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Influence of Different Organic Waste Ratio on Anaerobic Digestion

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Abstract The present study investigates the characteristics of the different organic waste obtained from dumping sites of the Campus of the university and Okhla region of Delhi. Three types of wastes; kitchen waste (KW), Food vegetable waste (FVW) and Garden waste (GW) were used for batch scale anaerobic digestion study. The prepared slurry was analyzed for pH, Alkalinity, Chemical oxygen demand (COD), Total solids (TS), and Volatile solids (VS). The results shows the initial characteristics ranges; pH 6.70 to 7.70; COD 1900 to 3000 mg/L, TS- 9.8 to 15.23 %, VS 79.2 to 85.70 %. The maximum COD = 86% and VS =44.32 % was removed with FVW and KW, respectively. The maximum biogas 3500 mL was observed when FVW was digested with Cow dung.

Keywords: *anaerobic digestion, organic wastes, kitchen waste, food vegetable waste, cow dung*

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1. Introduction

Anaerobic digestion (AD) is an attractive waste treatment technique in which both organic stabilization and energy recovery are achieved. Many agricultural and industrial wastes are also ideal substrates for AD because they contain high levels of easily biodegradable materials. Low methane (CH_4) yield and process instability are often encountered in AD process. The process inhibition is usually due to low C/N, poor buffering capacity and insufficient trace elements in the feed. A wide variety of inhibitory substances is the primary cause for failure of anaerobic digester since they are present in substantial concentrations [1] Production of the organic waste is directly related to the livelihood. The main forms of organic waste are household food residues, agricultural waste, human and animal waste. In industrialized countries the amount of organic waste produced is increasing dramatically every year.

In developing countries, there is a different approach to dealing with organic waste. In fact, the word 'waste' is often an inappropriate term for organic matter, which is often put to good use. The economies of most developing countries dictates that materials and resources must be used to their full potential, and this has propagated a culture of reuse, repair and recycling. In many developing countries there exists a whole sector of recyclers, scavengers and collectors, whose business is to salvage 'waste' material and reclaim it for further use. The three most important ways of using organic waste are for soil improvement, for animal raising and to provide a source of energy.

1.1. Various Organic Wastes

Domestic or Household Waste

This waste is usually made up of food residues, either cooked or uncooked. Sometimes known as domestic kitchen waste and is often mixed with non-organic materials such as plastic packaging, which cannot be composted. It is beneficial if this type of waste can be separated at source – this makes recycling of both types of waste far easier. Domestic or household waste is usually produced in relatively small quantities. In developing countries, there is a much higher organic content in domestic waste. Reports suggest that 60% (or more in some cases) of all municipal waste is organic matter, much higher than the figure for an industrialized country. It is therefore well worth intercepting this supply of useful material where it can be used effectively.

Commercially Produced Organic Waste

The waste generated at institutional buildings, such as schools, hotels and restaurants. The quantities of waste here are much higher and the potential for use in conjunction with small-scale enterprise is good.

Animal and Human Waste

There is serious health risks involved with handling sewage. Raw sewage contains bacteria and pathogens that cause serious illness and disease. It should be stressed that health and safety procedures should be followed when dealing with sewage and that people involved with its handling should have a clear understanding of the health risks involved. Raw sewage should never be applied to crops which are for consumption by humans or animals.

1.2. Human Fecal Residue

This is produced in large quantities in urban areas and is dealt with in a variety of ways. In the worst cases, little is done to remove or treat the waste and it can present enormous health risks. This is often the case in the slum districts or poor areas of some large cities. Sewage is often dealt with crudely and is pumped into the nearest water body with little or no treatment. There are methods for large-scale treatment and use of sewage as a fertilizer and a source of energy. The most commonly used method is anaerobic digestion to produce biogas and liquid fertilizer. Composting toilets facilitate the conversion of human fecal waste into rich compost.

Animal Residue is rarely wasted. This fertile residue is commonly used as a source of fertilizer, being applied directly to the land, or as a source of energy, either through direct combustion (after drying) or through digestion to produce methane gas.

The primary goal of the present study was to investigate the physicochemical and biological characteristics of the different types of organic wastes viz. Food waste (FW), Kitchen waste (KVW), and Garden Waste (GW) and to see investigate their potential for anaerobic digestion.

