Data Article

Enzyme-based lignocellulose hydrolyzation – Brief data survey for cellulase performance characterization on behalf of the Sauter mean diameter of raw material particles

Robert Glaser
Leibniz Institute for Agricultural Engineering Potsdam-Bornim, Max-Eyth-Allee 100, 14469 Potsdam, Germany

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A B S T R A C T
The data presented here supports the informational background of enzyme-based lignocellulose hydrolyzation, cellulase characterization, and sugar yield prediction for the work “Enzyme-based lignocellulose hydrolyzation – Sauter mean diameter of raw materials as a basis for cellulase performance characterization and yield prediction” by Glaser [1]. Glucose yields from the enzymatic hydrolysis of the raw materials were shown as a function of cellulase enzyme loading as well as of particle size with different solid loading. The data for the proposed methods of the determination of enzyme activity in inhomogeneous samples of lignocellulosic raw materials are presented. The data of the empirical model that was developed for the prediction of hydrolysis yields for different enzyme concentrations, substrate specific particle size, and solid loadings, are given. Data are also given in relation of terms of scale-up opportunities.
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E-mail address: robert.glaser@bsyt.eu

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**Specifications Table**

| Subject area | Biotechnology |
|--------------|---------------|
| More specific subject area | Bioresources, cellulases |
| Type of data | Table |
| How data was acquired | - Enzymatic hydrolyses of lignocellulosic raw materials  
- Glucose determination by high-pressure liquid chromatography  
- Mathematical model equation, parameter adjustment, and model simulation  
- Torque measurement by the used Heidolph stirrer and determination of the power number of the used setup |
| Data format | Raw, filtered, analyzed |
| Experimental factors | The raw materials were milled and used naturally dried. Different amounts of protein of the cellulase enzyme mixtures were used for hydrolyses of the lignocellulose raw materials. Characterization of cellulase enzyme mixtures by different particle size fractions of wheat straw was undertaken. Hydrolysis data are used to define a kinetic unit for the estimation of cellulase performance in inhomogeneous raw materials. The defined kinetic unit was used for the yield prediction with an empirically defined model equation in different scales |
| Experimental features | Using Sauter mean diameter of lignocellulosic raw materials for cellulase characterization and yield prediction in scale-up processes |
| Data source location | Potsdam, Brandenburg, Germany |
| Data accessibility | Data is presented in this article |

1. **Value of data**

- The estimation of cellulase performance for industrial-scale processes holds special challenges. There exists a gap between the enzyme performance in a laboratory and in large-scale processes. As a standard tool for cellulase characterization, the determination of the filter paper units (FPU) through the filter paper assay (FPA) [2] is given.
- With the data which is given in the following and the methods given by Glaser [1], it is possible to define a self-specified cellulase unit via easy measurable process properties, e.g. cellulase enzyme loading and mixture, lignocellulose solid loading, type of lignocellulose, and particle size distribution of the given raw materials. The thereby defined cellulase unit will be facile and generally understandable.
- The data given here will provide a first step to characterize and compare a user-defined process due to the easy application of the model [1].

2. **Data**

The cellulase performance was determined as a function of cellulase enzyme loading, particle sizes of different raw materials, and different solid loadings.

Raw materials such as wheat straw, pulverized wheat straw, grass, pine wood, aspen wood, and rice straw as well as glucose yields were used.

Torque data and power numbers of the reactor setting were obtained for scale comparison.
2.1. Lignocellulose raw material characterization by Sauter mean diameter

Different kinds of lignocellulose raw materials were used in the work by Glaser [1]. The raw materials used there were wheat straw (WS) with a Sauter mean diameter (SMD) of 435 μm, pulverized wheat straw (pWS) with an SMD of 202 μm, aspen wood with an SMD of 513 μm, pine wood (PW) with an SMD of 483 μm, grass with an SMD of 153 μm, and rice straw (RS) with an SMD of

