ISSN 1023-1072

Pak. J. Agri., Agril. Engg., Vet. Sci., 2017, 33 (1): 135-141

UTILIZATION OF BIOGAS USING PORTABLE BIOGAS ANAEROBIC DIGESTER IN REMOTE AREAS OF SHIKARPUR AND SUKKUR DISTRICTS: A CASE STUDY

A. N. Sanjrani[1], S. A. Shah[1], M. N. Sanjrani[2], S. A. Skeikh[3] and M. Malhi[2]

[1]Department of Mechanical Engineering, Mehran University of Engineering and Technology, SZAB Campus, Khairpur Mirs,
[2]Department of Veterinary Physiology and Biochemistry, [3]Institute of Food Science Technology, Sindh Agricultural University, Tandojam, Pakistan

ABSTRACT

Wood and natural gas are used as fuel for heating and cooking in country side. With the rapid growth in population, the demand of these resources has significantly increased, creating a bewildering shortfall of energy. This shortfall of the energy could be overcome by utilizing available natural energy sources. Biogas can be generated and utilized as an alternative source of energy; particularly for cooking, heating and power generation on small scale. Therefore, a case study on existing biomass sources such as dung was carried out in some rural areas of Shikarpur and Sukkur districts. In these areas the animal waste is generated in huge quantity that can be processed using any portable digester like a portable anaerobic digester used in this study. It is evident from this case study that the portable digester has a potential to generate biogas for domestic consumption. The selected digester can be used to produce methane rich gas, as an alternative to wood and natural gas supply in these areas.

Keywords: anaerobic digestion, biogas dung utilization, environmental sustainability

INTRODUCTION

Wood and natural gases are widely used as traditional sources of energy in urban and rural areas of Sindh for fulfillment of energy required for heating and cooking needs of the people. Therefore, fossil fuel demand for cooking and electrical power generation has increased considerably with the result that there is a shortfall of energy in most of these areas (Shah *et al.,* 2013; 2016). However, intensity of such demand can be optimized by using other available energy sources. Renewable energy has a potential to provide a solution to existing energy scarcity in environmentally sustainable manner (Shah and Zhang, 2011). Moreover, fossil fuels affect our environment, because of the burning process of fuel and release of carbon dioxide (CO_2), carbon mono oxide (CO) and sulphur dioxide (SO_2) by coal, firewood, stalk, straw and liquid petroleum gas (Datong, 1989).

Corresponding author: ansanjrani@gmail.com

Biomass is a renewable energy source and is available in bulk worldwide (Rollin *et al.,* 2015). It is considered a potential substrate for biogas production and can be processed in biogas digester for meeting cooking needs (Rajendran *et al.,* 2012). Biogas can be obtained from animal dung, after processing in an anaerobic gas digester it can be utilized as an alternative to wood and fossil fuels. Large quantity of CH_4 can be obtained from biomass processes, which may then be used for the cooking, heating, lighting and power generation and as a substitute of fossil fuels (Dayananda, 2013). Biogas can also be used for electrical power generation at small scale in remote areas. However, it is essential that knowledge regarding capability of biogas to produce specific amount of electrical power should be known. According to some estimates, to generate 1 kWh of electrical energy, 0.75 m^3 gas is required, which can be produced from 20 kg of cow dung, obtained from 2 cows (Hossain, 2003). The portable biogas anaerobic digester can facilitate efficient digestion process of animal dung. In this process, flammable part of biogas methane is produced, which does not produce CO during burning process and comparatively less amount of CO_2 are released in comparison to fossil fuels (James and Maringa, 2008). Anaerobic Digestion (AD) process can be used for manure stabilization, sludge drop, odour control and yield biogas**.** In the anaerobic digester, dung is converted into a biogas through sequential process of bacteria**,** i.e. anaerobic digestion of organic matter (Naik, 2010; Minde *et al.,* 2013). Nowadays dung and similar bio-wastes are the basic sources of energy generation using the process of Dark Fermentation (DF), which is considered one of the best technologies for making high yield hydrogen (Chong, 2009). Numerous studies have been conducted on the means and methods to obtain H_2, CO_2 and CH_4 and second generation biofuel. The biofuel is very useful for combined heat and power (CHP) generating industry and similar type of generators and there is considerable improvement regarding elimination of CO_2 (Graham, 2008).

