MANAGING THE BIOGAS PRODUCTION USING THE GREEN MARKET WASTE

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ABSTRACT: In recent years, countries around the globe have concentrated on renewable energy options in consideration of the ever-increasing demand for energy, the oil prices and unpredictable supplies for conventional power production, as well as the well-known adverse effects of conventional energy source on environment and human health. Raw biogas consists primarily of methane (CH_4), ammonia (NH_3), carbon dioxide (CO_2), water (H_2O), hydrogen sulphide (H_2S), nitrogen (N_2) and other trace components. The present research focuses on the processing of biogas in a domestic level scale biogas digester. Anaerobic digestion process was adopted. These experimental studies have been performed on domestic level to develop optimum process for biogas generation from organic waste of green market, for the purpose different samples were collected in different seasons. Pakistan has abundant raw material in the green market. Biogas produced from this green market waste is more cost effective and environment friendly, minimizes landfill waste, mitigates carbon dioxide.

Keywords: Biogas, Anaerobic digestion, Environment friendly, Organic waste, Green market.

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INTRODUCTION

At present, fossil fuels (petroleum, gas and coal) account for about 80 percent of world demand for electricity (IEA *et al*., 2011). Such sources are not limitless and the increasing price of energy further accelerates the need to substitute fossil fuels with cleaner, sustainable fuels (Esposito, Frunzo and Panico *et al*, 2012) (Sondergaard and Fotidis *et al*, 2015). Biogas is a gaseous biofuel produced from organic material by anaerobic digestion. This can be used to substitute fossil fuels for electricity (Börjesson, and Mattiasson *et al*, 2008) and heat generation and can be converted to electric vehicle gasoline (Gerardi *et al*, 2003) (Tippayawong, and Thanompongchart *et al*., 2010). Biogas has a wide variety of applications (Arthur, Baidoo and Antwi *et al*, 2011). As an alternative to fossil fuels, biogas therefore has immense potential (Forgács *et al*, 2012) (Awan and Ali, *et al*, 2014). Biogas is usually used for heat and power generation in Europe (Nayono, Gallert and Winter *et al*, 2010). In 2009, almost 1% of the electricity generated in the EU was using biogas (Korniłłowicz, Kowalska, and Bohacz *et al*, 2011). Yet biogas is still used as automotive fuel in transport in some EU countries (Resch, Wörl and Waltenberger *et al*, 2011) (Muha, Linke, Wittum, *et al*, 2015), including Sweden, while biogas is used for cooking, heating and lighting in developing countries (Weiland *et al*., 2010).

In the past decades, the focus has been on reducing carbon gases and saving the atmosphere through the use of a renewable energy (Ding, Niu, Chen, Du and Wu *et al*, 2012), reliable energy supply capable of replacing fossil fuels (Ryckebosch, Drouillon and Vervaeren *et al*, 2011). Biogas processing by anaerobic decomposition (AD) of agricultural waste has the benefit of providing useful clean (Hajji and Rhachi *et al*, 2013) (Hamlin *et al*, 2012) and renewable energy (methane) while the environmental burden of such waste has decreased (Amjid, Bilal, Nazir, Shahzad and Hussain *et al*, 2011). Thanks to their high organic content, waste from food production processes industries has the ability to generate biogas (Pourbafrani, Niklasson and Taherzadeh *et al*, 2011) (Zhiqiang L. and Jian L *et al*, 2016).

Biogas production in a regulated environment decreases greenhouse gas (GHGs), substantially as captured methane is a heavy greenhouse gas (Umer, Khan and Iftikhar *et al*, (2017) (Abbasi, T. and Abbasi *et al*., 2010). The release of GHGs is well known to cause significant problems (Azadeh and Jalal *et al*, 2011) (Wang and Kuninobu *et al*, 1999). Rise in global temperature is caused by the subsequent global warming (Khurshid *et al*, 2009) (Bensah, Mensah, and Antwi *et al*, 2011). During 2009, carbon dioxide (CO_2) accounted for the highest share (81.5 percent) of the impact of GHGs on global warming (Li, Yan, Fan, and Zhu *et al*, 2011) (Teerachark and Rachdawong *et al*, 2012). The major component of the CO_2 pollution (94 percent) was coal combustion, while the remaining 6 percent came from other manufacturing activities (Bhutto, Bazmi and Zahedi *et al*., 2012). At 9.0 percent of the overall GHG emissions, methane had the second highest impact (Chandra, Takeuchi and Hasegawa *et al*, 2011). The agriculture field, mainly related to rice cultivation and enteric fermentation, produced half of the methane emissions (Larisa *et al*, 2010) (Martín, Siles, Chica and Martín *et al*, 2010). In addition, the wastewater treatment industry (landfill and wastewater treatment,) created 31 percent of the methane emissions, while the remaining amount came from the combustion field and oil and natural gas systems (SOER, 2010).

