Potential of Using Kitchen Waste in a Biogas Plant

A. Apte, V. Cheernam, M. Kamat, S. Kamat, P. Kashikar, and H. Jeswani

***Abstract*—India's economic growth is contributing to a massive increase in the generation of solid waste. Approximately 55 million tones of Municipal Solid Waste is generated annually by urban areas in India. Over 59% of homes in urban India use Liquified Petroleum Gas (LPG) supplied in portable cylinders for their cooking needs. However, due to our country's dwindling petroleum reserves and increased costly imports of petroleum, non conventional energy resources are slowly gaining importance. The use of biogas using kitchen waste as feedstock can help solve the problem of energy deficit and at the same time, allow the safe disposal of kitchen waste which is often unscientifically dumped or discarded. Our institute campus (Bhavans' campus) has a number of campus kitchens that utilize several LPG cylinders and also generate large amounts of kitchen waste. The kitchen waste generated has high calorific value and moisture content; hence it can be anaerobically digested. The biogas produced can be used to supplement the fuel requirements of the campus kitchens that generate the kitchen waste. This study consists of carrying out survey, characterization of kitchen waste from several kitchens and exploring it's potential to be used for biogas production.**

***Index Terms*—Biogas, municipal solid waste, kitchen waste, calorific value.**

I. Introduction

Municipal Solid Waste (MSW) is defined as any waste generated by household, commercial and/or institutional activities and is not hazardous [1]. With rapid urbanization, the quantities of municipal solid waste, an important by-product of an urban lifestyle, is increasing at a rate faster than urbanization itself. In India, ten years ago, there were 2.9 billion urban residents, each generating 0.64 kg/capita/day of MSW. Today, there are about 3 billion residents generating 1.2 kg/capita/day. It is estimated that by 2025, these numbers will increase to 4.3 billion urban residents with 1.42 kg/capita/day of MSW [2]. Waste generation is directly related to the economy of a country. There can be variations in the generation rates within a country, and even within the same city. Industrial countries account for a large portion of the world's MSW relative to their share of world population, while developing countries give a large portion of MSW relative to their share of world income. Classification of the regions of the world based on their affluence provides a more organized outlook to waste generation rates and waste management practices. The World Bank has classified the 188 World Bank member countries based on the Gross National Income per capita (GNI) [3]. It's evident for Table I that the high income countries produce more waste per capita as compared to the low income countries.

TABLE I: Waste Generation rates

Income Level	Waste generation (kg/capita/day)
High	0.7-14
Upper Middle	0.11-5.5
Lower Middle	0.16-5.3
Lower	0.09-4.3

There is a country-wise classification of economies into the upper, middle and lower incomes. However, in a single country itself, the affluence varies among the population. For e.g., in India and China, there is disproportionately high urban waste generation per capita relative to overall economic status. This is because they have very high poor rural populations that dilute their economic status [4].

Solid Waste Management (SWM) is an organized process of storage, collection, transportation, processing and disposal of solid refuse residuals in an engineered sanitary landfill. It is an integrated process comprising several collection methods, varied transportation equipments, storage, recovery mechanisms for recyclable material, reduction of waste volume and quantity by methods such as composting, waste-to-power and disposal in a designated engineered sanitary landfill [5]. A major part of MSW is generated from urban areas i.e. cities and bigger towns. India is primarily a country with a huge rural population. However, it is estimated that about 40% of the Indian population will move towards urban areas by 2026. Currently, an estimated 48 million tonnes of solid waste and 4,400 million cubic meters of liquid waste are generated every year in the urban areas of the country. As per the study of "National Master Plan for Development of Waste to Energy in India", 17 (6%) cities have generation rate in excess of 1000 TPD, 80 (26%) cities generate between 150-1000 TPD and balance 202 (68%) cities generate less than 150 TPD. The MSW ranges from 250 gm to 700 gm per day per person with an average of 490 gm per day per person [6].

A study conducted by the Central Pollution Control Board (CPCB) on MSW management in India shows that waste generation is estimated to increase rapidly at present from 490 gm per person per day to 945 gm per person per day which would result in 300 million tonnes per year from 48 million tonnes per year by the year 2047.

To tackle the yearly 5% increase of waste in urban India, urban local bodies are investing around 35-50% of its available funds yearly, spending about Rs. 500-1500 per ton on solid waste management. In view of growing challenge,

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Central Government has incorporated solid waste management as one of the components in Jawaharlal Nehru National Urban Renewal Mission (JNNURM) for extending financial resources. As observed from Table II, of 62 cities are covered under this mission with total investment of US$20 billion in 7 years [7]. MSW contains compostable organic matter (fruit and vegetable peels, food waste), recyclables (paper, plastic, glass, metals, etc.), toxic substances (paints, pesticides, used batteries, medicines), and soiled waste (blood stained cotton, sanitary napkins, disposable syringes).