| Particle size distribution of milled wheat straw, pulverized wheat straw, pine wood, aspen wood, rice straw, and grass. |
|---|---|---|---|---|---|---|
| \(d_{\text{m},i} [\mu \text{m}]\) | WS | pWS | AW | PW | Grass | RS |
| 900 | 6.31 | 0.04 | 42.40 | 36.05 | 0.07 | 0.00 |
| 715 | 35.83 | 0.08 | 24.08 | 28.02 | 0.22 | 0.02 |
| 472.5 | 42.56 | 13.08 | 19.94 | 20.82 | 2.55 | 9.83 |
| 282.5 | 4.19 | 27.86 | 5.73 | 6.47 | 3.28 | 13.99 |
| 225 | 3.40 | 31.86 | 2.85 | 2.87 | 0.52 | 15.93 |
| 162.5 | 6.61 | 20.48 | 4.03 | 3.82 | 44.22 | 25.75 |
| 107.5 | 0.84 | 3.91 | 0.46 | 0.71 | 0.62 | 0.55 |
| 85 | 0.14 | 0.69 | 0.16 | 0.04 | 0.30 | 2.90 |
| 75.5 | 0.03 | 0.30 | 0.11 | 0.71 | 0.62 | 0.55 |
| 67 | 0.05 | 0.35 | 0.14 | 0.30 | 0.24 | 0.28 |
| 31.5 | 0.03 | 1.46 | 0.10 | 0.02 | 1.05 | 1.52 |
| SMD [\mu \text{m}] | 435 | 202 | 513 | 483 | 153 | 169 |

## Table 1

### Table 2

Mean glucose yields of two 60 min hydrolyses of different particle classes of WS in shacked reaction tubes with different enzyme loadings.

| Protein [mg/mL] | Glucose yield [g] | [%] | Glucose yield [g] | [%] | Glucose yield [g] | [%] | Glucose yield [g] | [%] |
|---|---|---|---|---|---|---|---|---|
| R1 | 10 | 0.00399 | 3.80 | 0.01030 | 12.3 | 0.00802 | 9.70 | 0.01475 | 14.0 | 0.01475 | 14.0 | 0.03129 | 29.6 |
| | 5 | 0.00339 | 3.2 | 0.01296 | 12.3 | 0.00729 | 8.8 | 0.01204 | 11.4 | 0.02705 | 25.6 |
| | 2.5 | 0.00268 | 2.5 | 0.00914 | 8.6 | 0.00732 | 6.9 | 0.00951 | 9.0 | 0.02407 | 22.8 |
| | 1.25 | 0.00245 | 2.3 | 0.00769 | 7.3 | 0.00468 | 4.4 | 0.00675 | 6.4 | 0.01845 | 17.5 |
| R2 | 10 | 0.00317 | 3.0 | 0.01019 | 9.6 | 0.00634 | 6.0 | 0.00791 | 7.5 | 0.01208 | 11.4 | 0.02937 | 27.8 |
| | 5 | 0.00290 | 2.7 | 0.00837 | 7.9 | 0.00540 | 5.1 | 0.00733 | 6.9 | 0.00962 | 9.1 | 0.02691 | 25.5 |
| | 2.5 | 0.00176 | 1.7 | 0.00636 | 6.0 | 0.00354 | 3.4 | 0.00624 | 5.9 | 0.00796 | 7.5 | 0.01954 | 18.5 |
| | 1.25 | 0.00118 | 1.1 | 0.00495 | 4.7 | 0.00227 | 2.2 | 0.00332 | 3.1 | 0.00416 | 3.9 | 0.01332 | 12.6 |
| R3 | 10 | 0.00424 | 4.0 | 0.01189 | 11.2 | 0.00788 | 7.4 | 0.01096 | 10.4 | 0.01443 | 13.6 | 0.02964 | 28.0 |
| | 5 | 0.00311 | 2.9 | 0.00977 | 9.2 | 0.00636 | 6.0 | 0.00962 | 9.1 | 0.01140 | 10.8 | 0.02597 | 24.6 |
| | 2.5 | 0.00235 | 2.2 | 0.00807 | 7.6 | 0.00545 | 5.2 | 0.00810 | 7.7 | 0.00857 | 8.1 | 0.02251 | 21.3 |
| | 1.25 | 0.00208 | 2.0 | 0.00672 | 6.4 | 0.00398 | 3.8 | 0.00525 | 5.0 | 0.00617 | 5.8 | 0.01711 | 16.2 |
| R4 | 10 | 0.00260 | 2.5 | 0.01101 | 10.4 | 0.00616 | 5.8 | 0.00917 | 8.7 | 0.01275 | 12.1 | 0.03109 | 29.4 |
| | 5 | 0.00228 | 2.2 | 0.00949 | 9.0 | 0.00517 | 4.9 | 0.00762 | 7.2 | 0.01035 | 9.8 | 0.02445 | 23.1 |
| | 2.5 | 0.00201 | 1.9 | 0.00774 | 7.3 | 0.00419 | 4.0 | 0.00602 | 5.7 | 0.00781 | 7.4 | 0.02112 | 20.0 |
| | 1.25 | 0.00175 | 1.7 | 0.00599 | 5.7 | 0.00321 | 3.0 | 0.00443 | 4.2 | 0.00527 | 5.0 | 0.01779 | 16.8 |
| CT2 | 10 | 0.00425 | 4.0 | 0.03396 | 32.1 | 0.00880 | 8.3 | 0.01666 | 15.8 | 0.01497 | 14.2 | 0.03953 | 37.4 |
| | 5 | 0.00245 | 2.0 | 0.02317 | 21.9 | 0.00880 | 8.3 | 0.01666 | 15.8 | 0.01487 | 14.2 | 0.03953 | 37.4 |
| | 2.5 | 0.00245 | 2.0 | 0.02347 | 22.2 | 0.00880 | 8.3 | 0.01666 | 15.8 | 0.01497 | 14.2 | 0.03953 | 37.4 |
| | 1.25 | 0.00224 | 2.1 | 0.01480 | 14.0 | 0.00564 | 5.3 | 0.00948 | 9.0 | 0.01049 | 9.9 | 0.02957 | 28.0 |

