. This reality is common in other countries, for example in areas of Sumatra where small farmers, who have few animals, face difficulties with the production of manure and, consequently, with the production of biogas; besides many farmers do not have knowledge about biogas technology and its benefits, and do not acquire investments or government incentives (ROUBÍK; MAZANCOVÁ *et al.*, 2020, p. 7).

However, biogas is a good alternative, even for small families, as it allows the substitution of firewood burning, promotes health benefits for families, and reduces greenhouse gas emissions (BENTZEN *et al*., 2018, p. 311). In addition, Huong *et al*. (2014, p. 785) claim Small-scale biogas digesters are widely promoted worldwide as a sustainable technology to manage livestock manure

It is important to emphasize that the present research became justifiable as it sought to investigate: to what extent can the biodigester be considered a simple and disseminable technique? Do the costs involved in the construction / maintenance of the biodigester make it economically viable? And what problems do the benefits come from the use of biodigesters by rural families? Thus, to give plausible answers to the aforementioned questions, was what motivated the referent study.

2. THEORETICAL FOUNDATION

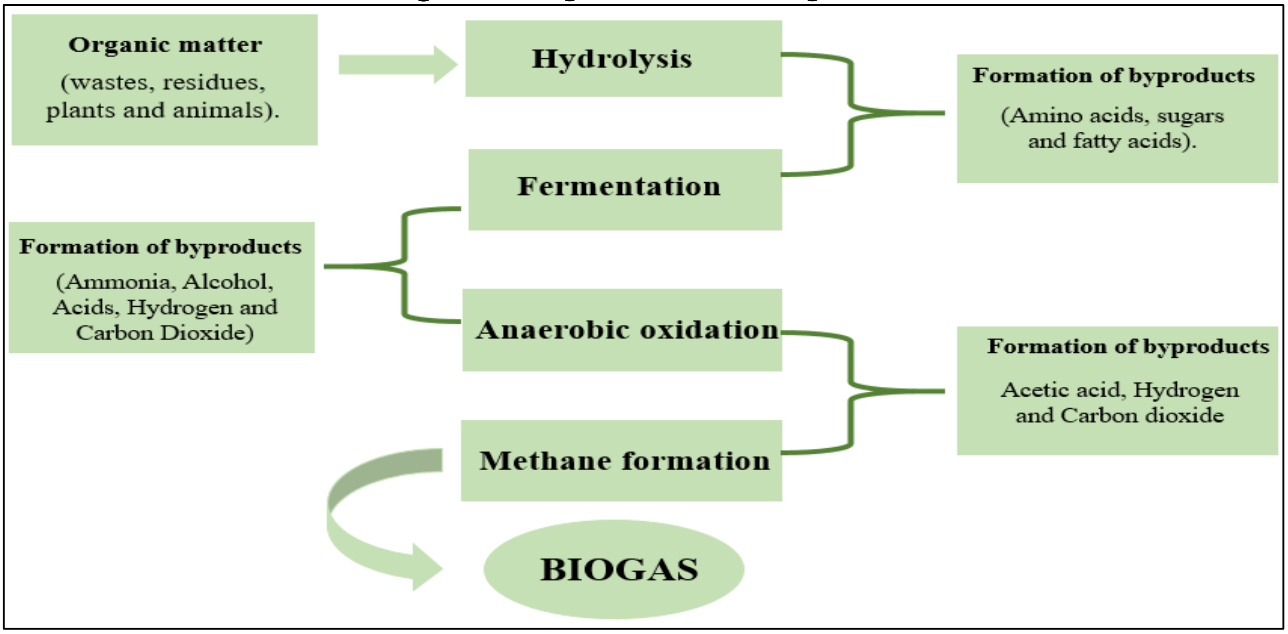
2.1. Production of biogas and its importance

The process of biogas production using animal excrement has been known for a long time and in several countries: China, India, the United States, Europe, etc. The interest in biogas in Brazil intensified in the 1970s and 1980s, as there were official programs that stimulated the implantation of many biodigestors, mainly aiming at generating energy, producing biofertilizer and reducing the emission of pollutants.

