CHEMICALS FROM BIOMASS VIA THE CONVERTECH SYSTEM

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ABSTRACT

Biomass is suspended in steam which acts as a mobile carrier in the Convertech System.The lignocellulose complex is disrupted so that hemicellulose can be separated from Cellulig . Cellulig can be converted into panelboard materials. Cellulig™ also can be further separated into low-MW cellulose and partly depolymerized lignin. The hemicellulose can be converted into furfural or lactic acid, if the starting material is a hardwood or grass. The low-MW cellulose is suitable for conversion into cellulose acetate which has prospects as a degradable polymer.The ethanol-soluble lignin can be used as an extender for phenolic resins. Additional opportunities will be discussed.

INTRODUCTION

Steam is a highly desirable reactant to use in processing biomass. It is environmentally benign, cheap, has excellent thermal properties, and can be easily removed by condensation or as a gas phase. Therefore, steam processing has a long history. Important milestones in this history include the following events. Mason developed the Masonite process and hardboard products in 1926 [1]. DeLong modified the Masonite gun and the processing conditions to disrupt and fractionate lignocellulose in a batch process [2]. Marschessault elucidated the chemistry of this steam explosion process [3]. Brown and Bender invented the Stake Technology continuous steam explosion process [4]. These three events occurred between about 1975 and 1983.

In 1989, Scott conceived the Convertech System which is a continuous steam processing technology in which the biomass particles are suspended in steam. Rafferty's patent that was assigned to Convertech was the first public disclosure [5].This paper focuses on the Convertech System which has not yet received much attention in this country.

DISCUSSION

Convertech System

The Convertech process uses steam hydrolysis to achieve a breakdown of the biomass into its chemical constituents (in particular, cellulose, lignin, volatiles, and sugars derived from hemicellulose). The main hydrolysis, chemical extraction and drying operations are carried out in a series of five continuously operated modules (Figure 1). Depending upon the nature of the lignocellulose, it is shredded or milled and fed into the plant as a stream of small particles.

The technology includes an interlock which is a rotating valve used to transfer in a continuous fashion the fine biomass material between the different pressure zones [6]. It is this device that makes possible the efficient cascading of heat and hydrolysis.

Steam is the sole medium used to transport the particles through each module, conduct the hydrolysis and chemical extraction operations, and carry out the drying. This contributes to making the process simple, robust, and clean while minimizing corrosion from strong acids.

The major technical differences between the Convertech System and steam explosion processes include focus on energy recycling and use of suspended solids. Convertech 's current emphasis is on separation of hemicellulose from lignocellulose and production of a low-moisture product. Steam explosion processes usually separate lignin from lignocellulose.

Materials and Chemical Opportunities

Processing of lignocellulose can provide a spectrum of products that include fuels, food products, animal feeds, materials for particle board products, and chemicals. In the chemicals area, there are

many alternative opportunities. Figures 2 and 3 are provided to summarize just the chemical opportunities.

Commercialization remains a problem for the Convertech System and for other systems that are based on steam treatment. If there are so many opportunities, why is there a problem? We believe that the answer may be that the diversity of potential products is a blessing but also a curse. Commercialization depends on focus on relatively short term goals, not on the entire spectrum. Therefore the following discussion pertains only to a few opportunities that may be relatively easy to implement. Once established, many other latent opportunities will be realizable.

Furfural from Hemicellulose

Acid digestion of hemicellulose in hardwoods and grasses (e.g., corn stover and bagasse) results in furfural. The Convertech process extracts and depolymerizes hemicellulose early in its sequence of operations so that this solution can be converted into furfural.

Furfural is used mostly for production of furfuryl alcohol. Furfuryl alcohol is used to make foundry core resins and coatings that are highly resistant to chemicals and heat. Furfural is also a source of tetrahydrofuran which is a powerful solvent and a source of chemicals for making urethanes and nylon polymers. Furfural also has considerable prospects as a binder for wood products (see below).

Cellulig

After removal of hemicellulose from lignocellulose, the resulting solid is a mixture of low molecular weight (low MW) cellulose and low MW lignin. This fibrous mixture is dried in the final module of the Convertech System (Figure 1). Thus, Cellulig is ready to be converted into a high density fiberboard for use as a construction material. This strong material does not need synthetic binders to make an attractive product. Enhancement of Cellulig's natural binder with furfuryl alcohol polymers results in super-strong materials that are interpenetrating polymers. Such products are the logical outcome of the Convertech System and may well be the basis for its initial success.