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169 μm. In Table 1 the data of the particle size distribution which was used to determine the SMD are shown.

### 2.2. Cellulase performance characterization

Five fraction classes with a range of different particle sizes were used for evaluation of cellulase performance on the wheat straw. Therefore, four different protein amounts of the cellulase mixtures were used. The used types of cellulases such as CTec2 (CT2), HTec2 (HT2), and the cellulase mixtures provided by the Moscow State University, are described in a more detailed way in the main article [1].

Data of hydrolyses as mean values of the glucose yield are shown in Table 2. The glucose yield differs depending on the cellulase amount used in the experiment. To smooth the data for further use, an exponential equation was adjusted to the data by fitting two parameters (see Eq. (2) in Section 3.1). The data of the fitted parameters are shown in Table 3. The kinetic unit, which was proclaimed on the basis of the cellulase performance, depends on the cellulase enzyme loading and the mean particle size of the wheat straw fraction. Further details and descriptions of the determination of the wheat straw units (WSU) are given in the main article [1].
The defined WSU was used to predict hydrolyses yield of the sugars from the different given raw materials in differently scaled shacked and stirred bioreactors. For these hydrolyses, different amounts of protein were used. Data of hydrolyses done in shaking flasks are shown in Table 4 for different lignocellulose raw materials in combination with the used WSU [1]. Data of hydrolyses of

2.3. Hydrolyses in shaking flask and 2 L and 10 L scale stirred bioreactors

| Table 5 | Hydrolyses data in 2 L and 10 L stirred bioreactor. |
|---------|--------------------------------------------------|
| WS 5%; 2 L | WS 7.5%; 2 L | WS 7.5%; 10 L | PW 5%; 2 L | AW 5%; 2 L |
| T | R1R2R3R4 | T | R1R2 | R3R4 | T | R1 | R3 | T | R1R2R3R4 | T | R1R2R3R4 |
| 0 h | 0.00 | 0.00 | 0 h | 0.00 | 0.00 | 0 h | 0.00 | 0.00 | 0 h | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 h | 8.68 | 8.48 | 1 h | 6.14 | 3 h | 26.54 | 24.97 | 20.00 | 0.5 h | 2.59 | 2.27 | 3 h | 2.09 | 1.50 | 3 | 0.80 | 3 | 8.97 | 7.90 |
| 6 h | 10.1 | 9.18 | 3 h | 10.54 | 6 h | 29.16 | 28.23 | 25.13 | 1.5 h | 5.51 | 4.21 | 17 h | 3.86 | 3.54 | 6.3 | 2.20 | 6 | 12.3 | 10.3 |
| 24 h | 11.4 | 10.0 | 6 h | 12.28 | 12 h | 30.66 | 28.90 | 29.10 | 2.5 h | 7.02 | 5.96 | 25 h | 4.28 | 3.99 | 12.59 | 18 | 18.1 | 16.0 |
| 29 h | 10.9 | 10.2 | 24 h | 14.03 | 24 h | 33.39 | 30.22 | 31.31 | 6 h | 10.7 | 9.89 | 42 h | 4.40 | 4.15 | 26 | 3.06 | 27.3 | 20.8 | 18.7 |
| 46 h | 11.7 | 10.3 | 30 h | 14.36 | 24 h | 33.39 | 30.22 | 31.31 | 22 h | 11.4 | 10.1 | 64 h | 4.15 | 4.34 | 50 | 3.92 | 53.3 | 23.3 | 22.2 |
| T: Hydrolysis time. |