Since the livestock population is considerable in the areas of Shikarpur and Sukkur regions, the amount of dung produced by the animal can resolve the problems of raw materials required for anaerobic digestion in portable anaerobic digester. Therefore, biomass can be utilized as an alternative fuel for cooking and electrical power generation at small scale. The problem of non-availability of natural gas and electrical power in remote areas of Sukkur and Shikarpur due to lack of utility companies infrastructure of natural gas and electrical power supply Biogas and electrical power can be supplied to these areas through utilization of anaerobic digestion process. It could emerge as a reliable and uninterrupted cooking, heating and electrical power supply process at household levels in these areas. Utilization of biomass can also be considered a source of gradual switchover from traditional wood, natural gas, which is either depleted or replete with release of CO_2 emissions and result in air pollutions in vicinity and various pulmonary diseases due to inhalation of polluted air. Since the quality of life depends on the uninterrupted and sustainable energy supply, it can be expected that livelihood in the remote areas can be improved to a considerable extent, if biogas plants are encouraged in these areas. Biogas generated by the portable anaerobic digester is capable to cater the cooking heating and electrical power requirements of the communites living in remote areas. The discharge waste of anaerobic digester can also be utilized in a dried form as a by product for fertilization of agricultural land. Scale of biogas generation can be increased by arranging subsidies for the producers and users of biogas anaerobic digester. It would not only contribute towards animal solid waste management, but also facilitate the process energy self-sufficiency for the people living in the vicinity of Sukkur and Shikarpur districts.

MATERIALS AND METHODS

Survey and sampling

Survey of the areas of Sukkur and Shikarpur (rural) districts was made and dung samples were collected. The related data on population of buffalo, cow, horse, mule and ass were collected from district offices of Livestock Department Government of Sindh.

Anaerobic digestion using portable biomass digester

Feeding raw material was crushed and mixed with the water at the ratio of 1:1, respectively, before feeding into the digester drum, so that the fermentation process within the plastic drum (anaerobe condition) can be initiated for production of methane gas. The cow and buffalo dung slurry initiated the process of gas forming and the gas holding tank stores for three days and after that period, gas tank was filled up but in presence of carbon dioxide, the methane gas did not ignite completely at first, but after few weeks the process had become active to generate flame.

Experimental setup

The proposed digester comprised of drum, pipes, elbows and valves made of Polyvinyl chloride (PVC), material, whereas other accessories were also economical for instance pressure gauge and the tie tube for storage of gas by viewing the financial capacity of people. Since drum is used as a digester therefore three openings were fabricated one at the top and two at side with the hack saw blade. As inlet, overflow, gas outlet, drain and pressure gauge pipes were fabricated according to the size and installed at drum top and side as reflected in Figure 1. For feeding organic waste pipe was projected at right side of the top, for slurry a small pipe was installed as outlet, and for gas delivery smaller pipe with non-return valve, control valve was installed at top left side along with a pressure gauge at the center. All joints were adhered with the sealant and finally through leak test to ensure no leakage from openings.

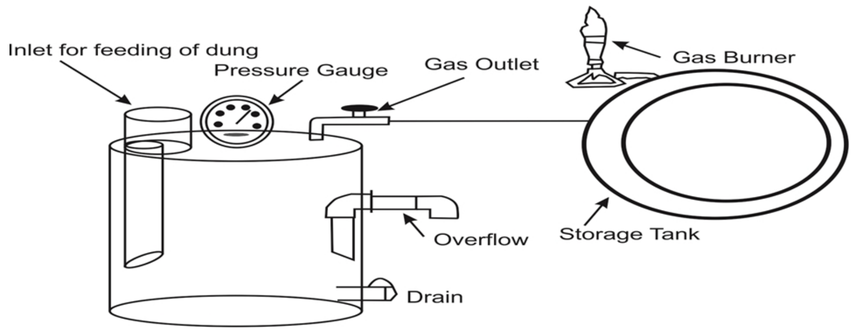

Figure 1. Portable anaerobic biogas digester

RESULTS AND DISCUSSION

Estimated livestock population

Estimated livestock population is given in the Table 1, which shows that the number of cattle and buffalo are considerable in these areas and can produce required quantities of dung for onward generation of biogas.

Table 1. Livestock population in Sukkur and Shikarpur districts

Animal	District Sukkur	District Shikarpur	Total population
Buffalo	196505	549631	746,136
Cow	211623	511040	722,663
Horse	794	1846	2,640
Mule	1192	1683	2,875
Ass	10324	56928	67,252

Estimated dung production in Sukkur and Shikarpur areas

The data on estimated quantity of dung production by buffalo, cattle, horse, mule and ass per day at Shikarpur and Sukkur areas are furnished in Table 2. The data show that buffalo produces more quantity of dung than cattle, horse, mule and ass. The estimated daily production of dung by various animals in district Sukkur and Shikarpur is given in the Table 2.

