Optimization of Biomass Pretreatment using Response Surface Method

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Presentation Outline

1. Background and Problem Statement
2. Response Surface Method and Results
3. Conclusion
Four key drivers to participate in Malaysia biomass industry, especially in the bio-chemical space

1. Growth in bio-based platform chemical is forecasted at a CAGR of ~8.7% until 2021

   ![Graph showing growth in bio-based platform chemicals](image)

   Revenue USD billion
   
   2017: 4.78
   2018: 5.29
   2019: 5.87
   2020: 6.52
   2021: 7.24

   Bio-based platform chemicals provide alternative and green feedstock for the fast growing chemical segment

2. Large availability of oil palm-based biomass waste across Malaysia present business opportunity

   ![Oil palm waste diagram](image)

   - 21 Major biomass resource
   - 18 Biomass waste
   - 13 Agricultural waste
   - 78 mtpa 80% total biomass waste

   This will also support Malaysia bio-economy agenda and “go-green” efforts

3. Diversification to petrochemical industry

   ![Petrochemical industry diagram](image)

   Commercialisation status (non-exhaustive)

   - Commercialized
     - Acetic Acid
     - Iso-Butanol
     - Ethylene
     - Ethylene glycol
   - Demonstration
     - n-butanol
   - Pilot
     - P-xylene

   Leverage on existing knowhow in petchem business

   - Capability
   - Customer/market
   - Supply chain
   - Technology

4. This will also support Malaysia bio-economy agenda and “go-green” efforts

   ![Policy/Program and Objective table](image)

<table>
<thead>
<tr>
<th>Policy/Program</th>
<th>Objective</th>
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<tbody>
<tr>
<td><strong>BIOECONOMY TRANSFORMATION PROGRAMME</strong></td>
<td>Promotes a knowledge-based bio-economy</td>
</tr>
<tr>
<td><strong>NBS2020</strong></td>
<td>Creates RM 30 billion in additional GNI, 66,000 high value jobs and 12% reduction in carbon emissions</td>
</tr>
<tr>
<td><strong>MALAYSIAN BIOMASS INDUSTRY ACTION PLAN 2020</strong></td>
<td>Mobilise participation of Malaysian SMEs and position biomass industry towards high value creation</td>
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Background: Why do we need to remove lignin from empty fruit bunch (EFB) prior to hydrogenolysis?

- To increase the accessible surface area of the cellulose and hemicellulose
- Base-catalyzed delignification (BCD) or alkaline wash delignification is proven to be a cost effective pretreatment
- The important parameters for BCD include the base concentration, temperatures, duration and size of the EFB fibers
- Lignin content of untreated empty fruit bunch (EFB) can range between 24 wt.% to 31 wt.%

Utilizing RSM (Box-Behnken) method as DoE, 17 runs of biomass EFB pretreatment including 5 center points were carried out to investigate the effects of 3 factors on lignin content, which is analyzed by methods of NREL and Van Soest.

Box-Behnken was chosen over CCD because the design of a CCD model that has axial points outside the box will cause too extreme conditions for the pretreatment purpose; i.e. high temperature and high base concentration.

A – Base Concentration: 0.5 wt% to 3.0 wt%
B – Temperature: 373K to 423K
C – Duration: 60min to 120min

Design Expert ® helped to carry out ANOVA showing that the main factors of Base Concentration and Duration to be significant for delignification, plus the factor interaction between Temperature-Base Concentration.

Since the overall model is significant and the LoF is not significant, the way forward is to move within the fitted model and the contour plots produced.
Pretreatment strategy is to maximize the cellulose-rich material while minimizing lignin content using alkali wash. The model was developed and confirmed that lignin content can be reduced from 26 wt.% to < 12.0 wt.%

Optimized Conditions: 1.75 wt.% NaOH, 150 °C (423K) and 90 minutes
Quality Control Study of the Pretreated EFB indicates good reproducibility & repeatability for the predictive model based on random sampling.

Summary:
1. Random samples were made over 15 times from 40 kg of cellulose rich materials (pretreated biomass) indicates good reproducibility and repeatability with standard deviation of 0.67 (lignin) and 3.20 (cellulose).

Note: Virgin materials have 26% lignin, 39.5% cellulose and remaining is hemicellulose.
Conclusion

• Biomass EFB pretreatment using low base concentration is a cost effective process that could lower the lignin content prior to conversion to chemicals.

• Response Surface Method (RSM) helped to ascertain the significant parameters for biomass base wash pretreatment i.e. temperature, base concentration and duration.

• Design Expert is an excellent tool to develop a predictive model for the lignin content of the pretreated biomass.

For further reading: Biomass Conv. Bioref. DOI 10.1007/s13399-017-0246-x

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Questions?
Thank you