TABLE II: WASTE GENERATION RATES IN INDIA

Population	Waste Generation Rate kg/capita/day
Cities with a population < 0.1 million (8 cities)	0.17-0.54
Cities with a population of 0.1–0.5 million (11 cities)	0.22-0.59
Cities with a population of 1–2 million (16 cities)	0.19-0.53
Cities with a population > 2 million (13 cities)	0.22-0.62

MSW composition at generation sources and collection points, determined on a wet weight basis, consists mainly of a large organic fraction (40–60%), ash and fine earth (30–40%), paper (3–6%) and plastic, glass and metals (each less than 1%). The C/N ratio ranges between 20 and 30, and the lower calorific value ranges between 800 and 1000 kcal/kg [8]. The disposal methods may include open dumping, incineration, composting, landfilling and using it as refused derived fuel.

Disposal of kitchen wastes in open dumps causes the public health hazards and diseases such as malaria, cholera, typhoid. Inadequate management of wastes like uncontrolled dumping bears several adverse consequences. It not only leads to polluting surface and groundwater through leachate and further promotes the breeding of flies, mosquitoes, rats and other disease bearing vectors. Also, it emits unpleasant odor & methane which is a major greenhouse gas contributing to global warming.

The techniques like incineration and pyrolysis are expensive and less efficient for recovering energy from the food wastes, owing to the fact that the food wastes contains a large amount of moisture content. Anaerobic digester will be an economical and viable option to serve the purpose of the project. Therefore, in this study, utilization of food waste for the production of biogas and design of the biodigester is carried out, along with the rate analysis, for the same.

The major goal of this study was to characterize the solid waste and find its potential to be recovered in the form of energy from the large amount of food waste generated. For this purpose a survey of campus kitchens was conducted by circulating a questionnaire will to collect the data of the daily food waste and the frequency of substituting the liquefied petroleum gas (LPG) cylinders

The characterization of the kitchen waste would consists of finding the basic parameters like moisture content, volatile matter and calorific value to check it’s feasibility to be used for production of biogas in various climatic conditions.

II. MATERIALS AND METHODS

A. Survey

The survey for the Bhavan’s Campus kitchens and the waste produced by the same was divided into two main parts:

a) A consideration of all the available canteens and kitchens, followed by a basic survey, which led to the selection of kitchens

b) Use of questionnaires to understand the actual amount of waste generated and the feasibility of utilising all the canteen kitchens for the project

Bhavan’s campus encompasses the following colleges and hence, their canteens:

a) Bhavan’s college of arts, commerce and science

b) Sardar Patel College of Engineering and Sardar Patel Institute of Technology

c) SP Jain Institute of Management and Research

d) Hansraj Morarji School and Raj Hans SchoolSubmit your manuscript electronically for review.

B. The Questionnaire

A questionnaire was designed for collecting information about waste generation in all the canteens. The questions included, were so as to get a basic idea about the two important qualities of the waste generated viz quantity and disposal.

Questionnaire for Canteen solid waste generation
Particulars Quantities
Canteen no. :
Source:
Name of owner:
Daily hours of operation:
Type(s) of waste generated:
Approximate quantity of daily waste:
Current method of disposal:
Location of disposal:
Time of disposal:
Current recovery from daily waste (if any):
Type of cooking fuel used:
Daily cooking fuel requirement:
Approximate daily expenditure:

The questionnaire gave the basic idea about the amount of waste generated and characterization of waste based on moisture content, organic matter and calorific value.

After giving due consideration, it was decided to use the waste generated from four main canteens of the campus:

a) Bhavan’s college canteen

b) Sardar Patel Canteen

c) Sardar Patel hostel Mess

d) SP Jain hostel Mess

Once the sampling kitchens were ascertained, sampling was carried on during peak hours of solid waste collection from the kitchens during rainy season. An average sample of 1.5 kg of solid waste generated was collected and characterized to find the quality. The characterization of solid waste was done to by finding total moisture content (Standard Methods, APHA), organic matter (volatile matter, Standard methods, APHA) and calorific value (Parr oxygen bomb calorimeter) of solid waste

III. Results and Discussion

As per the questionnaire prepared the results obtained weekly sampling are depicted in Table III.

TABLE III: Questionnaire Results

Canteen name	Bhavan's Canteen	Sardar Patel Canteen	Sardar Patel Mess	SP Jain Mess
SOURCE/ Type of Waste	Mostly Organic with some plastic and glass	Food and Plastic Mostly organic.	Food and peelings (organic)	Food+ Plastic
Name of owner	Santosh	Anna		Santosh
Hours of operation	8 am to 6 pm	7 am to 7:30 pm	7 am to 2:30 pm and 5 pm to 9:30 pm	8 am to 2:30 pm and 8 pm to 11pm
Approximate quantity	100 kg	3 large cans= approx 75 kg	2 large cans= approx 50 kg	1.5 cans= approx 40 kg
Method of disposal	Municipality Van picks from outside campus bin			
Location of disposal	Outside Campus			
Time of disposal	7 pm daily			
Current Recovery from waste	Not applicable			
Type of fuel	LPG	LPG	LPG	LPG
Daily fuel requirement	2.5 commercial cylinders	1.5 commercial cylinders	2.5 cylinders	2 cylinders

The bucket sampling method was adopted for first sampling which is quite different from the truck load method [9]. As described in materials and methods characterization of waste collected from canteen was performed and the results are as depicted in table 4.

