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Original Research Article

Process Technology for Biomethanation and Characterization of Spent Mushroom Substrate

Anupriya Gupta*, Sagar M. Chavan and Deepak Sharma

DREE, Senior Research Fellow, PFE, CTAE, MPUAT, Udaipur
**Corresponding author*

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A B S T R A C T

The cultivation of mushroom each year creates tons of waste, which is essential to dispose. The waste generated is rich in carbon, methane and other organic matters. This waste if not properly disposed would otherwise get rotten and is harmful for the environment as it creates foul odor and attract flies along with the production of carbon. Biogas technology has many advantages. It is used as a fuel for cooking, lighting and as an engine fuel in combination with engine oil. This study uses spent mushroom substrate (SMS) in different proportions with cow dung (CD) in a batch type digester for 40 days HRT. Five treatments were selected: T1=100%CD, T2=100%SMS, T3=75%CD +25%SMS, T4=50%CD+50%SMS, T5=25% CD+75%SMS. The total biogas production from 100 % SMS was nil whereas the biogas production from 100% CD (cow dung) was the maximum i.e. 16.32lt/Kg. The biogas production from treatment 3was 12.02lt/kg and the biogas production from treatment 4 was 11lt/Kg. From chemical analysis it was found that nitrogen, phosphorus were more in digested material as compared to fresh material. The investigation showed that the spent mushroom substrate can be used as an alternate for producing biogas.

Introduction

The global energy crises and ever escalating cost of fossil fuels have triggered off research activities all over the world seeding conservation of energy and searching alternate and renewable energy sources of energy. India is the second largest populous country with more than 700 million people of which 80 percent constitute the rural community depending for their livelihood on agriculture. In rural areas cooking is done mainly by noncommercial fuels like fire wood dung cake and agricultural waste.

These noncommercial fuels are our national assets burning them to ashes creates more problem than solving them. Out of these noncommercial fuels the major share is of fire wood. Forests are the main source of firewood. Our forests have already been deforested due to continuous cutting of trees.

Deforestation leads to soil erosion by water and ecological imbalance, besides the air pollution will be another disadvantage.

The organic wastes are available abundantly in distributed manner in various forms such as aquatic weeds, terrestrial weeds, agro-industrial and processing waste and agricultural waste. Generally these wastes are disposed of as it is thus polluting the environment and crating nuisance smell and health hazard. The estimated production of agricultural residue in India is 200 million tons per year. The agricultural waste is consumed in form of cattle feed fuel, housing material but the consumption has not matched the increase in agricultural residue as a result serious disposal problem can be visualized. Also agriculture residue are bunt in field causing air pollution. One the other hand long term availability of conventional fuel has become less certain and its price continue to rise, so there is an urgent need to look for alternative sources of fuel.

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 cannot be utilized directly without sterilization for animal feeding like dry leafy biomass (Wendi *et al.,* 2014). Biogas consists mainly of methane gas and produced by anaerobic digestion of organic matter such as cattle dung, agricultural waste, leaves etc. the digested slurry is excellent organic manure.

The biogas contains 60 percent methane and 40 percent carbon dioxide, with traces of other gases such as nitrogen, hydrogen, and hydrogen sulphide. Biogas technology has many advantages. It is used as a fuel for cooking, lighting and as an engine fuel in combination with engine oil. One cum of biogas is equivalent to 0.62 liter kerosene or 3.5kg of firewood or 0.4714 liter petrol or 4.698kw electricity. Majority of Indian farmers have only few animal and the dung produced by these animals is not sufficient to meet the fuel requirement of small family, for a family having five-six members, total requirement of biogas is around 1.5 to $2m^3$/day. This requires about 70kg of dung per day. However as the sufficient quantity of dung is not produced, the other alternative may be to use agricultural waste for production of biogas in combination.

Spent mushroom substrate is a byproduct of mushroom cultivation technique. It is the organic substrate material left over after harvesting of mushroom. 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). It is different from typically available dry leafy biomass. During the process of composting carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) is released in to the environment (Fleming *et al.,* 2006). Therefore biomethanation study of spent mushroom substrate provides an important role to utilized methane produced through anaerobic digestion and enriched organic solid-liquid fertilizer for agriculture production (Deublein and Steinhauser, 2008). Keeping these facts in view a project has been undertaken to produce biog as using spent mushroom substrate in different proportions with cow dung.

Materials and Methods

The spent mushroom substrate was collected from the Rajasthan College of Agriculture, MPUAT Udaipur. The production of biogas was done in batch type biogas digester using water replacement method. Glasswares like reagent bottles, aspirator bottles, volumetric flasks, measuring cylinders, beakers, etc. were used in the experimental setup (Fig. 1).

