PROCESSING BIOMASS

RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application Serial No. 61/151,724, filed February 11, 2009. The complete disclosure of this provisional application is hereby incorporated by reference herein.

BACKGROUND

Various carbohydrates, such as cellulosic and lignocellulosic materials, e.g., in fibrous form, 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

Generally, this ~~invention~~ disclosure relates to processes for manufacturing an intermediate or a product, e.g., energy, a fuel such as ethanol, a food or a material, from a plurality of different carbon-containing feedstocks and/or from a feedstock having a variable composition. The carbon-containing feedstock may include, for example, carbohydrate-containing materials (e.g., starchy materials and/or cellulosic or lignocellulosic materials), and may in some cases be a waste material having an unpredictable or variable composition.

The processes disclosed herein, alone or in combination, change the molecular structure and/or recalcitrance level of the feedstock(s), allowing a desired product to be obtained from the feedstock in an economically feasible manner. The inventors have found that the amount of change to the structure and/or recalcitrance level of the feedstock required to produce a product varies as a function of the lignin content of the feedstock. For example, the change in recalcitrance needed can be directly proportional to the lignin content.

utilized to power aircraft, such as planes, e.g., having jet engines, or helicopters. In addition, the products described herein can be utilized for electrical power generation, e.g., in a conventional steam generating plant or in a fuel cell plant.

In an aspect, there is provided a method for reducing the recalcitrance of a biomass feedstock comprising:

(a) providing a cellulosic or lignocellulosic biomass feedstock;

(b) determining the lignin content in a lignocellulosic biomass feedstock;

(c) recalcitrance-reducing the biomass feedstock comprising:

(i) to a first portion of the feedstock, irradiating the first portion with an amount of ionizing radiation sufficient to provide depolymerization of the feedstock or cellulose chain scission therein, thereby providing an irradiated first portion containing a recalcitrance-reduced biomass;

(ii) saccharifying the irradiated first portion under conditions and for a period of time sufficient therefor, wherein the recalcitrance-reduced biomass provides an increased rate of saccharification relative to the rate of saccharifying a feedstock not having been irradiated;

(iii) to a second portion of the feedstock, irradiating the second portion with an amount of ionizing radiation sufficient to provide depolymerization of the feedstock or cellulose chain scission therein, thereby providing an irradiated second portion containing a recalcitrance-reduced biomass, wherein the second portion irradiating amount is the irradiating amount provided to the first portion in step (c) (i) or a dose-adjusted irradiating amount sufficient to provide the recalcitrance-reduced irradiated second portion, said irradiated second portion capable of providing an increased rate of saccharification relative to the rate of saccharifying a feedstock not having been irradiated; and

(d) obtaining the saccharified, irradiated first portion or the irradiated second portion, thereby reducing the recalcitrance of the biomass feedstock.

In another aspect, there is provided a method for producing a product comprising:

(I) reducing the recalcitrance of a lignocellulosic biomass feedstock by:

(a) providing a cellulosic or lignocellulosic biomass feedstock;

(b) determining the lignin content of the biomass feedstock,

(c) recalcitrance-reducing the biomass feedstock comprising:

(i) to a first portion of the feedstock, irradiating the first portion with an amount of ionizing radiation sufficient to provide depolymerization of the feedstock or cellulose chain

scission therein, thereby providing an irradiated first portion containing a recalcitrance-reduced biomass;

(ii) saccharifying the irradiated first portion under conditions and for a period of time sufficient therefor, wherein the recalcitrance-reduced biomass provides an increased rate of saccharification relative to the rate of saccharifying a feedstock not having been irradiated;

(iii) to a second portion of the feedstock, irradiating the second portion with an amount of ionizing radiation sufficient to provide depolymerization of the feedstock or cellulose chain scission therein, thereby providing an irradiated second portion containing a recalcitrance-reduced biomass, wherein the second portion irradiating amount is the irradiating amount provided to the first portion in step (c) (i) or a dose-adjusted irradiating amount sufficient to provide the recalcitrance-reduced irradiated second portion, said irradiated second portion capable of providing an increased rate of saccharification relative to the rate of saccharifying a feedstock not having been irradiated; and

(d) obtaining the saccharified, irradiated first portion or the irradiated second portion, thereby reducing the recalcitrance of the biomass feedstock; and

(II) converting at least a portion of the irradiated second portion of biomass feedstock to a product, wherein the converting comprises contacting the irradiated second portion with a microorganism under conditions sufficient to produce the product, and wherein the product contains a material selected from the group consisting of an alcohol, a carboxylic acid, a salt of a carboxylic acid, an ester of a carboxylic acid, and mixtures thereof.

