Energy Recovery from Bakery Industry Waste Using Laboratory Scale Digester

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Abstract: Energy extraction from bakery waste was studied with the help of a 50 litre laboratory scale digester model. The experiment was performed by subjecting bakery waste (Bread & Biscuit) in Co digestion with cow dung in 9 batches. The cow dung to water was added in 1:1 ratio. The bakery waste was added in 1:1 ratio for bread and biscuit waste for each batch with increasing quantity. At first stage the quantity and percentage of methane for cow dung was determined which was about 20.29 litres and maximum methane was 65.28% was and later the digester was charged with bakery waste for which the volume of biogas for bakery waste in co digestion with cow dung for batch 3 resulted in 23.76 litres biogas and maximum methane yield of 76.82%. The PH of cow dung in anaerobic digestion process was ranging between 6.4 to 9.4 and for bakery in co digestion with cow dung was ranging between 5.1 to 8.7. The experimental observations showed that bakery waste could be a source for anaerobic digestion up to certain extent. It could be only used a co digestion material for digestion with some other materials like kitchen waste, agricultural waste etc.

Keywords: Anaerobic Digestion, Bakery waste, Cow dung, methane, co digestion

I. INTRODUCTION

In recent century the complications of solid waste mitigation is a challenging aspect for us. In India, because of unavailability of sufficient crude oil and to fulfil the need of energy at domestic as well as at industrial sector, there is urgent need to find alternative, eco-friendly and safer source of energy[6]. Sustainable resource management of waste and the development of alternative energy source are the present challenges due to economic growth. [10]. The present solid waste disposal techniques are incapable to sustain for long term operations. Even though new innovations for countering solid waste management will arise, but reduction of solid waste generation at source which is the basic principle of solid waste management is difficult to follow. Waste generation is inevitable. Eliminating the waste using thermal technologies is pollution causing hence pose threat in the vicinity. Hence it is better to switch over to Non thermal technologies for energy recovery from waste, which serves to be beneficial for the society and solves the problems of waste disposal. The energy recovery through non thermal processes like anaerobic digestion is optimum method.

Anaerobic digestion is a biological process. If favourable conditions are maintained the digestion functions without any hindrance and yields biogas as a fuel. Anaerobic digestion by installing a biogas digester has low capital cost if right material is selected. The biogas system along with biogas also provides good effluent slurry as manure for agriculture and plants. Hence Biogas technology has multifunctional advantages hence is best suited for energy recovery.

Organic materials are digested easily by the anaerobic bacterias, the food waste, agricultural waste, slaughter house waste, poultry waste, and horticulture waste etc. yield biogas when subjected to anaerobic digestion. In this project work one new part of food waste i.e. bakery industry waste containing bread and biscuit waste is subjected for anaerobic digestion in co digestion with cow dung. As the bakery waste has nutritive value with high organic content it could be used as a co digestion material for biogas enhancement.

II. LITERATURE REVIEW

Vilis Dubrovskis et.al. (2017) stated the results of investigated biogas potential from five different damaged bread. About sixteen 0.75 litre bioreactors were pervaded with inoculums or with inoculums combined together with various bread mass. Anaerobic digestion was subjected to a batch mode at a temperature of 38°C. The results were obtained after a time of 30 days, methane generated was

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represented in percentage The following specific gas volumes (methane percentage in biogas) were obtained after 30 days anaerobic digestion process: French bread gave about 0.723 l.g-1DOM (50.6%); whereas Rye flour bread produced 0.634 l.g-1DOM (49.9%); while Wheat flour(coarse) bread 0.731 l.g-1DOM (50.9%); and Toaster bread 0.694 l.g-1DOM (44.9%); White bread (with the addition of egg and milk additives) 0.943 l.g-1DOM (45.4%). The results showed that damaged bread can be used for biogas production successfully.

Rebecca Hamilton et.al. (2017) stated found that biogas digester has reduced the energy costs by producing biogas and found that a bakery could be feasible, but an in-depth market analysis should be conducted. This analysis was done by constructing bio digester system.

