Available online at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

BIOMASS & BIOENERGY

Research Paper

Optimization of dilute acid and hot water pretreatment of different lignocellulosic biomass: A comparative study

Robinson Timung [a], Mood Mohan [a], Balaji Chilukoti [a], Soumya Sasmal [b], Tamal Banerjee [a,*], Vaibhav V. Goud [a,*]

[a] Department of Chemical Engineering, Indian Institute of Technology Guwahati, Guwahati, Assam 781039, India
[b] Netaji Subhas Institute of Technology, Division of Biotechnology, New Delhi 110078, India

ARTICLE INFO

Article history:
Received 16 August 2014
Received in revised form
4 April 2015
Accepted 8 May 2015
Available online

Keywords:
Hot water pretreatment
Dilute acid pretreatment
Sugarcane bagasse
Bamboo

ABSTRACT

Pretreatment of biomass to alter their recalcitrant structures is an essential step to obtain high yield of products via bioconversion processes. In this study, main emphasis was to compare the results evaluated in terms of total reducing sugars (TRS) yield after acid and hot water pre-treatment process performed with laboratory scale equipment using different lignocellulosic biomass. The biomass chosen for this purpose i.e. sugarcane bagasse and bamboo were collected from Guwahati, Assam and their physico-chemical characteristics were examined using X-ray diffraction (XRD), Fourier transform infrared (FTIR) spectroscopy and thermo gravimetric analysis (TGA) including proximate and ultimate analysis. Crystalinity of the biomass used was observed to be 33.15% and 31.29% for sugarcane bagasse and bamboo respectively. Hot water and dilute acid pretreatment allows selective solubility of hemicellulose which improves the accessibility of enzymes for cellulose hydrolysis. The highest yield of TRS was observed at run order 8 for both acid and hot water pretreatment (23.49 and 26.50 gL^{-1}) with respect to sugarcane bagasse. But, the pretreatment results obtained for bamboo was slightly different to that of sugarcane bagasse. The highest yield of TRS was obtained at run order 8 for acid (15.6 gL^{-1}) and run order 10 for hot water (17.98 gL^{-1}) pretreatment respectively. Irrespective of biomass type, hot water pretreatment process produced more TRS than acid pretreatment process.

1. Introduction

The fluctuation of crude oil price and rising concern on environment, renewable energy resources have become top priority for many countries. The upsurge of biofuel production paves the way to search for lignocellulosic biomass materials. Unlike fossils and nuclear fuels, availability of lignocellulose materials is not limited around the world. Almost all countries are abundant with the lignocellulosic resources depending on their geographical locations. The policy in sustainability of renewable energy is the main motivation for inflating shares

* Corresponding authors. Tel.: +91 361 2582266, +91 361 2582272; fax: +91 361 2690762.
E-mail addresses: tamalb@iitg.ernet.in (T. Banerjee), vvgoud@iitg.ernet.in (V.V. Goud).
http://dx.doi.org/10.1016/j.biombioe.2015.05.006

on renewable energy. About 118 countries, of which more than half are developing nations, currently have fixed renewable energy goals and 109 nations have guidelines in support of renewable energy in the power sectors. The usage of bioenergy may increase up to 1791 million tons oil equivalent within 2020 [1]. Lignocellulosic biomass is generated from green plants, which converts sunlight into energy stored in the form of carbohydrate molecules such as sugars through a photosynthesis process, and includes all land and water-based vegetation, as well as all organic wastes generated via various human activities. Therefore, the biomass can be defined as an organic matter in which the energy of sunlight is stored in chemical bonds [2]. Characterization of biomass is necessary before using it as feedstock in a bio-refinery for the production of bio-fuel and other valuable green chemicals. The compositions of biomass within the same species may be altered with varying seasons and climatic conditions. The relative quantities of principle building block elements of lignocellulosic material, i.e. cellulose, hemicellulose and lignin content are often required in studies involving fractionation [3], biofuel production [4] or synthesis of green chemicals [5]. High Lignin content reduces the thermo-chemical yield and bio-energy product. Therefore, pretreatment is an essential step to disrupt lignin structure and improve the bio-fuel yield for the fermentation process of lignocellulosic biomass. The utilization of both cellulose and hemicellulosic sugars like hexose, pentose, etc. present in a typical biomass hydrolysate is essential for the economical production of biofuels. Lignocellulosic material is very resistant to enzymatic breakdown; hence pretreatment is required in order to enhance the susceptibility of biomass to enzymes. The main goal of all pretreatment methods is to create a platform for optimizing yield of fermentable sugars from biomass, in order to increase biofuel production invariably. However, the final sugar yield depends not only on biomass characteristics, but also on their interaction with pretreatment conditions and enzyme formulations. The most successful physico-chemical pretreatments include thermo-chemical treatments such as steam explosion, grind milling, hot water/auto hydrolysis, acid treatment and currently hydrothermal hydrolysis is being investigated [6].