In ~~one aspect~~an embodiment, the ~~invention~~ disclosure features a method of making a product comprising determining the lignin content of a biomass feedstock; treating the biomass feedstock material with a physical treatment; setting a process parameter of the process based on the lignin content; and converting at least a portion of the treated biomass feedstock, utilizing a microorganism, to produce a product or intermediate, such as energy, fuels, foods or materials.

The physical treatment can be, for example, selected from the group consisting of mechanical treatment, radiation, sonication, pyrolysis, oxidation, steam explosion, chemical treatment, and combinations thereof. Chemical treatment may include the use of a single chemical or two or more chemicals. Mechanical treatments include, for example, cutting, milling, pressing, grinding, shearing and chopping. Milling may include, for example, ball milling, hammer milling, or other types of milling.

Some implementations include one or more of the following features. The physical treatment can comprise any one or more of the treatments listed above, applied alone or in any desired combination, and applied once or multiple times. In some cases, the physical treatment can comprise irradiating with ionizing radiation, alone or accompanied by mechanical treatment before and/or after irradiation. Irradiation can be performed, for example, with an electron beam.

The setting step can comprise setting the dosage of ionizing radiation to be delivered to the feedstock material. For example, a radiation dosage of 0.1 Mrad to 5.0 Mrad can be delivered per 1% by weight of lignin in the biomass feedstock, e.g., 0.25 Mrad to 4.0 Mrad or 0.3 Mrad to 3.5 Mrad.

The intermediate or product can be, for example, any one or more of the products listed herein. In some cases, the product can be energy or a fuel, for example biodiesel or an alcohol such as ethanol or methanol. The intermediate or product can also be, e.g., a carboxylic acid, an ester of a carboxylic acid, a salt of a carboxylic acid, or a mixture thereof.

The method can further include repeating the determining, treating and setting steps with a second feedstock.

In another ~~aspect~~embodiment, the ~~invention~~ disclosure features a method of making a product or intermediate, the method including providing a cellulosic or lignocellulosic material having a plurality of pendent carboxylic acid groups, mixing the material in a fluid that includes water to provide a dispersion that has a first pH, and adding base to the dispersion to increase its pH to a second pH higher than the first pH. The first pH can be, for example, between 2.5 and 4.5, e.g., between 3 and 4.25. The second pH can be, for example, between about 5 and 7, e.g., between about 5.5 and 6.5.

Some implementations include one or more of the following features. The method can further include adding a cellulase to the dispersion to saccharify the cellulosic or lignocellulosic material. The method can further include contacting the saccharified material with a microorganism.

In some implementations, one or more components of the processing equipment, for example the mechanical treatment equipment, chemical (e.g., acid or base) treatment equipment, irradiating equipment, sonicating, pyrolyzing, oxidizing, steam exploding, saccharifying, and/or fermenting equipment, or any of the other equipment described herein, may be portable, e.g., in the manner of the mobile processing equipment described in U.S. Patent Application Serial 12/374,549, and Published International Application No. WO 2008/011598, the full disclosures of which are incorporated herein by reference.

Changing a molecular structure of a material, as used herein, means to change the chemical bonding arrangement or conformation of the structure. For example, the change in the molecular structure can include changing the supramolecular structure of the material, oxidation of the material, changing an average molecular weight, changing an average crystallinity, changing a surface area, changing a degree of polymerization, changing a porosity, changing a degree of branching, grafting on other materials, changing a crystalline domain size, or changing an overall domain size. A change in molecular structure may be effected using any one or more of the physical treatments described herein, alone or in any combination, applied once or repeatedly.

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

~~WHAT IS CLAIMED IS:~~

1. A method of making a product, the method comprising:

providing a cellulosic or lignocellulosic material having a plurality of pendent carboxylic acid groups;

mixing the material in a fluid that includes water to provide a dispersion that has a first pH; and

adding base to the dispersion to increase its pH to a second pH higher than the first pH.

2. The method of claim 1 wherein the first pH is between 2.5 and 4.5.

3. The method of claim 1 wherein the second pH is between about 5 and 7.

4. The method of claim 1 further comprising adding a saccharifying agent to the dispersion to saccharify the cellulosic or lignocellulosic material.

