PROCESSING BIOMASS

RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application Serial No. 61/179,995, filed May 20, 2009, and U.S. Provisional Application Serial No. 61/218,832, filed June 19, 2009. The complete disclosure of each of these provisional applications 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.

Various cellulosic and lignocellulosic materials, their uses, and applications have been described in U.S. Patent Nos. 7,307,108, 7,074,918, 6,448,307, 6,258,876, 6,207,729, 5,973,035 and 5,952,105; and in various patent applications, including "FIBROUS MATERIALS AND COMPOSITES," PCT/US2006/010648, filed on March 23, 2006, AND "FIBROUS MATERIALS AND COMPOSITES," U.S. Patent Application Publication No. 2007/0045456.

SUMMARY

In one aspect, there is provided a method comprising:

saccharifying a lignocellulosic feedstock in a vessel by mixing the lignocellulosic feedstock with a fluid medium and a saccharifying agent using a jet mixer to form a mixture, wherein the jet mixer comprises a jet-flow agitator and the vessel has an arcuate bottom surface, the jet mixer is mounted offset from a center axis of the vessel, and wherein saccharifying the feedstock comprises agitating the mixture with the jet-flow agitator.

In another aspect, there is provided a method comprising:

saccharifying a lignocellulosic material in a vessel by mixing the lignocellulosic material with a fluid medium and an enzyme using a jet mixer to form a mixture, wherein the jet-mixer comprises a jet-flow agitator and the vessel has an arcuate bottom surface, wherein the jet mixer is mounted offset from a center axis of the vessel, and wherein saccharifying the lignocellulosic material comprises agitating the mixture with the jet-flow agitator.

Generally, this ~~invention~~disclosure relates to processes for saccharifying or liquifying a material, e.g., a cellulosic or lignocellulosic feedstock, by converting the cellulosic portion of the material to low molecular weight sugars, e.g., using an enzyme. The ~~invention~~disclosure also relates to converting a feedstock to a product, e.g., by fermentation.

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 0.5 g/cm^3, e.g., less than about 0.35 g/cm^3, 0.25 g/cm^3, 0.20 g/cm^3, 0.15 g/cm^3, 0.10 g/cm^3, 0.05 g/cm^3 or less, e.g., 0.025 g/cm^3.

steps of measuring the lignin content of the feedstock and determining whether pretreatment is needed and under what conditions based on the measured lignin content.

In one ~~aspect~~embodiment, the ~~invention~~disclosure features a method that includes saccharifying a biomass feedstock by mixing the feedstock with a liquid medium and a saccharifying agent in a vessel, using a jet mixer.

Some embodiments include one or more of the following features. The feedstock can have a bulk density of less than about 0.5 g/cm^3. The feedstock may be, for example, a cellulosic or lignocellulosic material. The liquid can include water. The saccharifying agent can include an enzyme. The jet mixer may include, for example, a jet-flow agitator, a jet aeration type mixer, or a suction chamber jet mixer. If a jet aeration type mixer is used, it may be used without injection of air through the jet mixer. For example, if the jet aeration type mixer includes a nozzle having a first inlet line and a second inlet line, in some cases both inlet lines are supplied with a liquid. In some cases, mixing comprises adding the feedstock to the liquid medium in increments and mixing between additions. The method may further include monitoring the glucose level of the mixture of feedstock, liquid medium and saccharifying agent during mixing, and in some cases adding additional feedstock and saccharifying agent to the vessel during saccharification. The mixing vessel may be, for example, a tank, rail car or tanker truck. Saccharification can in some cases take place partially or completely during transport of the mixture of feedstock, liquid medium and saccharifying agent. The method may further include adding an emulsifier or surfactant to the mixture in the vessel.

In another ~~aspect~~embodiment, the ~~invention~~disclosure features saccharifying a biomass feedstock by mixing the feedstock with a liquid medium and a saccharifying agent in a vessel, using a mixer that produces generally toroidal flow within the vessel.

In some embodiments, the mixer is configured to limit any increase in the overall temperature of the liquid medium to less than 5°C over the course of mixing. This aspect may also include, in some embodiments, any of the features discussed above.

In yet a further ~~aspect~~embodiment, the ~~invention~~disclosure features a method that includes converting a low molecular weight sugar to a product by mixing the low molecular weight sugar with a microorganism in a liquid medium, using a jet mixer.

Some embodiments include one or more of the following features. The liquid medium can include water. The microorganism can include yeast. The jet mixer can include a jet-flow agitator, jet aeration type mixer, or suction chamber jet mixer.

In another ~~aspect~~embodiment, the ~~invention~~disclosure features an apparatus that includes a tank, a jet mixer having a nozzle disposed within the tank, a delivery device configured to deliver a biomass feedstock to the tank, and a delivery device configured to deliver a metered amount of a saccharifying agent to the tank.

Some embodiments include one or more of the following features. The jet mixer can further include a motor, and the apparatus can further include a device configured to monitor the torque on the motor during mixing. The apparatus can also include a controller that adjusts the operation of the feedstock delivery device and/or the saccharifying agent delivery device based on input from the torque-monitoring device.

The ~~invention~~disclosure also features a method that includes saccharifying a biomass feedstock in a vessel to form a saccharified mixture; inoculating the saccharified mixture in the vessel with a microorganism; and allowing the inoculated saccharified mixture to ferment in the vessel.

In some cases, the contents of the vessel are transferred to a transport vessel during fermentation and fermentation continues in the transport vessel. The method may further include agitating the contents of the vessel with a jet mixer during saccharification and fermentation. In some embodiments, the method further includes monitoring the oxygen content and ethanol and/or sugar content of the fermenting mixture.

In another ~~aspect~~embodiment, the ~~invention~~disclosure features a fermentation system that includes a vessel having a vent; a source of oxygen in communication with the vessel; an oxygen monitor configured to monitor the oxygen content of a liquid in the vessel; and a controller configured to adjust the oxygen content of the liquid, using the vent and oxygen source, in response to input from the oxygen monitor.

The flow rate of oxygen into the vessel, if oxygenation is required, can be relatively low. For example, the controller may be configured to oxygenate the vessel at a rate of less than 0.2 vvm, e.g., less than 0.1, 0.05, 0.025, or even less than 0.01 vvm.

The fermentation system may further include a fermentation monitor configured to monitor the sugar concentration and/or ethanol concentration of the liquid in the