Uganda Journal of Agricultural Sciences, 2003, 8 : 345 - 350 ISSN 1026-0919
Printed in Uganda

Biogas production for smallholder energy needs: Experiences in Uganda

Odogola R. W., Kato C., Bena B. and Makumbi G.
Agricultural Engineering and Appropriate Technology Research Institute
P.O. Box 7144, Kampala, Uganda.

Abstract

Although the discovery of biogas dates back to the 18th century, it was only in the early 1900s that the technology obtained some use in real life situations. In Uganda the first biogas plant was built in Mbarara district in the early 1950s. However, the first well-documented study on biogas technology was a PhD thesis by Boshoff (1970), then Lecturer at the Department of Agricultural Engineering, Makerere University. During the years that followed, world-wide threats of dwindling fossil fuel resources stimulated efforts to develop new and renewable energy resources including biogas technology. Uganda joined other countries in these efforts but drastically lost pace during years of civil strife. This paper briefly outlines developments in biogas technology with special focus on Uganda. It describes efforts NARO/AEATRI has made in the development of a floating gas-holder digester type, fixed half-dome type and a tubular digester type. The first two digester-types generate 0.20-0.25 m^3 of gas per m^3 of digester per day at optimal production. AEATRI has also developed several designs of biogas stoves that operate at a pressure of 50-75 mm of water, consuming 0.15-0.2 m^3 of gas per hr. The effluent (slurry) from AEATRI digesters has been chemically analysed for soil enhancement nutrients. The results show a significant increase in major nutrients: nitrogen – 18%, phosphorus – 24%, and potassium – 66%. The paper proposes a policy framework for integrated promotion of this technology with a view to making its contribution more responsive to agricultural modernisation in Uganda.

Key words: Biogas, Smallholder energy needs

Introduction and background

Historical perspective

Biogas is produced through decomposition of organic matter such as animal manure, human excreta, kitchen remains, crop straws and leaves by anaerobic bacteria under anaerobic conditions. In simplified form, the anaerobic reaction takes three main stages:

a) *The hydrolysis phase* – during which raw-material organic substances such as protein, polysaccharides and lipids are converted into mono-saccharides, peptides, amino acids, fatty acids and so on. These are further converted into acetate, propionate and butyrate. The aerobic or facultative microbes play a main role during this phase.
b) *The acidic phase* – converts the products of the first phase to acetate or hydrogen and carbon dioxide. At the same time, some transitional products can also be converted directly into these substances. The "acid former" microbes play a vital role during this phase.
c) *Methane phase* – is the final stage during which acetate or hydrogen plus carbon dioxide are converted into mixture of methane and carbon dioxide through complex reactions by *methanogens.*

The three-phase reaction in the production of biogas which is essentially a mixture of methane (60-65%) and carbon dioxide (30-35%), the remaining portion being made of nitrogen, hydrogen and hydrogen sulphide in traces all constituting less than 2%.

Though Plinius ( ) is quoted to have been the first to record seeing bubbles of gas emerging from below the surface of swamp water, it was not until 1776 that Volts ( ) carried out some experiments to show that the gas produced was biogas and that it is proportional to the quantity of decaying matter. Dalton, Henry and Davy later established the chemical composition of methane in 1804 as being (CH_4). In 1884 Grayon confirmed Volt's claim when he fermented 1 m^3 of manure at 35^{0}C obtaining 0.1m^3 of biogas. He also showed that biogas could be used for lighting and heating purposes. By 1896, biogas was being used to light the streets in England and some slums in Bombay and in 1920 biogas was being produced in a number of communal sewage farms in Central Europe. However the primary consideration of the gas at that time was not as an energy alternative, but rather as a solution to the problems of rational and hygienic disposal of sewage.

