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Research Article

ENERGY GENERATION POTENTIAL OF TRADITIONAL "KHANDESH" REGION FOOD RESIDUES

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ABSTRACT
With the rapid depletion of fossil fuel and severe environmental concerns, the dawn of new millennium has underscored the importance of alternative sources of energy. Energy from waste is a never ending resource. Till the civilization will exist, waste will also exist. Extracting energy from waste is like turning garbage into gold. In the present study, the methane generation potential of traditional "Khandesh" region food residues has been experimentally determined. Bench scale studies are carried out for various major ingredients of the food residues as well as the whole of the residue (cooking waste and left over food). The case study has been done for a mess of SSBT's College of Engineering and Technology, Bambhori, Jalgaon (MS). The mess food residue has been characterized quantitatively and qualitatively and its BMP has been determined. It has been observed that "Khichadi" the traditional common dinner item of Jalgaon region has the highest potential of generation of methane. The data generated through this study can be used for design of a real size anaerobic bio-digester for the College.

Key Words: *Traditional Food Residue, Anaerobic Digestion, Bio-Gas Potential*

INTRODUCTION

Population rise and energy intensive life style are the major curse of science and technology. On one side the fossil fuel resources are rapidly depleting on other side our energy demand is tremendously increasing. In the modern lifestyle, waste generation has also become a major problem. Bio-methane generation is a process in which the biodegradable solid waste is converted to a useful energy resource that is methane. The waste generation will continue till the civilization will exist (Wellinger, 1991). Rather it will increase. Conversion of waste into fuel is like converting *waste* into *wealth.* Municipal solid waste is a potential source of energy (Lusk *et al.,* 1996). However, most municipalities struggle to provide sufficient and adequate solid waste management services (Kassim and Ali, 2006). Considering the fact that the largest fraction of waste in developing countries is of organic nature and therefore amendable to anaerobic digestion, it makes environmental and economic sense to survey this option (Mbuligwe and Kassenga, 2004).

Urban solid waste management in general and inadequate disposal in particular are considered to be of the most immediate and serious environmental problems in urban areas of developing countries. The present SWM systems are predominantly based on an "end of pipe" solution, i.e. collection-transport-dumping of waste with limited recycling of inorganic waste, mainly done by the informal sector. In most cities of low- and middle - income countries the physical composition of solid waste consists mostly of organic, hence biodegradable matter (Troschinetz *et al.,* 2008), yet less than 50% of the total waste generated is collected and disposed of in sanitary manner (Deublein, 200B and Parrot *et al.,* 2008). Inadequate management like uncontrolled dumping bears several adverse consequences: It not only leads to an uglyfication of the living area, but also to a high risk of polluting surface and groundwater through leachate and furthermore promotes the breeding of flies, mosquitoes, rats and other disease vectors (Yhdego, 1995).

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Anaerobic biological decomposition is a complex process involving following steps (Mata-Alvarez, 2003).

Hydrolysis

The first step involves the extra cellular enzyme-mediated transformation of higher molecular mass organic polymers and lipids into basic structural building blocks such as fatty acids, monosaccharides, amino acids, and related compounds which are suitable for use as a source of energy and cell tissue (Liu *et al*., 1997).

Acidification

The fermentative bacteria degrade the soluble organic monomers of sugars and amino acids, producing volatile fatty acids (prop ionic, butyric and valeric acids), acetate, H_2 and CO_2. Ammonia is also produced by the degradation of amino acids (Kayhanian, 1995).

Acidogenesis

Both long chain fatty acids and volatile fatty acids (VFA) are degraded generating acetate, carbon dioxide and hydrogen.

Methanogenesis

The forth and last step involves the bacterial conversion of hydrogen and acetic acid formed by the acid formers to methane gas and carbon dioxide. The bacteria responsible for this conversion are strict anaerobes, called methanogenic. Due to their very slow growth rates, their metabolism is usually considered rate -limiting in the anaerobic treatment of organic waste (Noike et al 1985).

These processes are well described in figure 1.