It is important to remember that the aforementioned government programs did not show the expected results and most of the implanted systems ended up being deactivated due to some aspects: a) lack of technological knowledge about the construction and operation of biodigesters; b) cost of high implantation and maintenance (masonry, concrete or stone chambers, metal gasometers); c) use of the biofertilizer continued to require distribution equipment in the liquid form, with high acquisition, transportation and distribution costs; d) lack of equipment developed exclusively for the use of biogas and the low durability of equipment adapted for the conversion of biogas into energy (burners, heaters and motors); e) absence of condensers for water and filters for the corrosive gases generated in the biodigestion process; f) availability and low cost of electricity and LPG and g) no resolution of the environmental issue, since biodigesters alone are not considered as a complete treatment system.

However, biodigestors have now resurfaced as an alternative to rural farmers due to the availability of new materials for the construction of biodigesters and, of course, the low cost and easy construction of biodigesters. The biodigestor is widely used because it does not use electrical energy or chemicals in the gas production process. In this sense, it is enough to remember that biogas is produced naturally from the anaerobic decomposition that is developed by the action of a consortium of microorganisms, in which one of the final products of the degradation is methane (**Figure 1**).

Figure 1: Stages of anaerobic digestion



Source: Adapted from Araújo (2017) and translated by the authors.

The biogas, product of anaerobic degradation, is composed basically of: methane (CH4), carbon dioxide (CO2), hydrogen (H2), nitrogen (N2), oxygen (O2) and hydrogen sulphide (H2S) (MARÇAL *et al*., 2016, p. 146). The fact that biogas is composed mainly of methane (about 70%) and carbon dioxide, makes it easy to burn and with high power to generate heat. In this sense, Mittal *et al*. (2018, p. 361) claim Biogas contains high methane content (40–70%) that can further be upgraded to natural gas quality (75–99% methane content).

Methane is a colorless gas with tetrahedral molecular structure (CH4), with extremely low capacity to dissolve in water (ALMEIDA; BRUNO, 2016, p.4). Thus, when it comes into direct contact with the atmospheric air, its calorific power stands out, gaining high power of flammability. Thus, methane enables good combustion, which contributes to generate heat, which can be used to generate electricity, or cooking food in residential stoves. In summary, biodigesters are closed systems of anaerobic degradation in which the gases produced are collected and stored in compartments called gasometers for later use through burning.

Regarding the importance of biogas, it is observed that it is used in thermoelectric and as biofuels, but its ease of burning can provide great heat and this thermal energy can be converted into electric energy, it is enough for that some conversion systems mechanical, such as boilers and generators (ALMEIDA; BRUNO, 2016, p. 5).Despite many positive points, Khan and Martin (2016) emphasize that, currently there exists a substantial gap between technical and cost-effective potential and the achievable potential due to lack of technical knowledge, high installation and operation costs, feedstock availability and limited end user applications. Therefore, it is necessary to invest in research that makes it possible to increase the efficiency of biodigesters, as well as to seek to reduce construction and operation costs, as this will contribute to the dissemination of biodigesters, especially among low-income families.

In addition to the above, we have the fact that biogas is used, from its burning / combustion, as an energy source for the cooking of food in Brazilian rural residences. With this, there is a reduction of costs with the purchase of cooking gas - the basis of LPG; besides the use of a renewable energy source - waste / animal waste - that contributed to environmental sustainability. Finally, it is known that the implantation of biodigesters in rural areas is of paramount importance to contribute, as an alternative, to the development of rural communities (SILVA; ARAÚJO, 2016, p.181).

