# Supplementary Data

**Bioconversion of Food and Lignocellulosic Wastes employing Sugar Platform: A review of enzymatic hydrolysis and kinetics**

Raffel Dharma Patriaa,1, Shazia Rehmana,1, Arun K. Vuppaladadiyama,1, Huaimin Wanga, Carol Sze Ki Linb, Elsa Antunesc, and Shao-Yuan Leua,d,e\*

a Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong

b School of Energy and Environment, City University of Hong Kong, Hong Kong

c College of Science and Engineering, James Cook University, Australia

c Research Institute for Future Food, The Hong Kong Polytechnic University, Hong Kong

d Research Institute for Smart Energy, The Hong Kong Polytechnic University, Hong Kong

\* Corresponding authors: S.-Y. Leu [syleu@polyu.edu.hk](mailto:syleu@polyu.edu.hk) (Tel: +852-3400-8322)

1 Equal contributions as first authors.

**Table S1**. Effects of enzyme dosage and hydrolysis time on hydrolysis efficiency of various substrates of FW and LCB

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No | Subs-tratea | Initial subs-trate (g/L) | Composition | | | | Enzymatic hydrolysis conditions | Time (h) | Enzyme dosagebc | Concentration (g/L) | | | Hydrolysis efficiencyde | Reference |
| Starch | Cellu-lose | Hemi- cellu-lose | Lignin | Glucose | Xylose | Total RS |
| 1 | NP-FW | 100 | 62.70% | 5.90% | - | - | Amylase from FM, 50⁰C, 10 h, 200 rpm | 10 | 21.53 | 70.2 | - | 70.2 | 92.10% | Ma et al. (2017) |
| 2 | NP-FW | 100 | 62.70% | 5.90% | - | - | Glucoamylase, 50⁰C, 10 h, 200 rpm | 10 | 21.53 | 65.8 | - | 65.8 | 86.33% | Ma et al. (2017) |
| 3 | NP-FW | N/A | 54.30% | N/A | - | - | Amylase from FM, 60⁰C, 12 h, 100 rpm | 12 | 18.42 | 87.7 | - | 87.7 | 92.50% | Kiran et al. (2015) |
| 4 | NP-FW | N/A | 54.30% | N/A | - | - | Glucoamylase, 60⁰C, 12 h, 100 rpm | 12 | 18.42 | 74.3 | - | 74.3 | 80.00% | Kiran et al. (2015) |
| 5 | NP-FWa | 200 | 6.09% | 9.45% | 11.91% | - | Amylase NS22109, 65⁰C, 1 h, 150 rpm | 1 | 0.00 | 0.00 f | - | 0 | 0.00% | Salimi et al. (2019) |
| 1 | 36.38 | 5.15 f | - | 5.15 | 38.05% |
| 1 | 72.75 | 6.96 f | - | 6.96 | 51.43% |
