WOOD – A RENEWABLE RESOURCE FOR PRODUCTION OF SUGAR AND BIOFUEL

Lacrimioara Senila, Marin Senila, Adriana Gog, Marius Roman, Miclean Mirela, Levei Erika, Cecilia Roman

Research group INCDO-INOE 2000, Research Institute for Analytical Instrumentation, 67 Donath, 400293, Cluj-Napoca, Romania, e-mail: lacri.senila@icia.ro

ABSTRACT

Albies Alba wood samples were subjected to autohydrolysis extraction at different severities (180, 190 and 200°C), delignification with sodium chloride, and acid hydrolysis of pretreated and delignified substrates. After autohydrolysis pre-treatment under selected operation conditions, cellulose and lignin, in solid phases, and liquors containing hemicellulose products (monosaccharides, oligosaccharides and inhibitory compounds) have been obtained. The purpose of this study is to obtain glucose by autohydrolysis, delignification and acid hydrolysis of fir wood. Fir wood was pretreated at 180, 190 and 200 °C for 5, 10 and 15 minutes, followed by delignification with sodium chloride and acid hydrolysis. The acid hydrolysis of pretreated material and pretreated-delignified material was hydrolyzed using H_2SO_4 in two stages of impregnation with acid. The results show that elimination of hemicellulose by autohydrolysis pretreatment and lignin by delignification method improve acid hydrolysis yield.

INTRODUCTION

Biomass is a great source of energy and has a special attention as a new raw material for biofuels production [1]. Lignocellulosic biomass is a renewable and low-cost resource for production of fuels and many secondary products. Wood is the abundant resource of lignocellulosic biomass, and it is composed from cellulose and hemicelluloses that can be converted in carbohydrates. In addition, agricultural residues, municipal solid waste, industrial solid waste, forestry residues are composed from carbohydrates, which can be further converted into ethanol. Ethanol production from varieties species of wood was studied but is not reported the best species of wood for bioethanol production [2].

Cellulose and hemicellulose could be chemical, biochemical, physic and physico-chemical depolymerized to sugars. Cellulose is a linear polymer formed of long-chain D-glucose monomers, hemicellulose is a mixture of polysaccharide formed from glucose, mannose, galactose, xylose and arabinose and lignin is a three-dimensional polymer of phenylpronane with units of guaiacyl, and syringyl units. Cellulose and hemicellulose can be hydrolyzed to a mixture a pentoses and hexoses [3].

Bioconversion of woody biomass to ethanol consists of four stages: pretreatment, hydrolysis, fermentation and ethanol recovery/distillation. Pretreatment is the most important stage from entire process of conversion because it is a crucial factor for breaking the structure of wood. Various pretreatments were studied including physic, physico-chemical and biological methods. Ecofriendly pretreatment not involve the use of chemical reagents [4].

Different pretreatment methods for woody biomass were developed. Most of the chemical transformation of wood into components was performed using solvents, requires long processing time and presence of chemicals [5,].

In this study, autohydrolysis pretreatment and acid hydrolysis were performed for glucose production. Autohydrolysis was used for hemicellulose separation in liquid fraction and cellulose (and lignin) recovery in solid fraction. Numerous studies show that elimination of lignin before hydrolysis improve hydrolysis yield [6]. Delignification with sodium chlorite in acetic acid was used for lignin remove before acid hydrolysis.

MATERIALS and METHODS

Raw material and reagent

The raw material used in the experiments was fir wood chips (*Albies Alba)*. All chemicals were analytical reagent grade. Sodium chloride (80%) was purchased from Alfa Aesar (Germany). Acetic acid, sulphuric acid (98%), dicloromethane, ethanol were purchased from Merck (Darmstadt, Germany).

Autohydrolysis experiments

The mixture of wood and water was homogenized at the desired proportions (7 kg/kg dry solid) and reacted in a pressurized reactor (Parr Instrument) at 180, 190 and 200 °C for 5, 10 and 15 minutes. The pretreated material was separated by filtration into solid and liquid phases.

