Installing a biodigester

Selecting the site
The first step in installing the biodigester is to identify the most appropriate location. This should be close to the livestock pen where the waste is produced. It is an advantage if the waste from the pen can be washed out with water and then run with gravity directly into the inlet of the biodigester. It is relatively easy to transport the gas by pipeline, but difficult and tedious to transport wastes.

Preparing the site
Once the site is selected, the next step is to determine the size of the biodigester. As a general rule the waste produced by 10 fattening pigs will require a biodigester of 4 m3 liquid capacity. On average 80 percent of the total volume in the tube will be occupied by the liquid manure, so to process a liquid volume of 4 m3 will require a biodigester with a length of 10 m. To hold a biodigester of the above dimensions, a trench should be dug with the following dimensions: width at the top 90 cm; depth 90 cm; width at the bottom 70 cm; length 10 m.

When digging the trench it is important to consider that the sides and the floor should be smooth with no protruding stones or roots which could damage the plastic film. The sides should be sloping to avoid that the trench collapses. The floor should have a slight slope to enable a continuous slow flow of slurry through the digester. The soil that is dug out of the trench should be moved away from the edges, so that movement around the biodigester or heavy rains do not cause it to fall onto the plastic.

Preparing the plastic tube
The polythene plastic comes from the factory in rolls that weigh about 50 kg. The rolls should be handled carefully, especially the edges, and should be stored and handled in a horizontal position. Putting a steel rod (or bamboo pole) through the centre of the roll helps when measuring the required length of tube. If the biodigester trench is 10 m long then an additional 75 cm should be added to each end of the plastic tube to allow for wrapping the ends over the inlet pipes, so that the total length to be cut will be 11.5 m.

Two lengths of polythene plastic tube are required, as one will be put inside the other for added strength. When the second length of plastic tube is inserted inside the first length, care should be taken to ensure that the two layers fit snugly together and there are no folds or creases.

Materials required for the biodigester

- Transparent tubular polythene plastic film
- 2 ceramic, PVC or concrete pipes of 75 to 100 cm length and 15 cm internal diameter
- Plastic hosepipe or PVC pipe for the gas (length depends on the distance to the kitchen)
- Adapters, washers, elbows and T-pieces as well as 2 m PVC pipe of the same diameter as the hosepipe (12.5 mm)
- 4 used inner tubes cut into bands 5 cm wide
- 1 transparent plastic bottle for the gas escape valve

Fixing the gas outlet

The first step is to mark the place where the gas outlet will be placed. This should be 1.5 m from the end of the plastic tube and in the centre of what will the top of the biodigester.

Fixing the inlet pipe

Rubber bands 5 cm wide are cut from used inner tubes from a bicycle, motor cycle or car. The ceramic (or PVC) pipe is inserted into the plastic tube to one-half of its length, and the plastic tube is then folded around it. The join is secured by wrapping the rubber bands around the ceramic pipe, beginning 25 cm from the edge of the plastic and working towards the exposed part of the pipe, each band overlapping the previous one, and finishing on the ceramic pipe so that the edges of the plastic are completely covered.

Filling the plastic tube with air and fitting the exit tube

The inlet tube and the gas outlet are closed with plastic film (or a plastic bag) and rubber bands. The plastic tube is filled with air before the completed biodigester is put in the trench. From the open end, air is forced into the tube in waves, created by flapping the end of the tube with a forward propelling movement of the arms. The tube is then tied with a rubber band about 3 m from the end so that the air does not escape. This is to facilitate fitting the second ceramic pipe as an exit pipe. The second ceramic pipe is then fitted, using the same procedure as for the inlet.

Final stages in preparing the plastic tube

It is very important to check that the edges of the plastic are completely covered by the rubber bands, each overlapping the previous one, finishing on the ceramic pipes so that the edges of the plastic are completely covered. When each ceramic pipe is fixed, a square plastic sheet, held in place with rubber bands, is used to seal the pipe. The restraining rubber band, previously attached to prevent escape of air when the exit ceramic tube was inserted, is now removed. The bag will appear to deflate a little as air enters the ceramic pipe. The final step is to completely fill the bag with air by attaching a length (4 m) of plastic tube (same material as used for the biodigester) to the ceramic exit pipe, filling this with air using the flapping procedure, and then removing the plastic sheet to allow this air to enter the main bag. The process can be repeated until the biodigester bag is completely full with air. The square of plastic, held in place with a rubber band, is again put in place to seal the exit pipe.

