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Biogas production rate with methane content from market garbage in dry batch biogas system

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Abstract

Biogas technology can play a vital role in solving energy problems while utilizing the degradable solid organic waste as a raw material for the biogas generation. New researches on biogas technology are required for the better adoption within community. The present research was conducted for about six month period to find the possible avenues to evaluate the biogas production from market garbage. The objectives of the study were to (1) analyze the chemical and physical composition of market garbage, (2) to assess the biogas production from market garbage and (3) to analyze the methane content of biogas. Sri Lankan dry batch digester was used in the study with a volume of ~5m^3 and the total weight of market garbage filled in to the digester was ~3240kg (fresh weight). Cow dung (~80kg) was added as inoculums. Daily biogas production and its methane content were monitored during the study period. Temperatures at different depth of the digester were also recorded. Average total solids of market garbage fed into the digester were ~9.27 %. Results revealed that 43.38% ($\pm$2.89) and 11.50% ($\pm$2.22) of market garbage were cabbage and brinjal, respectively. The bulk density of market garbage was ~0.91g/cm^3. Carbon, Nitrogen, ash, volatile solids and C: N ratio of market garbage was 39.16% ($\pm$2.53), 1.57% ($\pm$0.05), 1.91%, 12.20%, 87.80% and ~20.47, respectively. The total biogas production was 89.13m^3 during the 127 days. The total biogas production per 1kg of total solids was ~283 L. Maximum biogas production (1.47 m^3/day) and methane content (67%) of biogas were observed at 86 and 84 days of initial charge, respectively. The energy content of produced biogas was ~1916 MJ. Based on the study, it can be concluded that market garbage could be easily utilized as a raw material for biogas production having higher methane content in the dry batch digester.

Keywords: anaerobic digestion, biogas, dry batch digester, market garbage, methane

Introduction

Sri Lanka is a developing country where the majority of the population is living in rural areas. The different types of energy sources are being utilized by them to obtain their energy needs. Three main sources of energy used in Sri Lanka are biomass, hydro power and petroleum energy sources. Biomass is the major source of energy used for the household cooking (Perera and Wijayatunga, 2000). With fuel wood becoming increasingly expensive and also scarce in several parts of the country, there is a need to look for alternative fuels for cooking. Under these circumstances biogas is a good alternative to tackle above problem. There is high potential for the development of biogas technology in Sri Lanka. Therefore, more research and application on biogas technology have to be further conducted.

Today, solid waste is collected and disposed at a large number of unprotected sites. These sites are generally located in areas where the poor people are living without the proper access to infrastructure to maintain, even the minimum level of hygiene. And this will causes for severe health problems as well as unacceptable impacts on the environment. Therefore, special attention should be paid to handle and dispose of solid waste (Bandara *et al.*, 2003). Biogas production using anaerobic digestion technology is a good alternative option for the management of market garbage while producing the bio fertilizer.

Sri Lankan type dry batch digester have been used for the production of biogas from agricultural wastes, especially rice straw, for several years in rural paddy farming systems in Sri Lanka. The dry batch system could easily be used for the production of biogas using market garbage also. However, no sufficient experimental evidences with respect to biogas production using market garbage in dry batch digester have been reported. Therefore, this study were conducted to analyze the chemical and physical composition of market garbage, to assess the biogas production from market garbage and to analyze the methane content of biogas. Further, the temperature profile in the digester was also evaluated.

Materials and Methods

Collection of market garbage and sampling

Market garbage was collected from Sunday fair at Matara and Kamburupitiya. Before filling the digester, market garbage was well mixed and samples were taken randomly from the bulk of market garbage for physical and chemical analysis.

Physical and chemical analysis of market garbage

Each market garbage sample was visually observed and sorted into different groups according to the types of fruit and vegetable present in samples. The moisture content, total solids, bulk density, total ash and volatile solids were determined in different waste components using standards methods. Nitrogen (N) and Carbon (C) percentages were also determined. Organic carbon was analyzed by Walkly and Black method while nitrogen (Total Kjeldahl nitrogen) analyzed by Micro Kjeldahl method (Tandon, 1993).