3. MATERIALS AND METHODS

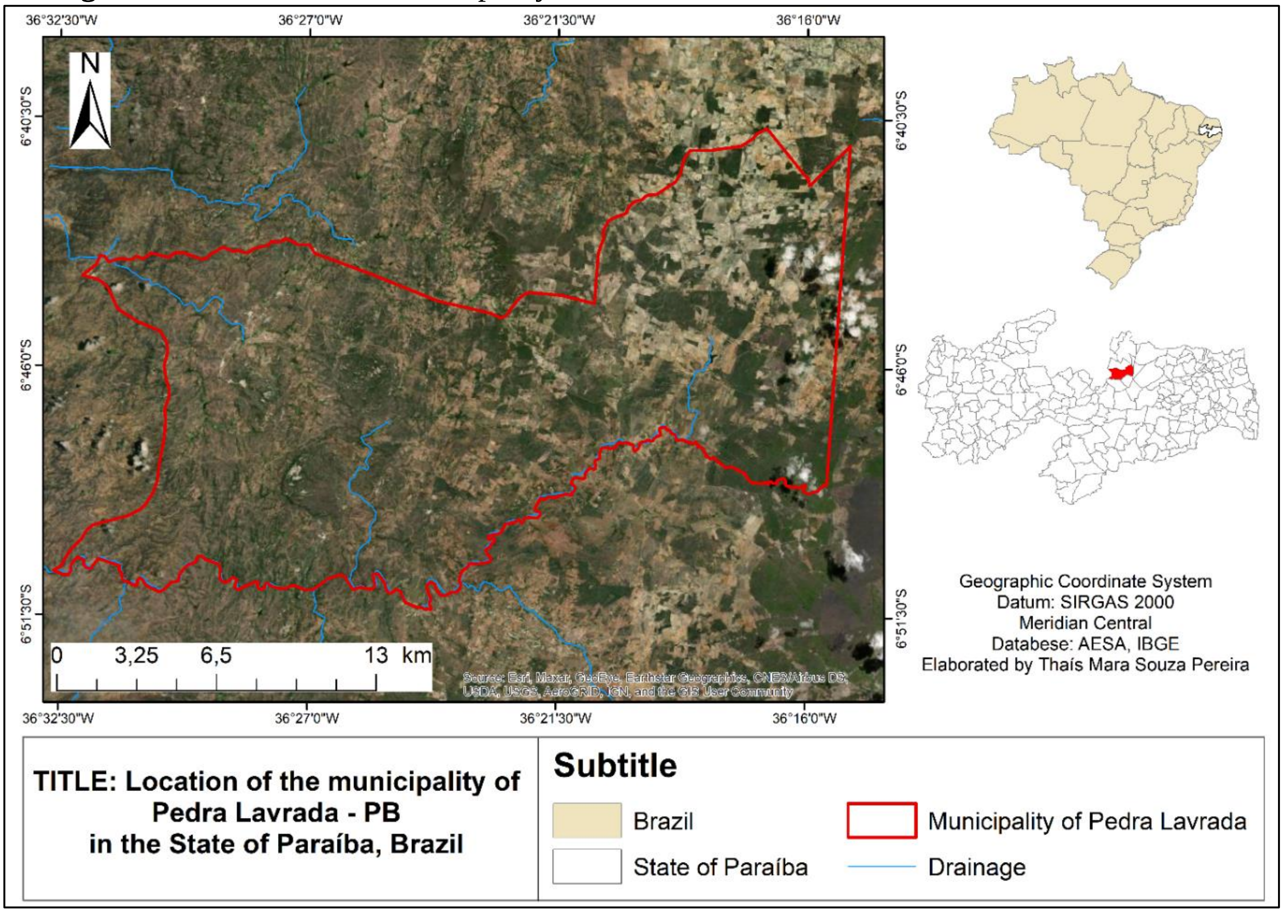
3.1. Search area

The present work was carried out in the rural area of the municipality of Pedra Lavrada (Latitude 06 ° 45'25 "S, Longitude 36 ° 28'49" W and Altitude: 516 meters), located in the micro-region of the eastern Seridó of the state of Paraíba (**Figure 2**). This municipality is located about 230 km away from the capital of Paraíba, João Pessoa and is limited to the municipalities of Nova Palmeira (to the north), Cubati and Seridó (to the south), with Sossego and Baraúnas (to the west), and with the state of Rio Grande do Norte (to the east), covering an area of 351 km² and a population of 7,475 (IBGE, 2010).