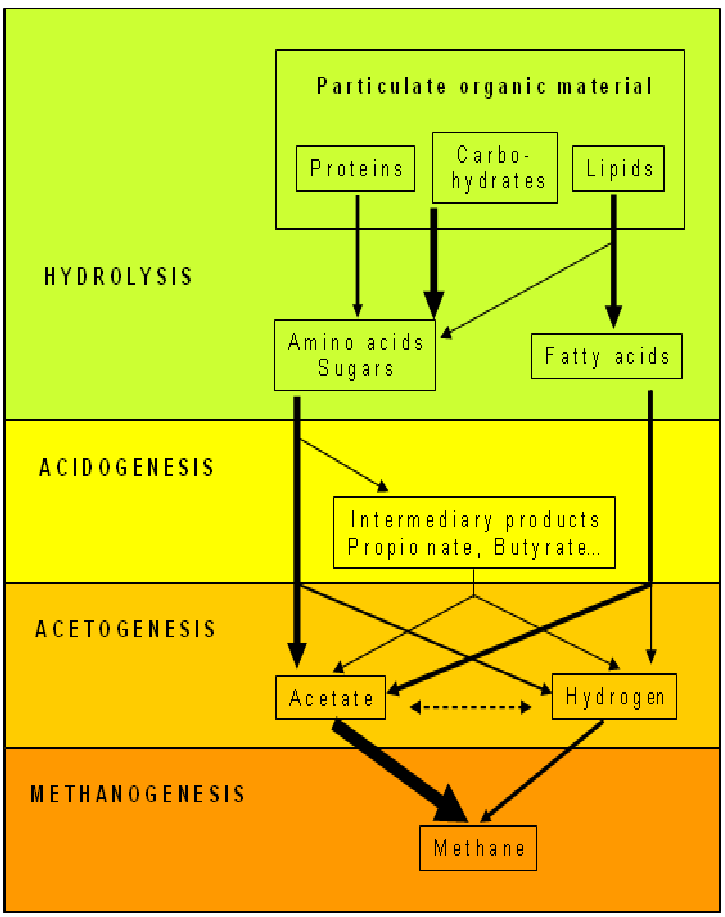

Figure 1: Scheme of the biodegradation steps of complex matter

Biogas consists primarily of utilizable methane around 55 to 60% with energy content 6 - 6.5kWh/m^3 (Scherer, 1999 and Deublein, 2008).

The present work is a case study for the campus of College of Engineering and Technology, Bambhori, located at Jalgaon (21.05N, 75.57E, at 250 m from mean sea level) in Maharashtra State, India. The there are 2500 students and 500 staff members in the college. Campus provides residence for 800 students and 200 staff members. They generate huge amount of kitchen waste. Presently the garbage is simply land filled. This creates odor nuisance and the energy potential associated with the garbage is also lost. The present work is an attempt to characterize quantitatively and qualitatively the garbage generated by the kitchens and to assess the methane generation potential of the same.

MATERIALS AND METHODS

Quantitative Analysis

The campus under study has three hostel, each having separate mess. One canteen is also there. Each of them is provided an empty container of 2.5 m^3 capacity. The mess keepers are asked to dump all the kitchen waste into these containers. The containers are weighed after 24 hours. The process is repeated for one week. The average weight of seven days is calculated as 83 kg.

Qualitative Analysis

The waste is segregated into four parts:

Brinjal waste b. Potato waste c. Khichadi waste d. Vegetable and fruit leftover waste.

The basis of this classification is that, Jalgaon is a city known for brinjals. Brinjals are very commonly and routinely included in the day to day menu. So they are the integral part of waste. Similarly, potato is a very common vegetable used either purely or mixed with other vegetables and is found in the waste. Rice or Khichadi is also a daily part of the waste.

Figure 2(a): Experimental setup for BMP estimation

The waste is characterized for its various parameters pertaining to the biodegradability. The biochemical methane generation potential of the waste is also estimated. All analysis is done in accordance to the standard methods (Standard Methods 1998). The bench scale studies are done to estimate the bio-methane generation potential (BMP) of the various types of wastes. The details are as follows:

Type of experiment	:	Batch
Bioreactor	:	330 ml (Borosil wide mouth glass bottle)
Inoculums	:	Slurry of an existing biogas plant
Substrate	:	Kitchen Waste
Biogas measurement	:	Water displacement method
Biogas analysis	:	Gas Chromatograph (5765, Nucon)
Volatile Fatty Acid (VFA analysis)	:	Gas Chromatograph (*Clarus 500*, Perkin Elmer)
Chemical analysis	:	According to the procedures of Standard methods (APHA, 1998)