Sri Lankan dry batch digester

The dry batch (Sri Lankan) digester constructed for previous study was selected for the study. The dry batch biogas digester system is comprised of reactor, gas holder, and manometer (Figure 1). The volume of the digester is approximately 5m^3. The reactor (digester) has been build underground using bricks and cement. Only opening of the digester could be seen in the outside.

Digester connected with gas holder and it was immersed in the water tank (90 cm depth and 165 cm in diameter). Gas holder consists of water tank and plastic barrel. Plastic barrel (0.5 m^3) was used to store gas. After removing the lid of plastic barrel it was immersed in water facing opening toward bottom. Plastic barrel was moved upward and downward in the water according to the volume of gas stored in the barrel. Along the longitudinal axis of the plastic barrel, a centimeter scale was fixed to measure the height of plastic barrel on the water surface. Digester outlet was connected to both manometer and gas holder through 'T' joint. The manometer was constructed and fixed beside the digester to measure the pressure of the biogas produced.

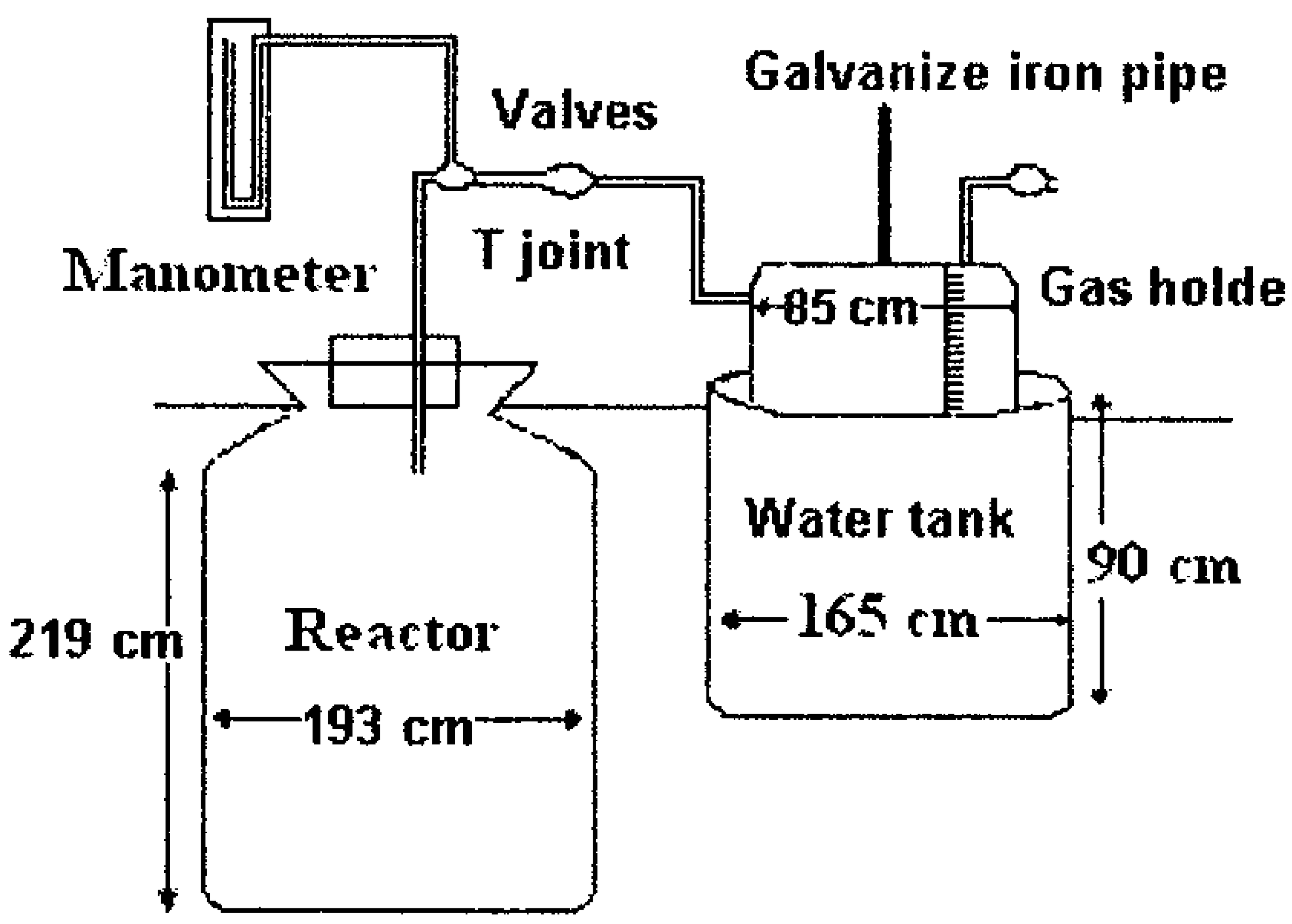

Figure 1: Dry batch digester (Sri Lankan type)

Digester filling

Large particles in the market garbage were chopped into small pieces and slow digestible materials such as banana peduncle and king coconut husks were removed. Total amount of market garbage filled into the digester was around 3240 kg. When filling the digester from market garbage 85 kg of fresh cow dung was mixed as inoculums. After the completion of filling, digester was sealed and connected to gas holder and manometer.

Temperature measurement inside the digester

Thermocouples were established in the digester, to measure temperature change in the digester in three places (digester dome, bottom of the digester and middle of the digester).

Data recording

Data recording was started after initial charge with the digester from market garbage. The biogas liberation from market garbage was measured daily using the displacement of water and it was converted into volume of standard temperature and the pressure. Methane content of the biogas was measured by methane meter (Drger pac Ex 2). Pressure developed by the biogas inside the digester was measured with the help of a manometer attach to a digester. Biogas volume and methane content was determined once a day while temperature in the digester was measured by thermocouples at three times a day.

Theoretical assessment of biogas liberation from market garbage