Regarding socioeconomic aspects, the municipality has an HDI of 0.574 and a GDP of US $ 5,805, which is derived from the economic activities of the primary (11%), secondary (12) and tertiary (77%) sectors. Also, regarding the physical aspects, according to the Mineral Resources Research Company (CPRM, 2005, p.3), the municipality of Pedra Lavrada-PB presents:

1. Geology and Geomorphology: Pedra Lavrada-PB is inserted in the geo-environmental unit of the Borborema Plateau. In the municipality, the average altitude is 500 meters. The relief is gently undulating. When it comes to soil fertility, it is quite varied, with a certain predominance from average to high;
2. Climate and vegetation: the local climate is of the hot and dry tropical type, conditioning the characteristics of the semi-arid climate: high average annual temperatures, high evapotranspiration index, low rainfall index, and spatial and temporal variation of rainfall. As a result of these climatic conditions, we can observe the native vegetation of the Caatinga: vegetation with low trees and shrubs, which usually lose leaves during the dry season (deciduous species), in addition to many xerophytic species (CPRM, 2005, p.3);
3. Hydrography: The municipality of Pedra Lavrada-PB is located in the areas of the Piranhas River basin, more specifically in the sub-basin that comprises the Seridó River. Affluent streams besides being periodic, they have a small outflow, and groundwater potential is low (CPRM, 2005, p.3).

Figure 2: Location of the municipality of Pedra Lavrada - PB in the State of Paraíba, Brazil



Source: Prepared by the author, (2019).

The choice of the municipality of Pedra Lavrada-PB as a research space, was due to the fact that it presented some criteria essential to this research, such as: 1) a large part of the local rural population is low income; 2) the costs of buying kitchen gas have become a limiting factor in family income and 3) there are numerous families that have in the biodigestor their main source of energy for cooking food. Thus, it has become essential to analyze the socioeconomic and environmental benefits of biodigesters. For that, some methodological procedures were used, which will be described next.