Biogas development in Uganda

The first biogas plant in Uganda was build by the Church Missionary Society (currently Church of Uganda) in Mbarara in early 1950s. Emphasis was on treatment of sewage. However, the first well-documented study on biogas technology was a PhD thesis by Boshoff (1969/70), then Lecturer at the Agricultural Engineering Department, Makerere University. His study evaluated a number of feed materials for biogas production including grasses, agricultural residues as well as livestock and poultry manure. A batch type digester that he built at Kabanyolo University Farm generated gas to light some residential houses in the farm's junior line. Some of the gas was also used to boil water to sterilise milking equipment at the farm. The project did not carry out any dissemination as it was only concerned with on-station technology development.

A consultancy report by Silrivasan in 1977, recommended biogas as a viable energy form to be popularised in Uganda. However recommendations of the report were not implemented due to the negative political climate at the time.

In 1980/85, the *Africa Energy Programme* funded by the Common Wealth Science Council sponsored a number of projects on New and Renewable Energy Sources in a number of African countries. Among these were research on biogas and solar crop drying by Makerere and an improved charcoal production project at Nakawa Forestry Station. Emphasis by the projects was on technology generation with little component of technology transfer.

In 1985 a Chinese biogas technical team carried out a comprehensive feasibility study on biogas potentials covering six (then) provinces in Uganda. The study covered eight government stock farms, twelve private farms and two co-operative farms. The findings were that biogas technology was a viable energy option on small scale zero grazing systems where animals were confined, fed and watered in a unit making it possible to easily access adequate, clean manure for biogas production. Minimum labour for biogas production would often be required in such feeding systems since an automatic flowing technique for the manure can be incorporated in the design. In such systems urine can also be harnessed for use in the digester thereby increasing gas productivity. Adequate water is also often available and management easier and more effective.

The Chinese study resulted in the construction of seven Chinese-type demonstration biogas plants in Tororo, Mbale and Kumi districts. The pilot project had a number of positive aspects and was an "eye opener" on the technology.

- It was rural based and appropriate size plants were constructed;
- The project had counterpart Ugandans understudying the Chinese experts;
- Ten technicians, artisans and masons were trained on various aspects of the technology;
- Sensitisation was conducted through mass media and a number of biogas plants were constructed;
- Some of the people and organisations that saw or heard of the technology actually emulated the example.

Methodology

AEATRI survey on biogas technology

In 1995 Agricultural Engineering and Appropriate Technology Research Institute carried out a PRA-survey in eight districts of Uganda aimed at establishing the main constraints in biogas technology. The survey targeted the following categories of potential biogas beneficiaries:

a) Sixty households with zero-grazing units, mainly keeping exotic and cross-bred cattle;
b) Twenty one households practising mixed grazing with cattle kept in paddocks during the day but under shelter during the night;
c) Twenty-eight households practising free-range grazing;
d) Twenty-four households with already existing biogas units;
e) The survey team also interviewed a number of persons and institutions with a good track record of biogas promotion in the country.

Where biogas plants already existed, the survey sought information on status of the plants, common design and building materials used, water availability, quality and ease of acquisition, constraints encountered in operating the systems, success and failure stories on management, among others.

Lessons learnt from the survey

a) Biogas technology is often misconceived as being simple and straightforward to design, construct, manage and implement. This was evidenced by obvious deficiencies in most available designs, in construction techniques and materials used, in management and implementation strategies etc all leading to premature failures of the system.

b) Poor selection of clients to benefit from the technology: be they individuals, groups or organisations. In most cases the technology has had a strong donor-drive. There were also cases of undue pressure by some highly placed persons as regards choice of beneficiaries.

c) Unreliable source of feed materials (source inadequate, distances far away, unreliable availability of feed materials, poor agreements on materials acquisition, livestock system not conducive to feed material acquisition and wrong placement of biogas plants).

d) Unreliable supply of biogas appliances due to total lack of local manufacturers and importers in Uganda.

e). In most sites, biogas technology was provided but with no person knowledgeable on its management, maintenance and repairs.

f) Biogas systems were often unaffordable by the needy poor in society. This calls for more intensive R & D in the use of locally available construction materials and techniques. There was also often need for some credit facility.

g) Non-integrated approach in biogas technology use. In most cases the system's use was only to generate gas for cooking

h) Past biogas plants have almost exclusively been financed by donor agencies with no contribution from the beneficiaries. This has not only caused a "dependency syndrome" in beneficiaries but also encouraged mismanagement and reduced adoption rates;

i) Inadequate follow-up by agencies who provided the technology or by the technology extension personnel (if any) in the field.