| Table 6 | Torque and power numbers of Ruston turbine equipment of 2 L stirred bioreactors. |
|---------|--------------------------------------------------|
| Rpm | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Torque of the drained reactor vessel | | | | | | | | |
| Measurement 1 | 6.40 | 6.60 | 6.80 | 7.20 | 7.40 | 7.70 | 8.20 | 9.10 |
| Measurement 2 | 6.30 | 6.50 | 6.80 | 7.30 | 7.30 | 7.70 | 8.50 | 9.00 |
| Measurement 3 | 6.30 | 6.40 | 6.90 | 7.10 | 7.40 | 7.70 | 8.30 | 8.90 |
| Mean M_{drained} | 6.33 | 6.50 | 6.83 | 7.20 | 7.37 | 7.70 | 8.33 | 9.00 |
| Torque of the lower Rushton-turbine | | | | | | | | |
| Measurement 1 | 6.40 | 7.30 | 7.70 | 8.60 | 9.30 | 10.50 | 11.80 | 13.40 |
| Measurement 2 | 6.40 | 7.20 | 7.80 | 8.50 | 9.20 | 10.40 | 11.90 | 13.30 |
| Measurement 3 | 6.40 | 7.20 | 7.90 | 8.60 | 9.30 | 10.30 | 11.70 | 13.50 |
| Mean M_{loaded} | 6.40 | 7.23 | 7.80 | 8.57 | 9.27 | 10.40 | 11.80 | 13.40 |
| M_{effective} | 0.07 | 0.73 | 0.97 | 1.37 | 1.90 | 2.70 | 3.47 | 4.40 |
| Po | 0.91 | 5.63 | 4.75 | 4.66 | 4.76 | 5.18 | 5.26 | 5.40 |
| Mean Po | 5.09 | | | | | | | |
| Torque of the upper Rushton-turbine | | | | | | | | |
| Measurement 1 | 6.40 | 7.10 | 7.70 | 8.30 | 9.10 | 10.10 | 11.40 | 13.00 |
| Measurement 2 | 6.40 | 7.20 | 7.60 | 8.40 | 9.30 | 10.20 | 11.50 | 13.10 |
| Measurement 3 | 6.50 | 7.10 | 7.60 | 8.40 | 9.10 | 10.00 | 11.50 | 12.90 |
| Mean M_{loaded} | 6.43 | 7.13 | 7.63 | 8.37 | 9.17 | 10.10 | 11.47 | 13.00 |
| M_{effective} | 0.10 | 0.63 | 0.80 | 1.17 | 1.80 | 2.40 | 3.13 | 4.00 |
| Po | 1.36 | 4.86 | 3.93 | 3.98 | 4.51 | 4.61 | 4.75 | 4.91 |
| Mean Po | 4.51 | | | | | | | |
| Combined torque of the lower and upper Rushton-turbine | | | | | | | | |
| Measurement 1 | 6.70 | 7.60 | 8.30 | 9.00 | 10.10 | 11.00 | 12.50 | 14.20 |
| Measurement 2 | 6.80 | 7.50 | 8.50 | 9.10 | 10.00 | 11.30 | 12.40 | 14.10 |
| Measurement 3 | 6.80 | 7.30 | 8.20 | 9.00 | 9.70 | 11.10 | 12.60 | 14.30 |
| Mean M_{loaded} | 6.77 | 7.47 | 8.33 | 9.03 | 9.93 | 11.13 | 12.50 | 14.20 |
| M_{effective} | 0.43 | 0.97 | 1.50 | 1.83 | 2.57 | 3.43 | 4.17 | 5.20 |
| Po | 5.91 | 7.42 | 7.37 | 6.25 | 6.43 | 6.59 | 6.32 | 6.39 |
| Mean Po | 6.68 | | | | | | | |
Table 7
Torque and power numbers of Ruston turbine equipment of 10 L stirred bioreactors.