Determination of Physico-chemical properties

Total solid analysis (oven dry method)

The total solid content in organic matter was determined by oven dry method . Samples were collected in clean and dry aluminium moisture boxes . These samples were then dried in a hot air oven at certain temperature (usually 103 to 110°C) to a constant weight (for about 24 hours). The loss in weight was moisture and remaining was total solid. The percentage of total solid was found out using following formula.

Total solid % = $(C - A)/(B - A) \times 100$

Where, A= weight of empty moisture box (g)

B = wt. of moisture box + wet sample (g)

C = wt. of moisture box + dried sample (g)

Volatile solid analysis

Volatile solid in the organic matter was determined by Muffle furnace method. Dried samples were taken in silica crucible and ignited at 550±50°C for about 3 hours. Loss in weight gave the VS content. Percentage of TVS was determined using following formula.

% of TVS = $\frac{Q-P}{(R-P)} \times 100$

Where P= wt. of the empty silica crucible (g).

Q =wt. of crucible + ash after ignition (g)

R =wt. of crucible + dry sample (g)

Carbon content in the organic matter was determined by the following formula.

Carbon % = $VS\%/1.724$

Nitrogen analysis (Kjeldahl method)

Nitrogen in the organic matter is estimated by Kjeldahl's method. It is determine by using the following formula.

(ppm) TKN = $(75 \times A)/(B \times C)$

Where A = mg/lt read from display

B = gram, sample taken

C = ml, analysis volume

Results are in mg/lt TKN

Preparation of different sets

For the experimental setup two transparent containers of 2 lt. capacity were taken with rubber cork.

The first container used as digester was provided with one hole on the top of the cork. Second container I.e. gas collector was graduated on its outside in liter. Two holes of 3 mm diameter were drilled in the lid, one for gas inlet and one for gas outlet.

One hole was drilled in the wall of gas collector at the bottom and a tube was inserted in it to allow the water to be discharge. The outlet of the digester and inlet of gas collector was connected by rubber tube. The outlet of gas collector was provided with a rubber tube and was closed using a pinch clip.

The whole system was made airtight by applying Araldite solution on each cork and joints. The treatments were prepared by mixing different substrates in various ratios.

The solid content of the slurry content was brought up to 10% by adding suitable amount of water.

Table.1 physico-chemical properties of various treatment digested sample

Properties	MC%	TS%	VS%	ASH	N%	P%
100% CD	94.12	6.08	69.90	30.10	1.45	1.06
100% SMS	93.45	6.55			2.0	
75%CD+ 25%SMS	92.33	7.67			1.5	
50%CD+ 50%SMS	92	8.10			1.69	
25%CD+ 75%SMS	89.36	10.7			1.8	

Table.2 Weekly gas production in lt/kg dm in various treatments

Treatments	1	2	3	4	5	6	7	8
T1	8.75	10.35	15.39	27.1	14.12	12.53	8.8	4.3
T2	-	0.90	1.5	2.8	4.68	0.85	0.76	0.14
T3	6.22	7.10	13.69	24.0	12.96	7.41	4.1	3.09
T4	4.21	5.04	8.61	14.3	9.18	6.03	3.69	2.81
T5	-	3.69	4.00	6.28	5.01	3.06	2.46	-

Where T1=100%CD
T2=100%SMS
T3=75%CD +25%SMS
T4=50%CD+50%SMS
T5=25%CD+75%SMS

Table.3 Average total gas production in lit/kg dm for 60 days HRT

Treatments	Total gas production in lit/kg dm
T1	101.03
T2	11.21
T3	78.60
T4	59.76
T5	26.45

Fig.1 Experimental setup of batch model of biogas digester

Gas production

The biogas produced in the digester creates a pressure on water surface in the gas collector and it displays equal amount of water through the outlet provided at the bottom of gas collector. Thus the amount of gas produced in a day can be measured as amount of water displaced in liters.

Physico-chemical analysis of various treatments

Various treatments were prepared by using spent mushroom substrate and cattle dung. The total solid contents of the input material as given in the table 1 gave the idea of amount of water to be added to bring the total solid content of the treatment to level of 10%.

Gas production and analysis

The data on gas production was collected for 60 days HRT. The experiment was continued till production started decreasing. The total gas production in 100% CD was 101.03lt/kg dm (Table 2 and 3).

Biogas is produced by biological decomposition of organic materials in anaerobic condition and it is gaseous mixture of methane, carbon dioxide and other gases. The project was taken for the comparative study of biogas production from spent mushroom substrate and cattle dung mixture in various proportion. The experiment was performed, experimental setup with 2 replications on batch model. The gas was collected in a gas collector by water displacement method. Now from comparative study it was found that highest gas was obtained from the treatment T1(100 % CD) then in treatment T3 (25 % SMS and 75 % CD) and very less in treatment T2(100 % SMS). From chemical analysis it was found that nitrogen, phosphorus were more in digested material as compared to fresh material. The reason may be due to presence of ammonical nitrogen. So digested waste material can be effectively used as manure.

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