

## **BAB V**

### **KESIMPULAN DAN SARAN**

#### **5.1. Kesimpulan**

Kesimpulan yang didapat dari penelitian ini adalah:

1. TKKS dengan perlakuan awal secara kimiawi mampu memberikan persentase rendemen furfural yang lebih tinggi dibandingkan tanpa perlakuan awal secara kimiawi.
2. Perolehan persentase rendemen furfural tertinggi pada penelitian ini menggunakan TKKS dengan perlakuan awal, konsentrasi asam sulfat menengah, waktu reaksi menengah, dan temperatur reaksi tertinggi.

#### **5.2. Saran**

Saran yang dapat diberikan pada penelitian lebih lanjut adalah sebagai berikut:

1. Perlu adanya penambahan variasi perlakuan awal secara kimia dengan kondisi operasi yang lebih rendah.
2. Perlu adanya penambahan variasi run utama hidrolisis lebih banyak dengan rentang yang pendek sehingga dapat diketahui titik optimum dan perubahan senyawa kimia yang terjadi.
3. Perlu adanya analisa awal terhadap TKKS dalam hal sumber, umur, dan kandungan awal TKKS.
4. Perlu adanya pembuatan *modelling* untuk kinetika laju reaksi.
5. Perlu adanya analisa kandungan kimia sampel larutan lebih lengkap.

## DAFTAR PUSTAKA

1. Ace. (2012). *Pembuatan furfural dari tongkol jagung : Hubungan antara suhu dan waktu proses hidrolisis terhadap yield.* 140.
2. Amborowati, C., Adriani, U., Aditya, I. L., Feviyasari, H., Hastin, T. K., & Adhiksan, A. (2016). *Pengaruh Waktu dan Temperatur Hidrolisis dari Sekam Padi Dengan Menggunakan Metode Hidrolisis dan Dehidrasi.* 2(2), 72–77.
3. Andaka, G. (2011). Hidrolisis Ampas Tebu Menjadi Furfural dengan Katalisator Asam Sulfat. *Jurnal Teknologi*, 4(2), 180–188.
4. Aniriani, G. W., Apriliani, N. F., & Sulistiono, E. (2018). *Hydrolysis of Polycoxarida Xylane Straw Using Strong Acid Acid Solution for Basic Materials of Bioetanol Production.* 1–5.
5. Badiei, M., Asim, N., Jahim, J. M., & Sopian, K. (2014). Comparison of Chemical Pretreatment Methods for Cellulosic Biomass. *APCBEE Procedia*, 9(December), 170–174. <https://doi.org/10.1016/j.apcbee.2014.01.030>
6. Baruah, J., Nath, B. K., Sharma, R., Kumar, S., Deka, R. C., Baruah, D. C., & Kalita, E. (2018). Recent trends in the pretreatment of lignocellulosic biomass for value-added products. *Frontiers in Energy Research*, 6(DEC), 1–19. <https://doi.org/10.3389/fenrg.2018.00141>
7. Beukes, N., & Pletschke, B. I. (2011). Effect of alkaline pre-treatment on enzyme synergy for efficient hemicellulose hydrolysis in sugarcane bagasse. *Bioresource Technology*, 102(8), 5207–5213. <https://doi.org/10.1016/j.biortech.2011.01.090>
8. Bittar, K. (2012). *Cellulose*.
9. Brown M. (2015). Cellulosa: molecular and Structural Biology. In *The effects of brief mindfulness intervention on acute pain experience: An examination of individual difference* (Vol. 1). <https://doi.org/10.1017/CBO9781107415324.004>
10. Cai, C. M., Zhang, T., Kumar, R., & Wyman, C. E. (2014). Integrated furfural production as a renewable fuel and chemical platform from lignocellulosic biomass. *Journal of Chemical Technology and Biotechnology*, 89(1), 2–10. <https://doi.org/10.1002/jctb.4168>
11. Cheng, Y. S., Zheng, Y., Yu, C. W., Dooley, T. M., Jenkins, B. M., & Vandergheynst, J. S. (2010). Evaluation of high solids alkaline pretreatment of rice straw. *Applied Biochemistry and Biotechnology*, 162(6), 1768–1784.
12. Cheng, W., (2009). *Rhizosphere Priming Effect: Its Functional Relationships with Microbial Turnover, Evapotranspiration, and C-N Budgets.* *Soil Biology and Biochemistry*, 41(9), 1795-1801.