| 1 | 109.13 | 8.90 f | - | 8.9 | 65.76% |
| 1 | 145.50 | 10.61 f | - | 10.61 | 78.40% |
| Cellulase NS22177, 50⁰C, 5 h, 150 rpm | 5 | 0.00 | 0.00 f | - | 0 | 0.00% |
| 5 | 20.43 | 1.99 f | - | 1.99 | 4.19% |
| 5 | 29.51 | 6.20 f | - | 6.2 | 13.06% |
| 5 | 63.56 | 8.76 f | - | 8.76 | 18.46% |
| 5 | 127.12 | 9.93 f | - | 9.93 | 20.92% |
| 5 | 188.41 | 11.00 f | - | 11 | 23.17% |
| 5 | 254.24 | 12.79 f | - | 12.79 | 26.95% |
| 6 | NP-SH | N/A | - | 43.80% | 40.40% | 10.80% | Cellulase from FM, 50⁰C, 48 h, 110 rpm, pH 4.8 | 48 | 5 | N/A | N/A | N/A | 11.01% | Waghmare et al. (2018) |
| 7 | NaOH-CS | 100 | - | 63.90% | 15.00% | 9.00% | Cellulase from FM, 50⁰C, 48 h, 140 rpm, pH 4.8 | 48 | 25 | 57.90 | 13.50 | 71.40 | 81.50% | Zhao et al. (2018) |
| 8 | NaOH-CS | 100 | - | 63.90% | 15.00% | 9.00% | Cellulase, 50⁰C, 48 h, 140 rpm, pH 4.8 | 48 | 25 | N/A | N/A | N/A | 54.30% | Zhao et al. (2018) |
| 9 | NaOH-RS | 100 | - | 60.00% | 12.10% | 9.50% | Cellulase from FM, 50⁰C, 48 h, 140 rpm, pH 4.8 | 48 | 25 | 46.10 | 10.40 | 56.50 | 70.50% | Zhao et al. (2018) |
| 10 | NaOH-RS | 100 | - | 60.00% | 12.10% | 9.50% | Cellulase, 50⁰C, 48 h, 140 rpm, pH 4.8 | 48 | 25 | N/A | N/A | N/A | 47.50% | Zhao et al. (2018) |
| 11 | SE-CS | 100 | - | 52.50% | 7.20% | 22.80% | Cellulase from FM, 50⁰C, 48 h, 140 rpm, pH 4.8 | 48 | 25 | 50.84 | 6.65 | 57.49 | 86.67% | Zhao et al. (2017) |
| 12 | SE-CS | 300 | - | 52.50% | 7.20% | 22.80% | Cellulase from FM, 50⁰C, 48 h, 140 rpm, pH 4.8 | 72 | 30 | 108.65 | 17.42 | 126.07 | 63.35% | Zhao et al. (2017) |
| 13 | A-SB | 100 | - | 52.20% | 22.80% | 4.50% | Cellulase and crude β-xylosidase, 50⁰C, 24 h, pH 4.8 | 24 | 15.33 | 25.58 | 21.95 | 47.53 | 57.04% | Patel et al. (2017) |
| 14 | A-CS | 180 | - | 31.60% | 17.80% | N/A | Cellulase and xylanase, 50⁰C, 72 h, 250 rpm, pH 4.8 | 72 | 55.10 | 65.8 | 22.9 | 88.70 | 89.78% | Li et al. (2019) |
| 15 | DL-CS | 180 | - | 27.20% | 12.70% | N/A | Cellulase and xylanase, 50⁰C, 72 h, 250 rpm, pH 4.8 | 72 | 55.10 | 47.7 | 28.3 | 76.00 | 95.24% | Li et al. (2019) |

