Development of Improved Biogas Plant for Biomethanation of Spent Mushroom Substrate and Cow Dung

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A B S T R A C T

Biogas plant of 2m³ was developed for the codigestion of 25% SpBMS +75% cow dung substrate. The dome has provided with additional stirring mechanism to break the scum formation inside digester. The developed plant was further evaluated continuously for 80 days by daily feeding a mixture of 12.5 kg of spent button mushroom substrate and 37.5 kg of fresh cow dung with 100 kg of water. 100 kg of water with 50 kg of selected substrate (12.5 kg SpBMS +37.5 kg cow dung) was mixed daily to maintain 10% solid content of material. The hydraulic retention time (HRT) of the modified biogas plant was 40 days, so the observations of produced biogas were recorded daily throughout two cycles of HRT (80 days). The observations were recorded from 4th February, 2016 to 23rd April, 2016. The average daily biogas production during 80 days of biomethanation period was observed as 1.852 m³/day.

Keywords

Biogas, Biomethanation, Spent mushroom substrate, Cow dung etc.

Introduction

Biomethanation is production of biogas through anaerobic digestion of spent mushroom substrate. Anaerobic digestion is a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen and produces biogas (Lin et al., 2014). Spent mushroom substrate is a byproduct of mushroom cultivation technique. It is the organic substrate material left over after harvesting of mushroom (Mehta et al., 1990). It is different from typically available dry leafy biomass. Spent mushroom substrate cannot be utilized directly without sterilization for animal feeding like dry leafy biomass (Wendi et al., 2014).

It was estimated that for one kg production of mushroom around 5 kg of spent mushroom substrate produced (Bisaria et al., 1983, Kumari et al., 2013). This huge quantity of spent mushroom substrate was not utilized most of the time and may be either buried openly in the environment or composted to
prepare enriched organic manure. Open burning of spent mushroom substrate can cause emission of harmful greenhouse gases in the environment which may result in global warming and climate change effects. Composting of organic manure takes a long time to convert organic material into enriched fertilizer and may create unhygienic surrounding conditions. During the process of composting, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) is released into the environment (Fleming et al., 2006).

These untapped greenhouse gases stay in the atmosphere for longer duration and contribute heavily in global warming of the earth. Therefore biomethanation study of spent mushroom substrate provides an important role to utilize methane produced through anaerobic digestion and enriched organic solid-liquid fertilizer for agriculture production (Deublein and Steinhauser, 2008).

Materials and Methods

The various parameters used in designing a biogas plant were as follows,

W = Weight of waste/substrate fed per day (kg/day)

G = Gas production rate (m³/day)

Vₛ = Active slurry volume in the digester (m³)

Vₐ = Dome volume (m³)

H = Height of cylindrical portion of the digester up to the top edge of the outlet opening (m)

D = Diameter of the digester (m)

dₖ = Height of the dome (m)

r = radius of the dome (m)

Various design parameters can be estimated with the help of following equation

**Gas production rate (G)**

From lab study, it was found that 0.2 kg of undigested mixture of spent button mushroom substrate and cow dung (25% SpBMS +75% Cow dung) can produce 7.183 L of biogas.

Therefore from 50 kg of this substrate when mixed with 100 kg of water will generate approximately around 1.795 m³ of biogas production.

G = 1.795 m³/day

Active slurry volume \( Vₛ \): \( Vₛ \) which is related to the HRT can be determined by following equation,

\[
Vₛ = HRT \times \frac{W_{sb} + W_w}{\rho_{sb} + \rho_w}
\]

Whereas, \( W_{sb} \) is weight of substrate 50 kg, \( W_w \) is weight of water mixed with substrate 100 kg, \( \rho_{sb} \) is the density of substrate 2325 kg/m³, and \( \rho_w \) is the density of water 1000 kg/m³.