2. Material and Methods

2.1. Collection of Substrates

The substrates were collected from vicinity of the university campus. After collection of the waste, immediately transported to the environmental engineering lab and samples were prepared for anaerobic digestion. The preparation of samples includes homogenization in a mixer, dilution with water to form slurry and fed to digester.

Kitchen Waste: KW Kitchen waste was collected from the canteen of Engineering & Technology faculty, Jamia Millia Islamia, New Delhi in a plastic container. Food waste contains cooked rice, vegetables, bones and bread. The bones were segregated from the kitchen waste and remaining KW grinded to a very thin paste/slurry with addition of tap water. The initial and final samples were collected for physico-chemical analysis.

Fruit-Vegetable Waste: FVW waste was collected from juice shops and vegetable market. It was physically assessed and grinded to make thin slurry by adding tap water.

*Garden Waste***:** GW was collected from lawns and hazes of university gardens. The collected sample of garden waste was physically assessed and was found to contain leafs, grasses, flowers. The collected sample of GW was grinded to thin paste and sufficient water was added to make slurry to perform anaerobic digestion of GW.

Inoculum: The inoculum used in present study was cow dung. It was collected in a poly bag and brought to environmental engineering lab, Jamia Millia Islamia. Initial characterization was carried out for inoculum in terms of pH, COD, alkalinity, Total solids and volatile solids.

2.2. Analytical Procedure

The physiochemical analysis of substrates was carried out as per standard method [2].

2.3. Experimental Design

The experiments were performed in a specially designed glass vessel of 5L capacity that contained one reactor vessel for anaerobic digestion equipped with stopper and glass tube attached with plastic pipe for carrying biogas and one for collection of biogas. The digester used in the study is shown in Figure 1. The waste was fed into the reactor and reactor closed airtight to ensure anaerobic conditions.

Figure 1. Schematic of the experimental setup

3. Results and Discussion

3.1. Characteristics of KW, FVW and GW

pH

The pH values of all substrates ranged 6.0 - 7.7 and are in the optimum range for the anaerobic digestion. Range within the prescribed limit indicates that microorganisms were not affected. Therefore, no inhibition was noted down due to change in pH. The experiments were performed at mesophilic temperature and that ranged from 25 – 40°C. Reduction in pH value before and after digestion indicates rapid acidification of the waste and production of larger amount of volatile fatty acids. The initial and final characterization of the study substrates is summarized in Table 1.

COD

To evaluate the organic removal efficiency of AD from different wastes, COD removal was compared. The highest COD removal was for the FVW (86%). It indicates that FVW was effective for COD removal. Initial and final COD of the FVW, KW and GW were measured and it was observed that FVW has got the highest COD in comparison of KW and GW. The final COD after anaerobic digestion was measured to be lowest for FVW.

Alkalinity

Several studies include alkalinity ratios as monitoring parameters. In fact, diverse stability limit values have been proposed in various works dealing with different substrates and experimental conditions. For instance, intermediate alkalinity to partial alkalinity (IA/PA) ratio of 0.9 was suggested in order to maintain total volatile fatty acids (VFA) below 2.5 g L^{-1} in thermophilic reactors treating sewage sludge, in which maximum total alkalinity (TA) values reached 4 g L^{-1}. In contrast, an IA/PA ratio of 0.4 was proposed to assure a stable reactor performance maintaining total VFA below 2.5 g L^{-1}. Figure 3 indicates the alkalinity pattern.

Table 1. Initial and Final Characteristics of KW, FVW and GW

	Initial Characterization					Final Characterization				
Substrates	pH	COD (mg/L)	Alkalinity (mg/L as $CaCO_3$)	TS (%)	VS (%)	pH	COD (mg/L)	Alkalinity (mg/L as $CaCO_3$)	TS (%)	VS (%)
KW	6.79	2700	1120	9.8	79.12	7.00	408	897	1.2	34.80
FVW	6.70	3300	960	15.23	85.70	5.85	250	749	5.78	46.0
GW	7.70	1900	500	12.30	80.0	6.20	342	443	4.75	48.90