As observed the quantities of waste generated from various canteens and mess was different due to several reasons. Mess caters around 200 students living in a hostel twice a day amounting for per capital generation as (total waste/no of students). Whereas the Bhavan's and SP canteen caters for snacks for total no of students of 2000 amounting for waste generation as 0.1325 kg per capita per day.

It was observed that no proper disposal method is followed resulting into smell and fly nuisance in and around campus. The collection bins are open with spillage around the area.

The total consumption of LPG gas for the campus is 8.5 cylinders amounting to 120.7 kg and the total monthly requirement as 3621 kg. Table IV gives the results of characterization of wastes from the various kitchens.

TABLE IV: Questionnaire Results

	Moisture Content (%)	Ash (%)	Volatile Matter (%)
Bhavan's	66.8	8.43	91.6
SPCE Mess	76.4	23.3	76.7
SPCE Canteen	81.6	10.9	89.2
SP Jain Mess	76.6	19	81

A. Moisture content

As observed the moisture content of the waste varied from 65 to 80% as expected from the kitchen waste. It is comparable to the moisture content obtained by Hafid et al., 2011. This can be a potential problem if we derive energy in the form of steam as a huge amount of fuel would be wasted in drying the waste. Biogas is a better option as there is a requirement of moisture in 50%.

B. Ash Content

Ash content of solid waste from the kitchens varied between 8-23 % which is in the range of ash content expected in municipal solid waste (3 -28%) [10]

C. Volatile Matter

It was observed that the volatile matter varied from 80% to 92%. This is comparable to the 92% of volatile matter content obtained from the kitchen waste from Burford, Shropshire [11]. Wastes with high volatile matter content produce more biogas if digested properly, as it is the organic matter that produces biogas.

D. Calorific Value

Following table indicates different values of calorific value obtained by experimental method as well as by analysis using the equations [9]:

$$CV=356.248\ VM - 6998.497 (kJ/kg) \quad (1)$$

$$CV= 356.047\ VM-118.035FC -5\,600.613\ (kJ/kg) \quad (2)$$

$$\text{Benton: } CV=4.2*(44.75\ VM-5.85\ W + 21.2) \quad (3)$$

where,
CV- calorific value in kJ/kg
VM- Volatile Matter in percentage
FC- Fixed Carbon content
W- Moisture Content

The calorific values for various kitchens were found out using the equations and are depicted in Fig. 1.

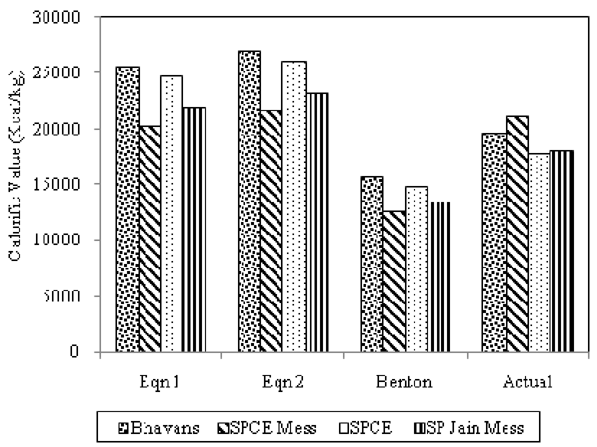

Fig. 1. Calorific value for various wastes in different kitchens in Bhavan's campus

On the basis of the experimental values and the values obtained using the above mentioned equations, as well considering the factors such as diurnal variation of food constituents, humidity and temperature, we infer that the possible calorific value for this set of kitchen wastes vary from 15000-25000 kJ/kg. The above results were compared with those obtained in the research paper by Kalantaifard and Yang (2011). They obtained a calorific value of 23000 kJ/kg. Thus, we conclude that the calorific values obtained in our project, are in a considerable range.

On the basis of the above results, we shall compute the volume of the gas required, and the discharge of waste sludge, anaerobic digester will be designed to fulfill the purpose of this entire project. Currently, LPG commercial cylinders are used at a rate of 8.5/day (2650 kJ/kg approx.), combining all the 4 locations. Therefore, as a result of the above project, the conventional fuel sources will be replaced by the biogas fuel source; thereby improving the efficiency of the fuel as well as the management of waste will be carried out in an effective manner.

IV. Conclusion

India's energy problems have made the need to turn towards waste-to-energy technologies extremely important, especially because landfills in India's urban centres are fast nearing the limits of their capacity.

The characterization of kitchen waste collected from four canteens in the Bhavan's campus, the average moisture content of the samples was found to be around 75%. High moisture content makes thermal recovery from solid waste uneconomical as considerable fuel is used up by the latent moisture in the solid waste. Anaerobic digestion, which requires high moisture content for the sustenance of the methane bacteria, was the preferred alternative for energy recovery from organic waste in the Bhavan's campus. A higher volatile matter content leads to a better biogas yield. The test samples contained an average of 85% of volatile matter, thus strengthening the case for the adoption of anaerobic digestion in the Bhavan's campus.

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