Delignification method

Pretreated material resulted after autohydrolysis pretreatment was delignified with sodium chlorite. The samples was treated with $NaClO_2$ in acetic acid 10%, at 70 °C for 1 h (repeated for three times) according to Sun method [7].

Acid hydrolysis

Acid hydrolysis experiments of solid fraction recovered after delignification of wood were carried out in 100 ml conical flasks containing 2% H_2SO_4 at 130°C for 60 min while the second step for cellulose hydrolysis was performed using 15% H_2SO_4 at 130°C for 90 min. After the hydrolysis process, liquid fractions are separated from unreacted solids and can be subjected to fermentation to bioethanol. The amount of acid used for cellulosic fraction hydrolysis was 38 g of sulfuric acid to 2 grams of dry solid.

Analytical methods

The moisture content of raw material was determined by the weight loss after drying (105°C, 12 h). Determination of ash in fir has expressed as the percentage of residue remaining after dry oxidation of raw material at 590°C. Extractives were analyzed by extracted by using one step extraction process which includes ethanol an extractive solvent.

The chemical content of wood was determined according to Teramoto method [8]. The concentration of reducing sugars was determined according to Miller method [9]. The concentration of hemicellulosic fraction was determined according to our method (Senila 2011) [10].

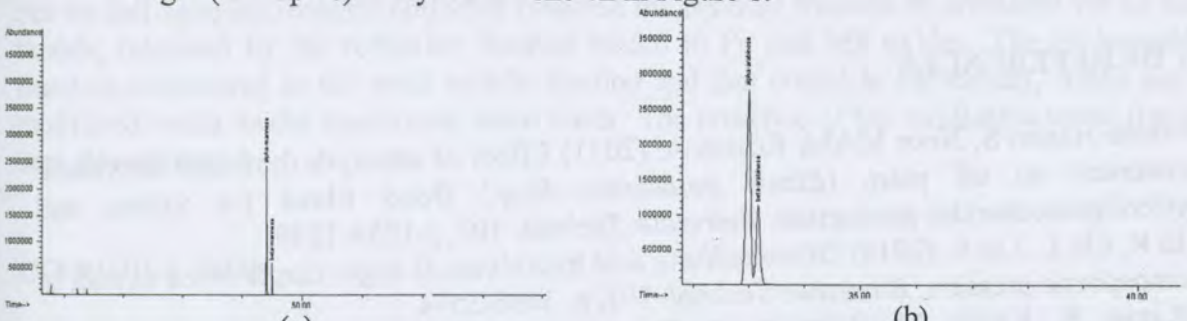
RESULTS

The content of wood was determined and is show in Table 1.

Table 1. Chemical composition of fir wood comparatively with other compositions of softwood reported in literature

Wood species	Hollocelulose	Cellulose	Hemicelulose	Lignin	Extractible	Ash
Fir wood –present study	69,99	46.00 ± 0.70	23.99 ± 0.60	28.38 ± 0.30	1.31 ± 0.10	0.32 ± 0.10
Fir wood	65,20	42,00	21,20	32,00	2,40	0,40
Douglas fir	69,00	42,00	27,00	28,30	2,50	0,20
Albies balsamea)	69,00	42,00	27,00	29,00	2,00	
Picea glauca	68,50	42,00	26,50	28,60	1,00	
Tsuga canadensis	64,00	41,00,	23,00	33,00	3,00	
Tsuga occidentalic	67,00	41,00	26,00	31,00	2,00	
Pinus nigra	60,50	49,50	11,00	27,20	2,00	

The content of fir wood is similar with other softwood species. Autohydrolysis pretreatment was applied to wood for hemicellulose recovery in liquid fraction. Hemicellulose is a mixture of pentoses (arabinose and xylose) and hexoses (glucose, mannose and galactose). Carbohydrates content from hemicellulose fraction was analyzed for its constituents. The method used for carbohydrates identification was conversion of each sugar into their oxime-trimethylsilyl derivatives and analyzed by GC-MS. The chromatograms of mannose and arabinose sugar (examples) analyzed are shown in Figure 1.