a Abbreviation: NP-FW = No pretreatment, food waste; NP-SH = No pretreatment, sorghum husk; NaOH-CS = NaOH pretreatment, corn stover; NaOH-RS = NaOH pretreatment rice straw; SE-CS = steam explosion pretreatment, corn stover; A-SB = Ammonia pretreatment, sugarcane bagasse; A-CS = Ammonia pretreatment, corn stover; DL-CS = dilute acid pretreatment, corn stover

b Unit of enzyme dosage for amylase = U/g-starch

c Unit of enzyme dosage for cellulase = FPU/g-cellulose

d Unless specified in the paper, hydrolysis efficiency when using amylase as enzyme = (g-RS/g-starch) x 0.9 x 100%

e Unless specified in the paper, hydrolysis efficiency when using cellulase as enzyme = (g-RS/g-cellulose+hemicellulose) x 0.9 x 100%

f Subtracted from control experiment (without enzyme)

**Table S2**. Enzymatic hydrolysis application in AD for various FW and LCB substrates

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No | Substrate | Enzymatic hydrolysis conditions | AD conditions | Yielda (mL CH4/g-VS) | Productivitya (mL CH4/g-VS/day) | Reference |
| 1 | FW | 10 U/g-dry FW of GA, 60⁰C, 100 rpm, 24 h | Mesophilic batch, 35⁰C, 150 rpm, 13 days | 457.3 *(197.9)* | 35.2 *(15.2)* | Kiran et al. (2015) |
| 10 U/g-dry FW of glucoamylase from FM, 60⁰C, 100 rpm, 24 h | Mesophilic batch, 35⁰C, 150 rpm, 13 days | 468.2 *(197.9)* | 36.0 *(15.2)* |
| 2 | FW rich in lipids | 0.5% (w/v) Lipase (Lip), pH 7.5, 40⁰C, 24 h | Mesophilic batch, 35⁰C, 50 days | 500.1 *(497.5)* | 10.0 *(9.95)* | Meng et al. (2015) |
| 3 | Corn stover (CS) | Cellulase (Cell) 1.0% g-TS/g-TS, 55⁰C, 18h | Mesophilic batch, 37⁰C, 30 days | 277.6 *(217.0)* | 9.3 *(7.2)* | Wang et al. (2020) |
| Amylase (Amyl) 0.6% g-TS/g-TS, 38⁰C, 18h | Mesophilic batch, 37⁰C, 30 days | 242.4 *(217.0)* | 8.1 *(7.2)* |
| 4 | Corn stover | 2 U/g-biomass laccase (LA), 30⁰C, 24 h | Batch, 30 days | 344 *(277)* | 11.5 *(9.2)* | Schroyen et al. (2014) |
| 5 U/g-biomass manganese peroxidase and 1.5 U/g-biomass versatile peroxidase (P), 30⁰C, 6 h | 309 *(263)* | 10.3 *(8.8)* |
| 5 | Corn stover | 2 U/g-biomass laccase and 1.5 U/g-biomass versatile peroxidase (LA+P), 30⁰C, 6 h | Batch, 30 days | 238.4 *(191.7)* | 7.9 *(6.4)* | Schroyen et al. (2015) |
| Wheat straw (WS) | 250.5 *(223.0)* | 8.4 *(7.4)* |
| Hemp (HE) | 241.0 *(184.1)* | 8.0 *(6.1)* |
| Ensilaged maize | 354.8 *(393.3)* | 11.8 *(13.1)* |
| Flax (FL) | 2 U/g-biomass laccase and 1.5 U/g-biomass versatile peroxidase (LA+P), 30⁰C, 24 h | 244.1 *(214.9)* | 8.1 *(7.2)* |
| Miscanthus (M) | 141.7 *(129.4)* | 4.7 *(4.3)* |
| Willow (W) | 97.2 *(82.7)* | 3.2 *(2.8)* |
| 6 | Corn cob (CC) | 0.2 U/g-dry-substrate of feruloyl esterase (FE), 40⁰C, pH 6.0, 150 rpm, 3 h | Mesophilic batch, 35⁰C, 150 rpm, 37 days | 291.4 *(254.2)* | 7.9 *(6.9)* | Pérez-Rodríguez et al. (2016) |
| Vine trimming shoots (VTS) | Mesophilic batch, 35⁰C, 150 rpm, 37 days | 206.4 *(129.2)* | 5.6 *(3.5)* |
| 7 | Switch grass (SG) | 1 U/mL lignin peroxidase (LiP), 22⁰C, pH 4.5, 150 rpm, 8 h | Mesophilic batch, 35⁰C, 150 rpm, 134 days | 202.1 *(157.0)* | 1.5 *(1.2)* | Frigon et al. (2012) |
| 2 U/mL manganese peroxidase (MnP), 37⁰C, pH 4.5, 150 rpm, 8 h | Mesophilic batch, 35⁰C, 150 rpm, 134 days | 222.9 *(157.0)* | 1.7 *(1.2)* |
| 50 U/g-VS poly-galacturonase (PG), 25⁰C, pH 5.0, overnight | Mesophilic batch, 35⁰C, 150 rpm, 78 days | 239.5 *(139.1)* | 3.1 *(1.8)* |
| 2525 U/g-VS pectate-lyase (PL), 25⁰C, pH 5.0, overnight | Mesophilic batch, 35⁰C, 150 rpm, 78 days | 279.2 *(205.1)* | 3.6 *(2.6)* |

a Number in bracket indicates control experiment (without enzymatic hydrolysis)