Organic matter subjected to anaerobic fermentation consists mainly of carbohydrates. The average cellulose and hemicelluloses percentages in market garbage are 35.8 and 52.3, respectively (Mathur and Rathore, 1992). Although lignin exists in market garbage it is not digestible. Total digestible carbohydrates in the market garbage were determined according to the procedure proposed by Mathur and Rathore (1992). According to them at the first step, total digestible carbohydrate amount should be calculated. It was calculated based on the equation 1.

Total Digestible Carbohydrates (kg) = IW x TS x Cellulose and Hemicelluloses Content (1)

Where, IW is wet mass of the market garbage in kg. The biodegradation of carbohydrates was 60 % (Mathur and Rathore, 1992). Therefore, total digested carbohydrate was 60% of total digestible carbohydrate. Equation 2 (Buswell equation) was used to calculate gas liberated from the market garbage.

$$C_nH_aO_b + \left[n - \left(\frac{a}{4}\right) - \left(\frac{b}{2}\right)\right]H_2O = \left[\left(\frac{n}{2}\right) - \left(\frac{a}{8}\right) + \left(\frac{b}{4}\right)\right]CO_2 + \left[\left(\frac{n}{2}\right) + \left(\frac{a}{8}\right) - \left(\frac{b}{4}\right)\right]CH_4 \quad (2)$$

According to the formula, one glucose mole (180.00 g/mol) produces three moles of CO_2 and three moles of CH_4. The number of glucose moles in the total digested carbohydrates was calculated by dividing the weight of digested carbohydrate by molecular weight of glucose. Since major component of biogas were CO_2 and CH_4, one glucose mole produces 3 moles of CO_2 and 3 moles of CH_4 by the anaerobic digestion process.

One mole of any ideal gas gets 22.414L under standard temperature and pressure. Then, the volume of biogas liberated from market garbage under the standard pressure condition can easily be calculated.

Results and Discussion

Composition of market garbage

The results revealed that there were about 23 different materials in samples of the market garbage. Table 1 shows major components in market garbage.

Table 1: Composition of market garbage

Components	Composition (%)
Cabbage	43.38 ± 2.89
Brinjal	11.50 ± 2.22
Sweet melon	6.86 ± 1.17
Pumpkin	5.30 ± 1.04
Luffa	5.24 ± 0.83
Papaya	3.70 ± 2.25
Cucumber	5.50 ± 0.28
Snake guard	2.98 ± 2.72
Thalana batu	2.06 ± 1.96

The result indicates that around 55% of market garbage is composed of cabbage and brinjals. However, the component shown in the table1 represents 87% of market garbage and remaining 13% are contributed by 14 different types of materials found in market garbage.

