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Impact of Small Anaerobic Digester on Household Economy of Bangladeshi Livestock Farmers

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ABSTRACT

An extensive survey was performed covering all the regions of the country to find out the overall impacts of bio-digester on the economy of livestock farmers. Five districts were selected; ten farmers with having bio-digester of 3.2 m^3 on average and ten farmers who have no bio-digester were selected from each district. Through direct interviewing and farm monitoring, all farm characteristics, i.e., diurnal biogas production, power generation, cooking time, income and expenditures, farmer's gross earnings, and manure management practices data were collected accordingly. Descriptive statistics and student t-test was made to express the comparison response of the farms by using XL and SPSS software. It was observed that the owners of anaerobic digesters earned significantly ($p < 0.001$) more than the traditional farmers by selling animals and biogas (1715 & 306; 1146 & 0.00 USD, respectively). Not only that, by selling milk and fresh manure, the owners of bio-digester harvested more ($p < 0.05$) annual income than non-bio-digester farmers (4162, 3408 & 60.91, 44.63 USD, respectively). Though the expenditure of farmers having digester was high, but in a single fiscal year, they earned more ($p < 0.05$) profit than the conventional farmers (USD 4329 & 2842, respectively). However, owners of bio-digester used 67.2 % of their produced manure for gas production. Regarding storing manure as biomass and using it for cooking purposes significant difference ($p < 0.001$) was observed that was also reflected in the total manure management system of a farm. The farmers having no bio-digester stored 71.95% of their total manure in solid form, whereas the farmers who had bio-digester only stored 20.4% of their manure, which made a significant ($p < 0.001$) difference. From the biogas chamber, in an average one farmer used a gas stove for 4-5 hours and a gas lamp for 6-8 hours, which saved at least the expenditure of 18 USD per month/household. The notable thing was that the bio-digester alone contributed 7% to those farmers' gross economy by producing gas. It can be recommended that the rural householders could generate power by installing bio-digester and turn a small bio-digester as a beneficial avenue of their household economy.

INTRODUCTION

Bangladesh has not had enough base energy to bloom its economy for a long time. Global energy demands, the price of energy, and its related politics are growing up day by day. Biogas production through recycling waste is the least cost-effective and justified technology for the rural ecological condition of Bangladesh. Fifty years ago, in 1972, biogas technology began its journey in Bangladesh. At present, more than 100,000 small households have anaerobic bio-digester in their premises, which accounts for 0.4 percent of total rural households in Bangladesh. Rural households, over 90 percent of the total, still depend on conventional biomass for their cooking, and surprisingly, this biomass is about half of the total supplied energy of Bangladesh (IDCOL Final Report 2018). In Bangladesh, home cooking mostly depends on solid fuels, and the direct combustion of wood hampered the environment.

Manure can be used for cooking purposes, and in this way, forests can save from loss, resulting in keeping the environment green along lowering greenhouse gas emissions at a significant level (Cuellar & Webber 2008). The energy derived from bio-digester replaces fossil fuels and substitutes biogas, which surely reduces cooking time and greenhouse gas emissions too (Axaopoulos & Panagakis 2003). Biogas energy brought factual benefits to those women who suffered the most by using fossil fuel, and at the same time, it ensured more economic returns in terms of money (Kohlin et al. 2011). Not only for cooking means but also for electricity generation, biogas is now considered as a cheap source of energy. Because of the worldwide renewable energy production demand and the shortage of harnesses on the natural gas reserve, the anaerobic digester is recognized as a promising technology nowadays. It needs rather a lowest investment to produce energy comparison to others. This potential source of power can secure electrification in rural areas. In case of shortfalls, it also can ensure the uninterrupted electricity supply in the urban and peri-urban areas. Biogas energy can also facilitate the irrigation of agricultural land (Hamid et al. 2013). The sustainability and secured growth of economics are closely interlinked with the uninterrupted energy supply that is truly vital for a nation, particularly for Bangladesh (Hasan & Ammenberg 2019). However, on the other hand, in the case of global warming, livetock is responsible for emissions of anthropogenic CH4 at a rate of 33% of total global emissions. Enteric methane emission from ruminants engulfs most of this portion (90%), and the manure produces the rest of the amounts. Though it looks negligible, it has huge impacts on agriculture and influences the climate. Substantial management practices of manure management are deleterious, and they exist only because of the lack of knowledge of farmers about the value of livestock manure and its integrated multiple management (Teenstra et al. 2014). On the basis of a study of 2016 in Bangladesh, Rahman et al. (2019) cited that around 102.6 million tons of cow dung and 12.9 million tons of poultry litter are being wasted in a year. Integrated or advanced practices like the adoption of an anaerobic digester can change the manure management scenario, and opportunities can be created to develop the economy of farmers. It is believed that an advanced system along with integrated infrastructure is required to develop for versatile and efficient use of biogas. It is assumed that as green fuel, biogas can bring synergy to a sustainable economy. Therefore, it is essential to identify whether the farmers who are adopting advanced technology like bio-digesters are being benefited and, if so, how. This experiment was conducted to figure out the beneficial opportunity of biogas digester and its related avenue of how it can impact the economy of rural households.

