Data Article

Data on the thermochemical potential of six Cuban biomasses as bioenergy sources

Marcel Pfeil, Ramón Piloto-Rodríguez, Yosvany Díaz, Yisel Sánchez-Borroto, Eliezer Ahmed Melo-Espinosa, Dominik Denfeld, Sven Pohl

Universidad Tecnológica de La Habana José A. Echeverría, Calle 114, No. 11901 e/119 y 127, Cujae, Marianao 15, 19390, Cuba

Technische Hochschule Mittelhessen, University of Applied Sciences, Centre for Energy Technology and Energy Management (etem.THM), Germany

Article info

Article history:
Received 9 January 2020
Accepted 23 January 2020
Available online 31 January 2020

Keywords:
Biomass
Gasification
Pyrolysis
Ash melting behaviour
Thermogravimetric analysis

Abstract

Data on the rapid, elemental and calorimetric analysis, such as ash melting behaviour and thermogravimetric profiles of six Cuban biomass feedstock are shown, in order to assess their potential for bioenergy production. The studied biomasses are Jatropha curcas husk, Moringa oleifera husk, Dichrostachys cinerea, Ulva lactuca, Chaetomorpha gracilis and Sargassum fluctuans. Seed, kernels or stems and algae were characterized by weight. Sample preparation and tests were established according to referenced German standards with particle size <75 mm. In addition, thermogravimetric analyses have been performed at 10 °C/min in Argon atmosphere. Data in the paper are shown in Tables and Graphs. The data represent valuable information for simulation or further implementation of gasification or pyrolysis processes using these biomasses.

© 2020 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
1. Data description

The report present data from rapid, elemental and calorimetric analysis, such as ash melting behaviour and thermogravimetric profiles of six biomass feedstock in order to assess their potential for bioenergy production. These biomasses were selected due to their availability in Cuban nature or agro-industrial sector. Some of them are of particular interest in the last years for bioenergy production or are non-explored feedstock. The studied biomasses are \textit{Jatropha curcas} husk, \textit{Moringa oleifera} husk, \textit{Dichrostachys cinerea} and three species of algae (\textit{Ulva lactuca}, \textit{Chaetomorpha gracilis} and \textit{Sargassum fluitans}). Proximate analysis was performed on the biomass samples to determine moisture, volatiles,
ash and fixed carbon content. Moisture, volatile matter and ash were determined according to the standards as shown in Table 1. Replication was performed for each parameter. The fixed carbon content was calculated by differences.

The results of rapid analysis, which involves water content, ash content and volatile components, are shown in Table 2, corresponding to mean values of three replicate analyses per biomass, on a dry basis (db). The results corresponding to elemental analysis on a dry basis are shown in Table 3. The heating value determination beside the ash melting behaviour is shown in Table 4.

The thermogravimetric profiles of *Jatropha curcas* husk, *Moringa oleifera* husk and *Dichrostachys cinerea* are shown in Fig. 1 and those corresponding to the algae species (*Ulva lactuca*, *Sargassum fluitans* and *Chaetomorpha gracilis*) are shown in Fig. 2. The data contained in this paper is enough information for further gasification or pyrolysis simulation processes or important parameters contributing to better device designs [1,2].

### Table 1

Used methods for biomass characterization.

| Item                               | Method                          |
|------------------------------------|---------------------------------|
| Water content and moisture         | DIN EN 14774                    |
| Ash content                        | DIN EN 14775                    |
| Volatile content                   | DIN EN 15148                    |
| Fixed carbon                       | DIN 51734                       |
| Elemental composition (C, H, N, S) | DIN EN 15104                    |

### Table 2

Proximate analysis of the selected biomasses.

| Biomass                 | Water content (wt.%) | Ash content (550 °C) (db) (wt.%) | Ash content (815 °C) (db) (wt.%) | C<sub>fixed</sub> (wt.%) | Volatiles (wt.%) | Coke (wt.%) |
|-------------------------|----------------------|----------------------------------|----------------------------------|--------------------------|------------------|--------------|
| *Jatropha curcas* husk  | 9.19                 | 4.12                             | 3.08                             | 27.17                    | 68.71            | 31.29        |
| *Moringa oleifera* husk | 6.25                 | 2.97                             | 2.80                             | 21.77                    | 75.26            | 24.74        |
| *Dichrostachys cinerea* | 43.96                | 7.03                             | 5.94                             | 17.37                    | 75.59            | 24.41        |
| *Ulva lactuca*          | 20.32                | 22.73                            | 22.19                            | 1.37                     | 75.90            | 24.10        |
| *Sargassum fluitans*    | 15.33                | 18.10                            | 16.68                            | 13.08                    | 68.83            | 31.17        |
| *Chaetomorpha gracilis* | 3.24                 | 62.53                            | 16.68                            | 13.08                    | 68.83            | 31.17        |