13. Choi, W. Il, Park, J. Y., Lee, J. P., Oh, Y. K., Park, Y. C., Kim, J. S., Park, J. M., Kim, C. H., & Lee, J. S. (2013). Optimization of NaOH-catalyzed steam pretreatment of empty fruit bunch. *Biotechnology for Biofuels*, 6(1), 2–9. <https://doi.org/10.1186/1754-6834-6-170>
14. Coniwanti, P., H, G. S., & Handayani, E. (2016). *Pembuatan Furfural Dari Campuran Biomassa Ampas Tebu ( Saccharum Officinarum)*. 22(2), 37–45.
15. Dalessandro, Ellen; Pliego Jr., Josefredo (2017). *Fast Screening of Solvents for Simultaneous Extraction of Furfural, 5-Hydroxymethylfurfural and Levulinic Acid from Aqueous Solution Using SMD Solvation Free Energies*. *Journal of the Brazilian Chemical Society*, (), -. doi:10.21577/0103-5053.20170140
16. Demirbas, A. (2008). Products from lignocellulosic materials via degradation processes. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, 30(1), 27–37. <https://doi.org/10.1080/00908310600626705>
17. Departemen, P. (2006). *Pedoman Pengelolaan Limbah Industri Kelapa Sawit*.
18. Ditjenbun. (2018). Statistik Perkebunan Indonesia Komoditas Kelapa Sawit 2017–2019. *Kementerian Pertanian*, 81.
19. Dunlop, A. P. (1948). *Furfural Formation and Behavior*. *Industrial & Engineering Chemistry*, 40(2), 204–209. doi:10.1021/ie50458a006
20. Erkman, Osman., Bozoglu, T. Faruk. (2016). *FOOD MICROBIOLOGY: Principles into Practice. Volume I: Microorganisms Related to Foods, Foodborne Diseases, and Food Spoilage*. NJ: John Wiley & Sons, Inc.
21. Gonzales, R. R., Sivagurunathan, P., & Kim, S. H. (2016). Effect of severity on dilute acid pretreatment of lignocellulosic biomass and the following hydrogen fermentation. *International Journal of Hydrogen Energy*, 41(46), 21678–21684. <https://doi.org/10.1016/j.ijhydene.2016.06.198>
22. Groenewoud, W.M. (2001). *THERMOGRAVIMETRY: Characterisation of Polymers by Thermal Analysis*, 61–76.
23. Hague, & Utrecht. (2019). *Call for proposals Value from Biomass*. February.
24. Hansen, T. S.; Mielby, J.; Riisager, A. Synergy of boric acid and added salts in the catalytic dehydration of hexoses to 5-hydroxymethylfurfural in water. *Green Chem.* **2011**, 13, 109–114, DOI: 10.1039/C0GC00355G
25. Harmaja Simatupang, Andi Nata, & Netti Herlina. (2012). Studi Isolasi Dan Rendemen Lignin Dari Tandan Kosong Kelapa Sawit (Tkks). *Jurnal Teknik Kimia USU*, 1(1), 20–24. <https://doi.org/10.32734/jtk.v1i1.1401>
26. Hasbullah. (2017). *Energi Biomassa, Biogas & Biofuel*.
27. Kenneth R. Heimlich; Alfred N. Martin (1960). *A kinetic study of glucose degradation in acid solution*. , 49(9), 592–597. doi:10.1002/jps.3030490909
28. Holtzapple, M. T., Torget, R., Davison, B. H., Wyman, C. E., & Finkelstein, M. (1996). *Biotechnology for Fuels and Chemicals*.
29. Ioelovich, M., & Morag, E. (2012). Study of enzymatic hydrolysis of mild pretreated lignocellulosic biomasses. *BioResources*, 7(1), 1040–1052.