Placing the biodigester in the trench

The inflated tube is carried to the trench, taking care that it does not come in contact with any sharp objects. It is lowered into the trench in such a way that the gas outlet is at the top of the tube, the inlet at the higher end of the trench and the outlet at the lower. A support is prepared to hold the hosepipe which functions as a gas line, made of 13 mm PVC tube.

Filling the biodigester with water

The biodigester is then filled with water until the inlet and outlet pipes are sealed (covered with water) from the inside. The air inside the bag is now trapped in the upper part. The plastic bags over the exit and entry pipes can then be removed.

The water trap (gas escape valve)

To ensure that the gas pressure within the tube does not build up too much, it is important to have a simple escape mechanism for the gas if the pressure becomes too high. This can easily be made from a plastic bottle partly filled with water. This "water trap" should be suspended in a convenient place so that the water level can be easily observed and replenished when necessary

The gas reservoir

This is a large plastic bag (4 m length) of the same polythene tube used for the biodigester. The reservoir plays a key role in the functioning of the biodigester and should be located in a convenient place (for example, suspended in the roof) close to the kitchen. This enables the collection and storage of the gas close to the point of use, which makes it possible to achieve a higher gas pressure.

Taking the gas to the kitchen

With the reservoir in place, the gas line attached to the outlet is fixed to the burners. A strap is placed around the middle section of the reservoir. By pulling on the strap, and tying it to some fixed object or hanging a heavy stone or a brick, the pressure of the gas delivered to the burners can be increased. This is usually necessary when cooking proceeds over an extended period of time.

Feeding the biodigester

The biodigester needs to be fed daily. If cow dung is used, the dung has to be mixed with water before feeding the digester. If pigs are raised on the farm, the pig pens can be connected directly with the biodigester so that the washing of the pens automatically forces the slurry into the biodigester, through constructed channels.

Protecting the digester

The biodigester needs to be protected from animals, children and sunlight which can damage the plastic. It is advisable to put a fence around the trench and to build a simple roof to shade the digester.

he completed biodigester

The area around the pens that used to be polluted with waste now consists of dry soil as the waste goes into the digester. There are no bad odours as the manure is fed to the biodigester daily. The farm family no longer needs to collect fuelwood or buy fuel for cooking. The savings will help pay for the cost of the biodigester in less than 12 months.

The time that elapses before gas is produced depends on the composition and quantity of the manure that is put into the biodigester. In certain farm households the washings from the pig pens may already be in an advanced state of fermentation when they are

introduced into the biodigester. The farm family would thus be able to begin cooking with biogas only 5 days after the installation. With fresh unfermented manure, the time lag is between 21 and 28 days.

Potential problems and some solutions - What do you do if:
There are not enough animals to supply manure for the biodigester? **If animals were sold or are just too small, this could be a problem. The family toilet can also be joined to the biodigester. Temporarily you can also add some readily fermentable materials such as cassava waste, damaged cassava roots, molasses or any similar carbohydrate source. If this done, it is wise to also add 30 - 40 grams of urea every day.**
There is not enough water in the biodigester? **Enough water is essential to the operation of the biodigester. The water level should be checked regularly and water added if necessary.**
There is a smell of gas? **This can be caused by a loose connection, a damaged tap in the kitchen or a hole in the plastic.Repair with sticking plaster or tape.**
Not enough gas is produced? **Could be caused by a loose connection, a broken section of pipe or a pipe doubled over, impeding the gas flow. Cut a new piece of hose pipe to replace the damaged one.**
There is not enough water in the trap bottle? **It is important to keep checking that evaporation hasn't caused the water level to fall below the tip of the gas tube.**
There is a lot of gas in the biodigester but very little in the reservoir bag? **This can be solved by opening the joins and taking out the water, or making a hole in the PVC pipe to take out the water then fixing it with tape. It is also possible to fit drain taps at the lowest points in the line.**
Cooking is too slow? **More pressure is needed inside the reservoir. Tighten the string around the reservoir.**
In the morning you find the reservoir bag with very little gas? **You forgot to loosen the string around the reservoir after finishing cooking the night before. Place the reservoir bag in the ceiling of the kitchen or in a place close by to facilitate the control of it.**
The biodigester has a hole through both layers? **If the hole is large, replace the plastic tubes and reinstall the system. Protect the biodigester with a fence.**
The first layer of plastic is broken? **Can be caused by deterioration of the plastic that does not have contact with water. Try to place the biodigester so that most of the plastic surface is in contact with the water. The solution is NOT to add extra layers of plastic**
There is a lot of soil in the trench of the biodigester? **Usually a more serious problem. It can happen when the biodigester is placed on very sandy soil or on low land so that the rain washes a lot of soil into the trench. Avoid this by choosing a good place to set the biodigester. Make channels to lead away the rain water. Cover the upper walls of the trench with bricks or with a mixture of cement and soil. Build a wall in front of the biodigester inlet.**
Slurry inside the biodigester is very hard? **Can be caused by soil in the trench of the biodigester or by too high manure content in the input slurry (more of a problem with cattle manure). The plastic has to be changed after about 2 to 4 years mainly because of this problem.**

