Biogas Potential from *Vetiveria zizaniodes* (L.) Planted for Ecological Restoration in China

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Abstract

Biogas is a promising renewable fuel all over the world. The experiment of biogas productivity from vetiver (*Vetiveria zizanioides* L.) was carried out to study the effect of different harvest times on the biogas yield and the dynamics of some fermentation parameters during 2011-2012. Micro-aerobic fermentation technology is used at the pretreatment of the vetiver plants. The batch anaerobic digestion technology and drainage collection process were used. The results showed that the harvest time of vetiver plants had greater effect on the biogas yield. There were more differences among the biogas yield, daily biogas yield and biomass utilization of the plants growing at different stages. Plant nutrient had less changes during anaerobic fermentation. The results suggested that *Vetiveria zizanioides* could be used as a raw material of biogas production and both ecological protect and energy production could exist in a mutually beneficial system.

1. Introduction

Biological conversion of biomass (energy crops, agricultural wastes) and various organic wastes is regarded as a sustainable production of renewable energy in future. Biogas is a versatile renewable energy source, which can be used for production of vehicle fuel, electric power and heat, chemicals and materials\[1\textsuperscript{,}2\textsuperscript{,}3\]. Meanwhile, the production of biogas can drastically reduce greenhouse gases (GHG) emissions compared to fossil fuels. Another by-product of biogas production named as digestate is an improved fertilizer in terms of its availability to crops which can substitute mineral fertilizer and reduce the nitrogen leaching from arable land to cycle the nutrient in the ecosystem\[3\]. It was reported that there are extremely
rich bio-natural gas resources in China and its annual productivity is expected to over 150 billion m$^3$. Distributed energy development is initiative in China\cite{4}. Therefore, it is more important to grow more plants in the marginal lands for both bio-energy production and ecological management.

Vetiver ($Vetiveria zizanioides$) is a perennial tufted grass belonging to the Poaceae family and the common domesticated cultivars used around the world are non-invasive. It has become known as a miracle grass with diverse environmental applications, including: a source of scented oil from its roots, fodder for livestock, soil and water conservation, rehabilitation, and remediation, and waste water treatment. It also sequesters significant quantities of atmospheric carbon\cite{5}. However, there is little information of vetiver plant as raw material of bio-energy. In this study, the experiment was carried out to compare the effect of harvest time on the biogas productivity in order to develop a new ecological industry of vetiver plants from the perspective of ecology and energy.

2. Methodology

The above-ground biomass of vetiver plant was sampled as feedstock for six harvests, which were grown as seedlings used in the ecological restoration engineering in Henan Nanyang National Agricultural Science and Technology park, Nanyang city, Henan Province, China. The samples were first cut into appropriate length, then crushed into about 0.5 to 1 cm length by a muller and stored in 4 °C refrigerator before pretreatment. Meanwhile, some feedstocks were taken to determine the moisture of material by dried method at 65±1°C.

The digested slurry from the running biogas digester was used as the inoculum from Henan Tianguan Group, Nanyang City. Total solids (TS) and volatile solids (VS) of inoculum were measured.

Vetiver plants were used as the mono-substrate in this experimental process without addition of manure or other N sources. The feedstocks (50 g/L, dried weight) are added with 10% inoculum, diluted with tap water (adjusted pH to 7.0) to 1.5 L, and then pretreated by pre-fermentation under micro-aerobic condition, 35±1°C, 4 d in the incubator.

The lab-scale trials were carried out in 2.5 L flask with bottom sampling outlets and operated in batch anaerobic fermentation. The working volume is 2.25 L. The flask was sealed with rubber stoppers with a “L” glass exit pipe, and connected with emulsion pipe for biogas removal. The biogas was collected by water-press method. The operational temperature was maintained under mesophilic condition (35±1°C) in the incubator. Each treatment was performed in triplicates. Assays with inoculum alone were used as blank controls.

The pretreated substrate was diluted with tap water (adjusted pH to 7.0) to 2.25 L before feeding. Air tightness inspection was done after the experimental setups are connected well. The batch digesters were manually stirred once per day.

