Pemulihan Limbah

Valorisasi merupakan konsep daur ulang limbah menjadi produk yang lebih bernilai guna.

Menggunakan "Green Processing Technologies", berbagai limbah dpt diubah menjadi produk kimia dan energi (Arancon et al., 2013)

Limbah sbg Energi

Limbah sbg Energi

Waste to Energy
Waste to Energy

Chemical conversion (Esterification):

Municipal Solid Waste

Forest Residue
Can be converted into energy using Thermochemical Stand-Alone Gasifier (Holladay et al., 2007)

Corn Stover
Can be converted into energy using Biochemical/Thermochemical Integrated Refinery (Holladay et al., 2007) → Gasification Technology

Forest Residue
Can be converted into energy using thermo-chemical treatment and followed by alcohol synthesis (Holladay et al., 2007)

Corn Stover
Can be converted into energy using Biochemical/Thermochemical Integrated Refinery (Holladay et al., 2007) → Pyrolysis Technology
Agricultural Waste

Mostly, agricultural waste are suitable candidates for anaerobic digestion for production of biogas (converted into heat and electricity) and digestate (for biofertiliser, solid media, soil conditioner) (Weiland, 2010)

Mean biogas yield of various waste feedstocks, including agricultural waste (Weiland, 2010)

Agricultural Waste

Agricultural Waste

Gross crop yield and biogas potential of different crops (Weiland, 2010)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Crop yield (t FM/ha)</th>
<th>Biogas yield (Nm³/t VS)</th>
<th>Methane content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar beet</td>
<td>46-70</td>
<td>730-770</td>
<td>53</td>
</tr>
<tr>
<td>Fodder beet</td>
<td>80-120</td>
<td>750-880</td>
<td>53</td>
</tr>
<tr>
<td>Maize</td>
<td>40-40</td>
<td>560-610</td>
<td>52</td>
</tr>
<tr>
<td>Corn cob mix</td>
<td>10-15</td>
<td>600-680</td>
<td>53</td>
</tr>
<tr>
<td>Wheat</td>
<td>30-50</td>
<td>630-700</td>
<td>54</td>
</tr>
<tr>
<td>Triticale</td>
<td>26-33</td>
<td>590-620</td>
<td>54</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>40-80</td>
<td>520-580</td>
<td>55</td>
</tr>
<tr>
<td>Grass</td>
<td>22-31</td>
<td>530-600</td>
<td>54</td>
</tr>
<tr>
<td>Red clover</td>
<td>17-25</td>
<td>510-620</td>
<td>56</td>
</tr>
<tr>
<td>Sunflower</td>
<td>31-42</td>
<td>420-540</td>
<td>55</td>
</tr>
<tr>
<td>Wheat grain</td>
<td>6-10</td>
<td>760-750</td>
<td>53</td>
</tr>
<tr>
<td>Rye grain</td>
<td>4-7</td>
<td>560-780</td>
<td>53</td>
</tr>
</tbody>
</table>

Maize Silage

Typical two-stage agricultural biogas plant (Weiland, 2010)

Food Waste

Food Waste Recovery Hierarchy

Components present in FOD and that can be converted into various feedstocks (Lin et al. 2013)
Food Waste

- Can be converted into energy such as biodiesel, bioethanol through transesterification process, enzymatic hydrolysis, fermentation
- Enzymatic hydrolysis and ethanol fermentation by using carbohydrate and Saccharomyces cerevisiae can be one of the alternatives

Schematic diagram of two-stage H2 and CH4 process using sludge recirculation method (Lee et al., 2010)

Valorization of metallurgical slags, red mud, boron wastes, fly ash, bottom ash etc. in:
- Cements
- Ceramics, heavy clay ceramics
- Light weight aggregates
- Absorbents, gas cleaning

Development of new materials:
- Low energy, low carbon cements (belite, sulfo-ferroaluminate cements)
- Ceramic Tiles with Photocatalytic properties
- Ceramic porous materials from wastes
- Geopolymers from wastes
Food Waste

Other than energy, food waste can also be used for production of other high-value products (Lin et al., 2013).

Food Waste

Or food waste can be valorised for continuous Black Soldier Fly Larvae Composting System, aimed for the production of the prepupae which is rich in protein and fat, can be used as an animal feedstuff (Dortmans, 2015).

Protein-rich waste

- Protein-rich waste currently used mainly as animal feed and fertilizers. Potential valorisation is for commodity chemicals such as precursors for polymers (Kumar et al., 2015).

Protein-rich waste

Amino acid content of some common protein-rich waste (mass % of amino acids in protein waste) (Kumar et al., 2015)

Using enzymatic conversion of aminoc acids to bulk organic compound (Kumar et al., 2015).

Tannery Waste

Arancon et al. (2013) reported that:

- Among the most promising compounds from meat industry-derived by-products include oily fats and collagen.

- A simple hydrolytic process was able to extract the collagen, followed by subsequent cross-linking to stable biopolymers or direct application upon purification by ultrafiltration.

- Meat and tannery-derived residues can be valorized to valuable collagenic biopolymers that can be formed into fibers, films, and sponges for various applications (see Figure below).
Tannery Waste

Fruit or vegetable waste

- Rich in both lipids and aromatic compounds
- Potential for flavored/aromatic vegetal oils
- This example has been developed by IRA-INP (France)

Fruit or vegetable waste from food industry

And when they are valorized, it is only for a SINGLE use

Bakery Waste

Arancon et al. (2013) reported that:
- Waste bakery can be converted into chemicals such as succinic acid or biodegradable polymers (e.g., polyhydroxybutyrate, PHB) by simply selecting adequate microbial strains in fermentation processes
- Their research used Halomonas boliviensis in fermentations for the bioconversion of bakery hydrolysate into PHB (see Figure in next slide).
- This microorganism is a moderate halophilic and alkali tolerant bacterium that can produce PHB through fermentative processes under aerobic condition

Bakery Waste

Biorefinery concept for the fermentative succinic acid production from bakery waste (Lin et al., 2013)
Betty (2011) reported that:

- Fish waste, such as salmon fish by-products, can be valorised for nutritional lipids.
- Using enzymatic hydrolysis (lipase) to extract the oils.