In this paper, main emphasis was on to compare the results evaluated in terms of TRS yield of acid and hot water pretreatment process performed with laboratory scale equipment using different lignocellulosic biomass. The biomass chosen for this purpose are bamboo and sugarcane bagasse. India has the richest bamboo reserves in the world [7]. The states of North-East India is known for its wide natural resources, among various types of biomasses bamboo and sugarcane forms an significant section in the traditional landscape of North East India [8]. The total production of sugarcane in Assam is 1.06 million tons, whereas in totality India produces 292.30 million tons [9]. The usage of bamboo as a fuel wood in India is 1145 tons [10]. Initially the selected biomass samples were characterized for their physico-chemical composition. Physical properties were estimated by proximate analysis, XRD and TGA. Chemical properties were determined by FTIR, CHNS-O and Soxhlet extractions followed by sugar contents analysis. The results of this study are useful to design the technology that is suitable for more efficient production of bio-fuel and for process economic analysis.

2. Materials and methods

2.1. *Materials*

The biomass used in this study i.e. bamboo (*Bambusa cacharensis*) and sugarcane bagasse were collected from Guwahati, Assam. After harvesting, biomass samples were sun dried in an open air then chopped and sieved (mesh size - BSS 30) to get homogeneous powder (diameter of particles lower than 0.5 mm). The powdered biomass samples were used as the starting material for characterization. AR grade sulfuric acid (98% Emplura) and Dinitrosalicylic acid were obtained from Merck India Ltd. and HiMedia respectively.

2.2. *Characterization of biomass*

2.2.1. *CHNSO analysis*

The carbon, hydrogen, nitrogen, sulphur and oxygen are the fundamental elements of any biomass which are commonly known as CHNSO. For the analysis purpose biomass sample (1.0 mg) was placed in a tin boat assortment to determine the percentage composition of carbon, hydrogen, sulphur and nitrogen. The percentage of oxygen was determined by means of difference and the results are tabulated in Table 1.

2.2.2. *Ash content*

The materials of ash are classified into three groups such as water soluble (free ionic form) organic solvent soluble and precipitated. The inorganic materials loosely adhered with the biomass known as extractable ash content. These are easily separated from biomass by simple extraction or washing techniques. Extractable ash is the result of soil remaining in the biomass. Structural ash materials are adhered with biomass strongly. The cations (K^{+}, Mg^{2+}, Ca^{2+}, Al^{3+}, Mn^{2+}, Fe^{3+}, Cu^{2+}, and Zn^{2+}) present in the ash has a positive inhibition effect on enzyme, which helps to hydrolyze the cellulosic substrates into glucose and other readily fermentable sugars [10]. The estimation of ash present in the biomass is necessary before processing the biomass for biofuel production. The procedure to estimate the amount of ash present in biomass was adopted from the NREL protocol. The biomass of 0.2(±0.02) gm was placed in an oven dried moisture free crucibles and heated up to 575 ± 25 °C in a muffle furnace for three hours. The dry weights of ash content in biomass samples were calculated using Equations (1) and (2).

$$\text{Dry wight of the sample} = \frac{\text{weight(air dried sample)} \times \text{Total solid(\%)}}{100} \quad (1)$$