Physical and chemical characteristics of market garbage

The physical and chemical characteristics of waste are very important to compare the results with other similar studies as well as to determine the degradability of materials and theoretical biogas production. Therefore, in this study, some physical characteristics were determined. These parameters were determined separately for individual waste components and average values of all components are shown in Table 2.

Table 2: Physical characteristics of market garbage

Characteristics	Value
Moisture (%)	90.28
Total dry weight of row material (kg)	315
Total solids (%)	9.72
Average bulk density (g/cm^3)	0.91
Ash (%)	12.2
Volatile solids (%)	87.8

The total organic Carbon, Nitrogen and C: N ratio of the market garbage was determined and shown in Table 3.

Table 3: Selected chemical parameters of market garbage

Chemical composition	Amount
Total Carbon	39.16
Total Nitrogen	1.91
C : N Ratio	20.47

The C: N ratio of the market garbage used for the study was 20:1 and it is not suitable range for anaerobic digestion (Mathur and Rathore, 1992). However, no attempts were made for the adjustment of C: N ratio.

Biogas production pattern from market garbage

Biogas liberation from market gårbage during the 127 days is shown in figure 2. The biogas generation commenced after 14 days of initial charge. However, burnable gas was produced after 35 days of initial charge. It appears that until 35 days after initial charge, the methane content of biogas is very low (<30). Maximum biogas production of 1.47 m^3 per day was observed after 86 days of initial charge. The total biogas production within the 127 days was 89.13 m^3 (282.98 L/kg of dry matter). According to the calculation, it was found that theoretical biogas production is about 124.3m^3 during the same period. The actual value is far less than that theoretical value. However, the biogas production efficiency is comparatively very high (72%). The higher efficiency of biogas production may be due to favorable condition for anaerobic digestion inside the reactor. Number of factors affecting for the optimum biogas liberation and some of them are temperature pH, C: N ratio, total solids, toxins and inhibitors.

Similar study conducted by Bandara *et al.* (2003) reported that the average biogas production was 238.02 L/kg of dry matter for 228 days. Low volume of biogas production may be due to the higher totals solid level. In our study, the total solid level was in proper range for anaerobic digestion.