- <https://doi.org/10.15376/biores.7.1.1040-1052>
30. Iriadi, Y. L., Amraini, S. Z., & Evelyn. (2019). *Produksi Furfural dari Tandan Kosong Sawit dengan Berbagai Perlakuan Awal*. 6, 2–7.
  31. João RM Almeida; Tobias Modig; Anneli Petersson; Bärbel Hähn-Hägerdal; Gunnar Lidén; Marie F Gorwa-Grauslund (2007). Increased tolerance and conversion of inhibitors in lignocellulosic hydrolysates by *Saccharomyces cerevisiae*. , 82(4), 340–349. doi:10.1002/jctb.1676
  32. Juwita, R., Syarif, L. R., & Tuhaloula, A. (2012). Pengaruh Jenis dan Konsentrasi Katalisator Asam terhadap Sintesis Furfural dari Sekam Padi. *Konversi*, 1(1), 34–38. <https://doi.org/10.20527/k.v1i1.113>
  33. Kim, T. H., Kim, J. S., Sunwoo, C., & Lee, Y. Y. (2003). Pretreatment of corn stover by aqueous ammonia. *Bioresource Technology*, 90(1), 39–47. [https://doi.org/10.1016/S0960-8524\(03\)00097-X](https://doi.org/10.1016/S0960-8524(03)00097-X)
  34. Kirk, & Othmer. (1994). Encyclopedia of Chemical Technology. In *Kirk-Othmer Encyclopedia of Chemical Technology* (Vol. 10, pp. 479–480).
  35. Kurniasih, E., Helmi, & Indraningsih, U. (2012). *Furfural Berbasis Tandan Kosong Kelapa Sawit*. 10(2), 40–45.
  36. Kusyanto, K., & Rahmadina, S. (2019). The Effect of H<sub>2</sub>SO<sub>4</sub> Concentration and Micro Wave Power in Microwave Assisted Hydrolysis of Furfural Production from Empty Palm Fruit Bunches. *Jurnal Bahan Alam Terbarukan*, 8(1), 72–76. <https://doi.org/10.15294/jbat.v8i1.15425>
  37. Lapierre, C. (2010). *Lignin and Lignans Advances in Chemistry*. <https://doi.org/10.1201/ebk1574444865-c2>
  38. Listiani, N., Iryani, D. A., & Rustamaji, H. (2016). Hidrolisis Ampas Tebu dengan Katalisator Asam Asetat untuk Memproduksi Furfural menggunakan Metode Steam Stripping. *Jurnal Rekayasa Kimia & Lingkungan*, 11(2), 53. <https://doi.org/10.23955/rkl.v11i2.4983>
  39. Liu, Yong; Ma, Cajun; Huang, Chunxi; Fu, Yan; Chang, Jie (2018). *Efficient Conversion of Xylose into Furfural Using Sulfonic Acid-Functionalized Metal-Organic Frameworks in a Biphasic System*. *Industrial & Engineering Chemistry Research*, (), acs.iecr.8b04070-. doi:10.1021/acs.iecr.8b04070
  40. Luque, R., & Leung, F. (2018). *Sustainable Catalysis: Energy-Efficient Reactions and Applications*.
  41. Lynd, L. ., Marsili-Libelli, S., & Parisi, F. (1989). *Lignocellulosic Materials*. <https://doi.org/10.1007/bfb0007857>
  42. Marcotullio, G., & De Jong, W. (2010). Chloride ions enhance furfural formation from D-xylose in dilute aqueous acidic solutions. *Green Chemistry*, 12(10), 1739–1746. <https://doi.org/10.1039/b927424c>
  43. Mardina, P., Prathama, H. A., & Hayati, D. M. (2014). *Pengaruh waktu hidrolisis dan konsentrasi katalisator asam sulfat terhadap sintesis furfural dari jerami padi*. *Jurnal Konversi UNLAM*. <https://doi.org/10.20527/k.v3i2.158>