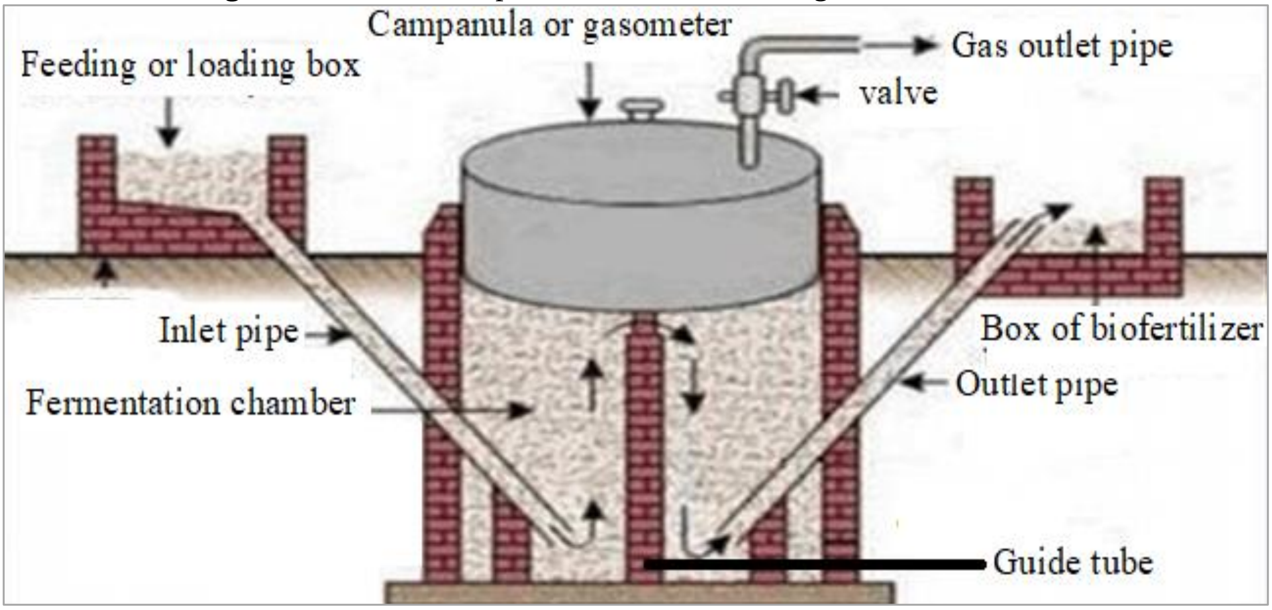
3.2. Methodological procedures

Several models of biodigesters have been developed and adapted to seek an increase in the efficiency of these systems combined with a reduction in equipment costs. In this work, the Indian biodigester model (**Figures 3 and 4**) was analyzed, comprising:

1. Feeding or loading box: made of masonry, it is used to introduce the diluted manures / manures;
2. Inlet pipe: is a 150mm PVC pipe that conducts waste from the feed box into the biodigester;
3. Fermentation chamber: built with masonry, it is in it that the process of fermentation and release of biogas occurs;
4. Campanula or gasometer: it consists of a 3000 liters (face down) PVC box, which works for biogas storage and to provide it with constant pressure. For this, it moves up or down according to the volume of biogas.
5. Guide tube: made of masonry or with 40mm PVC pipe and serves as a guide to centralize the gasometer when it moves up or down;

6. Outlet pipe: also known as discharge tube, it is made of cum pipe 150mm in diameter and serves to conduct the waste out of the biodigester;
7. Box of biofertilizer: it is a box of masonry that serves for the removal of the wastes that will serve as biofertilizer of the soil; and
8. Gas outlet pipe with a valve: it consists of a 40mm pipe that will serve to conduct the gas to be used in the residences. Just after the gas outlet, there is a valve to regulate the volume of gas within the gasometer.

Figure 3: Schematic representation of the Biodigestor, Indian model



Source: Adapted from Deganutti, 2002.

Figure 4: Biodigestor, Indian model, installed in the Cisplatina site, Pedra Lavrada-PB

Source: Prepared by the author, (2019).

