Enhancing biogas production from vegetables and fruits wastes by applying effective strategies

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ABSTRACT

Biogas is a new, able, eco-friendly, economical and feasible energy source for meeting daily need through cooking and kitchen use. Rise in crude oil prices and population created extreme pressure on fossil fuels and other non-renewable sources of energy which is deteriorating steps towards achieving sustainable lifestyle. Already research is going on to use biogas as vehicle fuel, but its low yield and impurities being hindrance, the main aim of this study was to enhance biogas at laboratory scale and objectives were to co-digest vegetables and fruits with cow dung and applying various techniques such as providing nutrient supplements mostly metal ion, metal nanoparticle and urea. Waste was co-digested for hydraulic retention time (HRT) of 7 days. Optimum enhancements were observed when substrate co-digested with cow dung and urea (30.8 ml) than metal ion (21.1 ml) and with only cow dung (13 ml) considering all the vegetables and fruits used such as spinach, cabbage, fenugreek, tomato, banana and orange peels. By using nanoparticles co-digested with mixed vegetables, (44 ml) highest biogas production was observed.

Key words: Biogas production, Biomethanation, Vegetable and fruit waste, Recycling, Renewable energy sources

Introduction

Biogas is an effective and economically feasible energy sources used as fuel used in automobiles leading us towards sustainable development (Phirke, 2012; 2013). Biogas is mixture of various gases such as 50 % - 70 % of methane (CH₄), 30% - 40 % of carbon dioxide (CO₂) and low percentage of other gases. Biogas is odourless and colourless gas that burns with clear blue flame similar to that of liquid petroleum gas, i.e., LPG (Ogur et al., 2013). Anaerobic digestion of biomethane generation done by hydrolysis, acidogenesis, acetogenesis and methanogenesis. In hydrolysis larger polysaccharide is converted into monosaccharide molecules which are easy to digest and having simple structure. In Acidogenesis, the acidogenic bacteria convert sugar, into various acids, alcohol and aldehydes along with CO₂. After that acetogenesis takes place along with acidogenic bacteria, acetogenic bacteria help to produce more acetic acid by reducing CO₂. Methane formation is the last process and the acetic acid formed in previous steps is converted into methane (CH₄) by methanogens (Gopinath et al., 2014).

Co-digestion process improve anaerobic digestion by adding nutrients and improve bacterial diversities in various wastes to optimize the digestion process (Ahring et al., 2003; Hartman et al., 2003; Parawira et al., 2004). Trace metal ions supplementaion when used in proper concentration, it promotes the growth of anaerobic microorganism increasing biogas production. A trace level of many metals required for activation and functioning of many enzymes and co-enzymes (Kumar et al., 2006). Micro nutrient played significant role in several metabolic pathways in anaerobic digestion (Schattaur et al.,
Iron (Fe), Nickel (Ni), Cobalt (Co) and Molybdenum (Mo) etc. acts as the micronutrients needed to be present in adequate amount in anaerobic digestion. Deficiency of trace metals will result into significant deterioration of the anaerobic digestion (Osuna et al., 2004). Nitrogen was influential parameter that affected the production of biogas. Anaerobic microbes needed nutrient such as nitrogen for growth and reproduction. If availability of nitrogen was too high, the bacteria would be hampered because nitrogen would be released as ammonia (Soubes et al., 1994). Nanoparticles were greatly influenced due to their chemical origin, which was responsible for their behaviour and fate in the environment (Farre et al., 2011; Stone et al., 2010). Nano particles (Np) in accelerating the hydrolysis process of anaerobic digestion, improving the methane yield and stabilizing the sludge (Suanon et al., 2016).

Materials and Methods

Collection of Kitchen wastes

The fruit and kitchen wastes were collected from the nearby markets of Amravati. The wastes contained the nonedible parts of Banana, Orange peels, Tomato, Cabbage, Fenugreek and spinach. The collected waste was chopped into smaller pieces and then by using blender thick slurry of respective vegetables and fruits were obtained.