**Table S3**. Effect of enzymatic hydrolysis on fermentation of various FW and LCB substrates

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No | Subs-tratea | Starch | Cellu-lose | Hemi- cellu-lose | Enzymatic hydrolysis condition | Glucose (g/L) | Xylose (g/L) | Total RS (g/L) | Hydrolysis yieldbc | Fermentation conditions | Max ethanol (g/L) | Ethanol yieldde | Reference |
| 1 | NP-FW | 62.70% | 5.90% | - | Amylase from FM*,* 200 g/L substrate, 50⁰C, 5% (w/w dry mass of fungal mash per FW), 24 h | 141.5 | - | 141.50 | 93.15% | Batch, 141.5 g/L initial glucose, *Z. mobilis*, 10% (v/v) inoculum loading, 200 rpm, 0.2 L/min aeration, 30⁰C, pH 6, 30 h | 64.90 | 34.99% | Ma et al. (2017) |
| 2 | NP-FW | 30.89% | 12.01% | 5.58% | Cellulase 60 FPU/g-cellulose and GA 60 FPU/g-starch, 300 g/L substrate, GA at 65⁰C for 0.5 h + Cellulase at 50⁰C for 6 h | N/A | N/A | 115.51 | 80.77% | Batch, *S. cerevisiae*, 250-mL shake flasks, 30⁰C, pH 5.0, 80 rpm | 42.74 | 34.29% | Loizidou et al. (2017) |
| 3 | NP-FW | 60.78% | 1.67% | - | GA, 85 U/mL, 60⁰C, 100 rpm, 6 h | N/A | N/A | 103.40 | 78.18% | Batch, *S. cerevisiae,* 10% (v/v) inoculum, 25 g/L RS, 120 rpm, 30⁰C, pH 7, 24 h | 10.92 | 38.01% | Hafid et al. (2017) |
| 4 | NP-FW | N/A | N/A | - | α-amylase (Sigma Aldrich), 100 g/L substrate, 60⁰C, 5% g-enzyme/g-dry food waste, 150 rpm, 9 h | N/A | N/A | 50.00 | N/A | Batch, 50 g/L initial RS, *S. cerevisiae*, 10% (v/v) inoculum loading, 150 rpm, 35⁰C, pH 5.5, 120 h | 24.77 | N/A | Jarunglumlert et al. (2021) |
| 5 | Dried and milled FW | 37.50% | 14.80% | - | Cellulase 265 FPU/g-cellulose, α-amylase 61 FPU/g-starch, and GA 31 FPU/g-starch, 100 g/L substrate, 50⁰C, pH 4.8, 150 rpm, 24 h | N/A | N/A | 42.50 | 86.89% | Batch, 50 g/L initial RS, *P. anomala* strain X19, 5% (v/v) inoculum loading, 150 rpm, 30⁰C, pH 4.7, 120 h | 15.41 | 42.00% | Ntaikou et al. (2021) |
| 6 | DA-CS | - | 27.20% | 12.70% | Cellulase 55.1 FPU/g-glucan and Xylanase 48000 U/g-glucan, 180 g/L substrate, pH 4.8, 50°C, 250 rpm, 72 h | 47.7 | 28.3 | 76.00 | 95.24% | Batch, *Z. mobilis* 8b*,* initial OD600 after inoculation is 8, 150 rpm, 30⁰C, pH 5.8, 24 h | 35.10 | 48.87% | Li et al. (2019) |
| A-CS | - | 31.60% | 17.80% | Same conditions as above | 65.8 | 22.9 | 88.70 | 89.78% | Same conditions as above | 35.70 | 40.15% |