### Table 3

Ultimate analysis of the selected biomasses.

| Biomass                 | C content (db) (wt.%) | N content (db) (wt.%) | S content (db) (wt.%) | H content (db) (wt.%) | O content (db) (wt.%) |
|-------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| *Jatropha curcas* husk  | 49.04                 | 0.60                  | 0.44                  | 5.76                  | 40.03                 |
| *Moringa oleifera* husk | 51.49                 | 1.52                  | 0.56                  | 6.65                  | 36.80                 |
| *Dichrostachys cinerea* | 47.16                 | 1.06                  | 0.56                  | 6.24                  | 37.95                 |
| *Ulva lactuca*          | 29.30                 | 1.39                  | 6.63                  | 4.85                  | 35.10                 |
| *Sargassum fluitans*    | 0.98                  | 1.61                  | 4.72                  | 37.09                 | 0.98                  |
| *Chaetomorpha gracilis* | 19.02                 | 0.91                  | 0.33                  | 1.24                  | 15.98                 |

### Table 4

Calorimetric analysis and ash melting behaviour.

| Biomass                 | Higher heating value (MJ/kg) (db) | Shrinkage starting temperature (°C) | Deformation temperature (°C) | Hemisphere temperature (°C) | Flow temperature (°C) |
|-------------------------|-----------------------------------|------------------------------------|-------------------------------|-----------------------------|----------------------|
| *Jatropha curcas* husk  | 18.59                             | 600                                | ≥1500                         | ≥1500                       | ≥1500                |
| *Moringa oleifera* husk | 20.83                             | 970                                | ≥1500                         | ≥1500                       | ≥1500                |
| *Dichrostachys cinerea* | 17.96                             | 565                                | ≥1500                         | ≥1500                       | ≥1500                |
| *Ulva lactuca*          | 15.19                             | 720                                | 900                           | 1160                        | 1390                 |
| *Sargassum fluitans*    | 16.73                             | 720                                | 900                           | 1300                        | 1390                 |
| *Chaetomorpha gracilis* | 3.98                              | 1140                               | 1365                          | 1390                        | 1410                 |
Seed, kernels or stems and algae were characterized by weight. For weight determination, 100 g of seeds were randomly selected and weighed to the nearest ±0.001 g using a sensitive digital electronic analytical balance (model: College B303). The weights were reported as mean ± SD of triplicate determination. The husk samples were prepared according to the standards DIN EN 14778: 2011 (Solid biofuels-Sampling) and DIN EN 14780 (Solid biofuels-Sample preparation). The essential principle of sample reduction is that the composition of the sample taken on site must not be changed during any phase of preparation. Each subsample must be representative of the original sample. To achieve this, all particles present in the sample prior to its division must have the same probability of being present in the sample after splitting. During sampling, two basic methods are used (the sample division and the reduction of the particle size of the sample (particle size < 75 mm)).

The ultimate analysis was carried out in a vario MACRO cube elemental analyser to determine carbon, hydrogen, nitrogen, and sulphur contents in the biomass samples. Oxygen content was calculated by differences.
2.2. Heating content

C7000 (IKA-Werke GmbH & Co. KG) adiabatic oxygen bomb calorimeter was used to measure the higher heating values (HHV) of the biomass samples according to the standards DIN 51900. The results were reported on dry basis. Since the heating content of a biomass depends on its chemical composition, the Equation (1) (according to DIN EN 14918) was used to calculate the lower heating value (LHV) based on the elemental analysis.