Biomethane potential assay

For the BMP assay, serum bottles were filled by standard weights of vegetable and fruit slurry. The Little space was kept unfilled as head space approximately 20%, to collect the biogas formed in that unfilled space. Serum bottle was shaken and valve was fixed to maintain anaerobic condition. For assurance of anaerobic conditions, plastic cover was also coated outside the valve to maintain the suitable condition. Whole batch fermenter was kept in an incubator to maintain the desired temp of 37 °C for hydraulic retention time (HRT) of 7 days (Iqbal et al., 2014). By using above method, the control was set up by digesting 50g of the waste slurry on its own without adding any supplements. Approximately 50 g of slurry and 50 g of cow dung was digested in the serum bottle achieving the ratio 1:1 (Agrahari et al., 2013). All the sets were implemented in Triplicate manner at 37 °C.

Bioaugmentation by (Urea, Trace metal ions, Nanoparticles)

By adding the slurry and cow dung in 1:1 ratio of 50 g, trace amount of metal ions mixture containing zinc, magnesium, iron, nickel and copper was added. By maintaining ratio of 1:1 of 50 g waste and cow dung each, urea was added. Before adding urea, 1mg of urea was dissolved in 1 ml of water. The serum bottle was kept at 37 °C. Nanoparticles were synthesized by using chemical method and characterization was done. After confirming the nanoparticles, mixture of silver and iron nanoparticles was added again 50 g of slurry and cow dung was added to get 1:1 ratio and nanoparticles were added total weighing 0.1 g.

Characterization of feed stock

Total solid (TS %), volatile solid (VS %), moisture content (MC %) and pH were calculated using standard procedures. Standard methods were used to calculate the various parameters for characterizing waste

Total solids (TS)

Total solids denoted organic as well as inorganic matter in the feedstock (Ahring et al., 2003). TS were determined according to APHA (Hartmann et al., 2003). In china dish of weigh W1, took 20 g of fresh waste, i.e. slurry of weigh W2. This was let too dry in a hot air oven overnight at temperature 105 °C (W3).

Volatile solid (VS)

Volatile solids give us organic matter of feedstock, not including inorganic salts, ash. It was also calculated in accordance with APHA (Hartmann et al., 2003). The dried sample from oven (W3) was heated for at least 1 hour at temperature 550 °C to get weight W4.

Moisture contents (MC %)

Moisture contents in biogas gives us idea of humidity present in it. In the (W1) China dish the 20 g of fresh waste (W2) is dried in oven overnight at temperature of 120 °C to get weight of dried sample in China dish (W3).

Data collection and analysis

The characterizations of waste were done before digestion and after digestion and gas produced were daily measured by using glass syringe. Daily data
were recorded and analyzed to compare with other sets.

Results and Discussion

Characterization of wastes

Table 1 showed characteristics of waste such as Total solids, volatile solids, moisture contents and pH before and after digestion. During anaerobic digestion, pH of all vegetable waste was affected by various factor such as alkality, volatile fatty acid concentrations. The total solid for tomato was least and for banana was most while in the case of volatile solids the least percent of organic waste was found in tomato and fenugreek showed most (Deressa et al., 2015). Moisture contents were more in fenugreek than other waste materials whereas least found in tomato. Orange contains citric acid so it shows acidic pH near 4.4, lowest in all waste materials. The pH is important parameters for the optimum degradability of fruit and vegetable wastes in anaerobic digestor (Garcia-Pena et al., 2011).

Table 1. Characterization of kitchen waste

<table>
<thead>
<tr>
<th>Waste</th>
<th>Total solids(%TS)</th>
<th>Volatile solids (%VS)</th>
<th>Moisture contents(%MC)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
<td></td>
</tr>
<tr>
<td>Cabbage</td>
<td>12.03</td>
<td>9.54</td>
<td>71.50</td>
<td>5.7</td>
</tr>
<tr>
<td>Orangepeels</td>
<td>12.70</td>
<td>13.06</td>
<td>56.48</td>
<td>4.4</td>
</tr>
<tr>
<td>Fenugreek</td>
<td>13.43</td>
<td>7.61</td>
<td>75.63</td>
<td>4.0</td>
</tr>
<tr>
<td>Tomato</td>
<td>10.60</td>
<td>6.76</td>
<td>42.02</td>
<td>4.6</td>
</tr>
<tr>
<td>Spinach</td>
<td>15.96</td>
<td>7.06</td>
<td>70.44</td>
<td>6.5</td>
</tr>
<tr>
<td>Banana</td>
<td>27.85</td>
<td>25.40</td>
<td>74.26</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Biogas production from various kitchen wastes