Cellulose

Although initial success may come from Cellulig products, there are additional opportunities that emerge as soon as this mixture of cellulose and lignin becomes readily available. Separation of Cellulig into its two constituents is easily accomplished with such volatile solvents as ethanol, methanol, or acetone (Figure 2). One result is a low MW cellulose that is chemically quite reactive and relatively pure.

There are two attractive uses for this cellulose: production of cellulose acetate and production of glucose oligomers.

Cellulose Acetate

Cellulose reacts with acetic anhydride to produce new grades of cellulose acetate [7] that were expected to be less strong but more easily degradable than are conventional grades of cellulose acetate. Actually, cellulose acetate is surprisingly slow to degrade because the standard plasticizers for this material are also stabilizers that inhibit hydrolysis. Recent advances in additives that enhance the degradability of cellulose acetate render degradable cellulose acetate a more attractive product [8]. The degradability and low cost of a properly plasticized Convertech cellulose acetate could lead to large markets.

Glucose Oligomers

The Superconcentrated HCl Process [9] provides a water-soluble product that is a mixture of glucose and glucose oligomers with degrees of polymerization of about 2 to 6 glucose units. The process was developed as a source of glucose and ethanol. However, it deserves to be evaluated for its potential for other uses that have higher potential value. An example is production of alkyl glucosides by reaction with methanol, ethanol, or other alcohols. The HCl catalyst for glucoside production is contained in the initial oligomer product.

Hydrolysis of the glucose oligomers described above is an alternative to direct hydrolysis of starch or cellulose to manufacture glucose. Glucose is a key chemical intermediate, in addition to its uses in food products (Figure 3).

Lignin

Utilization of the cellulose content of Cellulig would intensify the search for lignin uses to consume this by-product. The lignin that results from Convertech processing is not similar to that which results from kraft pulping or sulfite pulping. It does resemble "steam explosion lignin". That is, it is soluble in ethanol or acetone and does not contain any sulfur. It is low in molecular weight and more reactive than conventional lignins.

If available at low price, Convertech lignin may be desirable to use as an extender-type ingredient in many compositions. For example, epoxy resins are frequently extended with coal tar products ("coal tar epoxies"). Convertech lignin may compete quite well in such a market. Reactive extenders can be used in some phenolic resins.

If cellulose markets become large, still larger lignin markets must be sought. The high energy value of lignin makes it attractive as a fuel for gas turbine power generation or diesel fuel.

CONCLUSIONS

The Convertech System has great potential for enabling the conversion of lignocellulose into materials and chemicals. Realization of this great potential for commodity chemicals production depends on site-specific situations and/or soaring fossil fuel prices and/or serious action on global warming issues.

Developers of this type of technology have special problems in commercializing their processes. They need to be prepared for huge demand at an unknown future time. However, they must devote their current efforts to programs that do not require that petroleum prices rise or carbon taxes to be enacted for success to occur. Therefore, at present, prospects appear better for manufacture of reconstituted wood products that could use Cellulig as the feedstock, with furfural as a chemical coproduct. Development of other chemicals and fuels via the Convertech System need to be driven by the relevant end-use sectors.

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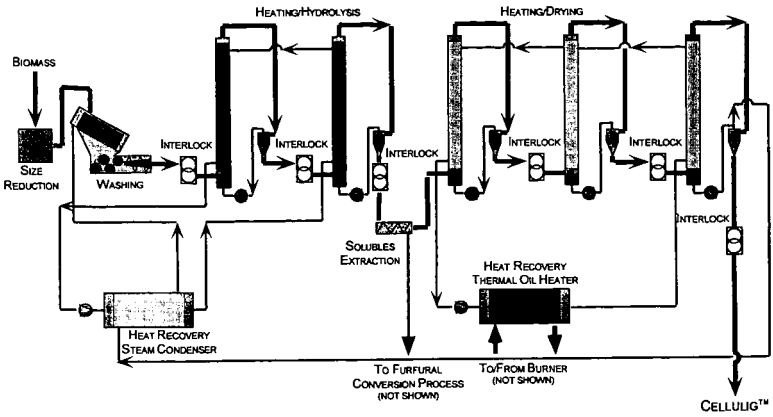