Results and discussion

On-station and field studies

Following the above survey, AEATRI adopted a strategy aimed at addressing most of the past short falls in biogas technology development and dissemination in Uganda. The new efforts have since focused client participatory research that has now generated the following major outputs:-

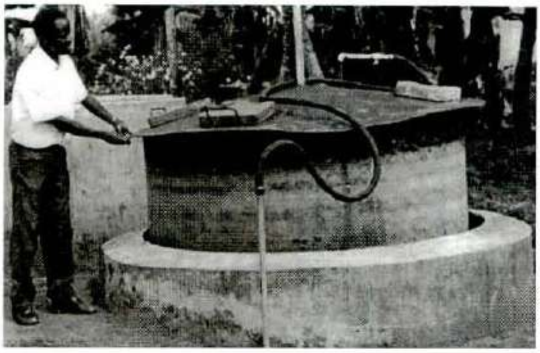

Fig. 1a: Floating gas-holder design in operation

Fig. 1b: Fixed-half-dome digester design

Biogas digesters

Three different designs of biogas digesters have been developed, including the floating-gas-holder type, fixed-half-dome type and tubular digester type. The first two types are shown in figs 1a and 1b. Technical performances of each of the digester designs have been studied. The results show a gas yield of 0.20-0.25 m^3 of gas perm^3 of digester per day at optimal production.

Biogas appliances

The institute has also developed three different designs of gas stoves, which are currently being fabricated for sale to clients. These stoves operate at an average gas pressure of 50-75 mm of water, consuming 0.15-0.2 m^3 of gas per hour. Fig 2 shows a typical AEATRI gas stove being used for cooking at household level in Jinja district. AEATRI has also adapted an ordinary kerosene pressure lamp to using biogas.

Fig 2: AEATRI biogas stove in actual use in Jinja District

Biogas slurry as fertiliser

The effluent (slurry) from AEATRI digesters has been chemically analysed for soil enhancement nutrients side by side with those in fresh cattle manure, Table 1. The slurry samples were taken from the bottom of the digester (relatively fresh), centre (half-digested) and finally from the exit point of the digester (fully digested). The results showed that the longer the digestion took place the more the critical plant nutrients in the dung were released. For example, potassium content in fresh cattle dung rose from an average of 2.09% to 2.25% in half-digested slurry, to a high of 3.41% in fully digested slurry. Similarly, nitrogen content increased by 18%, while phosphorus increased by 24%. In general, passing cattle manure through the digestion process resulted in the break down of the complex molecules constituting the slurry, releasing and making nutrients more readily available to plants than applying the manure fresh to crops. AEATRI also conducted studies applying different rates of fully digested slurry on both local and exotic vegetables. Average yield increases of 15-18%, 23% and 25-30% were recorded, respectively in egg-plants, cabbages and nakati a local vegetable.

Training of stakeholders

In 1998 AEATRI carried out a one-week training of extension agents, artisans and selected farmers on basic aspects of biogas technology. Thirty-six participants drawn from the districts of Mbale, Jinja, Mpigi, Masaka, Bushenyi and Masindi attended the course. Following the training, the institute initiated on-farm collaboration with stakeholders in a number of the above districts. This initiative involved joint construction of training-and-demonstration biogas plants at selected farmers' farms on a cost-shared basis. In this arrangement the client (if a lady) met 40% of the actual cost of the plant,