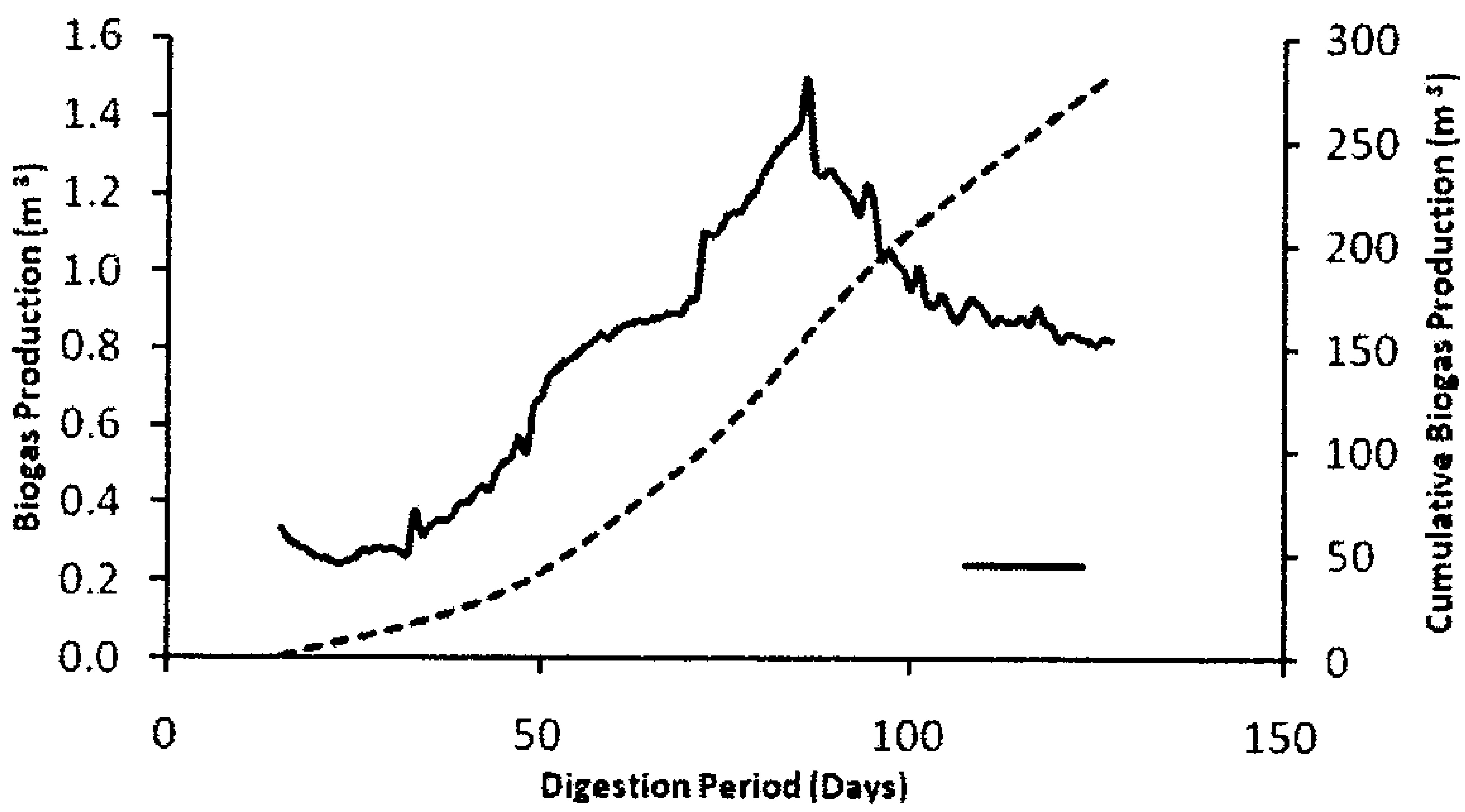

Figure 2: Biogas production rate and cumulative biogas production of market garbage during study period

Methane content of biogas

The methane content of biogas produced from market garbage during the 127 days is shown in Figure 3. Maximum methane content of 67% was observed after 84 days of initial charge. At the initial stage of the study, methane content was very low and after gradually it was increased up to 67% of the day of 84. Thereafter methane content was reasonably constant (Figure 3). However, it appears that it was still decreasing. The energy content of biogas produced during 127 days of study period with 3240 kg of fresh market garbage was (19.5 MJ/m^3) 1916.36MJ.