MATERIALS AND METHODS

The work was conducted by the Bangladesh Livestock Research Institute (BLRI) in collaboration with the Stockholm Environment Institute of Asia-Centre, Bangkok. The survey was operated through a random selection of dairy farmers from different districts of Bangladesh representing different dairy production areas. Having ten cows on an average number in their farms also was the selection criteria. The selected district was namely Dhaka, Chittagong, Mouluvibazar, Rangpur, and Mymensingh. From each region, ten farms having bio-digester and ten farms that have no bio-digester were selected for data collection. The average size of the bio-digester of all farmers was 3.2 m^3 installed by IDCOL/BCSIR. A questionnaire pertaining to farmers' responses on farming status, annual income and expenditures of farms, farming characteristics including cost efficiency, the contribution of bio-digester on farmer's gross earnings, and changing pattern of manure management for bio-digester was developed and surveyed accordingly. Prior to the survey, the questionnaire was tested among the farmers of the Dhaka district and updated with necessary revisions to make the questionnaire ready for use. A comparative study was conducted comprising a total of 100 dairy farms where 50 farms had bio-digester, and 50 farms had no bio-digester. The researchers visited each farm, and data were collected after an initial briefing on the purpose of the work through face-to-face information sharing. An in-depth interview, along with personal observations, was made with each farmer to collect authentic data from the respondent farmers. Average data on daily milk yield, use of feed, and manure production were collected. At the same time, the daily cost of feed, medical, maintenance, and all related expenditures were collected. Regarding bio-digester, information about biogas production, water and power use, cooking time, etc., was also collected daily, and in the case of any necessity to ensure the actual data, the help of family members was taken.

Additionally, farmers' stock books were used where available. Numerical collected data of the variables were inserted into Excel spreadsheets. Descriptive statistics was used to present the characteristics of all farms having a bio-digester and no bio-digester. A comparison of the response differences between the two types of farms was expressed using the Student t-test. All the analyses were done using the SPSS 20 software.

RESULTS

Economic Evaluation

Through the survey, it is revealed that farmers who installed bio-digesters in their homesteads were benefited. Considering the earnings from animal selling and biogas consuming farmers having bio-digester got more significant ($p < 0.001$) income (1715 & 306 USD, respectively) than the traditional farmers (1146 & 0.00 USD, respectively). By selling milk and fresh manure, the farmers having bio-digester earned more ($p < 0.05$) annual income (4162 & 60.91 USD, respectively) than the farmers who have no bio-digester (3408 & 44.63 USD, respectively). In total, on the basis of these income sources, the annual income of the first group of farmers (6245 USD) was significantly higher ($p=0.002$) than the later group of farmers (4599 USD). In the case of expenditure, it is observed that only the maintenance cost of two groups of farmers varied significantly ($p < 0.05$), and more money was spent by the farmers who have bio-digesters (1186 & 1015 USD, respectively). Though the feed costs, veterinary, and AI costs were not significantly varied between the groups, cumulatively, owners of bio-digester spent more money (1915 USD) at a 5% level of significance than the traditional farmers (1756 USD) to run their farms. At the end of the business year, it is calculated that farmers having bio-digester gained profit (4329 USD) at a significantly higher rate ($p = 0.004$) than the farmers who have no bio-digester (2842 USD) from their farms, shown in Table 1.