Table 1: Laboratory analysis report on fresh cow dung and bio-digester slurry

Fertility indicator	Fresh cow-dung samples				Biogas slurry samples			
levels	Sample 1	Sample 2	Sample 3	Means	Sample 1	Sample 2 (digester exit)	Sample 3 (digester top)	Means (digester centre)
Ph of sample	5.70	5.80	5.70	5.73	5.80	5.90	6.00	5.90
Carbon (% C)	34.00	32.60	35.40	34.00	30.04	29.00	28.60	29.21
Nitrogen (% N)	2.01	1.86	1.94	1.94	2.43	2.47	2.43	2.44
Magnesium (% Mg)	0.32	0.38	0.41	0.37	0.45	0.47	0.47	0.44
Calcium (% Ca)	0.70	0.85	0.85	0.80	0.75	0.80	0.70	0.75
Phosphorus (% P)	0.89	1.10	0.99	1.00	1.24	1.10	1.40	1.24
Potassium (% Ka)	1.94	2.25	2.06	2.09	4.00	3.25	3.00	3.41

besides provision of locally available materials and unskilled labour for the construction. If the client was a man, he had to meet 60% of the actual plant costs besides provision of locally obtainable construction materials and labour.

During the construction exercises, local artisans and masons selected by the involved communities were practically trained in the actual construction of various biogas digesters and later in the installation, management, maintenance and repairs of the structures. Extension agents and both male and female farmers from selected districts were also sensitised and trained. These efforts were consolidated by several groups of farmers getting more exposure on the technology through actual visits to the institute and participating in agricultural and other shows where various aspects of biogas technology were demonstrated.

The AEATRI biogas dissemination initiatives including those of its collaborators have been able to construct a total of 41 biogas plants at farmers' farms including five at NARO research institutes. The districts and locations that have benefited from this process are shown in Table 2. The station has also trained an estimated 80 rural artisans in biogas construction and maintenance. The institute is proud of having some of the best skilled personnel in biogas technology in the country.

Table 2 : Constraints of biogas plants by districs

District	Biogas digester types constructed			
	Floating Cover	Fixed Dome	Tubular type	Bio-Latrine
Mpigi/Wakiso				
a) Namulonge	**1**	**1**	**-**	**-**
b) Kasangat	**1**	**1**	**-**	**-**
c) Kiteetika	**1**	**-**	**-**	**-**
d) Kiteezi	**2**	**1**	**3**	**1**
e) Namalere	**1**	**1**	**1**	**-**
f) Wamala	**1**	**-**	**-**	**-**
g) Nansana	**-**	**-**	**4**	**-**
Kampala district				
a) Bunga	**1**	**-**	**-**	**-**
b) Namuwongo	**1**	**-**	**-**	**-**
c) Makerere	**1**	**-**	**-**	**-**
Jinja district	***7***	***2***	***3***	**-**
Mukono district	**-**	**-**	**-**	***1***
Masaka district	***2***	**-**	**-**	**-**
Hoima district	**-**	**-**	***1***	**-**
Iganga district	***1***	**-**	**-**	**-**
Bushenyi district	**-**	***1***	**-**	**-**
Soroti district	***1***	**-**	**-**	**-**
Totals	**20**	**7**	**12**	**2**

Collaboration with other institutions

Throughout its activities the institute realises the need for stronger collaboration with private small-scale manufacturers who could take on fabrication especially of biogas holders and appliances so that these are readily available to users who need them. AEATRI will also continue to develop local engineering capacity for the production of a range of biogas appliances that are to feed into private sector initiatives. It will experiment on alternative designs and construction materials, which meet cultural norms and reduce costs of biogas systems.

Policy and project sustainability aspects

The institute has all along made every attempt to ensure sustainability of its biogas initiatives. The approach has focused development of grass root capacity based on partnership with client beneficiaries, extension agents and local artisans:

- trained and skilled personnel are being left on the ground to propagate the technology,
- the cost-sharing concepts gradually removes the long-term "dependency syndrome" by clients, giving them the sense of ownership of technology and improving management.
- development of local capacity to design and fabricate biogas appliances will make the technology sustainably available in the country,
- the integrated and holistic approach to biogas technology development (gas, manure, sanitation) diversifies its benefits and increases chances for adoption.
- through NARO's policy of wider involvement of stakeholders in technology development and dissemination, the private sector and grassroots NGOs/CBOs will continue to play major role in the dissemination of boigas technology.
- AEATRI research portfolio includes work on new and renewable energy sources of which biogas in an important component.