\[
LHV_{db,\text{cal}} = \frac{HHV_{db} + 6.15 \cdot H_{db} - 0.8 \cdot (O_{db} + N_{db}) - 218.3 \cdot H_{db}}{1000}
\]

where:
- \(LHV_{db,\text{cal}}\): Lower heating value at constant pressure for water free fuel, in MJ/kg
- \(HHV_{db}\): Determined higher heating value, in J/g
- \(H_{db}\): Mass fraction of hydrogen of water free fuel, in percentage by mass
- \(O_{db}\): Mass fraction of oxygen of water free fuel, in percentage by mass
- \(N_{db}\): Mass fraction of nitrogen of water free fuel, in percentage by mass

2.3. Ash melting behaviour and ash composition

The ash melting behaviour was determined according to the standards DIN CES/TS 15370-1. This is a method for determining characteristic temperatures for the melting behaviour of ash from solid biofuels. An AF700 Ash Fusion Determinator was used for the experiments, with a measuring range limited to 1500 °C. The ash fusion temperature is the main factor, which is a critical quality control parameter in predicting the performance of a specific fuel and evaluating the trend of a fuel to slag. In that way, the four conventional ash fusion temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT), and flow temperature (FT)) of all samples should be determined. See details in Fig. 3.

Fig. 4 shows the pellets of Moringa oleifera and Jatropha curcas husk. A digital image appearance of samples inside the Ash Fusion Determinator in the beginning of the test can be in Fig. 3 observed (on the right). The experiments were carried out duplicated.

2.4. Thermogravimetric analysis

The application of thermogravimetric analysis to biofuel samples is a strong and useful tool for the thermal decomposition assessment in order to understand the kinetic of each step but for an experimental simulation of gasification, pyrolysis and combustion of solid fuels [3,4]. The biomass samples

![Fig. 3. Ash melting behaviour (taken from DIN CES/TS 15370-1).](image)
were analysed in a NETZSCH, model STA 449 F3 in an Ar atmosphere, with 10 °C/min of heating rate. Around 75 mg of each sample were inserted in the thermo balance.

CRediT author's statement

Ramón Piloto-Rodríguez: Conceptualization, investigation, data curation, writing-Reviewing and Editing, supervision.
Sven Pohl: Conceptualization, Investigation, resources, Reviewing and Editing, supervision, project administration, funding acquisition.
Marcel Pfeil: Formal analysis, investigation, resources, data curation.
Dominik Denfeld: Formal analysis, investigation, resources, data curation.
Yosvany Díaz: Investigation, resources.
Eliezer Ahmed Melo-Espinosa: Investigation, resources.
Yisel Sánchez-Borroto: Investigation, resources.

Transparency document: Supplementary material

Supplementary data associated with this article can be found in the online version at https://data.mendeley.com/datasets/sk6m66x4tj/2 [5].

Acknowledgments

The authors wish to express their thanks to the German Federal Ministry of Economics and Energy (BMBF), funding the project entitled “Potentials of biogenic resources for a sustainable and environmental friendly energy use in Cuba, BioReSCu”, because of their greater support to this research, which was performed under project.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dib.2020.105207.

References

[1] W. Duan, Q. Yu, K. Wuan, Q. Qin, L. Hou, X. Yao, T. Wu, ASPEN Plus simulation of coal integrated gasification combined blast furnace slag waste heat recovery system, Energy Convers. Manag. 100 (2015) 30–36.

[2] Q. Yi, J. Feng, W.Y. Li, Optimization and efficiency analysis of polygeneration system with coke-oven gas and coal gasified gas by Aspen Plus, Fuel 96 (2012) 131–140, https://doi.org/10.1016/j.fuel.2011.12.050.

[3] V. Sricharoenchaikul, D. Atong, Thermal decomposition study on Jatropha curcas L. waste using TGA and fixed bed reactor, J. Anal. Appl. Pyrol. 85 (2009) 155–162.

[4] R. Abreu, J.A. Conesa, E.F. Pedretti, O. Romero, Kinetic analysis: simultaneous modelling of pyrolysis and combustion processes of dichrostachys cinerea, Biomass Bioenergy 36 (2012) 170–175, https://doi.org/10.1016/j.biombioe.2011.10.032.

[5] R. Piñata-Rodríguez, Y. Díaz, Y. Sánchez-Borroto, E.A. Melo-Espinosa, S. Pohl, M. Pfeil, D. Denfeld, Potential of selected Cuban biomasses for thermochemical conversion into bioenergy, vol. 2, Mendeley Data, 2019. https://data.mendeley.com/datasets/sk6m66x4tj/2.