Kanchai Singharat et.al (2017) has explained that Biogas production from bakery wastewater was studied using a semi-continuous, two-stage anaerobic digestion system, consisting of 2 l-first-stage digester and 5 l-second-stage digester under the temperature of 35 °C. Substrate feed rates were examined in a batch experiment by varying in the range of 50 to 200 ml/l/d. Characteristics of substrate and effluent of the digester (i.e. pH, SS, TS, VS, VFAs, COD, sCOD, TN, TP, total sulphate), biogas yields and compositions were investigated. The experimental results showed that substrate feed rate of 100 ml/l/d produced the maximum yield of biogas. The biogas yield was directly proportional to the concentration of VFAs in the second-stage digester. The approximate pH values in the first stage and the second stage digesters were 6.13 and 7.25, respectively. The average biogas yield of 0.481 l/ g VS removed and 0.609 l/ g sCOD removed was observed at a hydraulic retention time (HRT) of 10 days. Biogas contained 46.4%-60.8% methane. Removal efficiencies of SS, VS, COD, and sCOD in this system were 85.58%, 93.35%, 87.91% and 75%, respectively. The amounts of total nitrogen and total phosphorus after digestion increased whereas that of sulphate decreased.

J K Evicks (2016) stated that this research intends to supplement small data available for using bakery waste in the AD process. The pizza dough was used as a primary feedstock in this study to evaluate the potential through Food to Mass (F/M) ratios. The best F/M ratio for this process considering feed rate, COD removal, and gas production were determined to be 0.5 g COD/g VS. Although this product does perform well in the AD process, current market rates for waste disposal in Oklahoma would not support the construction of an industrial scale digester. This work could be expanded in the future by further evaluation of bakery feedstock, a potential for beneficial co-digestion, methane analysis or further specific financial analysis.

Katerina Chamradova et.al. (2015) stated by A laboratory experiment of two-stage mesophilic, low-dry mass, anaerobic digestion was carried out, focused on verifying the benefit of processing the biscuit meal EKPO-EB instead of triticale silage Agostino (GPS) and corn silage LG3266 in a regular batch for the agricultural biogas station in Pustějov. While anaerobic digestion of ensilages is largely difficult due to the content of lignocellulose, biscuit meal provides a high yield of biogas or methane, respectively, thanks to its high content of simple saccharides and lipids. At the initial stage the GPS showed 0.81 % weight of every days input blends/mix amount. Better acceptable results were seen in first stage which shown an increase in volume of methane of about 20%. The feedstock (Biscuit meal EKPO-EB) was fully decomposed by microorganisms at 1^{st} stage and an increment of volume of methane was seen up to 54% in initial(first) stage and 16% in later(second) stage for a rise 1.63% weight of the feed dose provided on every day basis.

Chandratre Sangita J et.al. (2015) has carried an experiment by designing a small laboratory scale digester unit and using agricultural waste like black gram stalk, Groundnut shells, Soybean straw, Wheat stalk, Red grams straw as feedstock. The current work is an endeavour to study on the chemical analysis of agricultural waste with respect to its different parameters for biogas generation to make an active feedstock. The paper also highlights the general presentation for design a small scale biogas unit intended to be used for further analysis of screened materials for biogas production.

Wioleta KOT et.al. (2015) stated in their article that the results of laboratory tests of the suitability of the baking industry waste such as wheat roll, wheat bread, and a donut, as a substrate for biogas production. The study used the eudiometric stand, located at Chemical Analysis Laboratory of the Institute of Engineering Bio systems UP in Poznan. The experiment was conducted in accordance with DIN 38 414 S8. It was found that the wastes containing bread waste showed good performance in case of periodic mixing and reduced process temperature. Waste-based on stale bread can be successfully used for methane fermentation process.

Leta Deressa et.al. (2015) revealed from their research that the anaerobic digestion of fruit and vegetable waste mixed with different waste took 55 days to produce biogas (for complete digestion). It is important to maintain pH of 6.7-7.4 for a healthy system. Fruit, vegetable waste and cow manure gives optimum yield of biogas and it is found that addition of extra nutrients is not essential if all the parameters are under limits.