The European Environment Agency's study suggests that eliminating the reduction of methane will have the greatest impact on the climate (Nasir, Ghazi and Tinia *et al*, 2012) (Waheed, Ahmed, and Zahedi *et al*, 2011); methane has a life-span of 20 years and 72 times the global warming potential over 20 years, relative to carbon dioxide (SOER, 2010).

Thus, the production of biogas has immense potential to mitigate methane emissions (Dumont, Luning, Luchien and Yildiz, Ismail and Koop, Klaas *et al*, 2013), thereby reducing demand for fossil fuels and make it more appealing to switch over quickly on biogas (Rehl, and Müller *et al*, 2011). Currently in Europe about 10,000 biogas plants generate biogas from dung, sludge as well as energy crops and different forms of waste (REN21, 2011).

This research examined the feasibility of green waste, used as substrates for anaerobic degradation.

METHODOLOGY

Location of Material and Biogas Production

The Dimension of the Biogas Plant: Design dimension was necessary to make a robust and reliable design (Orhorhoro and Atumah, *et al*.2018) (Talukder *et al*, 2010). Furthermore, each dimension was linked to others (Singh, Jain and Singh *et al*, 2017). If we did not pay head towards accurate dimensioning, we could not get maximum production of biogas that was our ultimate target (Drosg *et al*, 2013) (Appels, Baeyens, Degrève and Dewil *et al*., 2008). For this, a detailed flow diagram and plant layout was made showing different parts and their dimensions.

Raw Materials Selection: Selection was done to make appropriate use of mixture containing an appropriate amount of green vegetable waste with some quantity of cow dung as an inoculum which remained helpful to start anaerobic digestion process along with some quantity of additives to boost up the system.

The waste that was collected for this phase of the study was pre-treated to reduce the size to 1mm and 5mm by shredding. The process was operated at different temperatures i.e., 20^{o}C, 35^{o}C and 45^{o}C, while the retention time for this phase was 60days. Each subsequent loading of the waste was ensured to be of the respective particle size of the feedstock and the biogas produced from each particle size feedstock over a period of 60 days was quantified with the flow meter.

Collection of the Samples: During the whole experimental period, samples on per batch were taken of the most frequent varieties of fruit and vegetables produced from Shahdara's vegetable market. The samples obtained were of different types of fruits and vegetable waste.

Sample Collection for Raw Material: For purpose of this research, the organic/green waste from the markets was used as a raw material. Samples were collected from green market Sheikhupura on different places.

Screening: Before loading into the digester, all the visible stones, sticks, and any foreign matter were picked carefully from the wastes.

Shredding: The green waste was chopped into an appropriate size of 1mm and 5mm, before using it in the digester.

Mixing: Chopped green waste was then properly stirred with the mixing of 50% water as per volume of green waste in order to make a homogenised mixture (Zhou, Elbeshbishyand and Nakhla *et al*, 2013) (Tarekegn, Mekonnen, Abebe and Massreshaw *et al*, 2017). Extra material like stones etc. was removed from the inlet, otherwise, the digester volume will decrease and the result will not be reliable.

Biogas Analysis: GC and elemental analyser were used for producing the quantitative data as real values of biogas composition for improving the efficiency of methane gas. The sample of gas was injected to the GC, which was linked to the Chromato-Integrator. The results were graphically shown by the Chromato-Integrator and summarised by the Integrator. Results showed the existence of CH_4, CO, CO_2 with their percentage.