5. The method of claim 4 further comprising contacting the saccharified material with a microorganism.

6. The method of claim 1 wherein the product comprises a fuel.

7. The method of claim 1 wherein the product comprises an alcohol.

8. The method of claim 4 wherein the saccharifying agent comprises a cellulase.

WHAT IS CLAIMED IS:

1. A method for reducing the recalcitrance of a biomass feedstock comprising:

(a) providing a cellulosic or lignocellulosic biomass feedstock;

(b) determining the lignin content in a lignocellulosic biomass feedstock;

(c) recalcitrance-reducing the biomass feedstock comprising:

(i) to a first portion of the feedstock, irradiating the first portion with an amount of ionizing radiation sufficient to provide depolymerization of the feedstock or cellulose chain scission therein, thereby providing an irradiated first portion containing a recalcitrance-reduced biomass;

(ii) saccharifying the irradiated first portion under conditions and for a period of time sufficient therefor, wherein the recalcitrance-reduced biomass provides an increased rate of saccharification relative to the rate of saccharifying a feedstock not having been irradiated;

(iii) to a second portion of the feedstock, irradiating the second portion with an amount of ionizing radiation sufficient to provide depolymerization of the feedstock or cellulose chain scission therein, thereby providing an irradiated second portion containing a recalcitrance-reduced biomass, wherein the second portion irradiating amount is the irradiating amount provided to the first portion in step (c) (i) or a dose-adjusted irradiating amount sufficient to provide the recalcitrance-reduced irradiated second portion, said irradiated second portion capable of providing an increased rate of saccharification relative to the rate of saccharifying a feedstock not having been irradiated; and

(d) obtaining the saccharified, irradiated first portion or the irradiated second portion, thereby reducing the recalcitrance of the biomass feedstock.

2. The method of claim 1, wherein the irradiating of the first portion of biomass feedstock comprises irradiating with 0.1 Mrad to 5.0 Mrad of ionizing radiation per 1% by weight of lignin in the biomass feedstock.

3. The method of claim 2 wherein the irradiating of the first portion of biomass feedstock comprises irradiating with 0.25 Mrad to 4.0 Mrad of ionizing radiation per 1% by weight of lignin in the biomass feedstock.

4. The method of claim 3 wherein the irradiating of the first portion of biomass feedstock comprises irradiating with 0.3 Mrad to 3.5 Mrad of ionizing radiation per 1% by weight of lignin in the biomass feedstock.

5. The method of claim 1 wherein the irradiating with ionizing radiation comprises irradiating with an electron beam.

6. A method for producing a product comprising:

(I) reducing the recalcitrance of a lignocellulosic biomass feedstock by;

(a) providing a cellulosic or lignocellulosic biomass feedstock;

(b) determining the lignin content of the biomass feedstock,

(c) recalcitrance-reducing the biomass feedstock comprising:

(i) to a first portion of the feedstock, irradiating the first portion with an amount of ionizing radiation sufficient to provide depolymerization of the feedstock or cellulose chain scission therein, thereby providing an irradiated first portion containing a recalcitrance-reduced biomass;

(ii) saccharifying the irradiated first portion under conditions and for a period of time sufficient therefor, wherein the recalcitrance-reduced biomass provides an increased rate of saccharification relative to the rate of saccharifying a feedstock not having been irradiated;

(iii) to a second portion of the feedstock, irradiating the second portion with an amount of ionizing radiation sufficient to provide depolymerization of the feedstock or cellulose chain scission therein, thereby providing an irradiated second portion containing a recalcitrance-reduced biomass, wherein the second portion irradiating amount is the irradiating amount provided to the first portion in step (c) (i) or a dose-adjusted

irradiating amount sufficient to provide the recalcitrance-reduced irradiated second portion, said irradiated second portion capable of providing an increased rate of saccharification relative to the rate of saccharifying a feedstock not having been irradiated; and

(d) obtaining the saccharified, irradiated first portion or the irradiated second portion, thereby reducing the recalcitrance of the biomass feedstock; and

(II) converting at least a portion of the irradiated second portion of biomass feedstock to a product, wherein the converting comprises contacting the irradiated second portion with a microorganism under conditions sufficient to produce the product, and wherein the product contains a material selected from the group consisting of an alcohol, a carboxylic acid, a salt of a carboxylic acid, an ester of a carboxylic acid, and mixtures thereof.

7. The method of claim 6, wherein the product contains an alcohol and wherein said converting comprises fermenting.

8. The method of claim 6, wherein the product contains a material selected from the group consisting of a carboxylic acid, a salt of a carboxylic acid, an ester of a carboxylic acid, and mixtures thereof, and wherein said converting comprises fermenting.