Morris E Demitry et.al. (2015) stated that BW is an easily biodegradable substrate for creating a favourable microorganism growth environment, which enhances the biogas production needed for wastewater facilities. It is found that newly created ADM1 model performed well

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and deviations in parameters like pH, volatile fatty acids (VFA), propionic acid and methane gas production were checked. The output results of the model were compared with experimental batch reactor results of actual BW addition percentages in order to authenticate the model. Stability of the digestion process was achieved until the ratio range of 37-40% BW: 60-63% MS, and the digestion processes were inhibited at higher ratios of BW. This research gives an alternative to BW management through utilizing the BW to increase methane production.

Ukpai, P.A et.al. (2012) has studied by constructing a 45 litres metallic prototype biogas plant at NCERD, University of Nigeria that the anaerobic digestion in generating biogas from three types of wastes: Cow dung, Cowpea, and cassava peeling. The research experiment was batch operated and daily gas output from the plant was supervised for 30 days. The waste to water ratio of following proportions were feed into the digester, 1:2, 1:5, and 1:5 respectively. The mesophilic ambient temperatures range attained within the testing period were 20^{o}C-32^{o}C and slurry temperature range 22^{o}C-36^{o}C. The results obtained showed that cowpea produced the highest methane content of 76.2% followed by cow dung with 67.9% content and cassava peeling with lowest of 51.4% of methane. The highest cumulative biogas output of 124.3 L/Total mass of slurry (TMS) was observed from cow dung whereas cowpea generated 87.5 L/TMS and cassava peeling with 87.1 L/TMS for 30 days retention time.

S. Potivichayanon et.al. (2011) stated that Production of biogas from bakery waste was enhanced by an additional bacterial cell. This study was divided into 2 steps. A first step, grease waste from bakery industry's grease trap was initially degraded by Pseudomonas aeruginosa. The by-product concentration, especially glycerol, was determined and found that glycerol concentration enhanced from 12.83% to 48.10%. Secondary step, 3 bio digesters were set up in 3 different substrates: non-degraded waste as the substrate in the first bio digester, degraded waste as a substrate in the secondary bio digester, and decomposed waste mixed with swine manure in ratio 1:1 as a substrate in the third bio digester. The highest concentration of biogas was found in third bio digester that was 44.33% of methane and 63.71% of carbon dioxide. During anaerobic digestion of stage 2 digester it was found that methane and carbon dioxide was about 24.9% and 18.98% respectively. .Whereas the least was found in the non-degraded waste bio digester. It was demonstrated that the biogas production was greatly increased with the initial grease waste degradation by Pseudomonas aeruginosa.

J.B. Holm-Nielsen et.al. (2009) found in their analysis that large magnitude of solid waste always coexists with the production of a excess of animal manure, representing a rise in pollution dangers to the ecology in the vicinity areas . Avoiding over-fertilization is not only important for environmental protection reasons but also for economic reasons. The waste generated from animals is highly organic and huge quantities of waste requires a proper utilization of waste as a resources for recovery of energy and economy. Anaerobic digestion of animal manure and slurries offers several benefits by improving their fertilizer qualities, reducing odours and pathogens and producing a renewable fuel – the biogas. The EU policies regarding renewable energy systems (RES) have set a firm baseline goal of supplying 20% of the European energy demands from RES by the year 2020. A major part of the renewable energy will originate from European farming and forestry. In further coming years Biogas/ Bioenergy can provide about 25% of energy from overall organic materials like animal manure, whole crop silages, food waste etc.

J. Paul Chen et.al. (2006) has discussed various bakery waste and water sources, their characteristics, different types of treatment systems available and suitable for bakery waste and cater the preventive measures to be followed for reducing waste and increasing cost-saving benefits.