Experimental set up

Total volume	:	330 ml
Active volume	:	280 ml
Head space	:	50 ml
Inoculums	:	90 %
Substrate	:	10 %

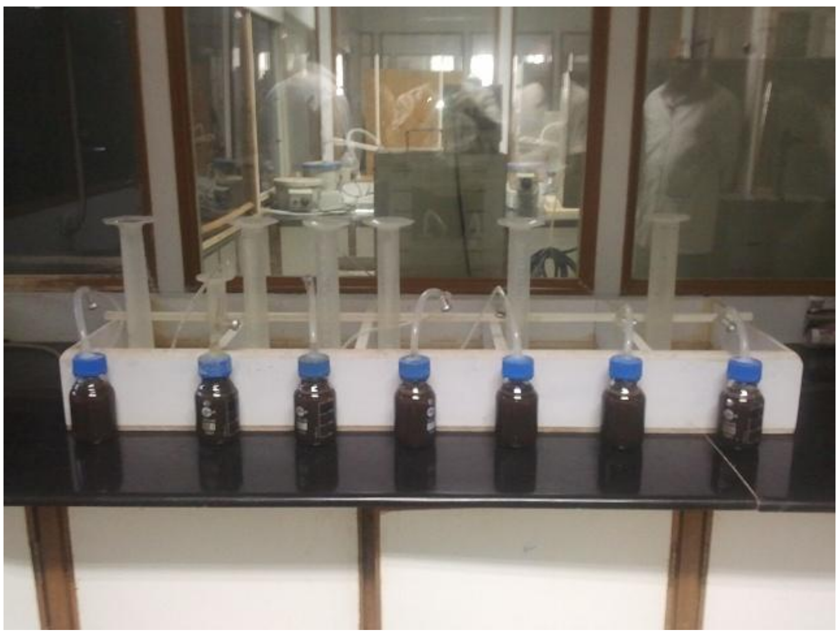

Figure 2(b): Experimental setup for BMP estimation

Gas collection tube was attached with in-line sampling port for biogas analysis. Initial and final analysis for the major parameters like pH, TS, VS, TOC and TKN was carried out for the batch reactor. The volatile acid profile is also determined for the waste as it is a very significant parameter for the working environment of the microorganisms. Figure 2(a) and 2(b) describes the experimental setup for the same.

RESULT AND DISCUSSION

The initial characteristics of the kitchen waste are given in table 1. It can be seen that the waste is free from any toxicant, contains necessary nutrients and trace elements required for biological decomposition. The TOC of Khichadi waste is relative high compared to other wastes by an order of around two. Its C/N ratio is also very high and it shows feasibility for anaerobic decomposition.

All the four major ingredients of the waste as indicated in table 1 are used for bio-methane generation in bench-scale reactors. The combined waste is also used in a separate reactor. The reactors are inoculated with culture collected form a running bio-reactor. The BMP of inoculums itself is determined separately.

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It is referred as control. This value will be subtracted from the BMP of other ingredients as seed correction.

Table 1: Initial characteristics of waste

S. No.	Parameter	Unit	Potato Waste	Brinjal Waste	Vegetable leftover	Khichadi Waste
1	pH	---	3.78	3.54	3.93	3.42
2	E.C.	mS /cm	4.76	8.39	7.72	10.72
3	Total Phosphorus	%	0.014	0.065	0.026	0.018
4	Total Potassium	ppm	535.19	476.91	1198.80	467.54
5	Total Sodium	ppm	197.45	1306.87	292.36	1804.82
6	Total Calcium	ppm	498.44	299.33	361.08	280.54
7	Total Copper	ppm	1.09	0.96	3.26	1.30
8	Total Zinc	ppm	1.80	2.35	3.67	2.09
9	Total Iron	ppm	29.85	320.42	37.66	10.31
10	Total Manganese	ppm	0.99	15.79	2.08	1.23
11	Total Magnesium	ppm	145.74	149.85	146.61	139.05
12	Total Lead	ppm	Nil	Nil	Nil	Nil
13	Total Cadmium	ppm	Nil	Nil	Nil	Nil
14	Total Sulphur	ppm	6.69	124.56	121.52	68.54
15	Total arsenic	ppm	Nil	Nil	Nil	Nil
16	Chloride	ppm	8933.40	3970.40	2977.80	6948.20
17	TS	%	4.03	3.12	3.33	6.60
18	VS	%	94.33	81.03	82.18	86.51
19	TOC	%	1.40	1.46	1.25	3.32
20	C /N	Ratio	10.22	28.08	11.57	29.12

