BIOGAS PRODUCTION FROM CHICKEN MANURE

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http://mebig.marmara.edu.tr
Anaerobic Digestion (AD)

- A process in which complex organic materials are converted to biogas in the absence of $O_2$ via activity of several groups of anaerobic microorganisms linked trophically to each other.
# Composition of Biogas

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane ($\text{CH}_4$)</td>
<td>50-70</td>
</tr>
<tr>
<td>Carbon dioxide ($\text{CO}_2$)</td>
<td>30-40</td>
</tr>
<tr>
<td>Nitrogen ($\text{N}_2$)</td>
<td>0-5</td>
</tr>
<tr>
<td>Hydrogen ($\text{H}_2$)</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Oxygen ($\text{O}_2$)</td>
<td>&lt;0.4</td>
</tr>
<tr>
<td>Hydrogen sulfide ($\text{H}_2\text{S}$)</td>
<td>0-0.4</td>
</tr>
<tr>
<td>Energy Content of Biogas</td>
<td>Energy Content (kWh)</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>1 Nm³ biogas (60%CH₄)</td>
<td>6.0</td>
</tr>
<tr>
<td>1 Nm³ upgraded biogas (97% CH₄)</td>
<td>9.7</td>
</tr>
<tr>
<td>1 Nm³ natural gas</td>
<td>11.0</td>
</tr>
<tr>
<td>1 L gasoline</td>
<td>9.2</td>
</tr>
<tr>
<td>1 L diesel</td>
<td>9.8</td>
</tr>
<tr>
<td>1 kg coal</td>
<td>7.8</td>
</tr>
</tbody>
</table>
Wastes suitable for biogas production

- Sewage sludges (primary and secondary sludge)
- Animal manures (chicken, cow etc.)
- Agricultural residues, Energy crops
- Yard (green) wastes
- Organic fraction of municipal waste
- Fruit and vegetable processing wastes
- Slaughterhouse wastes
- Algal biomass
- Waste paper
- Industrial wastewater (Potato, sugar, dairy, brewery, etc.)
Energy Production of Biogas in EU
(EurObserv’ER, 2012)

- Landfill gas
- Urban sewage & industrial effluent sludge gas.
- Decentralised agricultural plant, MW methanisation plant, centralized co-digestion plant.

Over 13 800 biogas plants in Europe in 2012 and more than 7 400 MW_{el} of installed capacity (EBA-European Biogas Association)
Turkish Regulation for Renewable Energy Generation

- Turkey aspires to have an installed capacity of 30% of renewable energy by 2023.
- REL (No. 5346): Law on Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy
- Installed capacity < 1 MW → no need to obtain a license
- Feed-in tariff\(^1\) applied to biogas (incl. LFG) investments: 13.3 USD cent/kWh
- Local equipment bonus: 5.6 USD/kWh

\(^1\) Feed-in tariff (FIT) is a pricing mechanism designed to promote investment in renewable energy technologies.
# Biogas Potential in Turkey

<table>
<thead>
<tr>
<th>Source</th>
<th>Biogas Potential (TWh/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal Manure</td>
<td>21.78</td>
</tr>
<tr>
<td>Industrial Waste</td>
<td>4.11</td>
</tr>
<tr>
<td>Agricultural Residue</td>
<td>2.33</td>
</tr>
<tr>
<td>Municipal Waste</td>
<td>3.06</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31.28</strong></td>
</tr>
</tbody>
</table>

*Turkish-German Biogas Project, 2011*
Biogas Plants in Turkey

- Landfill gas (131 MW)
- Manure/agricultural waste (26.5 MW)
- Sewage sludge (25.5 MW)

Total installed capacity: 183 MW
Use of Biogas Potential

94.9% Potential not used

Energy production with installed capacity: 5.1%

- Landfill gas: 3.7%
- Manure/agro waste: 0.7%
- Sewage sludge: 0.7%

Potential not used: 94.9%
# Number of Livestock in Turkey

<table>
<thead>
<tr>
<th>Livestock Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bovine (cattle etc.)</td>
<td>11,518,827</td>
</tr>
<tr>
<td>Ruminants (sheep, goat, etc.)</td>
<td>29,382,924</td>
</tr>
<tr>
<td>Poultry (broiler and laying hen)</td>
<td>234,918,385</td>
</tr>
<tr>
<td><strong>Total Number</strong></td>
<td><strong>275,820,136</strong></td>
</tr>
</tbody>
</table>

TUIK (Turkish Statistical Institute), 2010
# Biogas Yield & Energy Value of Manure

<table>
<thead>
<tr>
<th>Animals</th>
<th># of animals for 1 ton/d of manure</th>
<th>Dry matter, %</th>
<th>Biogas yield, m3/ton</th>
<th>Energy value, kWh/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>20-40</td>
<td>8-12%</td>
<td>25</td>
<td>150</td>
</tr>
<tr>
<td>Laying hen</td>
<td>8000-9000</td>
<td>25-30%</td>
<td>90-150</td>
<td>540-900</td>
</tr>
<tr>
<td>Broiler</td>
<td>10000-15000</td>
<td>50-60%</td>
<td>50-100</td>
<td>300-600</td>
</tr>
<tr>
<td>Pig</td>
<td>250-300</td>
<td>9-10%</td>
<td>26</td>
<td>156</td>
</tr>
</tbody>
</table>

http://www.anaerobic-digestion.com
Chicken Manure Digestion

- Chicken manure is rich in org. N but can cause severe decline in biogas production if digested with no dilution.
- To achieve biogas production without dilution, ammonia has to be removed.
- Besides, poultry wastes are generally deficient in trace metals such as Se, Co, Mo and W.
- Se & Co may cause stable biogas production at free NH$_3$ concentrations higher than inhibitory levels.
- Increase of biogas production as a result of TM addition to chicken manure digesters is predictable.
Afyon Enerji Biogas Plant