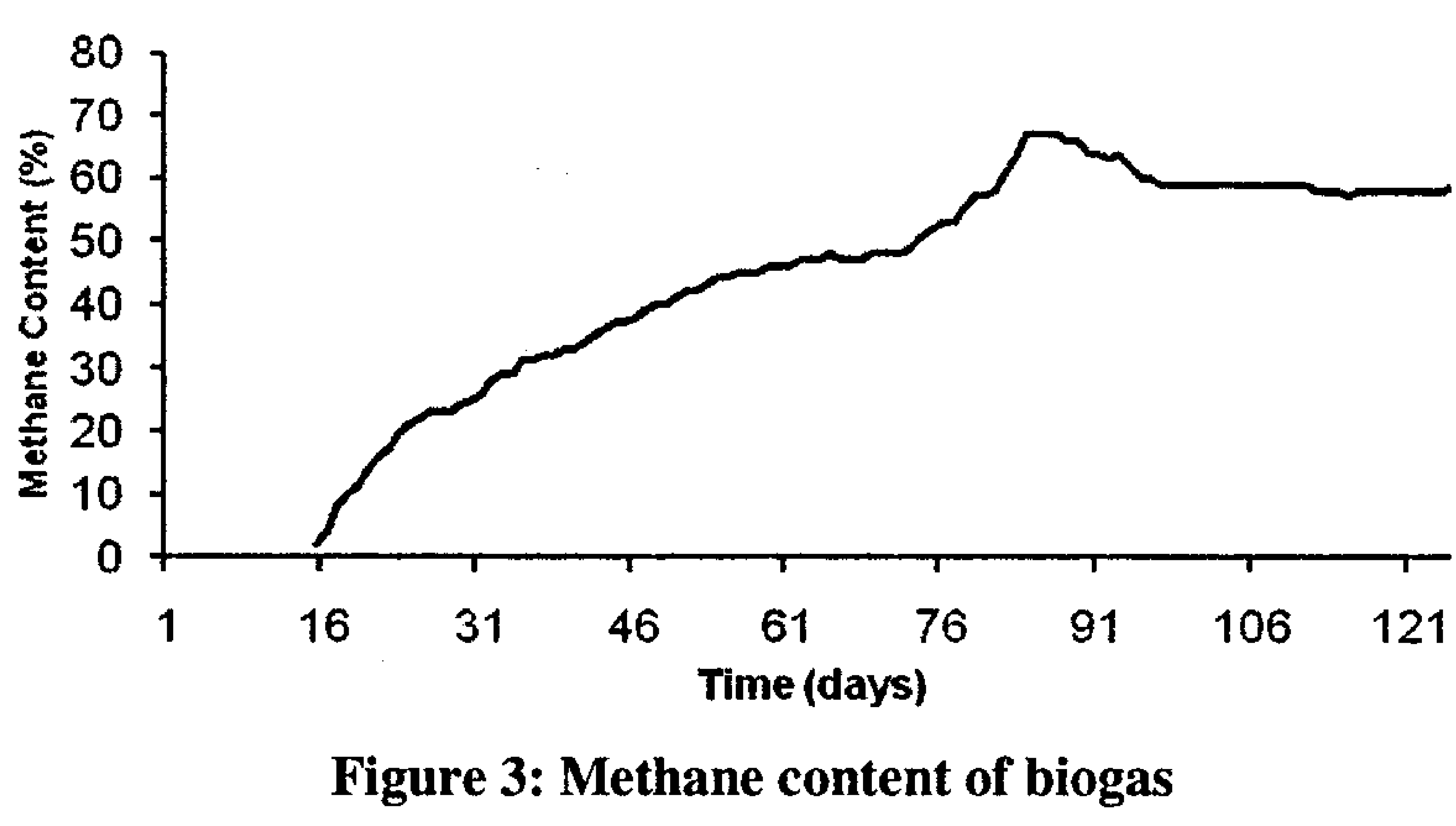

Figure 3: Methane content of biogas

Temperature variation inside the digester

Temperature recoded during study period in the digester (dome, middle, and bottom) and air temperature during the 69 days is shown in figure 4. Inside temperature of the digester dome is relatively lower than the air temperature in many days. However temperature variation inside the digester dome and air temperature was approximately same. Temperature in the middle of the digester was relatively constant. Temperature in the bottom of the digester was relatively constant in most of the days during the data recording period. Mean temperature inside the digester is relatively lower than the air temperature in many days. The temperature variation inside the digester was relatively minor compared to temperature variation of air.