A manual on this type of biodigester, called "Recycling Livestock Wastes" is available from the UTA Foundation

The role of low-cost plastic tube biodigesters in integrated farming systems in Vietnam: Part I

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Second FAO Electronic Conference on Tropical Feeds
Livestock Feed Resources within Integrated Farming Systems

THE ROLE OF LOW-COST PLASTIC TUBE BIODIGESTERS IN INTEGRATED FARMING SYSTEMS IN VIETNAM (Part I)

Bui Xuan An

University Agriculture & Forestry, Thu Duc, Ho Chi Minh City Vietnam

E-mail: an%sarec%ifs.plants@ox.ac.uk

INTRODUCTION

For the past 10 years or so, Vietnam has adopted modern farming techniques that use imported agro-chemicals and fossil-fuel products in order to increase exports of agricultural products and feed its population which has grown to 75 million. The rising environmental problems and costly socio-economic dependence on external inputs have alarmed certain leaders and many of the population. Facing this situation, the use of environmentally-friendly techniques at all levels of farming have had an important role in rural development. Low cost plastic biodigesters make efficient use of manure in the integrated farming system to produce gas for cooking and effluent to fertilize ponds for fish, aquatic plants and crops, bring advantages to the economy and to the environment. They have been adapted from the "bag" digester or Taiwan model, simplified by using cheaper polyethylene tubular film to replace the welded PVC sheet.

Many developing countries, such as Colombia, Ethiopia, Tanzania, Vietnam, Cambodia and Bangladesh, have promoted the low-cost biodigester technology, aiming at reducing the production cost by using local materials and simplifying its installation and operation. Within three years, more than 1000 polyethylene digesters were installed in Vietnam, mainly paid for by farmers. This report discusses the role of plastic biodigesters in integrated farming systems in Vietnam and describes experience with the introduction of biodigesters under local conditions.

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BIOGAS IN DEVELOPING COUNTRIES

After 1975, slogans such as "biogas for every household" led to the construction of 1.6 million digesters per year in China, mainly concrete fixed-dome digesters. Up to 1982, more than seven million digesters were installed in China (Kristoferson and Bokhalders, 1991). In 1980, more than 50% of all digesters were not in use (Marchaim, 1992). The rapid development of biogas in China received strong government support and sometimes subsidies from local government and village government were up to 75% (Gunnerson and Stuckey 1986). In recent years, the number of plants built each year has fallen dramatically because of the reduction in subsidies with a consequent switching from biogas to coal as a fuel. The biggest constraint in the biogas programmes has been the price of the digesters. It was also learned that the popularization of biogas would only be successful when the direct benefits to the farmers were obvious.

In many respects, the same situation as in China prevailed in India where a rapid biogas digester implementation policy exceeded the capabilities of India's research and development organizations to produce reliable designs and to optimize digester efficiency. As a result, earlier digesters in the country were expensive and inefficient. This situation has been remedied somewhat in recent years. According to
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Kristoferson and Bokhalders (1991), new developments and designs are not incorporated as rapidly as they might, and improved coordination and feedback will be required if development is to be achieved. The poor performance of earlier biogas digesters can also be attributed to poor backup services. This situation, which is still largely prevalent, has led to a relatively high breakdown rate. Problems can be classified as (a) design faults; (b) construction faults (c) difficulty of financing; (d) operational problems due to incorrect feeding or poor maintenance and (e) organizational problems arising from the differences of approaches and lack of coordination.