| 7 | NP-SH | - | 43.80% | 40.40% | Cellulase from FM, 5 FPU/g crude cellulase dosage, 50⁰C, pH 4.8, 110 rpm, 48 h | N/A | N/A | 0.103 g-RS/g- substrate | 11.01% | Batch, *S. cerevisiae* and *P. tannophilus* (1:1, v/v)*,* 5% (v/v) inoculum loading, 50 g/L RS, 30⁰C, 48 h | 23.48 | 5.94% | Waghmare et al. (2018) |
| 8 | DA-M | - | 88.60% | 7.90% | Cellulase, 90 g/L initial substrate, 46⁰C, pH 4.8, 150 rpm, 72 h | N/A | N/A | 65.40 | 67.77% | Batch, *S. cerevisiae,* 28⁰C, pH 4.7, 72 h | 30.00 | 15.85% | Skiba et al. (2016) |
| DA-OH | - | 79.20% | 9.20% | N/A | N/A | 73.30 | 82.92% | 28.00 | 14.48% |
| 9 | A-SB | - | 52.20% | 22.80% | Cellulase 8 FPU/g and crude β-xylosidase 23 U/g, 100 g/L initial substrate, 50⁰C, pH 4.8, 24 h | 25.58 | 21.95 | 47.53 | 68.47% | Batch, *S. cerevisiae,* 10% (v/v) inoculum, 30⁰C, 24 h | 10.50 | 14.00% | Patel et al. (2017) |
| 25.58 | 21.95 | 47.53 | 68.47% | Batch, *S. cerevisiae* and *P. stipistis,* 10% (v/v) inoculum, 30⁰C, 24 h | 14.59 | 19.45% |
| 10 | NaOH-CS | - | 63.90% | 15.00% | Cellulase from FM, 25 FPIU/g glucan, 100 g/L substrate, 50⁰C, 48 h, 140 rpm, pH 4.8 | 57.9 | 13.5 | 71.40 | 81.50% | Batch, *S. cerevisiae,* 30⁰C, 150 rpm, 9 h | 27.6 | 31.50% | Zhao et al. (2018) |
| Batch, *P. stipistis*, 30⁰C, 150 rpm, 24 h | 31.5 | 35.96% |
| NaOH-RS | - | 60.00% | 12.10% | 46.1 | 10.4 | 56.50 | 70.50% | Batch, *S. cerevisiae,* 30⁰C, 150 rpm, 6 h | 20.5 | 25.58% |
| Batch, *P. stipistis*, 30⁰C, 150 rpm, 18 h | 23 | 28.70% |
| 11 | SE-CS | - | 52.50% | 7.20% | Cellulase from FM, 25 FPU/g glucan, 100 g/L substrate, 50⁰C, 48 h, 140 rpm, pH 4.8 | 50.84 | 6.65 | 57.49 | 86.67% | Batch, *S. cerevisiae,* 30⁰C, 150 rpm, 6 h | 24.45 | 36.86% | Zhao et al. (2017) |
| Same conditions as above, except with 30 FPU/g glucan, 300 g/L substrate, 72 h | 108.65 | 17.42 | 126.07 | 63.35% | Batch, *S. cerevisiae*, 30⁰C, 150 rpm, 12 h | 51.17 | 25.71% |

a Abbreviation: DA-CS = Dilute acid pretreatment, corn stover; DA-M = dilute acid pretreatment, miscanthus; DA-OH = dilute acid pretreatment, oat husks

b Unless specified in the paper, Hydrolysis efficiency when using amylase as enzyme = (g-RS/g-starch) x 0.9 x 100%

c Unless specified in the paper, Hydrolysis efficiency when using cellulase as enzyme = (g-RS/g-cellulose+hemicellulose) x 0.9 x 100%

d Fermentation yield when using amylase as enzyme = (g-ethanol/g-starch) x 100%

e Fermentation yield when using cellulase as enzyme = (g-ethanol/g-cellulose+hemicellulose) x 100%