RESULTS AND DISCUSSION

Chemical Analysis of Green Waste: Proximate analysis of any material from which energy was required to be derived, offered the ratio of the content burning in a gaseous state (volatile substance).Inorganic waste material (ash) and was therefore of vital significance for the use of biomass energy (Pavi, Suelen and Kramer, Luis and Gomes, Luciana and Miranda, Luis *et al*, 2017). Proximate analysis provided the total composition of the biomass, and therefore calculation was fairly straightforward. Where, as in the more detailed Ultimate Analysis, was based on quantitative analysis of different elements contained in the waste sample such as hydrogen, carbon, oxygen, sulfur and nitrogen;

Proximate analysis was performed to determine the following i.e. Air-Dried Moisture, Volatile Matter, Fixed carbon, Ash content.

Table 1. Analysis of Green Market Waste Dry Basis.

No.	Compound	Mean±S.D	Range	Elements	Mean±S.D	Range
1	Fixed Carbon	16.30 ± 1	5 – 20	Nitrogen	0.65 ± 0.02	0.1 – 1.5
2	Ash	8.30 ±0.5	2 -12	Hydrogen	5.45 ± 0.1	2 -11
3	Volatile Matter	70.00 ±5	10 – 93	Oxygen	46.09 ± 2	5 – 53
4	Air Dried Moisture	7.25 ±0.4	1.7 – 10	Carbon	45.00 ± 2	4 – 52
5	Gross Heating Value (Dry Basis, MJ/Kg)	17.11±		Sulfur	0.17± 0.002	0.005 – 0.3

Green Market Waste Composition: Biogas output optimization from any waste was based on a waste composition analysis. Variations in the composition of the substrates could induce the microbial imbalances in the anaerobic digestion system (Jensen and Batstone *et al*, 2014) (Yirong, Heaven and C. J. Banks *et al*, 2015). Business activity started early in the morning, and ends after noon in the fruit and vegetable market. Because of this it was decided that waste was to be collected in the afternoon from the market to reflect the actual figures of waste generation.

Waste collected from the green market during the course of the experimentation showed that the average waste composition was as shown in the figure 1.

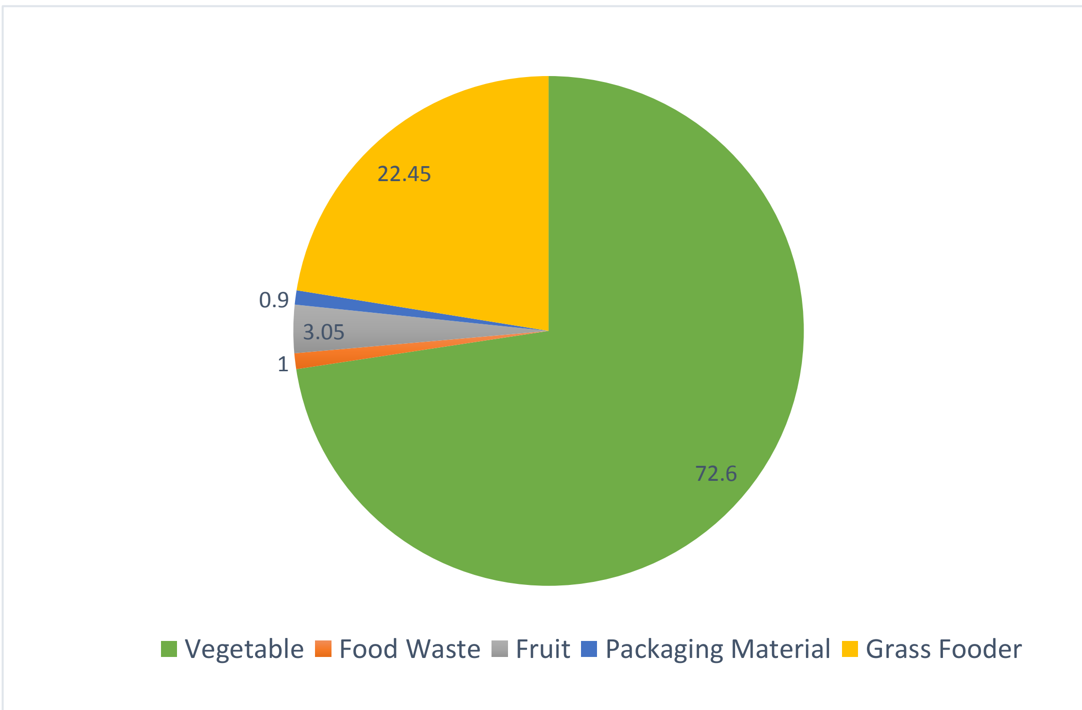

Figure 1. Green Market Waste Composition

Temperature Impacts on Gas Concentration Rate: The impact of temperature on the generation of the biogas was observed at 20°C, 35°C and 45°C (Leta, Libsu, Chavan, Manaye, Dabassa *et al*, 2015). The following figures 2 and 3 in this section represented the daily production and the cumulative production of the biogas at the three experimental temperatures. It was found that the maximum production rate was at 45°C, while the production was least at 20°C. On the other hand, at 35°C the production was observed to be less than at 45°C but considerably more than what was recorded at 20°C.