Biogas production has been stimulated by popular publicity campaigns and subsidized construction of biogas plants by central and local governments. The floating cover design, introduced by the All-Indian Coordinate Biogas Programme, is the most common system currently in use in India. This system is more expensive than the fixed dome (Chinese) digester. Despite having the world's second largest number of installed biogas digesters, the biogas program has mainly concentrated on the expensive systems capable of being installed only by the wealthier inhabitants in the rural areas (Kristoferson and Bokhalders, 1991). India has placed far more emphasis on the survival of small-scale farmers than ensuring their efficiency and growth in a competitive environment through various policy instruments like the biogas programme.

The situation is almost the same in many other developing countries, such as the Philippines, Thailand, Nepal, Brazil. For example in Nepal, many authors considered that, with the installation of more than thirteen thousand biogas plants, the strategic plan and activity of biogas program implementation was gaining more popularity and becoming a well developed example of technology dissemination. The government has provided up to Rs 7000 for a plant built in the lowlands and Rs 10000 in the hill areas (about 30-70% of the cost for construction). According to a report from the Consolidated Management Services Nepal, although biogas was introduced in Nepal about two decades ago, the present infrastructure seems so weak that there is still the dependency upon foreign countries for supply of some biogas accessories and equipment. With subsidies of more than 50% of the cost of a family size plant, many farmers who demanded biogas plants were more attracted to the amount of available subsidies than by the utility of the plant as such. Many newly-formed private companies were finding their business quite profitable and a considerable part of the government subsidy was taken by these companies as profit (Karki et al, 1994). Without subsidies the simple pay-back period varied between 6 and 12 years in Nepal.

In many developing countries, frequent changes in government policies on interest rates and subsidies have also had negative impacts on biogas dissemination. These changes have disappointed the investors in long-term biogas development. The progressive farmers who would like to have biogas also become doubtful about their long-term biogas investments.

Biogas production was introduced into Vietnam more than 10 years ago as an alternative source of energy to partially alleviate the problem of acute energy shortage for household uses. Biodigesters of various origins and designs were tested in rural areas under different national and international development programmes, using household or farm wastes as fermentation substrates. Indian-type, Chinese-type and ferro-cement-type digesters were installed and evaluated in many provinces but concentrated in urban areas (Thong et al, 1989; Khoi, 1989). However, few farmers used them in practice.

The poor acceptability of these concrete digesters was mainly due to: (a) high cost of the digesters; (b) difficulty in installing them; and (c) difficulty in obtaining spare parts for replacement. A digester of a size adequate for the fuel needs of an average family would normally cost VND 1.8 to 3.4 million (US$ 180 to 340) (Thong, 1989). This scale of investment is considered unaffordable by the average farm family (An et al, 1994). In addition, it would take about 2.5 to 3.5 years to pay back the initial investment (Thong, 1989; Khoi et al, 1989). Besides, the replacement of worn-out parts posed another technical problem, apart from the fact that such spare parts are not always locally available. Khoi et al (1989) reported that 33% of biodigesters installed in Cantho City had stopped functioning while only 8 out of 17 of those set up in Quangnam-Danang Province were still operable.

Vietnam is a nation with a low gross national product per capita, so getting support for any kind of environmental program is difficult. Without the support from the Vietnamese government or from overseas, the concrete digester development is progressing slowly. Only the richest farmers in rural or peri-urban areas can afford the construction of concrete digesters. The development of concrete biogas digesters is therefore not sustainable in rural areas. To disseminate the biogas fermentation technology in rural areas, it is necessary to reduce the cost and use simple means of construction.