Table 2: Initial chemical analysis of BMP Experiment

S. No.	Parameter	Unit	Potato waste	Brinjal waste	Vegetable waste	Khichadi waste	Mix of four waste	control
1	pH	-	7.40	7.40	7.25	7.15	7.40	7.36
2	TOC	% by weight of solid waste	4.39	3.93	4.98	4.26	4.99	4.95
3	TKN	% by weight of solid waste	0.42	0.41	0.47	0.45	0.40	0.467
4	TS	% by weight of solid waste	9.37	9.42	10.37	10.01	10.37	10.05
5	VS	% by weight of solid waste	73.00	73.17	75.13	74.11	71.14	73.84

Note: Control refers to the seeding done initially to initiate the biodegradation.

During the process of anaerobic biodegradation, volatile acid profile (VFA) is an important concern. The table 3 describes VFA content of slurry of various reactors as described above.

Table 3: Initial VFA content of Kitchen waste of BMP Experiment

Parameter	Unit	Potato waste	Brinjal Waste	Vegetable leftover	Khichadi Waste	Mixture of four waste	Control
Total VFA	ppm	1041	1058	1056	1052	1030	957

At the end of the experimentation when BMP estimation was over, the VFA content of every reactor was again determined. It is given in table 4. At the end of the experimentation, the chemical analysis of waste was done again. It is given in table 5. It can be seen that the pH has remained in the near neutral range at the end of bio-reactions. The drop in TOC is higher compared to the drop in TKN. This is because the anaerobic micro-organisms utilize less nitrogen.

Table 4: Final VFA content of Kitchen waste of BMP Experiment

Parameter	**Unit**	**Potato Waste**	**Brinjal Waste**	**Vegetable leftover**	**Waste Khichadi**	**Mixture of four waste**	**control**
Total VFA	ppm	306	150	200	135	170	74

Table 5: Final chemical analysis of BMP Experiment

S. No.	**Parameter**	**Unit**	**Potato Waste**	**Brinjal Waste**	**Vegetable leftover**	**Waste Khichadi**	**Mixture of four waste**	**Control**
1	pH	-	6.98	7.73	7.77	7.71	7.74	7.21
2	TOC	% by weight of solid waste	3.48	3.52	3.16	3.50	3.94	3.14
3	TKN	% by weight of solid waste	0.40	0.44	0.39	0.45	0.46	0.45
4	TS	% by weight of solid waste	9.63	8.83	8.59	8.95	8.91	8.47
5	VS	%	73.52	72.07	71.49	72.46	72.76	71.69

Table 6: Bio-methane generation

Parameter	**Unit**	**Potato Waste**	**Brinjal Waste**	**Vegetable leftover**	**Waste Khichadi**	**Mixture of four waste**	**Control**
Biogas could be produced from 1 L of Substrate	L	11.64	7.04	4.18	**46.82**	4.43	-

The most significant information is the quantum of bio-methane generation by various ingredients. It is given in table 6. The BMP of control is taken as zero (reference) value and is deleted from the BMP of other wastes. It is interesting to note that there is vast difference in the BMP of various ingredients. In fact Khichadi waste generates methane ten times more than of the combined waste. As Khichadi is a major food taken in evening meals in Jalgaon region, it has a good potential to be used an input for bio-reactors.

Conclusion

The mess residue has significant potential of methane generation. It does contain all necessary nutrients required for biodegradation. The waste characteristics are such that it has buffering capacity to maintain pH during the entire process of biodegradation. It is a very essential requirement of waste; else the pH regulation during the process becomes a requirement for them. It is also very interesting to see that the traditional food (Khichadi) of the region under study (Khandesh) has much higher potential of gas generation. In Jalgaon region, Khichadi is a common food taken in dinner. Thus biogas generation form kitchen waste has tremendous scope in this region. The college as well as other such residential premises must consider this aspect seriously. This will not only solve the problem of waste disposal and nuisance associated with this, rather will also provide useful and economical source of energy and will lead to the saving of cooking gas whose cost is increasing day by day.

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