How livestock and associated bio-digester had contributed to the farmer's gross economy was also evaluated. It was recognized that the contribution that comes from livestock was higher for farmers having bio-digesters than the conventional farmers (36% and 32%, respectively). The most important thing was that the bio-digester, by producing gas, contributed on gross economy of farmers by 7 % alone. So, livestock part with gas contributed almost half (43%) of the economy of those farmers who had bio-digester. This consequence revealed that the farmers who had digester were much more benefited from livestock in comparison with the farmers who had no bio-digester. It is also found that the farmers of non-bio-digesters earned almost one-third of their whole income (29%) from otherwise businesses, whereas the farmers having bio-digesters earned only 16% from other businesses (Fig. 1). So, it can be said that the bio-digester contributed as a factor to change the gross economy of farmers to some extent.

Besides the farm economy, it was found that the bio-digester had multidimensional effects on the manure

Table 1: Farmers annual income and expenditure from livestock farms (USD).

Parameter	Farmer category		*P* value	Significance
	Digester	Non-digester		
Income				
Animal Selling	1715.44 ± 29.34	1146.16 ± 32.36	0.000	***
Milk Selling	4162 ± 53.05	3408 ± 194.4	0.02	*
Biogas Consumption	306.41	0.00	0.000	***
Fresh manure selling	60.91 ± 3.20	44.63 ± 0.93	0.006	**
Total (USD/Year)	6245.46 ± 26.76	4599.08 ± 218.70	0.002	**
Expenditure				
Feed	495 ± 3.01	512 ± 7.89	0.116	NS
Maintenance	1186 ± 10.63	1015 ± 47.57	0.025	*
Veterinary and AI	232 ± 12.69	228 ± 4.07	0.760	NS
Total (USD/Year)	1915.54 ± 7.90	1756.93 ± 40.84	0.019	*
Profit	4329 ± 31.97	2842 ± 245	0.004	**

AI = Artificial insemination, * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; NS = non-significant

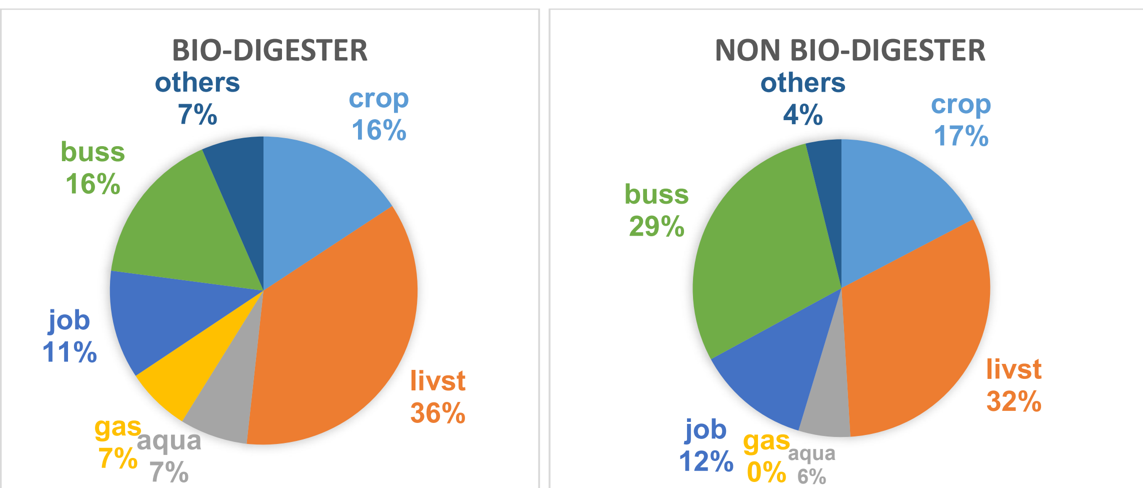

Fig. 1: Contribution of bio-digester on farmers' gross earnings.