| Rpm | 100  | 200  | 300  | 350  | 400  | 450  | 500  | 550  | 600  | 650  |
|-----|------|------|------|------|------|------|------|------|------|------|
| Torque of the drained reactor vessel |
| Measurement 1 | 5.10 | 6.00 | 6.30 | 6.35 | 6.40 | 6.55 | 6.70 | 6.85 | 7.00 | 7.15 |
| Measurement 2 | 5.00 | 5.70 | 6.30 | 6.35 | 6.40 | 6.50 | 6.60 | 6.70 | 6.80 | 6.90 |
| Measurement 3 | 5.00 | 5.80 | 6.20 | 6.25 | 6.30 | 6.55 | 6.80 | 7.05 | 7.30 | 7.55 |
| Mean $M_{\text{drained}}$ | 5.03 | 5.83 | 6.27 | 6.32 | 6.37 | 6.53 | 6.70 | 6.87 | 7.03 | 7.20 |
| Torque of the lower Rushton-turbine |
| Measurement 1 | 5.10 | 6.50 | 8.40 | 9.40 | 10.60 | 11.80 | 13.40 | 15.10 | 17.00 | 19.20 |
| Measurement 2 | 5.20 | 6.60 | 8.30 | 9.50 | 10.50 | 11.70 | 13.50 | 15.00 | 16.70 | 18.70 |
| Measurement 3 | 5.10 | 6.50 | 8.50 | 9.30 | 10.60 | 12.00 | 13.20 | 15.20 | 17.20 | 18.00 |
| Mean $M_{\text{loaded}}$ | 5.13 | 6.53 | 8.40 | 9.40 | 10.57 | 11.83 | 13.37 | 15.10 | 16.97 | 18.63 |
| $N_{\text{effective}}$ | 0.10 | 0.70 | 2.13 | 3.08 | 4.20 | 5.30 | 6.67 | 8.23 | 9.93 | 11.43 |
| $Po$ | 1.35 | 2.36 | 3.20 | 3.39 | 3.54 | 3.53 | 3.60 | 3.67 | 3.72 | 3.65 |
| Mean $Po$ | 3.62 |
| Torque of the upper Rushton-turbine |
| Measurement 1 | 5.30 | 6.80 | 8.90 | 10.20 | 11.50 | 12.90 | 14.90 | 17.00 | 19.30 | 21.90 |
| Measurement 2 | 5.10 | 6.70 | 9.00 | 10.10 | 11.40 | 12.80 | 14.80 | 16.90 | 19.40 | 21.70 |
| Measurement 3 | 5.20 | 6.90 | 8.80 | 10.00 | 11.60 | 13.00 | 15.10 | 16.80 | 19.50 | 21.80 |
| Mean $M_{\text{loaded}}$ | 5.20 | 6.80 | 8.90 | 10.10 | 11.50 | 12.90 | 14.93 | 16.90 | 19.40 | 21.80 |
| $N_{\text{effective}}$ | 0.17 | 0.97 | 2.63 | 3.78 | 5.13 | 6.37 | 8.23 | 10.03 | 12.37 | 14.60 |
| $Po$ | 2.25 | 3.26 | 3.94 | 4.16 | 4.33 | 4.24 | 4.44 | 4.47 | 4.63 | 4.66 |
| Mean $Po$ | 4.46 |
| Combined torque of the lower and upper Rushton-turbine |
| Measurement 1 | 5.30 | 7.80 | 11.00 | 12.30 | 14.90 | 17.20 | 20.30 | 24.00 |
| Measurement 2 | 5.50 | 7.60 | 10.90 | 12.50 | 14.80 | 17.60 | 20.50 | 24.30 |
| Measurement 3 | 5.40 | 7.70 | 11.00 | 12.20 | 15.10 | 17.30 | 20.80 | 24.00 |
| Mean $M_{\text{loaded}}$ | 5.40 | 7.70 | 10.97 | 12.33 | 14.93 | 17.37 | 20.53 | 24.17 |
| $N_{\text{effective}}$ | 0.37 | 1.87 | 4.70 | 6.02 | 8.57 | 10.83 | 13.83 | 17.30 |
| $Po$ | 4.94 | 6.29 | 7.04 | 6.62 | 7.22 | 7.21 | 7.46 | 7.71 |
| Mean $Po$ | 7.21 |