Table 2. Unit weight of daily dung production by each animal

Description of Animal dung	Age (Years)	Unit weight of fresh dung (kg per animal)	
Buffalo dung	4-5 years	12 to 13	**24 hrs**
Cow dung	4-5	10.50 to 11.5	
Horse	3-4	4.5 to 6	
Mule	3-4	4.5 to 5	
Ass	3-4	3 to 4	

The estimated annual dung production quantities of buffalo, cow, horse, ass and mule is illustrated in Table 3, which reinforces the importance of buffalo for dung production in these areas.

Periodic results of portable anaerobic biomass digester

In order to assess input dung and output biogas generation relationship, it is necessary to workout performance capacity of proposed anaerobic biomass digester. Therefore, an exercise was performed to calculate approximate amount of biogas and electrical power consumption per person per day in these areas. It is calculated that the quantity of natural gas required for cooking for a family comprising four persons is 0.908 m^3 on basis of per person required consumption of gas, i.e. 0.227 m^3, which is approximated to 1 m^3 and required dung is 25kg (Rai, 1998). Moreover, if lighting energy needs for three 40 W tube lights are considered then there would be increase in the capacity of plant, which is estimated as1.13 m^3.

Table 3. Annual dung production (Million tons)

Animal description	**Unit day dung production (kg/animal)**	**Population**	**Annual dung production (kg)**	**Annual dung production (Million tons)**
Buffalo dung	12.50	746,136	3,404,245,500	3.404
Cow dung	11.00	722,663	2,901,491,945	2.901
Ass	3.50	67,252	58,914,430	0.0589
Horse	5.25	2,640	5,058,900	0.00505
Mule	4.75	2,875	4,984,531.25	0.00498

Anaerobic digester capacity is calculated on the basis of availability of dung and based on family size, which is illustrated in Table 4.

Table 4. Anaerobic digestion capacities based on dung and family size

Daily dung production (kg)	**No. of cattles and buffaloes**	**Anaerobic digester capacity (m³)**	**No. of family members**	**CH_4 generation (MJ)**
25	1+2=3	1	3-4	11
50	2+3=5	2	5-8	22-40
75	3+4=7	3	9-12	40-60
100	4+5=9	4	13-16	60-85
125	5+6=11	5	17-20	85-110
150	6+7=13	6	21-25	110-130

Since, buffalo and cattle outweigh in production of dung per day, their dung was selected for processing in proposed anaerobic biomass gas digester. Anaerobic gas digestion process is comprised over a period of burning process. Periodic results obtained from proposed biogas digester using dung were compiled in Table 5.

Table 5. Biogas digester working cycle results

Cattle and buffalo dung with water ratio 1:1	**Yielding**
5 kg : 5 liter	On 1st day no burning because of CO_2 presence
5 kg : 5 liter	On 2nd day no burning because of CO_2 amount presence
5 kg : 5 liter	On 3rd day no burning because of CO_2 amount presence
5 kg : 5 liter	On 4th day flash generated, because of presence of larger amount of CO_2 and smaller amount CH_4
5 kg : 5 liter	On 5th day small flame generated, because of increasing amount of CH_4 and decreasing amount of CO_2
5 kg : 5 liter	On 6th day only long flame generated, because of increasing amount of CH_4 and decreasing amount of CO_2
5 kg : 5 liter	From the 7th to 40th days digestion process continue with increasing amount of methane and decreasing amount of CO_2

It is observed that maximum pressure achieved from biogas digester is sufficient for cooking and lightening purpose as shown in table 6. Once all the substrates were anaerobically digested, maximum methane production was harnessed during the period of digestion. However, after retention period the treated buffalo and cow dung produced more methane than the rest of the treatments during digestion. It is also observed that the percentage of methane and CO_2 largely depend on the feedstock of dung.

Table 6. Biogas digester average methane gas flow rate according to temperature and pressure after 40 days.