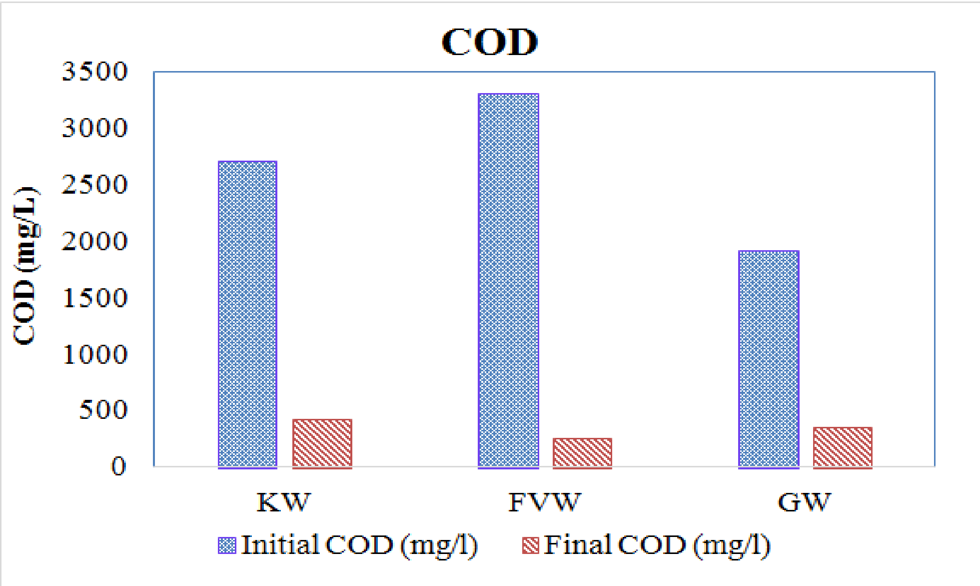

Figure 2. COD Pattern

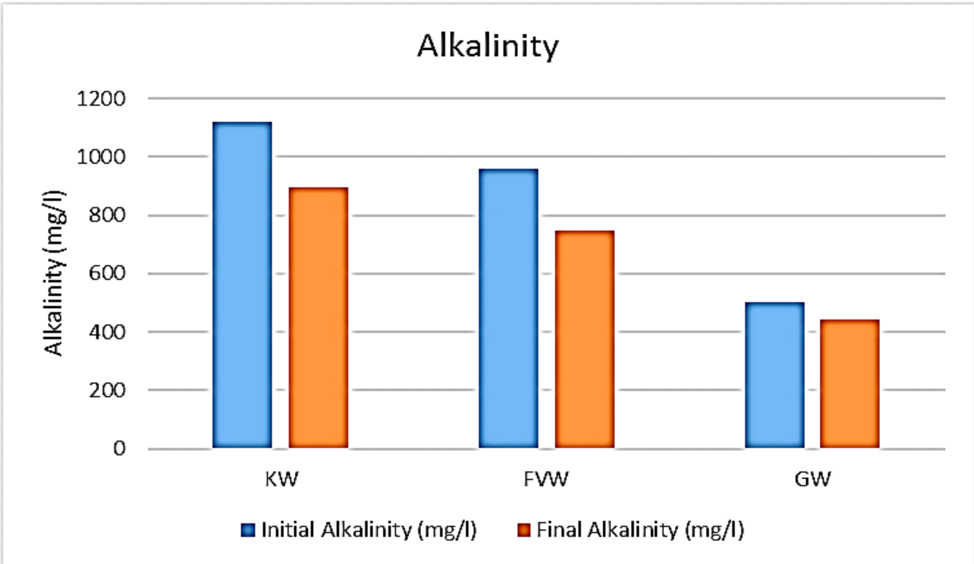

Figure 3. Alkalinity pattern

Total Solids (TS) and Volatile Solids (VS)

The results analyzed have showed that volatile solids and total solids reduction was highest for the fruit-vegetable waste indicating it to be the easily biodegradable material for digestion. Though reduction in all wastes was similar. Results obtained shows FVW, KW and GW can be used for anaerobic digestion instead of dumping into the landfills. Figure 4 (a & b) indicates the total solids pattern.