Biogas production in orange peels reactor after adding metal ion, urea and co-digesting it with cow dung separately Figure 1 (A). Orange peels were digested with cow dung, it showed increase in gas production and increase daily, it was found that biogas production increases after 24hrs and reduced on 3rd day (12 ml) and then decreased gradually.

Giving peak after 2hrs (21.5 ml) and decrease slowly. Co-digestion of metal ion with orange peels and cow dung showed increased in biogas production as metal cations could enhance the density of the bacteria (Milán et al., 2010(a and b)). Orange substrate supplemented with urea with cow dung, fenugreek figure 1(B), produced optimum quantity of biogas (Agrahari et al., 2013).

The biogas production in spinach Figure 1(D) showed maximum biogas when co-digested with urea (30ml) and on 1st day. In banana figure 1(E), adding urea proved to be helpful to microorganism rather than adding metal ions which were showing inhibitory effect on biogas production from banana using metal ion (Menon et al., 2016). Co-digesting banana with cow dung was also satisfactory but adding urea proved effective. It showed highest peak production after 24hrs (64 ml) and then decreased gradually as no feedstock was added in batch process. As tomato contain less cellulosic part, it is easy for microorganism to degrade it to give good results. Theoretically, the highest biogas yield can be achieved from lipids (1.01 Nm3 CH4/ kg VS), followed by proteins (0.50 Nm3 CH4/ kg VS), and carbohydrates (0.42 Nm3 CH4/ kg VS) (Moller et al., 2004). Addition of urea proved effective giving maximum production (46.5 ml) where as it showed decline after it. Tomato already being acidic and adding metal ion helped acidogenic microorganism to increase their activity and further adding urea helped methanogenic microorganism, as it showed optimum activity at pH 7 (Ziauddin et al., 2015).

Urea supplementation (Soubes et al., 1994) proved effective for all vegetables and fruits studied, mostly for orange and banana. Co-digesting with cow dung was traditionally mostly used method to increase biogas production but now on providing other supplement such as micronutrients like nitrogen and other metal ions proved effective and promising method to enhance biogas production yield even in small batch scale (Menon et al., 2016).

Biogas produced after adding nanoparticles

Nanoparticles synthesised were confirmed to be silver nanoparticles by morphological character. The synthesized nanoparticles were black or charcoal grey in color. The nanoparticles are lustrous in nature. The dried nanoparticles were crystalline and...
Fig. 1. The cumulative gas production from different Kitchen waste by applying various strategies

(A) ow-orange waste, B) fw-fenugreek waste C) cw-cabbage waste, D) sw- spinach waste, E) bw-banana waste, F) tw-tomato waste, cd- cow dung, mi- metal ion, u-urea)

resembles with silver oxide nanoparticles (Elamawi et al., 2018). Maximum biogas production was seen on first day in all digester (Figure 1). Mixed waste co-digested with nanoparticles and metal ions were as in control mixed waste was co-digested with cow dung, co-digestion with metal ions increased(13.4 ml) biogas production than the control (3.2 ml), but adding nanoparticles showed highest biogas production (44 ml) (Farre et al., 2011).

Conclusion

From this work, it concluded that various treatments like using metal ion and urea, enhance biogas yield in major quantity. Urea supplement provide nitrogen source in biogas production three times more than control. Nanoparticle like silver oxide were found effective. Biogas as sustainable source of energy, in coming days it will become point of interest for achieving eco-friendly environment. It is cost ef-
Fig. 2. Comparative study of biogas produced after using nanoparticle on mixed kitchen waste material

effective and efficient hence it will be prime attraction for research. Biogas could be used in automobiles too, along with household purposes.

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References