Afyonkarahisar, TR

Started up on May 2014
Afyon Enerji Biogas Plant

- Biogas Plant
- Digesters & biogas holders
- Dewatering & drying units
- Feeding/buffer tank
- Manure receiving area
- Water storage tank
- Ammonia stripper
- Biogas cleaning & cogeneration

Dewatering & drying units
Afyon Enerji Biogas Plant

- Digester
- Biogas holder
- Post-digester
Afyon Enerji Biogas Plant

- Anaerobic Digester (37 °C)
  - Biogas 36,000 m³/d
  - Chicken manure 300 ton/d
  - Spent poppy straw 70 ton/d
  - Fresh water 400 m³/d

- Cogeneration (4,2 MWₑ)
  - Heat
  - Electricity 89,000 kWh/day

- Dewatering
  - Digestate (6-8% DM)

- Drying
  - Fertilizer (85% DM) 75 ton/d
  - Liquid fertilizer (400 m³/d)

- Ammonia stripping
  - Recycled water 100 m³/day

- Ammonia

- Liquid fertilizer (400 m³/d)

- Fresh water 400 m³/d
Feasibility Results

- Investment cost: App. 15 million USD
- Electricity Generation: 30 million kWh/year
- Profit (electricity): 4 million USD/year
- Fertilizer Production: 25000 ton/year
- Profit (fertilizer): 4 million USD/year
- Payback period: 2-2.5 years
Laboratory Experiments in Marmara University
## Operation Conditions

<table>
<thead>
<tr>
<th>Period Days</th>
<th>I 0-49</th>
<th>II 49-70</th>
<th>III 70-128</th>
<th>IV 128-140</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLR, kgVS/m$^3$.d</td>
<td>3,01</td>
<td>3,51</td>
<td>3,58</td>
<td></td>
</tr>
<tr>
<td>TKN$_{inf}$, mg/l</td>
<td>3960</td>
<td>5020</td>
<td>5950</td>
<td>6560</td>
</tr>
<tr>
<td>HRT, d</td>
<td></td>
<td></td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>TS$_{inf}$, %</td>
<td>9,8</td>
<td>12,4</td>
<td>13,5</td>
<td></td>
</tr>
<tr>
<td>Temperature, °C</td>
<td></td>
<td></td>
<td></td>
<td>37</td>
</tr>
</tbody>
</table>
Results – TS & VS

<table>
<thead>
<tr>
<th>TS &amp; VS, %</th>
<th>Time, days</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>2%</td>
<td>20</td>
</tr>
<tr>
<td>4%</td>
<td>40</td>
</tr>
<tr>
<td>6%</td>
<td>60</td>
</tr>
<tr>
<td>8%</td>
<td>80</td>
</tr>
<tr>
<td>10%</td>
<td>100</td>
</tr>
<tr>
<td>12%</td>
<td>120</td>
</tr>
<tr>
<td>14%</td>
<td>140</td>
</tr>
</tbody>
</table>

- **TS%**
- **VS%**
- **TS-influent**
Results – TKN & NH$_4^+$-N

![Graph showing the concentration of TKN and NH$_4^+$-N over time. The graph includes data points for TKN and NH$_4^+$-N, with TKN influent shown as a horizontal line. The x-axis represents time in days, ranging from 0 to 140, and the y-axis represents nitrogen concentration in mg/l, ranging from 0 to 8000. The graph shows an increase in nitrogen concentration over time.]
Results – pH & Alkalinity

- pH
- Alkalinity

<table>
<thead>
<tr>
<th>pH</th>
<th>Alkalinity, mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>9.5</td>
<td></td>
</tr>
</tbody>
</table>

Time, days

Alkalinity, mg/l
Results – CH$_4$ Yield

CH$_4$ Yield, m$^3$/kgVS

Time, days
Results - VFAs

The graph demonstrates the concentration of VFAs (Volatile Fatty Acids) over time, specifically showing the levels of acetate and propionate. The x-axis represents time in days, ranging from 0 to 140, while the y-axis indicates the concentration of VFAs in mg/L, ranging from 0 to 1600.

- Acetate is represented by blue squares, while propionate is shown in red circles.
- The data points for acetate and propionate are distributed across the time range, with acetate generally decreasing and propionate increasing as time progresses.

This graph provides insights into the metabolic processes and the dynamics of VFAs production and consumption over the observed time frame.
Conclusions

• Feasibility result
  – CH₄ production = 19800 m³/d

• Laboratory study
  – CH₄ yield = 0.3-0.35 m³/kgVS (NH₄⁺-N <5000 mg/l)
  – CH₄ production = 19.500-22.500 m³/d
  – CH₄ yield = 0.25-0.3 m³/kgVS (NH₄⁺-N >5000 mg/l)
  – CH₄ production = 16.000-19.500 m³/d

• NH₄ has to be kept below 5000 mg/l in the digester
Future Study Plan

- **COST-ES1302** action ‘European Network on Ecological Functions of Trace Metals in Anaerobic Biotechnologies’
  - Effects of TM supplementation will be investigated
  - Stripping and membrane separation will be tested to continuously remove ammonia from the digester
Welcome to MEBiG

Environmental biotechnology is the integration of natural sciences and engineering for development of environment–friendly processes in order to
- develop, use and regulate biological systems for remediation of contaminated environments and
- produce value-added chemicals and bio–energy from waste
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