Scio-economic analysis

Drawing conclusions about the feasibility of the anaerobic digestion process can be approached through one of the two ways below:

a) A strictly financial approach involving analysis monetary benefits such as sale or re-use of products (methane, carbon dioxide and slurry with all its applications, costs of constructing an maintaining facilities, etc.
OR

b) A social assessment of inputs and outputs from the biogas system including such intangibles as:

- improvement in public health,
- reduced deforestation and desertification,
- reduced reliance on imported fuels for cooking lighting and heating,
- greater rural self-sufficiency.

It is often difficult to quantity the above social benefits. Consequently rigorous economic comparisons between biogas and other renewable (solar, wind, photo-voltaic) as well as conventional energy sources (wood, fuel, gas charcoal, petroleum bye-products, electricity, etc), is always the favoured approach and must be done according to local conditions.

Policy recommendations and way forward

a) A national renewable energy co-ordinating desk should be created within the Ministry of Energy and Power to co-ordinate research, development, extension and networking and to monitor renewable energy transfer and adoption including biogas technology in order to reduce duplication of efforts.

b) In India and Chaina organisation and co-ordination of government support on biogas technology promotion was strengthened and reached all villages of the countries. Government subsidy towards construction of biogas plants reached over 70%. In Uganda Government and private sector institutions involved in biogas development initiatives should address this constraints by availing low interest rural credits through grassroots financial institutions.

c) Government should adequately finance research and developments in the area of environmental conservation and protection where biogas technology has a major contribution. It should also support information collection and disseminated as well as training of trainers and of technicians and masons in the biogas area

d) Research should aim at reducing the cost of biogas technology to make it affordable to poor households, which require it most.

e) Biogas activities should concentrate on districts with high potentials as regards climatic conditions and availability manure, which can be accessed.

f) These programmes should be co-ordinated jointly with those improved cook stoves, reforestation and or rural electrification.

Conclusion

Biogas is an important renewable energy, source that can be used decently where organic waste is produced in appropriate quantities. It can make important contribution to the protection and improvement of natural resources and environment. Studies by AEATRI have shown that slurry, a residue for the process, is a high quality fertility, which can replace expensive mineral fertilisers, in particular nitrogen, phosphorus and potassium. Besides the above, the technology provides an efficient sanitary system that enhances waste product disposals.

The use of biogas enables women especially in rural areas to save time for productive agriculture leisure, family care and welfare. The technology also improves the standard of living and can directly contribute to economic and social development of a country. To attain all the above, biogas technology must be used in an integrated

manner: gas for cooking, heating and lighting, effluent as

fertiliser, and its value as a means of destroying diseasecarrying pathogens in waste matter.

Acknowledgement

The research and dissemination efforts on biogas technology in NARO was made possible through the financial assistance of the Ashden Trust Foundation, UK with modest support by NARO in terms of staff facilitation, transport and workshop facilities for all of which support AEATRI is extremely grateful. Warm appreciation is extended to the unflinching support given by extension artisans and farmers during filed activities.

References

AEATRI 1995: Biogas Technology Participants rural appraisal survey Report in selected districts of Uganda, by Agricultural engineering and appropriate technology Research Institute, AEATRI-NARO.

Boshoff, 1970: Processed in Biogas Production. PhD Thesis by the University of Londo, UK.

Hu rongdu 1998: Process for household digesters. Paper presented at the Asia Pacific Biogas research and Training workshop, Chenngde, Chaina.

Odogola R. Wilfred, Kato Christopher, 2000: an overview of biogas technology: origin, development, challenges and future prospects. Paper pressed at the conference on New and Renewable Energy source, organised at the International conference centre, Kampala by the Ministry of Energy.