Efficiency of Total Solids and Volatile Solids Reduction

The total solids and volatile solids are an important parameter to analyze to produce biogas. The reduction in TS/VS values indicates production of biogas in the reactor. The initial TS/VS values of KW were 0.124 and after digestion, these values dropped to 0.034 showing a total reduction of 0.089. The initial values of fruit vegetable waste and garden waste were found to be 0.178 and after digestion these values dropped to 0.126 showing a total reduction of 0.052. These results obtained were in close reference to reported article [3,4]. For GW the TS/VS were 0.154, after digestion these achieved a value of 0.097, showing a total reduction of 0.057. The data for TS/VS is shown in Table 2 and shown in Figure (4a and 4b) and Figure 5

Biogas Generation Profile

The biogas generated was recorded on daily basis at mesophilic conditions in the reactor. Comparative results of biogas production for KW, FVW and GW are represented in Figure 6 and Figure 7. Results indicate maximum cumulative production of biogas occurring in FVW and KW. The lowest biogas was observed in GW. The minimum biogas yield was zero and maximum biogas yield was noted as 3500 mL in FVW. The daily variation of biogas yield was shown in Figure 8.

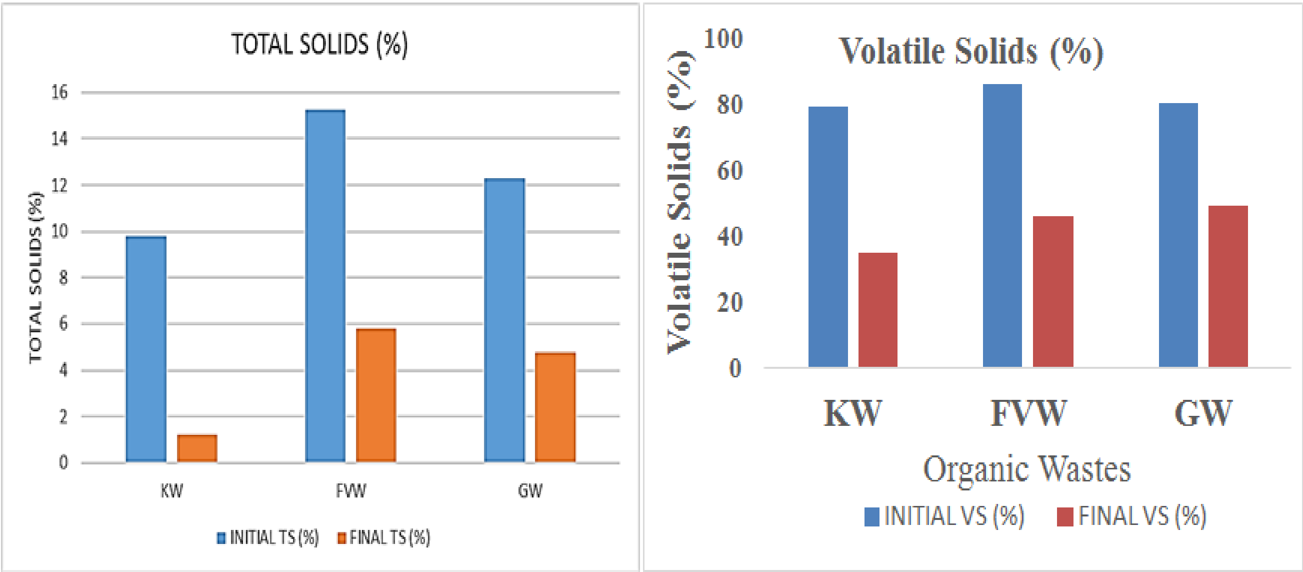

Figure 4 (a and b). Total Solid (TS) Volatile Solids (VS) pattern

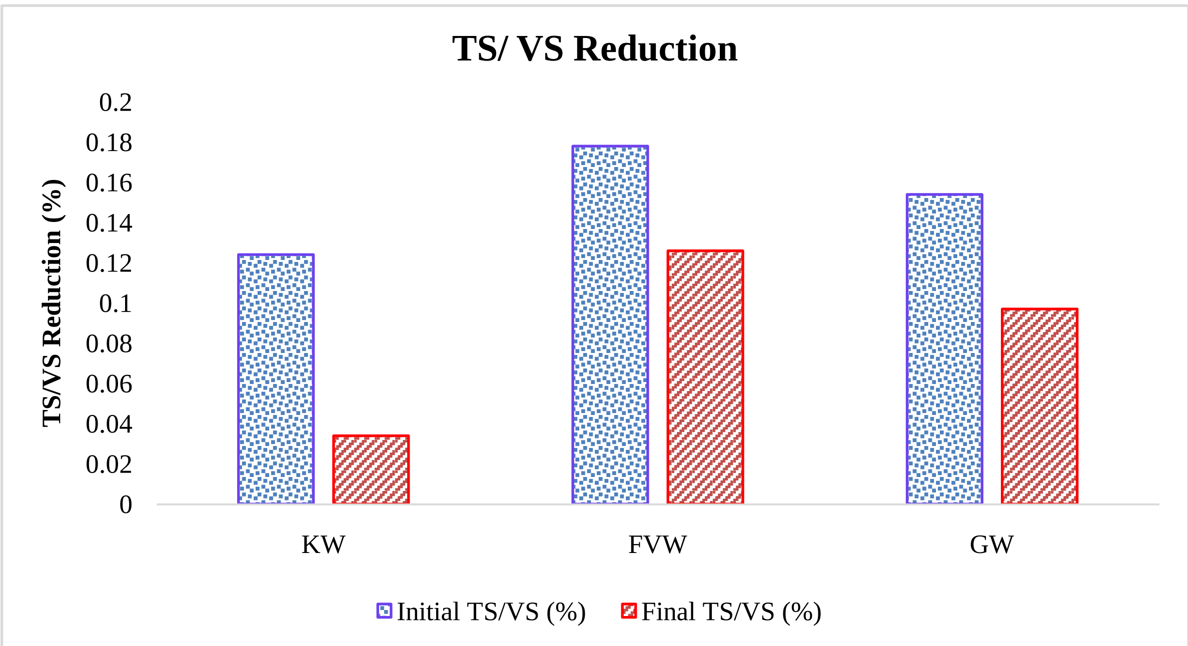

Figure 5. Total Solid (TS) and Volatile Solid (VS)

Table 2. TS/VS for KW, FVW and GW

Parameters	KW+CD			FVW+CD			GW+CD		
	Initial	Final	Reduction	Initial	Final	Reduction	Initial	Final	Reduction
TS (%)	9.80	1.20	8.60	15.23	5.78	9.45	12.30	4.75	7.55
VS (%)	79.12	34.80	44.32	85.70	46.00	39.70	80.00	48.90	31.10
TS/VS	0.124	0.034	0.089	0.178	0.126	0.052	0.154	0.097	0.057