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LOW-COST POLYETHYLENE TUBULAR DIGESTER

In the light of these constraints, many developing countries such as Colombia, Ethiopia, Tanzania, Vietnam, Cambodia, Bangladesh have promoted the polyethylene tubular digester technology, aimed at reducing the production cost by using local materials and simplifying its installation and operation. To this end it was decided to use a continuous-flow flexible tube biodigester based on the "Taiwan" model and later simplified by Preston and co-workers (An et al, 1994). The low-cost biodigester technology has been well received by poor smallholder farmers in Vietnam for producing a clean fuel to replace firewood. Within three years, more than 800 polyethylene digesters were installed in Vietnam, mainly paid for by farmers (An and Preston, 1995).

Data on the design parameters and cost of digesters around Ho Chi Minh City are presented in Table 1. The average length of the digesters was 10.2 m with an estimated digesta volume of approximately 5.1 m^3 (length x 0.5 m^3). The material cost was slightly more than US$25 for a family digester.
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Table 1: Mean values for some design parameters and cost of 194 digesters installed around Ho Chi Minh City

	Mean	Range
Length (m)	10.2	4 - 30
Digester liquid volume (m^3)	5.1	2 - 15
Distance to kitchen (m)	23	8 - 71
Material cost (US$)	25.4	14 - 82
Time to first gas production (days)	17	1 - 60
Digesters in rural areas(%)	91	
Floating digesters (%)	5	

Source: An et al., 1996.

However, the biodigesters are still not fully integrated into the farming system as there is only limited use of the by-product (the effluent) as fertilizer for vegetables, fruit trees, fish and water plants (An et al 1994). The use of the effluent from biodigesters should be studied as a resource for small scale farmers. The farmers always put questions about quantities of manure fed to the digester, ratios between manure and water, time of cooking, quantities of gas produced and the useful life of biodigesters. The relevant data almost all comes from temperate countries and from concrete biodigester plants.

Extension of the technology has had different successes in different countries. It has been successful in Colombia, Vietnam and Cambodia but there have been negative reports from other countries such as Bangladesh, Nepal and Tanzania. The same technology was used but different results were obtained. The difference is not only between countries but also in different areas of a country (An et al, 1996). Many authors presented the advantages of low cost and easy installation of the plastic digesters; meanwhile some have been doubtful of life expectancy of the digester and the ability to repair it.

It is necessary to study the constraints in each area carefully and seek experiences from institutions with knowledge in this field. All institutions and personnel who are involved in the biogas research and development should be informed about experiences and results obtained elsewhere. The electronic mail system is one of the most appropriate means to this end.

In most developing countries, when the subsidies from governments are reduced, the number of plants built each year falls dramatically. The most important problem in biogas programs in developing countries has been the price of digester plants. For example, the price of a concrete digester plant installed for an average family in Vietnam varied from 180 to 340 US$ (see above). Chinese designers tried to reduce the cost of red-mud digesters to 25-30 US$/m^3 (Gunnerson and Stuckey 1986) but it was still high in comparison with the polyethylene digesters (5 US$/m^3). This is obviously one important feature which makes the polyethylene digesters attractive and no farmer in the present study complained about the price.

Among the polyethylene digesters installed, 5% of them were floated in ponds, adding an innovative feature to the development. According to Khoi et al (1989), in the Mekong Delta where most land is low-lying, the application of concrete digesters was very difficult especially when the water level went up. The floating digesters solved this problem and, as they also required little space, they were very well suited for use in low-lying areas. More than 90% of the plants were installed in rural areas indicating the good impact of the technology in these parts of Vietnam.

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INTRODUCTION OF BIOGAS TO SMALL FARMS IN THE THUAN AN DISTRICT

The effects of the introduction of digesters on small farms are presented in Tables 2-5 (An et al 1996). Most of the farms with biodigesters belonged to the medium-income group (sufficient food all year around). In this group animal production is a very important component of their farming systems and a sufficient number of animals is important for the dissemination of biodigesters. The expense for the digester plant was paid back within slightly more than 5 months, so most of the farmers found a great benefit from installing digesters.

Table 2: Economic aspects of biogas introduction in 31 small farms in Thuan An district, Vietnam

	MEAN	RANGE
Cooking time (hour)	4.4	1 - 9
Fuel saved in cooking (US$/month)	6.5	1.8 - 13.6
Biogas plant cost (US$/unit)	34.8	18 - 53
Number of pigs/farm	10.7	0 - 40
Payback time (month)	5.4	2 - 19

Source: An et al 1996.