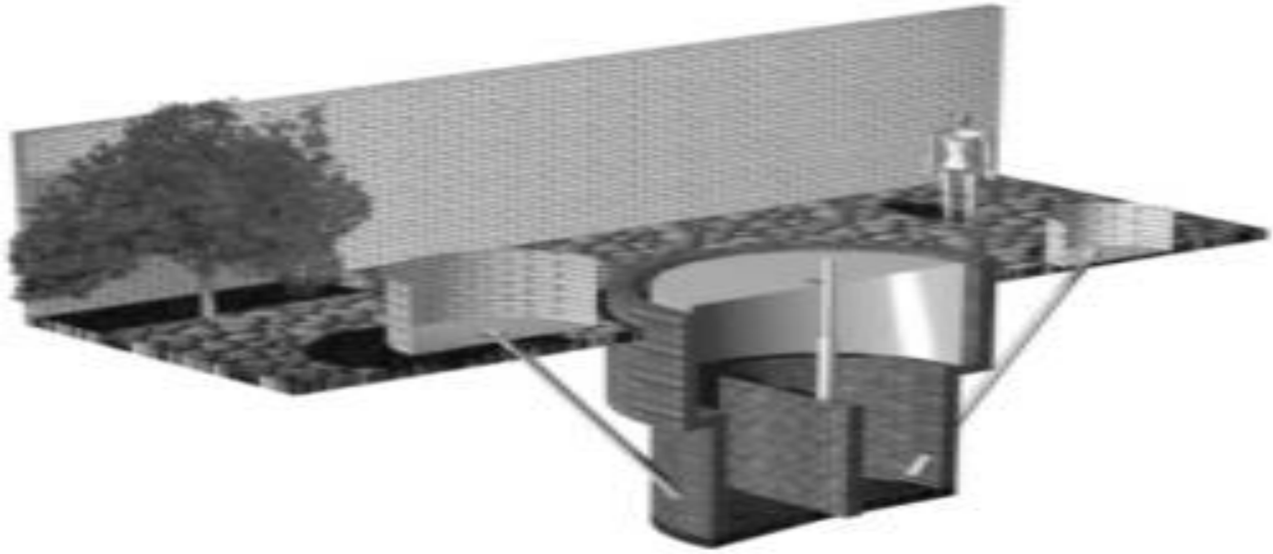
In short, the choice of the Indian biodigester was due to its being efficient to convert biomass into biogas, and because it is low cost and easy to acquire (MOURA *et al.*, 2017, p. 253).

Finally, with the qualitative studies performed, significant results were obtained, which will be described next.

4. RESULTS AND DISCUSSIONS

At first, the biodigester constructions were identified. In this sense, it was observed that they were constructed following the technical parameters listed by the Indian biodigestor model (**Figures 5 and 6**). It is opportune to remember, again, that the choice of the Indian model of biodigester was made due to the fact that it is of easy construction and of good efficiency. In this sense, Deganutti *et al*. 2002 state that the Indian biodigester is more efficient than other models, such as the Chinese and the batch, because the Indian is more efficient in terms of biogas production and reduction of solids in the substrate.

Figure 5: 3D record of the Biodigestor, Indian model



Source: Adapted from Deganutti, 2002.

Figure 6: Biodigesters, Indian model, installed in Canoa de Dentro site, Pedra Lavrada - PB

Source: Prepared by the author, (2019).

When analyzing the construction of the biodigestors, it was verified that they were constructed by the families themselves, in the form of mutirões, using materials of low economic cost and of easy accessibility, such as PVC pipes (150mm and 40mm), cement, bricks, PVC box, etc.

In relation to the costs related to the construction of the biodigestor, an affirmation of a figure of R$ 1,500.00 per unit was obtained through the families investigated. This amount corresponds to the same amount spent on the purchase of a cooking gas cylinder (R$ 70.00 reais) for 22 months. This contributes to the biodigester becoming economically viable, especially for rural households with a low income. Studies carried out by Silva, 2019 (p. 36) show that the investment required for the construction of a biodigector is R $ 1,796.00, a value close to that found in this work.

To maintain biogas production, local households use manure from goats, sheep and especially cattle. The cattle are confined, during dusk at dawn the other day, in corrals, which contributes to increase the production of waste near the biodigester.

After analyzing the constructions of the biodigestors, we identified the use of biogas produced locally. In this perspective, it was observed that: all the families investigated use biogas to cook food (**Figure 7**), thus replacing cooking gas. With this, the following socio-economic and environmental benefits were obtained: i) good gas production for domestic use; ii) inhibition of the expenses previously used for the purchase of cooking gas; iii) promotion of biogas with low investment costs; iv) use of animal manure as a natural and renewable source to produce methane gas; and (v) stopping the burning of butane present in cooking gas, which contributes to the reduction of greenhouse gas emissions.