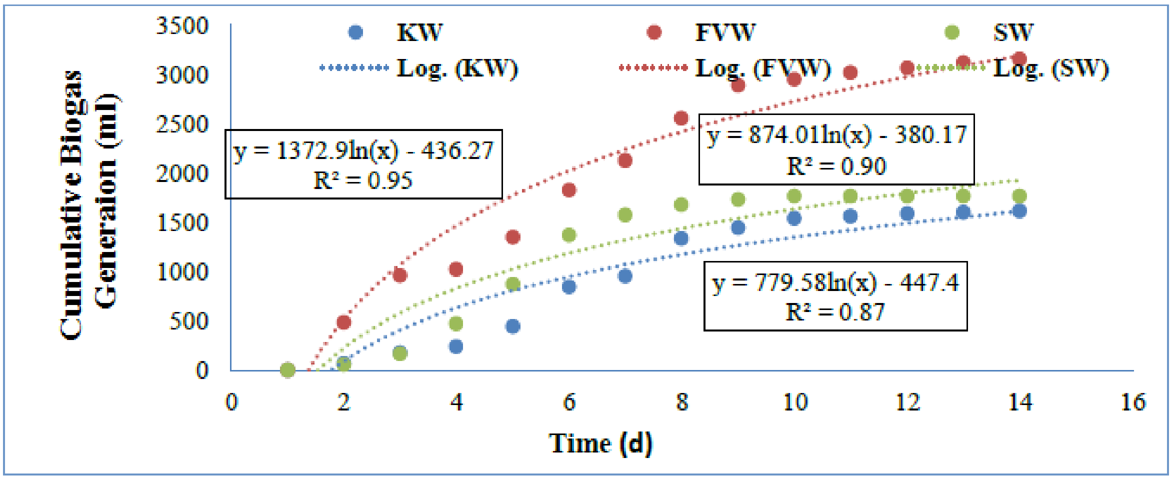

Figure 6. Comparative Results for KW, FVW and GW Biogas Production

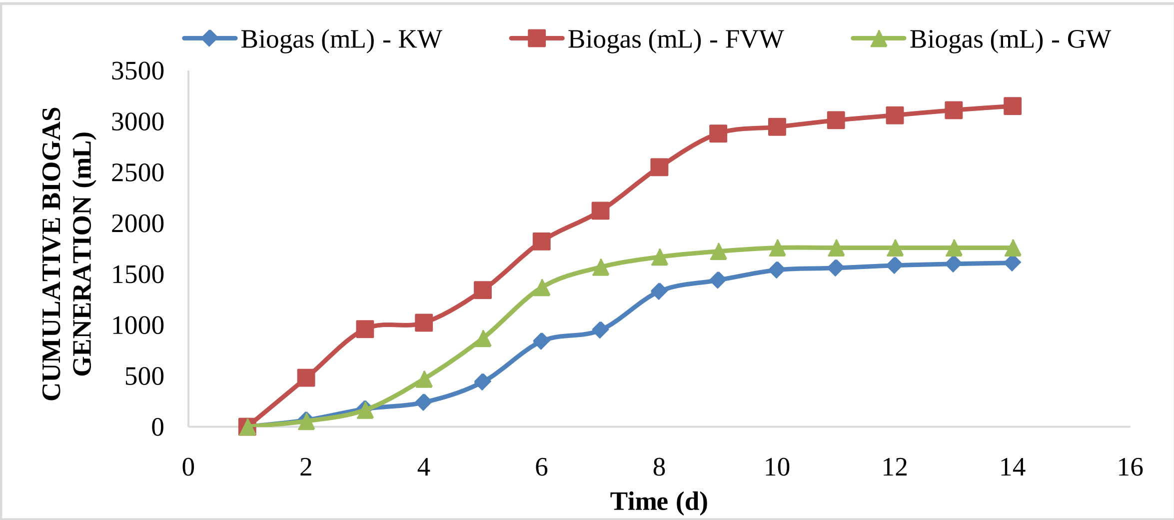

Figure 7. Cumulative Biogas Yield

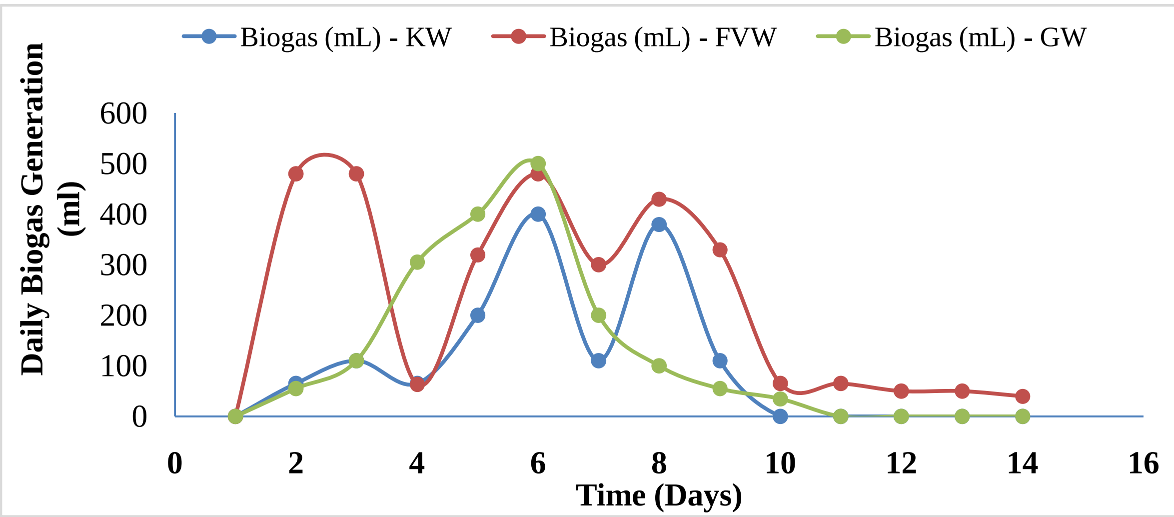

Figure 8. Daily Variation of Biogas Yield

4. Conclusion

Results obtained in the experimental study indicate that a large amount of waste can be handled easily at low cost to produce sufficient amount of energy and soil conditioner. The highest biogas generation was observed from FVW. Sufficient energy could produce by using FVW with cow dung for anaerobic digestion.

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