D.R.Ranade et.al. (1989) found that Chocolate and biscuit waste contains sugars as a common and in great proportions and its degradation by anaerobes provides better results hence a 180-liter capacity biogas plant of floating dome type was designed. Three different hydraulic retention times (HRT) viz.20, 30 and 40 days were studied with 10% total solids in the influent slurry. The data collected showed that waste is amenable to anaerobic digestion. After the Anaerobic digestion process, the results obtained stated that biogas produced was more at 40 days HRT, viz.466 litres kg-1 waste added per day with 57% methane and 65% degradation in volatile solids. The anaerobic digestion at lower HRT, viz 20 and 30 days, resulted in high VFA concentration and low PH of the fermenting slurry.

III.MATERIALS AND METHODS

Feedstock Materials used for Co digestion.

The feeding material used in the project work is bakery waste consisting of bread and biscuit waste. The bakery waste is obtained from the bakery shop and suppliers of bakery products of industries. The bakery waste consisted mainly of bread and biscuits, hence used as co digestion material with cow dung.

Image 2.1: Bread Waste

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Image 2.2 Bread & Biscuit Waste in Crushed

Material used for Biogas Digester Model

A laboratory scale digester was also constructed using plastic drums of 50 litres for digester and 30 litres for floating dome. A shunt mixer system was provided for pre mixing of the feeding material which had 30 litres drum with a helical mixer fitted inside the mixing drum. The biogas digester model was placed in our college project room. The model is constructed using plumbing fixture units which are easily available. The pictorial representation of the model and the mixer is shown below.

Image 2.3 Shunt Mixer

Image 2.4: Laboratory Scale Digester

Methodology

The Methodology of operating the Project Experiment on biogas plant is as follows:

1. The Biogas plant is feed with 9 batches at an interval of one week period.
2. The first batch of pure cow dung is fed in the digester and checked for methane yield.
3. The next batches are added with bakery waste materials in increasing quantity and checked for methane yield.
4. The feed material is firstly fed in the shunt mixer.
5. The material inside the mixer is agitated steadily without any vigorous stirring. The mixer is rotated about 20 to 30 times for achieving proper mixing of all the component materials.
6. Then after a mixing the given amount in the mixer the material is passed further to the main biogas digester.
7. The material after completely passing to the digester is kept without any disturbance for a week period.
8. Addition of water at certain intervals in the digester via mixer is done at certain times.
9. The drum rise is noted daily at constant interval of times.

Note: - The feed material used is bread waste and bakery waste. The ratio of bread waste to biscuit waste was in the proportion of 1:1

IV.RESULT AND DISCUSSION

4.1 Comparison of temperature VS Batches

Sr. No	Batches	Maximum Ambient Temperature (^{o}C)	Maximum Slurry Temperature (^{o}C)
1.	1	32.5	30.3
2.	2	29.9	29.1
3	3	29.2	28.8
4	4	27.1	26.1
5	5	26.8	26
6	6	25.8	25.2
7	7	25.6	25.2
8	8	25.8	25.5
9	9	26.4	25.5

Table 4.1: Temperature of various batches

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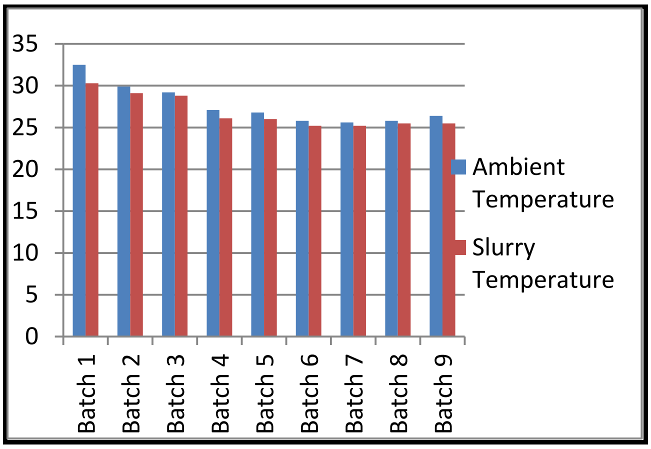