During the studies, it was observed that the biodigesters contributed to reduce possible impacts related to the waters of the adjacent rivers, in addition to reducing the consumption of methane previously carried out with the burning of liquefied petroleum gas - LPG - in cooking food. In this sense, Lewis *et al.*, (2017) state that Biogas contributes in reducing negative externalities that contaminate waters of adjacent rivers, besid emission of local air pollutants like dioxins and furans as well as methane, a potent greenhouse gas. It is important to translate:

> The use of biodigesters for biogas generation in rural properties is a viable alternative and has attracted the attention of rural producers, for the possibility of adding value to animal waste. However, the issues surrounding the final disposal of biodigester effluents must be addressed within technical criteria, to avoid the environmental impact of this in the environment, since the final residue still presents a high polluting potential (SILVA; ARAÚJO, 2016, p.194).

Figure 7: Consumption / use of biogas in the rural residences of the municipality of Pedra Lavrada

Source: Prepared by the author, (2019).

Thus, it was observed that the final residues, called digestate, are collected in the discharges boxes and later used in the fertilization of the local soils where subsistence agriculture is practiced. This practice has contributed ecologically, since animal manures, used in formulations as substrates, contribute to positive effects on soil fertility (ANTUNES *et al*., 2017, p. 568).

It is important to remember that biodigestors, besides producing biogas for cooking in homes, also produce a large amount of biofertilizer, which is collected in the landfill and later used in the fertilization of local soils where subsistence agriculture is practiced.

In summary, it has been observed that biodigestors are a simple technology, easy to learn, and low cost, which allows their social dissemination. Added to this is the fact that biodigestors are produced by the families themselves, which promotes autonomy, participation and social transformation in the construction of social technologies.

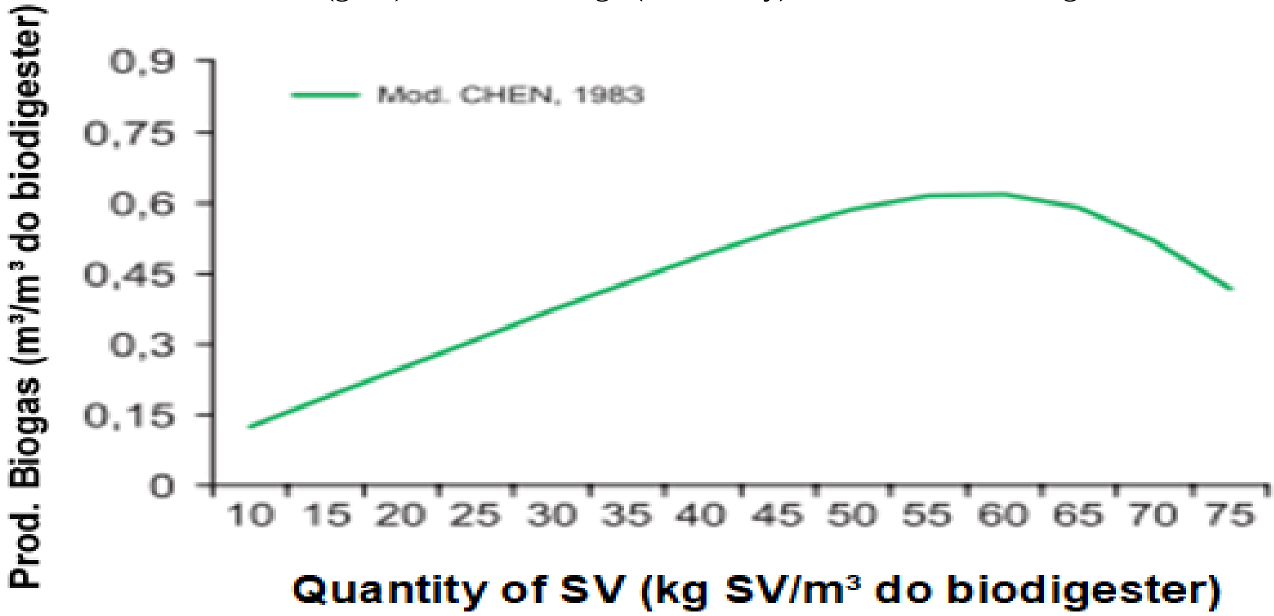
In view of the previous assertion, it can be stated that the locally constructed biodigestors are a Social Technology - TS, considering that the TS are "products, techniques and / or methodologies reusable, developed with the interaction with the community and that represent effective solutions of social transformation "(ABREU; TIBIRIÇÁ, 2017, p. 135).