44. Mariana, F. L., Zulfansyah, & Fermi, M. I. (2010). *Delignifikasi Tandan Kosong Sawit Dalam Media Asam Formiat*. October. <https://doi.org/10.13140/RG.2.1.3979.1846>
45. Mathew, A. K., Abraham, A., Mallapureddy, K. K., & Sukumaran, R. K. (2018). Lignocellulosic Biorefinery Wastes, or Resources? In *Waste Biorefinery*. Elsevier B.V. <https://doi.org/10.1016/b978-0-444-63992-9.00009-4>
46. McMillan, J. D. (1994). *Pretreatment of Lignocellulosic Biomass*. 292–324. <https://doi.org/10.1021/bk-1994-0566.ch015>
47. Muslimah, H. H. (2017). *Alkali pretreatment tandan kosong kelapa sawit dengan microwave heating pada produksi bioetanol husna hanifatul muslimah*.
48. Najafpour, G. (2007). *Acid Hydrolysis of Pretreated Palm Oil Lignocellulosic Wate*.
49. Nurwahdah, Naini, A. A., Nadia, A., Lestari, R. Y., & Sunardi. (2015). Pretreatment Lignoselulosa dari Jerami Padi dengan Deep Eutectic Solvent untuk Meningkatkan Produksi Bioetanol Generasi Dua. *Jurnal Riset Industri Hasil Hutan*, 10(1), 43–54.
50. P, K., D.M, B., M.J, D., & P, S. (2009). Methods for pretreatment of lignocellulosic biomass for efficient hydrolysis and biofuel production. *Industrial and Engineering Chemistry Research*, 48(8), 3713–3729.
51. Panjaitan, J. R. H., Monica, S., & Gozan, M. (2017). Production of furfural from palm oil empty fruit bunches: Kinetic model comparation. *IOP Conference Series: Earth and Environmental Science*, 65(1). <https://doi.org/10.1088/1755-1315/65/1/012042>
52. Praputri, E., Sundari, E., Firdaus, F., & Sofyan, S. (2018). *Penggunaan katalis homogen dan heterogen pada proses hidrolisis pati umbi singkong karet menjadi glukosa The use of homogeneous and heterogeneous catalysts in hydrolysis process of rubber cassava starch into glucose*. 105–110. <https://doi.org/10.24960/jli.v8i2.4189.105-110>
53. Putra, A. S., Nakagawa-izumi, A., Kajiyama, M., & Ohi, H. (2018). Peer Reviewed Biorefinery of Oil Palm Empty Fruit Bunch by Nitric Acid Prehydrolysis Soda Cooking. Production of Furfural and Dissolving Pulp. *Japan Tappi Journal*, 72(6), 641–649. <https://doi.org/10.2524/jtappij.1701>
54. Pyo, Sang-Hyun; Glaser, Sara Jonsdottir; Rehnberg, Nicola; Hatti-Kaul, Rajni (2020). Clean Production of Levulinic Acid from Fructose and Glucose in Salt Water by Heterogeneous Catalytic Dehydration. *ACS Omega*, (), acsomega.9b04406-. doi:10.1021/acsomega.9b04406
55. Rahim, M., dan M. N. (2015). Optimasi Waktu Hidrolisis Tandan Kosong Kelapa Sawit Menjadi Furfural Berbantuan Gelombang Mikro. *Konversi*, 4(2), 12–15.
56. Raman, J. K., & Gnansounou, E. (2015). Furfural production from empty fruit bunch - A biorefinery approach. *Industrial Crops and Products*, 69, 371–377. <https://doi.org/10.1016/j.indcrop.2015.02.063>
57. Rentzelas, A. A. (2016). Biomass storage. In *Biomass Supply Chains for Bioenergy and Biorefining*. Elsevier Ltd. <https://doi.org/10.1016/B978-1-78242-366-9.00006->