At 20°C it was found that the generation of biogas was very low as well as slow. It was also seen in the figure 2 that the biogas generation started from the 16th day and was considerably low in amount. At the 20th day, the daily generation of the biogas was about $0.01m^3$/day. Then in the subsequent days till the day 45, the general upward rise in the biogas generation was observed, and the maximum biogas generation was seen to be generated on this day. Onwards from the day 45, the declines in the biogas production was prominent and continued till the 60th day, where the daily biogas production at the last day of these experimental conditions yielded 0.025 m^3/day of biogas. In terms of the cumulative biogas production, this was shown as during the 60 days' time period the overall biogas that was generated was 2.75 m^3, which is lesser than the experiments at higher temperatures.

The low generation of the biogas during the experimental conditions with 20°C temperature was attributed to the fact that at lower temperatures the rate of conversion of biological substance into biogas was reduced as the operation of microbes was not unlimited. As significance, more duration of residence in the digester was required to produce any significant amount of biogas.

For the experiment that was done at 35°C, it was found from the Figure 3 that the biogas generation was not started until day 12, whereas for 20°C it started at day 15. However, the biogas production significantly started from the day 22, where the daily biogas generation was recorded to be 0.01 m^3/day. Then onwards the daily biogas generation trend was upward, but on days 28 and 29 it was recorded as .05m^3/day, on days 46, 47 and 48 was recorded as 0.20m^3/day. The maximum daily biogas generation during this stage of the experiment was generated on the days 46,47 and 48. Then until the 60 day there was a decline in the daily biogas production and the daily production on Day 60 was 0.05 m^3/day. The cumulative biogas produced during this experiment was 4.387 m^3. The 35°C experiment yielded 37.14% more biogas as compared to experimental yield at 20°C.

It was evident from the graphical representations of the experiments that biogas generation was maximum at 45°C. The biogas started generating at the 10^{th} day and on the 20^{th} day of this experiment the biogas generation was 0.02 m^3/day. Then the daily biogas generated on the subsequent days was more than the biogas that was generated at 20°C and 35°C on the same days. The daily biogas generation kept increasing till the day 43 where the biogas generated was 0.26 m^3/day. This was the maximum biogas generated on a single day on either the three temperatures i.e., 20°C, 35°C and 45°C. Later on, till the 60^{th} day, the biogas generation saw a decline but the amount being generated on the daily basis was still more than the amount at 20°C and 35°C. On the last day of this experiment, the biogas generation was recorded to be 0.07 m^3/day. The cumulative biogas production, over the 60 days' time period at 45°C was 5.625m^3. This value is 104.5% more than the experimentally yielded values at 20°C and 22.22% more than the experimental results at 35°C.

The higher biogas production at 45°C was attributed to the fact that the bulk of methanogens (microbes that produce methane from organic substance) were mesophilic. Methanogens grow rapidly in the 40°C and above range and show high levels of organic matter conversion to biogas. The growth and stability conditions of the digester under mesophilic conditions.

In exercise, unexpected environmental fluctuations, such as drastic increases or temperature drops, could create significant disruption to all process parameters and the system needed a long period of time to adjust a stable state. Temperature variations greatly affected the development and metabolic function of methanogens (Masebinu *et al*. 2018) (Griffin *et al*., 1998). It was then necessary to control the temperature in order to boost the output of biogas during the methanogen process.