Table 3: Farmers' participation and opinions on plastic biodigesters in
Thuan An district, Vietnam

	ALTERNATIVES	No.*
Getting first information from		
	Neighbours or relatives	32
	Mass media	3
Payment of the digester plants		
	Farmers paid totally	33
	Partially (demonstration)	2
Using slurry for	Plants	3
	Ponds	3
	Nothing	31
Status of gas production	Enough gas	26
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	Little gas	5
	No gas	4
Advantages of biogas	Saves money	34
	Less pollution	35
	Easy cooking	35

*No: Number of farmers

Source: An et al 1996

Table 4: Input and output of 31 digesters working at small farms around Ho
Chi Minh City, Vietnam

	MEAN	RANGE
Size of family	5.9	3 - 12
Manure loading (kg/d)	16	2 - 27
Ratio Water/manure	5.1	2.9 - 8.1
Loading rates (kg DM/m^3)	0.7	0.1 - 1.2
Temperature of loading (deg C)	26.4	25.7 - 28.5
Temperature of effluent (deg C)	27.0	26.0 - 29.1
pH of loading	6.7	6.4 - 7.1
pH of effluent	7.2	6.8 - 7.5
Gas production (l/unit/day)	1235	689 - 2237
Vol. Gas/capita (l/person/day)	223	68 - 377
Methane ratio (%)	56	45 - 62
COD of loading (g/litre)	35.6	22.4 - 46.0
COD of effluent (g/litre)	13.5	8.8 - 23.9
COD removal rate (%)	62	42 - 79

COD = Chemical Oxygen Demand

Source: An et al 1996.

Table 5: Effect of biodigestion on some microorganisms of manure in small
farms in Vietnam

	MEAN	RANGE
E. coli of loading (10^3cell/ml)	52,890	11,000 - 150,000
E. coli of effluent (10^3cell/ml)	75	2 - 450
Coliforms of loading (10^3cell/ml)	266,780	11,000 - 480,000
Coliforms of slurry (10^3cell/ml)	236	7 - 250

Source: An et al. unpublished.

Among 35 farmers interviewed, four of them were poor (not enough food in certain months). The most important thing for them is food and they could not afford a sufficient number of animals for feeding manure to the digester. They wanted to borrow money to be able to raise animals. Four farmers had no gas when the interview was carried out. Three of them did not have animals because they found raising animals unprofitable if they had to borrow money from local lenders at 5-10%

monthly interest. This was an important aspect, especially as resource-poor farmers cannot support the digester installation and keep animals, although they know the advantages of biogas.

The average DM percentage of manure was 25% and the loading rates ranged from 0.1 to 1.2 kg DM/m^3 digester liquid volume.

Previously, animal manure was an environmental problem in villages in the district, mainly in crowded and lowland areas where it caused pollution of the air, water and soil. After installation of the digesters, all 35 families recognized better environmental conditions, less smell, fewer flies, cleaner waste water, etc. Summarizing details of experiments conducted with pig slurries, Pain et al. (1990) concluded that the digestion reduced odour emission by between 70 and 74%. According to the women who were responsible for food preparation, use of biogas meant that they could attend to other work, while cooking. This is in contrast to the situation when using solid fuels such as firewood which require much closer supervision. The women stressed that they could now cook in a clean environment, free of smoke. Their pots and pans were clean and they did not have to spend time on tedious cleaning. They stated that they could cook all food items on gas.

In the study, biodigestion decreased COD from 35610 mg/lit in the inlet to 13470 mg/l in the effluent, indicating a process efficiency of 62% (COD removal rate). The digestion in biodigesters reduces the pathogens in waste water so it prevents contamination from animal production. The volume of gas per capita per day was about 200 litres, enough to cook three meals. The loading rates were low and gas production could be improved by increasing the amount of manure fed to the digesters. Beside cooking meals, five farmers cooked animal feeds, three made wine, one made cakes and two prepared tea and coffee in their cafeterias. This demonstrates that there are several reasons for uptake, as discussed by Dolberg (1993).

An on-farm study on the use of slurry for some crops was carried out to evaluate the effect of biodigesters in farm economics. The results were presented in table 8. The crops were Lilium flower, elephant grass and sweet potato. The use of slurry increased by 100% the benefit of biodigester introduction in comparison with gas use only.

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