## X

58. Rupaedah, B., Purwoko, D., Safarrida, A., Tajuddin, T., Wahid, A., Sugianto, M., Sudjai, I., & Suyono, A. (2019). Skrining Dan Identifikasi Mikroba Ligninolitik Pada Pengomposan Alami Tandan Kosong Kelapa Sawit. *Jurnal Bioteknologi & Biosains Indonesia (JBBI)*, 6(1), 139. <https://doi.org/10.29122/jbbi.v6i1.3237>
59. Sadrina, I. N., Harahap, A. F. P., Rahman, A. A., & Gozan, M. (2019). Effect of microwave assisted sodium hydroxide pretreatment on hemicellulose content of oil palm empty fruit bunch for furfural production. *IOP Conference Series: Materials Science and Engineering*, 673(1). <https://doi.org/10.1088/1757-899X/673/1/012008>
60. Sampepana, E., & Saputra, S. H. (2011). Hidrolisis Furfural Dari Tandan Kosong Sawit. *Riset Teknologi Industri*, 9(2), 149–156.
61. Santi, S. S. (2004). *Kinetika Reaksi Hidrolisis Enceng Gondok Menjadi Furfural Dengan Katalisator HCl*.
62. Setyadji, M. (2007). Hidrolisis pentosan menjadi furfural dengan katalisator asam sulfat untuk meningkatkan kualitas bahan bakar mesin diesel. *Prosiding PPI - PDIPTN*, 159–165.
63. Sluiter, A et.al. (2008). *Determination of Sugars, Byproducts, and Degradation Products in Liquid Fraction Process Samples*. NREL/TP-510-42623.
64. Sluiter, A et.al. (2012). *Determination of Structural Carbohydrates and Lignin in Biomass*. NREL/TP-510-42618.
65. Soetedjo, J. N. M. (2017). *Biobased Furanics From Sugars*.
66. Takkellapati, S., Li, T., & Gonzalez, M. A. (2018). An overview of biorefinery-derived platform chemicals from a cellulose and hemicellulose biorefinery. *Clean Technologies and Environmental Policy*, 20(7), 1615–1630. <https://doi.org/10.1007/s10098-018-1568-5>
67. Tan, L., Wang, M., Li, X., Li, H., Zhao, J., Qu, Y., Choo, Y. M., & Loh, S. K. (2016). Fractionation of oil palm empty fruit bunch by bisulfite pretreatment for the production of bioethanol and high value products. *Bioresource Technology*, 200, 572–578. <https://doi.org/10.1016/j.biortech.2015.10.079>
68. Tutt, M., Kikas, T., & Olt, J. (2012). Influence of different pretreatment methods on bioethanol production from wheat straw. *Agronomy Research*, 10(SPEC. ISS. 1), 269–276.
69. Wang, D. (1960). Structure and Properties of Hemicellulose. *Journal of Polymer Science*, 42(140), 580–581. <https://doi.org/10.1002/pol.1960.1204214027>
70. Yokoyama, S. (2008). Buku Panduan Biomassa Asia: Panduan untuk Produksi dan Pemanfaatan Biomassa. *The Japan Institute of Energy*.
71. Yong, T. L. K., Mohamad, N., & Yusof, N. N. M. (2016). Furfural Production from Oil Palm Biomass Using a Biomass-derived Supercritical Ethanol Solvent and Formic Acid Catalyst. *Procedia Engineering*, 148, 392–400. <https://doi.org/10.1016/j.proeng.2016.06.495>
72. Yusrin & Mukaromah, A. H. (2010). Proses Hidrolisis Dengan Variasi Asam Pada

- Pembuatan Ethanol. *Prosiding Seminar Nasional UNIMUS*, 20–25.
73. Zeitsch, K. . (2000). *The Chemistry and Technology of Furfural and Its Many By-Products*.
74. Zhao, X., Cheng, K., & Liu, D. (2009). Organosolv pretreatment of lignocellulosic biomass for enzymatic hydrolysis. *Applied Microbiology and Biotechnology*, 82(5), 815–827. <https://doi.org/10.1007/s00253-009-1883-1>