Figure 1. Convertech Flow Diagram

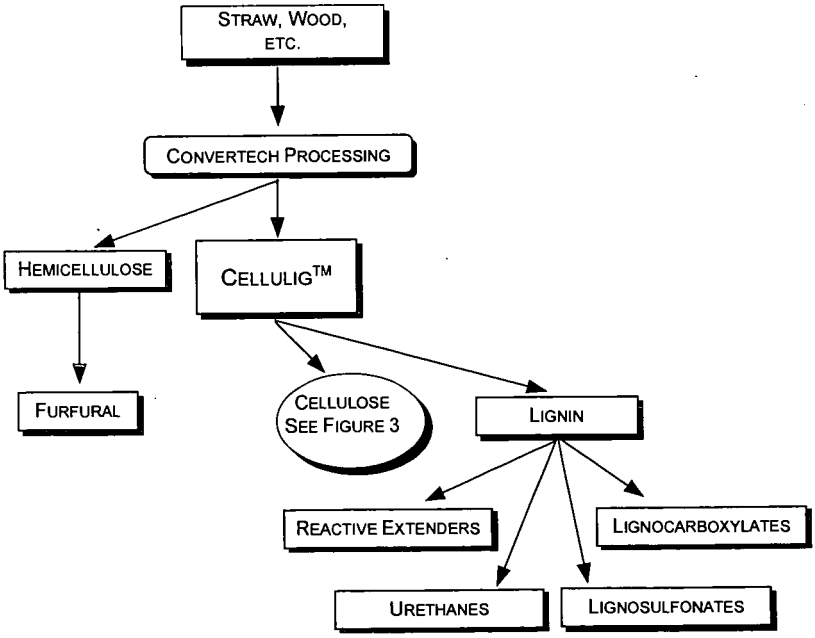

Figure 2. Lignocellulose Processing for Chemicals by Convertech Process

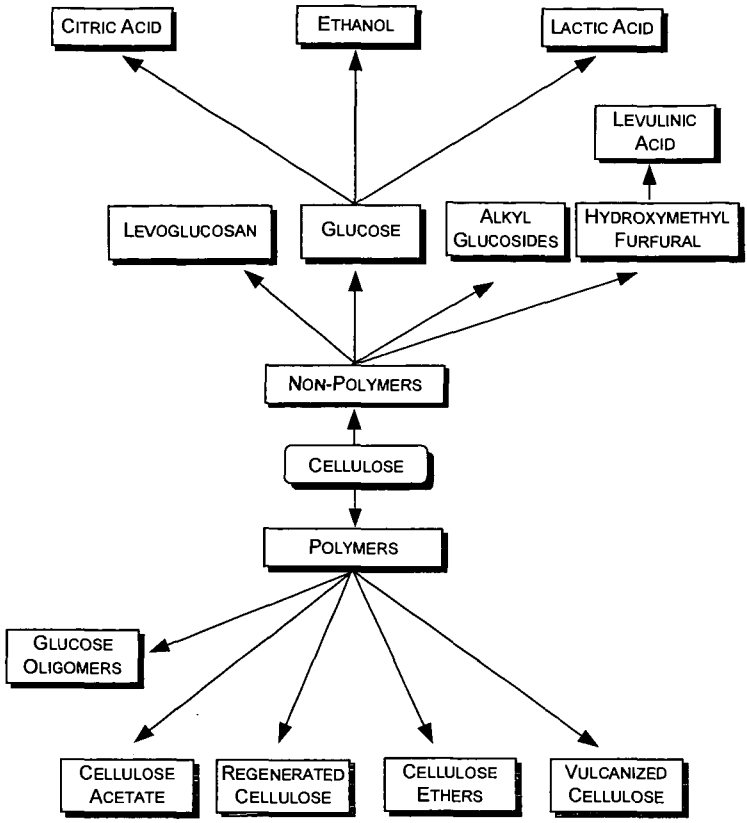

Figure 3. Chemicals from Convertech Cellulose