Industry 4.0: Fusing digital, physical & biological

"The fourth industrial revolution is not only about the smart and connected machines and systems. Its scope is much wider. Occurring simultaneously are waves of further breakthroughs in areas ranging from gene sequencing to nanotechnology, from renewables to quantum computing. It is in the fusion of these technologies and their interaction across the physics, digital and biological domains that make the fourth industrial revolution fundamentally different from previous revolutions." Klaus Schwab, founder and Executive Chairman of the World Economic Forum

I think the biggest innovations of the 21st century will be at the intersection of biology and technology. A new era is beginning." -Steve Jobs (2011)

Enzyme meet Industry: Hydrolase and Oxidoreductase Application

- Collagenase which produced by bacteria isolated in slaughterhouse based on collagen waste
- Lipase which produced by thermophilic bacteria with intestinal cattle fat as a substrate
- Laccase produced in a highly temperature
- Chitin deacetylase produced with crab shell as substrate and useful for molecular modification of polymer like chitin
- Cellulase useful for molecular modification starch based materials
- Keratinase have function to molecular modification several feather based keratin
Meat softness test

21% tenderized meat in 15 min by collagenase treatment at room temperature

Aplikasi Enzim Pada Substrat

Enzymatic production of chitosan

Biological Process
Chitin Deacetylase
EC 3.5.1.41

Chemical Process
Degradasi Polimer ACAK

Degree of deacetylation by different source of chitin deacetylase

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Glucosamine standard (uM)</th>
<th>Reaction at 50°C for 60 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>219</td>
<td>585</td>
</tr>
<tr>
<td>Degree of deacetylation (%)</td>
<td>454</td>
<td>483</td>
</tr>
<tr>
<td></td>
<td>533</td>
<td></td>
</tr>
</tbody>
</table>

Synowiecki et al., (2003), degree of deacetylation of chitin more than 50% has transformed become chitosan

FTIR spectra of enzymatic chitosan

Problems:
- physico-chemical heterogeneity
- low reactivity
- low dispersion properties
- immiscibility

Lignin

Only 2% used commercially
**Monitoring reduction of TMAMQ and formation syringaldazine**

![Graphs showing the reduction of TMAMQ and formation of syringaldazine over time.](image)

<table>
<thead>
<tr>
<th>Antioxidant</th>
<th>Reduced TMAMQ (µM)</th>
<th>Formed syringaldazine (µM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha Tocopherol</td>
<td>3.99 ± 0.07</td>
<td>4.96 ± 0.9</td>
</tr>
<tr>
<td>Gamma Tocopherol</td>
<td>1.58 ± 0.04</td>
<td>1.16 ± 0.05</td>
</tr>
<tr>
<td>Tocotrienol</td>
<td>4.75 ± 0.04</td>
<td>4.64 ± 0.05</td>
</tr>
<tr>
<td>Lutein</td>
<td>2.40 ± 0.02</td>
<td>2.02 ± 0.42</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>4.44 ± 0.03</td>
<td>4.50 ± 0.02</td>
</tr>
</tbody>
</table>

**Monitoring antioxidant capacity of human serum samples**

![Graph showing the antioxidant capacity of human serum samples over time.](image)

**Online HPLC and rapid test antioxidant activity**

![Diagram showing the setup for online HPLC and antioxidant activity testing.](image)

**Fabric antioxidant**

![Fabric samples treated with different antioxidants.](image)

Blind fabric samples to which flavonoids had been enzymatically grafted were able to quench TMAMQ by concentration rank of grafted flavonoids.

**Phenolics removal from Olive Oil Mill Waste (OMW) by CDH-Laccase combination treatment for biogas plant**

![Biogas plant and phenolics removal setup.](image)

Decrease in phenolics concentration

**Fabrics bleaching by CDH**

- Figure 3: Q1: amylase, bleaching with GDX + glucose.
- Q1: same procedure as C1; but half volume of buffer.
- K: standard scouring and bleaching with 35% H2O2.
- U: untreated cotton fabrics.
- K2: bleaching with 25% H2O2.
3 postdoc
2 PhD
3 Master
25 Bachelor

Thank you