Sample Taken time	**Day**	**Temp. ^0C**	**Avg. Temp ^0C**	**Pressure (mbar)**	**Avg. Pressure (mbar)**	**Flow Rate (cu ft./min)**	**Avg. flow rate (cu ft./min)**
8:00 am	1st day	27	32.33	15	16.66	0.76	2.56
1:00 pm		38		22		0.90	
6:00 pm		32		16		0.90	
8:00 am	2nd day	24	30.66	14	17.00	0.75	2.53
1:00 pm		30		15		0.87	
6:00 pm		38		22		0.91	
8:00 am	3rd day	23	31.33	14	17.66	0.75	2.53
1:00 pm		31		16		0.90	
6:00 pm		40		23		0.92	
8:00 am	4th day	22	31.00	14	17.66	0.74	2.30
1:00 pm		30		15		0.90	
6:00 pm		41		24		0.93	
8:00 am	5th day	24	33.00	15	18.66	0.75	2.57
1:00 pm		32		16		0.88	
6:00 pm		43		25		0.94	
8:00 am	6th day	22	31.60	14	18.30	0.74	2.60
1:00 pm		31		16		0.92	
6:00 pm		42		25		0.94	
8:00 am	7th day	21	35.00	13	20.60	0.72	2.59
1:00 pm		41		24		0.93	
6:00 pm		43		25		0.94	

CONCLUSION

Maximum pressure achieved from biogas digester was 20.6 mbar which is quiet sufficient for cooking and lightening purpose. Maximum methane production lies between the 15th to 18th days of digestion. The amount of methane production from 50% buffalo dung and 50% cow dung increased with an increase in retention period. The scale of production of methane and CO_2 largely depends on the quantity and quality of feedstock of dung. The production of methane was hindered by the presence of some trace gases such as hydrogen sulphide, which limited the methane producing bacteria, which implied that methane production varied with the type of substrate being digested.

ACKNOWLEDGEMENTS

We are thankful for the support provided by the Department of Mechanical Engineering, MUET, SZAB Campus, Khairpur Mir's, Department of Veterinary, Physiology and Biochemistry, Sindh Agriculture University, Tandojam and

Institute of Food Science and Technology, Sind Agriculture University, Tandojam, in completion of this research project.

REFERENCES

Chong, M. L., V. Sabaratnam, Y. Shirai and M. A. Hassan. 2009. Biohydrogen production from biomass and industrial waste by dark fermentation. Int. J. Hydr. Energy, 34: 3277-3287.

Datong, Z. 1989. An analysis of domestic biogas storage installations in China. Biomass J., 20: 61-71.

Dayananda, B. S. and L. K. Sreepathi. 2013. An experimental study on gasification of chicken litter. Int. J. Environ. Sci., 2 (1): 63-67.

Graham, L. A., G. Rideout, D. Rosenblatt and J. Hendren. 2008. Greenhouse gas emissions from heavy-duty vehicles. Atmospheric Environ. J., 42 (19): 4665-4681.

Minde, G. P., S. S. Magdum and V. Kalyanraman. 2013. Biogas as a sustainable alternative of current energy need of India. J. Sustain. Energy Environ., 4: 121-132.

Naik, S. N., V. Vaibhav, K. R. Prasant and K. D. Ajay. 2010. Production of first and second generation biofuels: A comprehensive review. Renew, Sustain. Energy Revi., 14: 578-597.

Rai, G. D. 1998. Non- Conventional Energy Sources, Dhanapat Rai and Sons, New Delhi.

Rajendran, K., S. Aslanzadek and M. J. Taherzadeh. 2012. Household Biogas Digester-A review, Energies J., 5 (8): 2911-2942.

Rollin, J., J. M. Campro, S. Myung, F. Sun, C. You, A. Bakovic, R. Castro, S. K. Chandrayan, H. O. Chang, W. Adams, R. S. Senger and Y. H. P. Zhang. 2015. High yield hydrogen production from biomass by *In vitro* metabolic engineering. Proc. Nat. Acad. Sci., 112 (16): 4964-4969.

Shah, S. A. and R. Edwards. 2011. Sustainable energy generation processes in the deserts of Sola-Rich countries. Int. J. Sustain. Energy, 32 (3): 196-203.

Shah, S. A. and Y. Zhang. 2011. The impact of desert solar power utilization on sustainable development. Appl. Solar Energy J., 47 (4): 336-341.

Shah, S. A., A. F. Abbasi and J. Daudpoto. 2013. Case study of electrical energy requirements for various needs in desert dwelling, Mehran Univ. Res. J., 32 (3): 529-534.

Shah, S. A., M. Soomar and A. Hussain. 2016. Comparative emission analysis of bituminous coal, sugarcane bagasse and rice husk. Sindh Univ. Res. J., 48 (3): 685-688.

(Accepted: October 27, 2016)