WS, PW, and AW in stirred bioreactors of 2 L and 10 L scale are shown in Table 5 alongside the used WSU [1]. The given data provide the opportunity to compare the glucose yield kinetic between different cellulase mixtures and raw materials.

2.4. Torque and power numbers of Ruston turbine equipment

For the scale-up from the shacked reaction tubes over shacked flasks towards the 2 L and 10 L bioreactor vessels, the power number was estimated by torque measurement. Table 6 shows the torque data of the 2 L vessel with the single and double used Rushton turbines. Table 7 shows the data for the 10 L vessel. The stable power number was derived in turbulent flow. Different scale-up criteria can be assumed, for example, constant power input and constant flow characteristics described by a constant Reynolds number. However, as a scale criterion between the 2 L scale and the 10 L scale, a constant stirring speed was used. See Glaser [1] for more details. For more information concerning the determination of the power characteristics, refer Kraume [3], Sieblist et al. [4], and Zlokarnik [5].

The Leibniz-Institute of Agricultural Engineering is interested and open for new interdisciplinary cooperation, especially in biotechnology in the area of bioeconomy. It provides a working environment with enthusiastic researchers. With its pilot plant bio-refinery, it is also interested in topics of biotechnological production of value added products, such as lactic acid or succinic acid from industrial residues and wastes. The Leibniz-Institute of Agricultural Engineering defines principles for best practice of scale-up and scale-down of diverse biotechnological processes.
3. Experimental design, materials, and methods

To check for statistical significance, the data were evaluated by the analysis of variance (ANOVA) in combination with variances and standard mean deviations in correlation coefficients. Those data were given in the main article [1].

3.1. Characterization of lignocellulose raw materials by Sauter mean diameter

The Sauter mean diameter was calculated through the mean fraction diameter of a particle class \( d_{m,i} \) and the mass fraction of the particle class \( m_{3,i} \) (Eq. (1)). The fractions of the particle classes were determined by sieving with standard screens and different mesh sizes.

\[
\text{SMD} = \frac{1}{\sum_{i=1}^{N} \frac{m_{3,i}}{d_{m,i}}} 
\]  

3.2. Hydrolyses in reaction tubes for cellulase characterization

The amount of 200 mg of WS was weighed out directly in reaction tubes and charged with two milliliters of 50 mM sodium acetate buffer with pH 5 and preheated to 52 °C, as were the enzymes. Two milliliters of enzyme dilutions were added to the WS-filled tubes. Resulting protein concentrations of cellulase enzyme solution were 1.25, 2.5, 5, and 10 mg/mL. The closed tubes were then placed on a planar shaker at 100 rpm in combination with an incubator at 52 °C for 60 min (Certomat U, B. Braun Dienst Biotech.). To stop the hydrolysis, the tubes were placed in a boiling water bath for 20 min. Afterwards they were cooled down to –20 °C and stored for further use.

A regression fitting with an exponential equation (Eq.(2)) was done in order to smooth the data of the hydrolysis in the reaction tubes for the definition of a kinetic unit [1]. The fitted parameters are shown in Table 3. The parameter \( S \) [g] was defined by the amount of the cellulose part of the lignocellulosic substrate, while \( C \) [–] was defined as the conversion factor of the substrate after the hydrolysis. The parameter \( k \) [1/gp] defines the turnover of cellulose to glucose per gram of cellulase protein in 60 min while \( E_p \) is defined by the amount of the used cellulase protein [gp]. The parameters \( C \) and \( k \) were the optimized parameters by minimizing the root mean squares between the experimental data and data given by Eq. (2).

\[
Y = S\cdot C\cdot (1 - \exp(-k\cdot E_p)) \tag{2}
\]

