PROCESSING BIOMASS

RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application Serial No. 61/495,217, filed June 9, 2011. The complete disclosure of this provisional application is hereby incorporated by reference herein.

BACKGROUND

Cellulosic and lignocellulosic materials are produced, processed, and used in large quantities in a number of applications. Often such materials are used once, and then discarded as waste, or are simply considered to be waste materials, e.g., sewage, bagasse, sawdust, and stover.

SUMMARY

Processes are disclosed herein for saccharifying or liquifying a biomass material, e.g., cellulosic, lignocellulosic and/or starchy feedstocks, by converting biomass material to low molecular weight sugars, e.g., saccharifying the feedstock using an enzyme, e.g., one or more cellulase and/or amylase. The ~~invention~~ disclosure also relates to converting a feedstock to a product, e.g., by bioprocessing, such as fermentation. The processes include wet milling a feedstock. The inventors have found that wet milling the feedstock tends to reduce the time required for saccharification, and increase the concentration of sugar that can be obtained in a given saccharification time. Wet milling alone or working synergistically with any treatment described herein can reduce recalcitrance of a biomass material.

The processes disclosed herein can utilize low bulk density materials, for example cellulosic or lignocellulosic feedstocks that have been physically pretreated to have a bulk density of less than about 0.75 g/cm^3, e.g., less than about 0.7, 0.65, 0.60, 0.50, 0.35, 0.25, 0.20, 0.15, 0.10, 0.05. or less, e.g., less than 0.025 g/cm^3.

Such materials can be difficult to disperse in liquids, e.g., with water or a solvent system for saccharification, fermentation, or other processing. Due to their low bulk

density, the materials tend to float on the surface of the liquid rather than being wetted out and dispersed into the liquid. In some cases, the materials can be hydrophobic, highly crystalline, or otherwise difficult to wet. At the same time, it is desirable to process the feedstock in a relatively high solids level dispersion, in order to obtain a high final concentration of sugar in the saccharified material, or a high concentration of the desired product after processing (e.g., of ethanol or other alcohol(s) after fermentation). In some cases, utilizing the methods described herein the solids level of the dispersion during processing can be, for example, at least 10, 15, 20, 22.5, 25, 27.5, 30, 35, 40, 45, or even at least 50 percent by weight dissolved solids. For example, the solids level can be from about 10 to 50%, e.g., about 10-40%, 10-30%, or 10-20%.

According to one aspect, there is provided a method for producing a product from lignocellulosic material, comprising reducing the recalcitrance of the lignocellulosic material by irradiating the lignocellulosic material, thereby making a reduced recalcitrance lignocellulosic material; wet milling and simultaneously jet mixing the reduced recalcitrance lignocellulosic material using a wet milling system comprising one or more jet mixers and one or more wet mills, wherein one or more jet heads and one or more wet milling heads are disposed in a tank containing a fluid having the reduced recalcitrance lignocellulosic material dispersed therein, thereby making wet milled lignocellulosic material; saccharifying the wet milled lignocellulosic material with a saccharifying agent, thereby producing a sugar solution; fermenting the sugar solution with a microorganism in the tank, with jet mixing during fermenting, to produce a product selected from the group consisting of: alcohols, organic acids, hydrocarbons and mixtures thereof.

According to another aspect, there is provided a wet milling system comprising a jet mixer comprising one or more jet mixers and one or more wet mills, wherein one or more jet heads and one or more wet milling heads are disposed in a tank containing a fluid having biomass dispersed therein.

According to another aspect, there is provided a method for producing a sugar solution from lignocellulosic material, comprising: reducing the recalcitrance of the lignocellulosic material by irradiating the lignocellulosic material, thereby making a reduced recalcitrance lignocellulosic material; wet milling and simultaneously jet mixing the reduced recalcitrance lignocellulosic material using a wet milling system comprising

one or more jet mixers and one or more wet mills, wherein one or more jet heads and one or more wet milling heads are disposed in a tank containing a fluid having the reduced recalcitrance lignocellulosic material dispersed therein, thereby making wet milled lignocellulosic material; saccharifying the wet milled lignocellulosic material with a saccharifying agent, thereby producing a sugar solution.