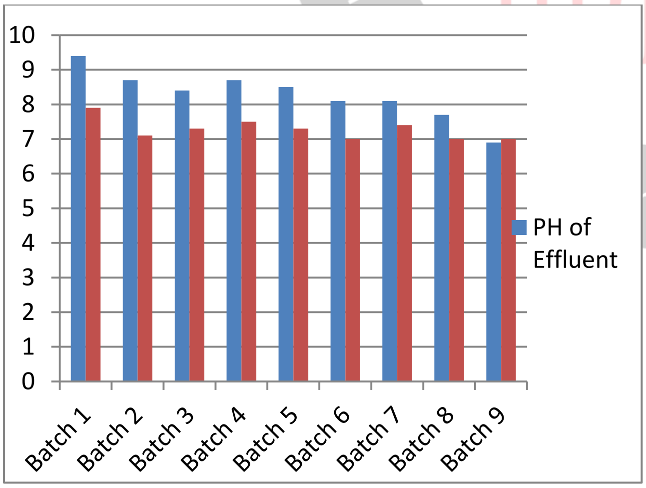
Graph 4.1: Maximum Temperature for batches

The above graph states the maximum readings of temperature for nine feed batches of bakery waste in co digestion with cow dung.

4.2 Comparison of pH VS batches

Sr. No	Batches	pH of Effluent	pH of Digester Slurry
1.	1	9.4	7.9
2.	2	8.7	7.1
3.	3	8.4	7.3
4.	4	8.7	7.5
5.	5	8.5	7.3
6.	6	8.1	7
7.	7	8.1	7.4
8.	8	7.7	7
9.	9	6.9	7

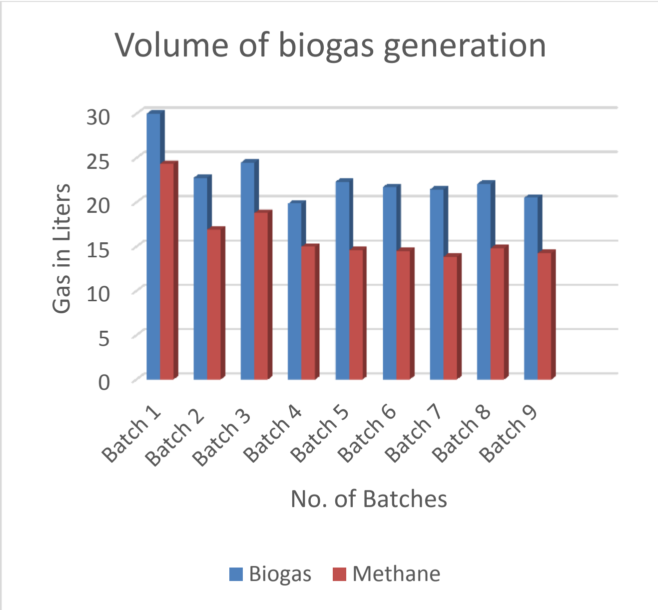
Table 4.2: pH of various batches



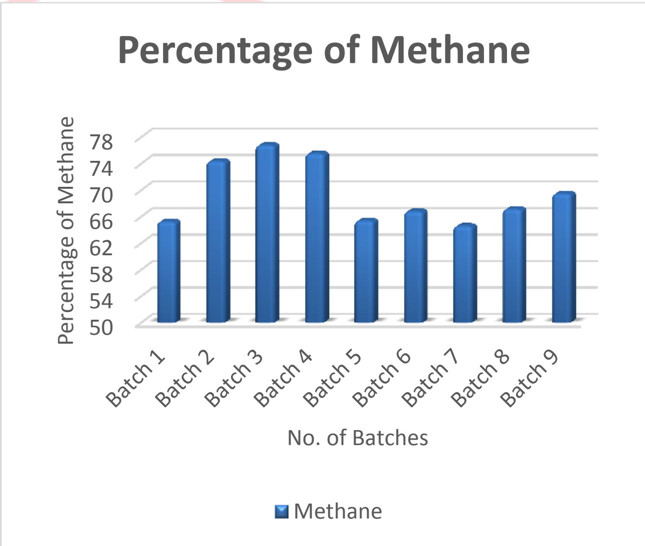
Graph 4.2: Maximum PH for batches

4.3 Quantity of biogas and methane generation

The chart below shows the quantity of biogas produced for each batch and the corresponding methane depicted in litres. Cow dung produced large quantity of biogas but the methane content was found maximum when bakery waste was added.