The daily yield of biogas was measured according to the volume of water. Net yield of biogas of the tested biomass was obtained by subtracting the biogas volume of the control.

The biogas slurry was sampled on the first day, the third day, and then every other 7 days until the end of the experiment. Chemical Oxygen Demand (COD) was analyzed according to the manual of Lovibond COD instrument (Germany). Volatile Fatty Acid (VFA), total nitrogen (TN) and total phosphorus (TP) were determined according to the normal methods.

3. Results and Discussion

3.1. Dynamics of biogas production from vetiver plant
The characteristics of biogas production from vetiver plant under 35 °C ±1 °C were shown in Table 1 and Fig.1. There were 2–3 waves of biogas yield from different sampled times of vetiver plants (Fig.1). The sample V11 shown the highest biogas yield, daily biogas yield and biomass utilization (Table 1 and Fig.1), the biogas parameters of which were more higher than those of the sample V13. There was a difference between the yield of biogas of the samples at the same period in 2011 and 2012. Some detailed studied might be done.

The harvest time of vetiver plant had greater effect on the biogas yield, and had lower biogas yield when the time was postponed. There was a difference between the biogas production of the plants at the same time in two years. The results suggested that the right time of harvest should be the vigorous growth when the vetiver plant was used as the raw material of biogas production.

<table>
<thead>
<tr>
<th>Harvest time (Year.month.day)</th>
<th>Sample code</th>
<th>Volumetric gas yield (m³/m³/t)</th>
<th>Daily biogas yield (m³/m³/t/d)</th>
<th>Highest daily biogas yield (L/L/d)</th>
<th>Biomass utilization (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011.8.27</td>
<td>V11</td>
<td>140434</td>
<td>3266</td>
<td>0.98</td>
<td>58.46</td>
</tr>
<tr>
<td>2011.10.20</td>
<td>V12</td>
<td>111411</td>
<td>2591</td>
<td>6.66</td>
<td>43.29</td>
</tr>
<tr>
<td>2011.11.30</td>
<td>V13</td>
<td>81735</td>
<td>1901</td>
<td>0.59</td>
<td>42.52</td>
</tr>
<tr>
<td>2012.10.24</td>
<td>V22</td>
<td>82647</td>
<td>2850</td>
<td>0.52</td>
<td>45.54</td>
</tr>
<tr>
<td>2012.11.25</td>
<td>V23</td>
<td>49340</td>
<td>1701</td>
<td>0.33</td>
<td>41.45</td>
</tr>
<tr>
<td>2012.12.29</td>
<td>V24</td>
<td>45512</td>
<td>1517</td>
<td>0.63</td>
<td>27.35</td>
</tr>
</tbody>
</table>

Fig.1. Dynamics of daily biogas production from vetiver plant during 2011-2012

3.2. Dynamics of physico-chemical parameters during anaerobic fermentation of vetiver plant

The dynamic characteristics of TP, TN, COD and VFA of the biogas slurry during the fermentation process of Vetiver plants were shown in Fig.2. There was the greatest effect of sample time on VFA among these four parameters (Fig.2d). The values of the measured parameters in 2011 were higher than those in 2012 at the same sampled time (Fig.2d). TP and TN had less changes during the whole fermentation stages and at the last stage of the process shown much lower result (Fig.2a and 2b). The content of COD and VFA also had the above change except the sample V11(Fig.2c and 2d). The results suggested that the biogas slurry might be used as organic fertilizer.

4. Conclusions

The study showed that vetiver plant can be used as a raw material for biogas production. The highest
biogas yield, daily biogas yield and biomass utilization of the sampled plants growing vigorously were 140434 m$$^3$/m$$^3$/t, 3266 m$$^3$/m$$^3$/t/d, 58.46 %, respectively. During the process of the anaerobic digestion, plant nutrient such as N and P had less change and exited in the fermentation system. The results suggested that ecological protect and energy production could exist in a circulation system, which might be most deeply studied to maximize the benefits.

Fig.2. Dynamics of physico-chemical parameters during anaerobic fermentation of smashed vetiver plant

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**References**