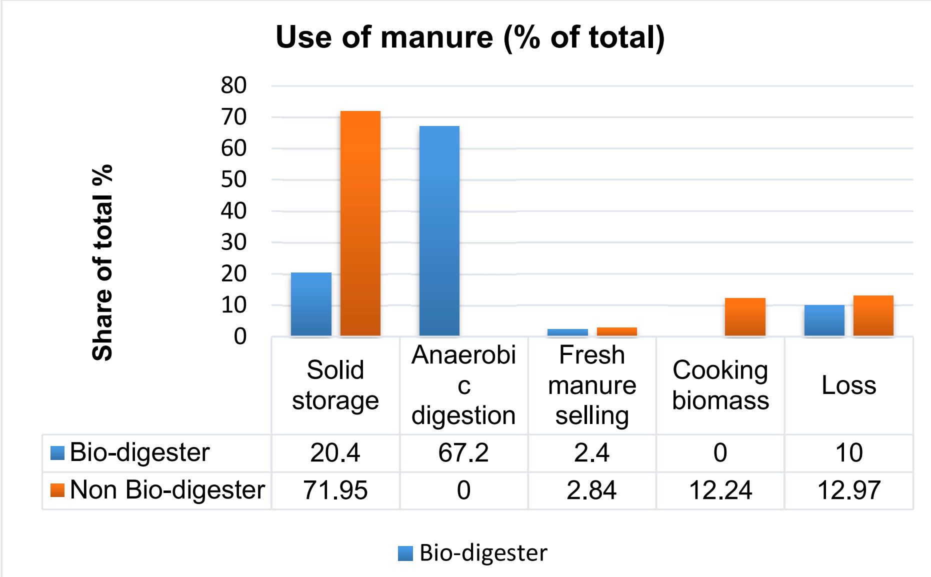

Fig. 2: Effect of bio-digester on changing manure management systems.

management system. The conventional farmers stored 71.95% of their total manure in solid form, whereas the farmers having bio-digesters only stored 20.4% of their total manure. The difference between the systems was significantly large ($p < 0.001$). Because of having a bio-digester, the farmer used manure for gas production at 67.2% of the total amount. As the conventional farmers had no bio-digester, the parameter of anaerobic digestion represented zero value. Vice versa, as those who had bio-digesters, they did not used biomass for cooking. In this regard, the conventional farmers used 12.24% of their total manure for cooking purposes. In the case of wasting manure, there was no significant difference between the two groups (Fig. 2). The farmers, having bio-digesters or not, waste 10% and 12.97% of their total manure, respectively.

From these findings, it can be said that the bio-digesters may play a significant role in changing the pattern of manure management very widely.

Collateral Efficacy of Bio-digester

The gas produced from anaerobic digester is used for cocking purposes. The gas was also used to enlighten the household. According to the data obtained from different households, it was found that they used gas stoves for 4-5 hours and were able to illuminate gas lamps for 6-8 hours. In this way, the farmers having anaerobic digester saved at least 14 and 5 USD monthly from firewood and electricity expenditures, respectively. As the conventional farmer store most of their manure, a huge amount of methane is emitted from stored manure. In this context, it can be assumed that biogas plants controlled the methane emission at a large rate. Besides this, it was identified through the statement of farmers that both the respondent groups used cow dung or slurry as fertilizer in their crop fields directly or by sun drying, respectively.

Prospects of Small Household Bio-digester in Bangladesh

From this study, along with different survey results, it was estimated that at present, in Bangladesh, 100,000 small household anaerobic digesters are functioning. The average size of their bio-digester is 3.1 m^3 and each of them produce 2920 liters of gas individually daily. The owners of the digesters are capable to support their household with one burner and three gas lamps for at least four hours. From these pieces of information, it can be assumed that an annual gas production of 113.15 million m^3 is possible following this approach. Furthermore, 87,038 MW of electricity can be produced from this source, and it can be added to the national grid. These estimated data could be used for policymaking to targeting the betterment of rural people of the nation (Table 2).

DISCUSSION

Figuring the overall income and expenditure of this study, the profitability of biogas farmers showed a significantly higher rate than the conventional farmers. This finding was fully agreeable with the study of Moli et al. (2021); they also found significantly higher income of biogas adopters than

Table 2: The prospects of small household bio-digester in Bangladesh.