Graph 4.3: Volume of Biogas generated



Graph 4.4: Percentage of Methane for all 9 batches

The graph above shows the percentage of methane for corresponding batches of feedstock. The methane content is maximum for bakery waste at 100 gm. The bakery waste sustains the co digestion at best feed quantity between 100 to 150 gm. The bakery waste at 900 gm. gave some good results but later showed a decline in methane content.

Cow dung showed methane percentage of 65.28%, whereas the maximum methane content for batch 3 for feeding of 150 gm. showed 76.82%.

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4.4 Discussion

The ambient temperature was found to be maximum 32.5 °C to minimum 24.2 °C. The Temperature of slurry inside the digester was found maximum to be 30.3 °C and minimum 24.7°C. The results showed that alkaline PH was found at effluent and digester PH was found to tend towards acidic. PH for cow dung effluent which is maximum of 9.4 and minimum of 7.3 and for digester slurry maximum at 7.9 and minimum at 6.4. The rest of batches with co digestion with bakery waste have maximum effluent PH of 8.7 and minimum at 5.1 and digester slurry had maximum PH at 7.5 and minimum at 5.3. Results showed that at a feed quantity of 900 gm. bakery waste in digester led to enhancement at initial stage but a decline of methane content at later stage. Drum rise was not seen at later stage during final batch of 900 gm. as no blue colour flame burning was observed indicating the decrease of methane content. The maximum methane content was found to be 76.82 % for 100 gm. of bakery waste with cow dung. The VFA/ TIC ratio was found between 0.23 to 4.54. The VS reduction was found to be maximum at 95.06% and minimum at 21 %. Maximum amount of gas was generated at batch 5 which was 22.31 litres at 1 atmospheric pressure. The cow dung produced 65.28 % methane generation whereas when co digested with bakery waste, maximum methane was found to be 76.82 %. The maximum amount of gas produced during the digestion was found to be 22.31 litres (at 1 atmospheric pressure) for co digestion of bakery waste with cow dung for batch 5. The gas burning was found to be 2.3 minutes for 0.55 litres of biogas. Maximum energy from biogas was found to be 30.58 MJ/m^3 for bakery waste in co digestion with cow dung.

4.5 Energy Recovery Analysis

Energy recovery from bakery waste is performed and the results obtained are being presented in the report. The energy recovery analysis shows the comparison of energy obtained from pure cow dung, Co digestion of bakery waste with cow dung, LPG. The results achieved shows that certain part of energy from bakery waste could be utilized by the users. The comparative analysis gives a clear view about the amount of energy recovery from the graph 4.21 shown below. The results of energy obtained in MJ/m^3 are been tabulated below.

4.5.1 Calculation of Biogas generated per Kg of Bakery waste in our digester.

Production of Bakery Food Items in the Bakery Industry is 500 kg/Day.

Daily Bakery waste from Bakery Industry is found to be 30% of production i.e. 150 kg waste.

1 kg of bakery waste produces about 0.00213 m^3 of biogas in co digestion with Cow dung.

Hence with proportion to the above values, the biogas produced for 150 kg is 0.319 m^3

Comparative analysis of energy recovery from pure cow dung biogas, bakery waste with cow dung, and LPG is shown in below Table.

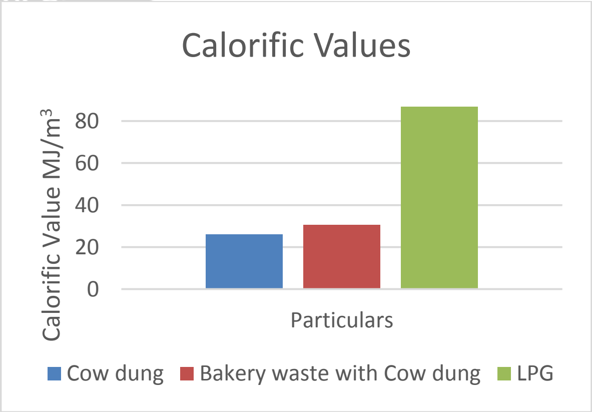
Sr. No	Particulars	Caloric Value (MJ/m^3)
1	LPG commonly used in House hold	86.98
2	Biogas from Co digestion of Bakery waste with cow dung from our digester	30.58
3	Biogas from pure Cow dung from our Digester	26.066