In one ~~aspect~~exemplary embodiment, the ~~invention~~ disclosure features reducing the particle size of a lignocellulosic material to less than 3000 μm, e.g. less than 2000 μm, less than 1000 μm or even less than 500 μm, e.g., less than 250 μm or less than 100 μm. The particle size range can be between 100 - 3000 μm, e.g., 200-2000 μm, 200-1000 μm, 500-1000 μm.

In one ~~aspect~~exemplary embodiment, the ~~invention~~ disclosure features reducing recalcitrance of a lignocellulosic material and wet milling the lignocellulosic material. In some cases, recalcitrance is reduced prior to wet milling. The material can be densified prior to reducing the recalcitrance or after reducing the recalcitrance and prior to wet milling the material.

In another ~~aspect~~exemplary embodiment, the ~~invention~~ disclosure features a method comprising wet milling a lignocellulosic material, e.g., a lignocellulosic material having a reduced recalcitrance.

~~Either of these aspects~~Exemplary embodiments of the ~~invention~~ disclosure can include, in some implementations, any of the following features.

The recalcitrance of the biomass material, e.g., a lignocellulosic material, can be reduced, for example, by irradiating the lignocellulosic material, e.g., by exposing the material to an electron beam. In some cases, irradiating comprises delivering a dose of at least 5 Mrad to the lignocellulosic material, e.g., at least 10, 20, 30, 50, 100, 150 or even 200 Mrad. For example, doses can be in the range of 5-200 Mrad, e.g., 5-100 Mrad, 5-50 Mrad, 5-10 Mrad, 10-100 Mrad, or 10-50 Mrad.

The lignocellulosic material may be, for example, a material is selected from the group consisting of wood, particle board, sawdust, agricultural waste, sewage, silage, grasses, rice hulls, bagasse, cotton, jute, hemp, flax, bamboo, sisal, abaca, straw, wheat

ketones, aldehydes, alpha unsaturated acids, beta unsaturated acids, such as acrylic acid, olefins, such as ethylene, butenes, and mixtures of any of these. Specific examples include ethanol, propanol, propylene glycol, butanol, 1,4-butanediol, 1,3-propanediol, methyl or ethyl esters of any of these alcohols, methyl acrylate, methylmethacrylate, . Products also include sugars, e.g., glucose, xylose and xylitol. These and other products are described in U.S. Serial No. 12/417,900 filed April 3, 2009; the full disclosure of which is incorporated by reference herein.

In one aspect exemplary embodiment, the invention disclosure features a wet milling system comprising a wet mill disposed in a fluid having a biomass material dispersed therein. The system can, for example, be used for processing lingocellulosic material that has optionally been irradiated (e.g., with an electron beam). The system can include a jet mixer disposed in the fluid. The wet milling systems can include a rotor/stator head, for example with the rotor and stator including nesting rings of teeth. Furthermore, the stator can have two or more concentric rings of teeth. Other aspects exemplary embodiments of the invention disclosure include a tank with one or more jet head, and one or more wet mill disposed in the tank.

Bulk density is determined using ASTM D1895B. Briefly, the method involves filling a measuring cylinder of known volume with a sample and obtaining a weight of the sample. The bulk density is calculated by dividing the weight of the sample in grams by the known volume of the cylinder in cubic centimeters.

All publications, patent applications, patents, and other references mentioned herein or attached hereto are incorporated by reference in their entirety for all that they contain.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram illustrating the enzymatic hydrolysis of cellulose to glucose.

FIG. 2 is a flow diagram illustrating conversion of a feedstock to sugars and other products. FIG. 2A is a diagrammatic illustration of a saccharification system according to one embodiment. FIG. 2B is a diagrammatic illustration of a saccharification system according to another embodiment.

FIG. 3 is a schematic diagram of an ethanol manufacturing facility that has been retrofitted to utilize the solutions and suspensions disclosed herein.