Considering 40 days of HRT period and 50 kg/day of substrate feeding along with 100 kg of water,

\( Vₛ \) = 4.86 m³

**Estimation of height and diameter of digester**

For a cylindrical shaped digester of diameter (D) and height (H) requisite volume of the digester was calculated using following equation. Knowing the active slurry volume from the previous equation, H was determined from the following equation,
Considering cylindrical shaped digester with diameter (D) to depth or height (H) ratio as 1:2.5.

\[(\pi/4) D^2. H=V_s\]

\[(\pi/4) D^2. H=4.86\]

\[(\pi/4) D^2. 3.4=4.86 (*Assuming height H=3.4 m)\]

\[D=1.35 m\]

**Estimation of gas holder size/ dome volume**

Based on the presumption that gas is to be used regularly and withdrawn at more or less constant rate therefore gas holder needs to have only half the volume of estimated daily gas production. Thus for daily biogas production of 2 m³/day, gasholder needs to have a capacity of only 1 m³. For a proper movement of drum, 5 inch gap was kept in between movable dome and inner wall of digester (Kumari et al., 2010). Therefore in total gasholder diameter was 10 inches (approx 25 cm) smaller than digester diameter. Hence diameter of gasholder/dome was kept as 1.1 m. The height of gasholder is thus given by;

\[\text{Height of gasholder} = \frac{\text{Volume}}{\text{Area}}\]

\[\text{Height of gasholder} = \frac{1 \times 4}{\pi \times (1.1^2)}\]

Height of gasholder = 1.1 m
Gasholder diameter = 1.1 m
Gasholder height = 1.1 m

**Results and Discussion**

Biogas plant of 2m³ was developed for the codigestion of 25% SpBMS +75% cow dung substrate. The designs of the various parts of developed biogas plant are shown in Figure 1, 2, 3, and 4. The developed plant in pictorial view is shown in Figure 5. The dome has provided with additional stirring mechanism to break the scum formation inside digester as shown in Figure 1. The developed plant was further evaluated continuously for 80 days by daily feeding a mixture of 12.5 kg of spent button mushroom substrate and 37.5 kg of fresh cow dung with 100 kg of water. 100 kg of water with 50 kg of selected substrate (12.5 kg SpBMS +37.5 kg cow dung) was mixed daily to maintain 10% solid content of material.

The basic components of developed biogas plants are;

- Digester or fermentation chamber,
- Plant dome/Gas holder or gas storage chamber
- Inlet (pipe or tank),
- Outlet (pipe or tank),
- Mixing tank,
- Gas outlet pipe.

Biogas produced from the developed plant was measured continuously for 80 days from the day it was fed with spent button mushroom substrate and cow dung mixture in the proportion of 1:3. The hydraulic retention time (HRT) of the modified biogas plant was 40 days, so the observations of produced biogas were recorded daily throughout two cycles of HRT (80 days). The observations were recorded from 4th February, 2016 to 23rd April, 2016. The volume of biogas generated was measured by using biogas flowmeter.

Figure 6 shows the relationship between the daily biogas production yield, daily biogas production at STP and substrate temperature with respect to days of biomethanation for codigestion of spent button mushroom substrate (SpBMS) and cow dung (CD) (25% SpBMS+75%CD) at feeding rate of 15.4 kg dm/day.
**Fig. 1** Dome/gas holder of developed biogas plant

**Fig. 2** Digester of developed biogas plant

All dimensions of Fig 4.16 and 4.17 are in meter.
Fig. 3 Top view of developed biogas plant

Fig. 4 Design of central guide frame of biogas plant

All dimensions of Fig 3 and 4 are in meter.
The average daily biogas production during 80 days of biomethanation period was observed as 1.852 m$^3$/day. It was observed that biogas production was started from seventh day and biogas production rate became stable after fifteenth (15$^{th}$) day of digestion process. The substrate temperature
during anaerobic digestion of spent button mushroom substrate and cowdung was observed in the range of 31.5 °C to 37.9 °C.

The observed substrate temperature indicates that the digester was operating in mesophilic temperature range. It has been reported that mesophilic methanogens are more active in the temperature range of 20-45°C and the biogas production reaches maximum when substrate temperature inside digester is maintained around 35°C (Zeeman et al., 1983).

Furthermore it has been also reported by Deublein and Steinhauser (2008) that at 30-35 °C substrate temperature, methanogens are more active.

**Acknowledgement**

Authors are highly thankful to Department of Renewable Energy Engineering, College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan), India for providing necessary facilities and financial support to carry out this research work.

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**How to cite this article:**

Pradip Narale, Surendra Kothari and Nafisa Ali. 2018. Development of Improved Biogas Plant for Biomethanation of Spent Mushroom Substrate and Cow dung. *Int.J.Curr.Microbiol.App.Sci.* 7(04): 2429-2435. doi: [https://doi.org/10.20546/ijcmas.2018.704.279](https://doi.org/10.20546/ijcmas.2018.704.279)