Indicators	Status	Supporting References
Total Biogas plant (Small household)	100,000	IDCOL Final Report (2018)
The average size of installed plant	3.1 m^3	Hamid et al. (2013)
One household burner and three gas lamps (60 W bulb) can run four hours by	2920 L of Gas (can produce from 3 m^3)	Vogeli et al. (2014)
Annual gas production	113.15 million m^3	Zareei (2018)
Electricity can produce at least (~ 1300 m^3= 1 MW)	87,038	Osei-Marfo et al. (2018)

All these estimated values generated based on the supporting references

that of those farmers who had no biogas chamber. Not only that, but they also stated that raising the number of cattle on farms and expenditure on fuel are positively interlinked with the anaerobic digester. The present study also observed a similar trend in the case of selling animals from farms. Selling milk from farms is the primary source of income; it is recognized for any dairy farm. Like animal selling, farmers having bio-digesters got more profit by milk selling than the non-bio-digester farmers, as observed from the present survey. Pochwatka et al. (2020) gave a supportive statement with this finding. Additionally, many scientists around the world referred to the biogas digester as a substantial income source for rural people. Garcia et al. (2019) and Zemo et al. (2019) stated that the production of biogas helps farmers in rural areas to develop their economies. In society, it promotes the circular economy as well. In this context, Kabir et al. (2012) very much appropriately stated that raw materials used in digesters came from animals or feed waste of farms and returned a valuable product as gas, additionally energy as a bonus. It can be said that this is how the economy of farmers having bio-digesters under this study was improved. This study revealed that the farmer's gross economy concentrated through the adoption of the digester. This statement is agreed with the findings of Chakrabarty et al. (2013). They said that when biogas plants generated income for rural farmers by creating green employment, others were influenced to adopt this. It can be said that this feature influenced the biogas farmers of this study to give more emphasis on the biogas business rather than engage with other businesses. In this study, those who have no bio-digester were engaged higher in number with other businesses. This finding was in line with the observations of Hafeez et al. (2017); they found 44% engagement of biogas farmers compared with 70% engagement of conventional farmers in other businesses. In this study, it is found that conventional farmers stored most of their farm manure (71.95%) in solid form. On the other hand, farmers having anaerobic digesters store 20.4% of their total farm manure because of using manure as substrate, resulting in impacts on keeping the environment clean and green. Using manure in a bio-digester was recognized as a profitable solution by scientists (Achinas & Euverink 2020), and a scientist in another study recommended that this approach has a huge impact on keeping the environment clean (Zareei 2018). Not only the economic or environmental aspects but also the human health aspect, the use of manure in biogas plants rather than stored in solid form has an additional benefit. It is proven that through anaerobic digestion, the antibiotics of manure are destroyed (Taleghani et al. 2020). In another study, Thu et al. (2012) stated that an anaerobic digester has several effects on the manure management of respective farms that are in line with the statement of this study. It was found through this study that conventional farmers used manure (12.24% of the total) for cooking purposes. Kelebe (2018) claimed this is dirty fuel, and he identified that women are the main victims of this practice. But, through this study, no biogas farms were seen using raw manure as fuel. Regarding the size of the installed biogas plant, it was found that the diameter was as it is according to the statement of IDCOL report 2018 and Hamid et al. (2013). The observation of cooking and lighting was in line with the findings of Vogeli et al. (2014). Farmer's monthly savings from firewood and electricity expenditure were roughly evaluated in-country context, which was justified by the statement of Rahman et al. (2019). In this context, Kelebe (2018) stated that farmers having anaerobic digesters can save 20–36% of their monthly expenditure than conventional farmers. Amigun et al. (2012) also support this statement of saving money, and additionally, they stated that it ensures the use of clean cooking fuel alongside motivating others to adopt the digester. The secondary data on annual gas production estimated through this study was based on the observations of Zareei (2018), who stated that Iran can produce 2740 million m^3 of methane gas each year using the anaerobic digester. Besides this, the findings of electricity generation of this study were produced following the results of the study of Osei-Marfo et al. (2018). In Ghana, through combined heat and power, they converted 2,800 m3 of gas into 2.2 MW of electricity. On the contrary, Pochwatka et al. (2020) calculated 1770 MWh of electricity production from 443,000 m^3, which showed much more volume than the previous one. However, they discussed that it may vary for the capacity of the plant and its installation technique for producing electricity.

CONCLUSION

Based on all the findings, it can be said that owners of anaerobic digesters had various avenues to gain profit. Biogas chambers played a significant effect in changing farmers' gross economy and the manure management pattern of farms. The anaerobic digester has a huge prospect for gas production and power generation. Most importantly, it mitigates the emission of methane gas from farm premises.

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