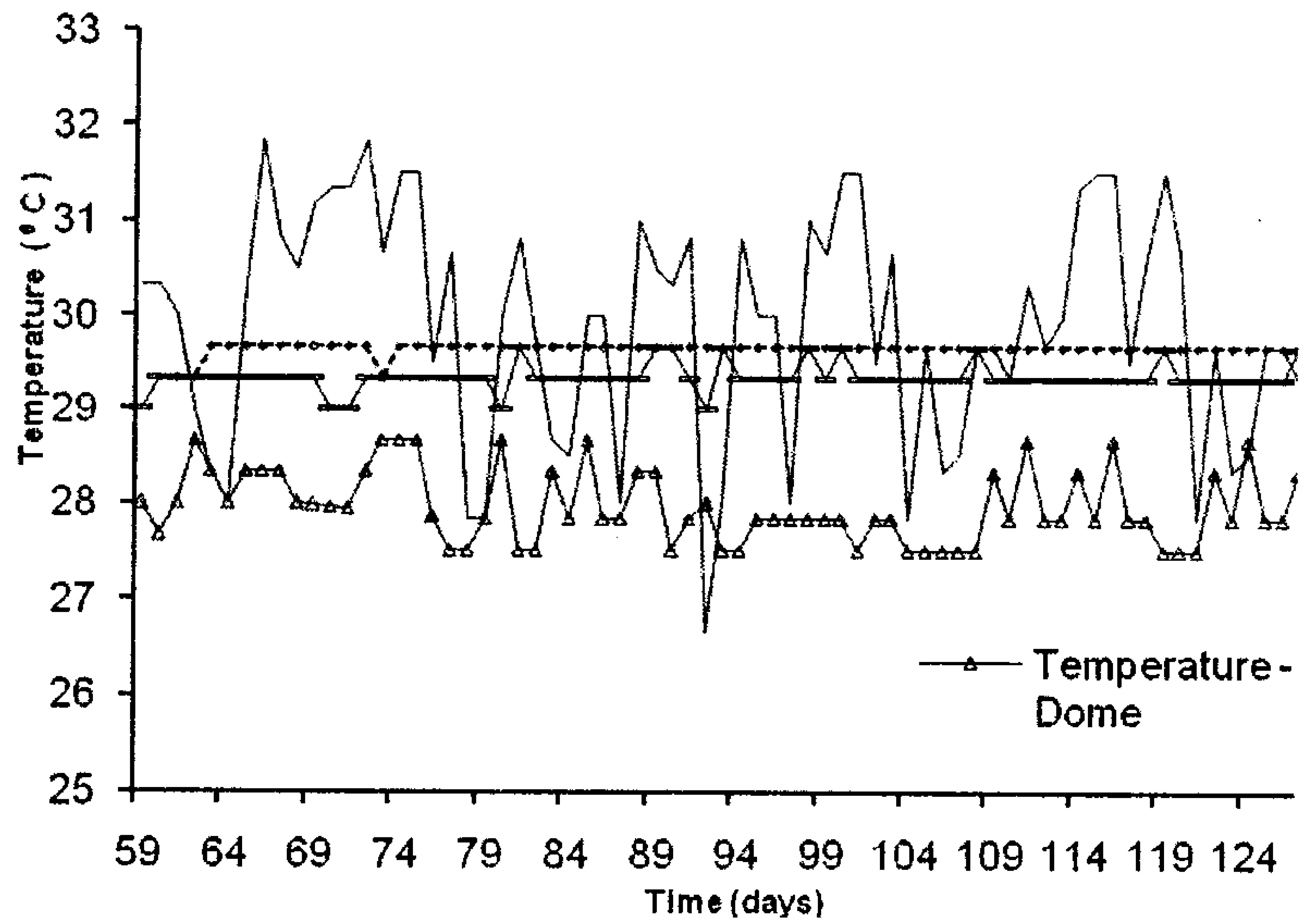

Figure 4: Temperature variation in the digester and outside the digester

Conclusion

The composition of the market garbage collected from Sunday fair at Matara and Kamburupitiya have a considerable higher variation and major components were cabbage and brinjal representing of 43.4% and 11.5% respectively. Initial total solids percentage of the market garbage was 9.72 and which may improve the gas production performance, since the higher gas production can achieve at 9% - 11% dry matter content. Carbon, Nitrogen, ash, volatile solids and C: N ratio of market garbage were 39.16% ($\pm$2.53), 1.57% ($\pm$0.05), 1.91%, 12.20%, 87.80%, and 20.47 respectively. Theoretical biogas production potential of market garbage was 124.3m^3. Total biogas gas production from 3240 kg of market garbage was 89.13 m^3 during the 127 days of research period. The total biogas production per 1kg of dry matter was 282.98 L. The biogas production efficiency of the dry batch digester fed with market garbage was 71.7%. Methane content of biogas was gradually increased in to maximum methane content of 67% of 84 days and it was reduced to 59% within 12 days and remains constant thereafter. Based on the results, it can be concluded that market garbage could be easily utilized as a raw material for biogas production in the dry batch digester with higher methane content. However further investigation has to be conducted to arrive at a firm conclusion on this regard due to the large heterogeneity of market garbage in the place to place.

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