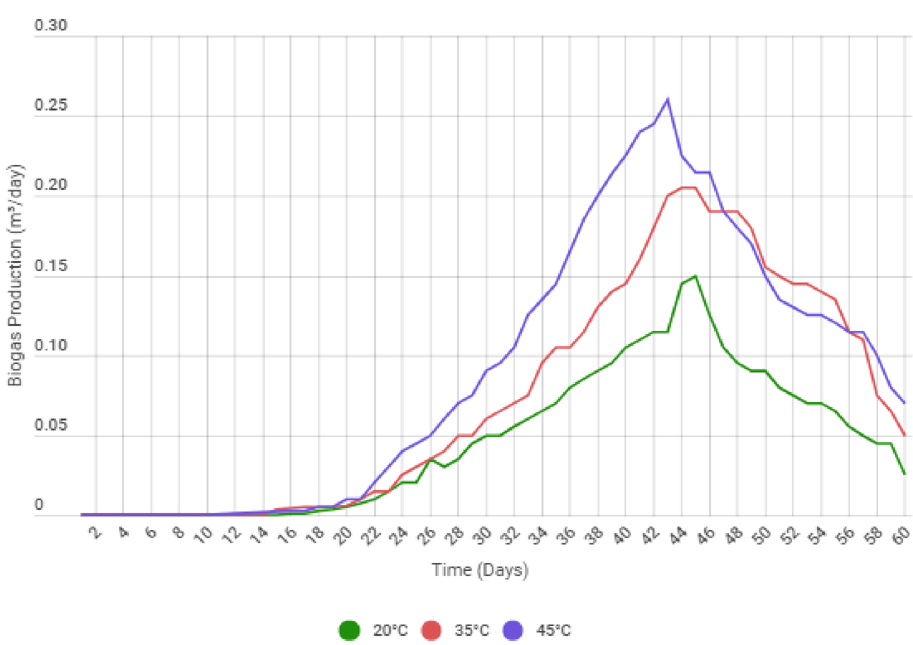

Figure 2. Biogas Production at Different Temperatures

The figure 3 below depicted the cumulative biogas production from green waste at the three experimental temperatures. From these results, it was evident that the maximum biogas was produced at 45°C, which was followed by 35°C and 20°C.

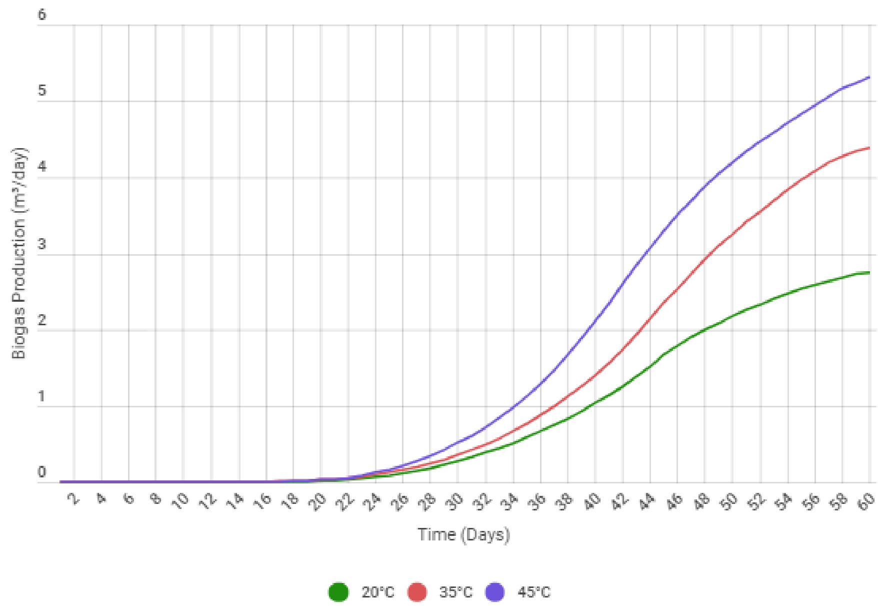

Figure 3. Cumulative Biogas Production at Different Temperatures.

Conclusions: Biogas generation at 45°C was the highest, and it took lesser retention period as compared with 20°C and 35°C. From the results obtained from the experimental process of this study, it can be inferred that the green waste should preferably be fed in the digester at loading rate of 187kg, (maximum as per design) because of the fact that maximum biogas production i.e., was obtained at this rate. It was also observed in the study that when the loading rate of the green waste was higher as per digester design the process result positively, and the amount of biogas generated was increased. The efficiency of methane and biogas recovery after the process of anaerobic degradation of green waste was based on maintaining it on a suitable loading rate and other conditions remained stable.

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