In view of the above, it is observed that the biodigester is a viable technology, especially for the low-income families of the Brazilian semi-arid region. In this sense, Silva and Araújo (2016, p. 179) affirm that the biodigester can be built on rural properties, and its implementation presents a viable and acceptable solution for the family farmer to develop within the sustainable universe.

During the researches it was observed that local rural families had technical knowledge of the use and management of biodigesters. From this perspective, it was possible to observe that the biodigesters were daily supplied with new portions of manure and, mainly, the amount of water added to the manure was controlled to the point of being only moistened, because: "for there to be a larger production of biogas it is necessary that the waste is moist but not dissolved in water, that is, the amount of water must be controlled so that the manure is not totally dissolved, which would decrease the production of biogás" (SILVA; ARAÚJO, 2016, p. 181).

In agreement with what was previously reported, Oliveira *et al* (2005, p.12) affirm that to obtain a greater production of biogas it is necessary to obtain higher concentrations of volatile solids (**Figure 8**), and to avoid the dilution of the wastes with the exaggerated amount of water.

Figure 8: Specific biogas production (m^3 / m^3 biomass), using the observed values of temperature, volatile solids (g / L), waste discharge (liters / day) and load of the biodigester



Source: Oliveira *et. al.* (2005, p.13).

Figure 8 shows that there was an increase in biogas production (m3 / m3) when moistening the waste and increasing the volatile solids load; but when the volatile solids load reaches values above 60 kg / Sv / m³, there is a drop in biogas production. This occurs because with large amounts of water in the biodigester causes the manure to dissolve, which reduces the production of biogas. In this sense, it is assumed that for the economically acceptable production of biogas, the management of the waste in the production unit should seek to obtain the highest concentration of volatile solids and avoid the dilution of the waste caused by mixing with large amounts of water (OLIVEIRA *et. al*., 2005, p.13).

Finally, it was observed that local families feel satisfied with the use of biodigestors, since they consider this social technology a simple mechanism that has contributed to improvements in the local quality of life.

5. CONCLUSIONS

With the accomplishment of the studies, it was concluded that the biodigestors constructed: 1) they assemble simple techniques and of easy construction; 2) are low-cost implementation technologies; 3) produces biogas for food cooking, which inhibits costs with the purchase of cooking gas; and 4) provides environmental benefits from the use of animal manure - renewable - to replace the use of liquefied petroleum gas (LPG - non-renewable), which contributes to atmospheric pollution.

It is important to remember that animal manure in addition to the production of biogas for cooking food, it can also be used for various purposes: nutrient recycling, biofertilizer production; can be used in the natural fertilization of agricultural and garden soils; and for the generation of electric energy. In this sense, it is important to carry out new research on the use of animal manure for a wide range of purposes, because with this, it is possible to reconcile the use of this renewable resource with the economic and environmental assumptions.

It should also be said that the potential of the reuse from the biodigester must be analyzed, especially with regard to its use in soil fertilization, since the knowledge of factors related to the composition of the organic materials of the waste implies the saving of fertilizers, and in order to obtain better agricultural products (PEIXOTO FILHO *et al*., 2013).

Finally, with the knowledge that biodigestors are simple, low-cost social technologies and essences to promote socioeconomic and environmental benefits, it can be concluded that biodigesters can and should be a practical mechanism to improve living conditions of thousands of Brazilian rural families.

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