3.3. Technical-scale hydrolyses in shaking flask, 2 L and 10 L stirred bioreactors

Shaking flask hydrolyses experiments were carried out in Erlenmeyer flasks charged with 200 mL of 50 mM sodium acetate buffer at pH 5, 52°C, and 5% w/v of solid loading. The flasks were shaken at 100 rpm. In comparison to this shaking flask system, hydrolyses were also carried out in 2 L and 10 L stirred bioreactors. The WS hydrolyses took place with 5% w/v and 7.5% w/v solid loadings, and the AW and PW were used at 5% w/v solid loading. The working volumes were 1 L for the 5% w/v or 1.5 L and 8 L for hydrolyses at 7.5% w/v of solid loadings.

3.4. Detection of sugars

The detection of sugars was done by anion-exclusion high-pressure liquid chromatography (HPLC) with a EurokatH column (300 mm × 8 mm, 10 lm, eluent: 0.01 N H₂SO₄, RI 75 detector) (KNAUER). The column was used at a constant temperature of 35 °C and under constant acidic pH conditions with 0.005 mol/L H₂SO₄ in the mobile phase. The injection volume was 10 µL at a pressure of 1.5 MPa.
3.5. Determination of torque and power numbers

The experimental determination of the power input \( P_{\text{effective}} \) was accomplished using the internal torque sensor of the used Heidolph stirrer (RZ 2052). The power input into the loaded stirred vessel of the bioreactor \( P_{\text{loaded}} \) must be subtracted by the power input into the unloaded vessel of the bioreactor \( P_{\text{drained}} \). Due to this setup, the friction and other losses of the agitation system were considered [4].

\[
P_{\text{effective}} = P_{\text{loaded}} - P_{\text{drained}}
\]  

(3)

The data of effective power input were used for the calculation of the corresponding power number of the stirring system by the following Eq. (4).

\[
\rho_0 = \frac{P_{\text{effective}}}{\rho_1 n^3 d^5} = \frac{2\pi n (M_{\text{loaded}} - M_{\text{drained}})}{\rho_1 n^3 d^5}
\]  

(4)

where \( \rho_L \) is the liquid density, \( n \) is the stirrer speed, and \( M \) is the measured torque. \( M_{\text{loaded}} \) is the torque of the loaded and stirred vessel while \( M_{\text{drained}} \) is the torque of the unloaded stirred bioreactor vessel.

The 2 L reactor was equipped with two six-blade Rushton turbines and the physical parameters were: the mean stirrer diameter: \( d = 0.053 \pm 0.001 \) m, the relation of the stirrer diameter and the inner vessel diameter: \( d/D = 0.42 \), the relation of the lower Rushton turbine and vessel diameter: \( h_1/D = 0.08 \), the relation of the upper Rushton turbine and vessel diameter: \( h_2/D = 0.32 \), and the relation of the filling height and vessel diameter: \( H_{\text{fill}}/D = 0.71 \) at 300 rpm. The reactor of the 10 L scale was also equipped with two six-blade Rushton turbines with parameters of \( d = 0.07 \) m, \( d/D = 0.42 \), \( h_1/D = 0.71 \), \( h_2/D = 1.05 \), and \( H_{\text{fill}}/D = 1.58 \) at 300 rpm.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.dib.2015.11.008.

References

[1] R. Glaser, Enzyme-based lignocellulose hydrolyzation – Sauter mean diameter of raw materials as a basis for cellulase performance characterization and yield prediction, J. Biotechnol. 214 (2015) 9–16.
[2] T.K. Ghose, Measurement of cellulase activities, Pure Appl. Chem. 59 (1987) 257–268. http://dx.doi.org/10.1351/pac198759020257.
[3] M. Kraume, Mischen und Rühren, Wiley-VCH Verlag GmbH & Co. KGaA (2005) http://dx.doi.org/10.1002/3527603360.
[4] C. Sieblist, M. Jenzsch, M. Pohlscheidt, Equipment characterization to mitigate risks during transfers of cell culture manufacturing processes, Cytotherapy (2015) 1–21. http://dx.doi.org/10.1016/s1061-6015-9899-0.
[5] M. Zlokarnik, Stirring – Theory and Practice, Whiley-VCH Verlag Gmbh, Weinheim (2001) http://dx.doi.org/10.1002/9783527612703.