(a) (b)

Figure 1. Examples of GC-MS data from monosaccharide standards: (a) GC-MS chromatogram for a derivatized solution of mannose; (b) GC-MS chromatogram for a derivatized solition of arabinose

The content of wood after autohydrolysis method and content of sugars from hemicellulosic fraction are shown in Figure 2.

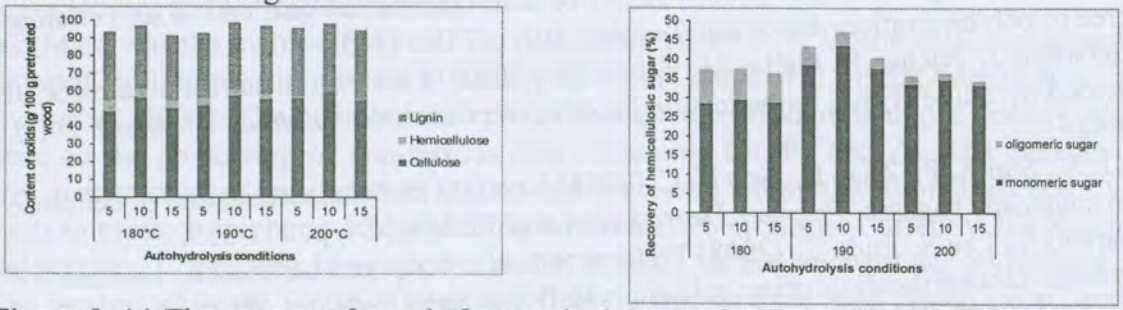


Figure 2. (a) The content of wood after autohydrolysis treatment; and (b) Hemicellulosic sugar recovery in liquid fraction

The cellulosic substrate resulted after delignification method was hydrolyzed into glucose. Acid hydrolysis was performed in all cases with H_2SO_4, in two stages of impregnation with

acid (2% concentration of acid in first stages and 15% concentration of acid in second stage). Figure 3 (a and b) shows the acid hydrolysis yields determined from the reducing value.

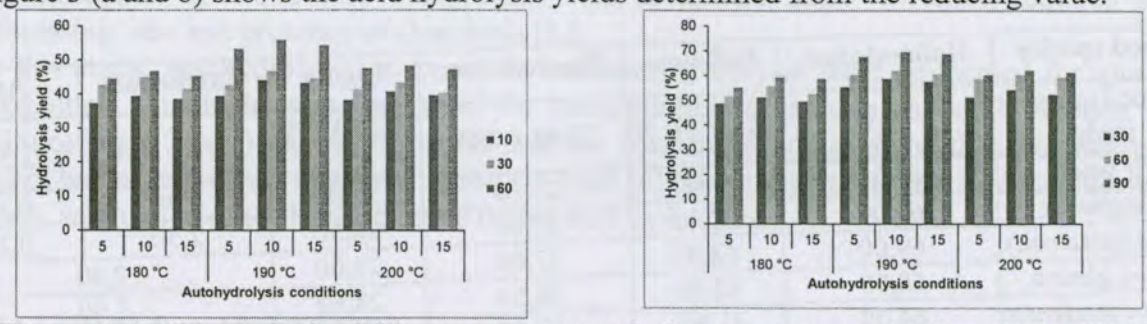


Figure 3. Acid hydrolysis yields, expresses as reducing sugar concentration obtained in the acid hydrolysis, for: (a) 2% acid concentration and, (b) 15% acid concentration

CONCLUSIONS

Woody biomass can be used as renewable resource for production of sugar. Sugar obtained can be subjected to fermentation for bioethanol production. Autohydrolysis pretreatment was applied for hemicellulose remove in liquid fraction and cellulose and lignin recovery in solid fraction. Delignification method was applied for lignin remove before acid hydrolysis. The results show that elimination of hemicellulose and lignin before acid hydrolysis improve acid hydrolysis yield.

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