Table 4.3: Calorific values of LPG, Bakery waste with cow dung and pure cow dung

Calorific Value of LPG = 46.1 MJ/kg = 86.98 MJ/m^3

Calorific Value of Conventional Cow dung biogas obtained from our digester = 26.066 MJ/m^3

Calorific Value of Bakery waste with Cow dung biogas from our digester = 30.58 MJ/m^3



Graph 4.21: Calorific Values of cow dung, Bakery waste with cow dung and LPG.

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The data shows that the calorific value of biogas co-digestion of cow dung with the bakery is 64.84% less than that of LPG. If a large capacity digester is installed for household or for bakery industry it will prove to be economical as energy saving with respect to conventional LPG.

V. CONCLUSION

During the Project work, it is found that the Energy recovery from bakery waste is possible up to a certain extent when co digested with cow dung. The Parameters tested show the results for conventional anaerobic digestion for cow dung and for bakery waste co digested with cow dung in the Comparison Chart.

Sr. No	Parameters	Conventional Cow dung (From Our Project)	Bakery waste co digested with cow dung.	Permissible Values
1	PH	6.4 to 9.4	5.1 to 8.7	Between 5.5 to 10
2	Temperature	29°C to 30°C	24.7°C to 29.1°C	25°C to 40°C
3	Percentage of VS reduction	89.22 to 21	95.88 to 26.1	NA
4	Volume of Biogas Generated	20.29 liters	23.76 liters	NA
5	Percentage of Methane	65.28%	76.82%	NA
6	VFA/TIC	0.23 to 0.8	0.27 to 4.54	0.3 to 0.4
7	Calorific value (Kcal/m^3)	6230	7310	NA

Table 5.1: Comparative analysis chart of Parameters for anaerobic digestion of cow dung and Bakery waste co digestion with cow dung.

The table 5.1 shows the parameters being tested in our project and results obtained from the test.

It is revealed that Proper disposal of bakery waste is required so as it may have adverse effects on water and land resources. The parameters before disposing of must be checked by the bakery industries and then only should dispose of after proper treatment.

The following are the findings of our project work.

- It is found that the waste bakery feedstock like bread and biscuits when added directly without prior treatment to the anaerobic digester, it will slowly turn the system acidic and make the digestion process to come to a halt. Hence due treatment is necessary.
- It is found in the work that the system becomes acidic when large amount of bakery waste is added, because of the presence of acids used in the bakery products for preservation.
- Treatment process to be used includes heating of the waste materials in sun i.e. sun drying for removal of moisture.
- The anaerobic digestion of bakery waste in co digestion with cow dung is found to be in the mesospheric range at temperature between 24°C and 32°C which holds true for Indian conditions.
- It is found from the experiment that dried bakery waste yield enhancement of biogas up to 3.76 litres and methane content rise up to 11 %.
- Increasing the quantity of bakery waste in cow dung leads to a decline of PH value at 5.1 due to increase in VFA's 21.83 gm. /l and thus leading to the destroying of methanogen bacteria.
- Results show that when the final batch of 900gm bakery waste, when added to the cow dung slurry produced some biogas at initial level but later showed a decline in methane content as no blue flame of methane was burnt to indicating a decrease in the population of methanogens and no gas formation.
- Excess quantity of bakery waste should not be added to the biogas plant because it may cause shock loading for bacteria's, which will bring the system to go out of service. Hence initially starting from 50 gm. waste must be added and the quantity has to be increased at constant intervals up to 800 gm. So the system remains stable.

The project work has achieved the objective of extraction of energy from waste and reduction of the land requirement for waste disposal. Hence considering the all above aspects the project work suggests that use of bakery waste as a supplement material with cow dung in a very small quantity will produce biogas with enhanced methane content.

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