Hydrogen production from fruit waste through dark fermentation

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Objectives
This research was meant for investigating the possibility to produce hydrogen from waste of whole fruits generated from agriculture sectors and/or fresh fruit grocery market through dark fermentation process.

Background
There were more than 400 million tons of fresh fruits being harvested in 2009 to meet global demand. Throughout the cultivation until consumption, some portion of the fruits turn into waste. According to Global Food Losses, at least 10% of fresh fruits turn into waste. Among the fruits, global top four fruit commodities i.e. melon, banana, apple, and grape were selected as feedstock for the experimental investigation (Figure 3).

Methodology
Fruit waste containing organic polymers e.g. carbohydrate is subjected to dark fermentation process in which the polymers are hydrolyzed to sugars. In the presence of microorganisms e.g. Clostridia, Enterobacteriaceae, sugars are converted into $\text{H}_2$, volatile fatty acids, alcohols (Figure 4. left). Batch biohydrogen production was conducted using serum vial bottles for this research purpose through sequential steps such as grinding, mixing, pH adjustment and incubation at thermophilic condition $55^\circ\text{C}$ (Figure 4. right).

Results and Discussion
Dark fermentation of the selected fruits waste was conducted successfully to produce $\text{H}_2$ without any methane gas being detected. Among the four, banana yielded higher $\text{H}_2$ with potential global production more than 309 million cubic metric based on the 10% of harvested banana in 2009 being wasted. Simulation calculation of $\text{H}_2$ production from the four fruits is presented in Table 1. Total $\text{H}_2$ production can reach 726 million m$^3$.

Table 1 Potential $\text{H}_2$ production from fruit waste

<table>
<thead>
<tr>
<th>No</th>
<th>Fruits</th>
<th>Quantity (tons)</th>
<th>Percent Wasted</th>
<th>$\text{H}_2$ Yield (mmol/g VS)</th>
<th>Potential $\text{H}_2$ Production (STP m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Melon</td>
<td>101 000 000</td>
<td>10</td>
<td>5,96</td>
<td>185 808 197</td>
</tr>
<tr>
<td>2</td>
<td>Banana</td>
<td>95 000 000</td>
<td>10</td>
<td>8,61</td>
<td>309 093 490</td>
</tr>
<tr>
<td>3</td>
<td>Apple</td>
<td>71 700 000</td>
<td>10</td>
<td>7,30</td>
<td>153 941 162</td>
</tr>
<tr>
<td>4</td>
<td>Grape</td>
<td>66 900 000</td>
<td>10</td>
<td>7,28</td>
<td>77 457 569</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>726 300 418</td>
<td></td>
<td></td>
<td>726 300 418</td>
</tr>
</tbody>
</table>

*Volume of harvested fruit in 2009 (FAO UN)

Conclusion
Fruit waste is potential raw material for producing renewable $\text{H}_2$ through dark fermentation without any methane gas being detected. It benefits downstream purification process for further application such as fuel for fuel cell, internal combustion engine. Considering 10% of global harvested fruits being wasted, total potential $\text{H}_2$ production from the four selected fruits reaches 726 million cubic metric.

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