sugars, which can then be converted by bioprocessing into a variety of products, such as alcohols or organic acids. The product obtained depends upon the microorganism utilized and the conditions under which the bioprocessing occurs.

Unlike traditional fermentation feedstocks such as corn, grapes, and the like, cellulosic and lignocellulosic materials generally contain relatively low to negligible levels of nutrients. This is particularly true of feedstocks that have been processed, e.g., by pulping, for example waste paper and waste paper pulp. As a result, when such feedstocks are used fermentation generally proceeds slowly (if at all), and it can be difficult to obtain high concentrations of ethanol. While commercially available nutrient packages, such as peptone or yeast nitrogen base, can be added to the fermentation medium, such materials are generally expensive, impacting the economic viability of large-scale fermentation processes.

The inventors have found that by adding particular nutrients to the bioprocessing medium to feed the microorganisms, the efficiency of the bioprocess can be significantly enhanced and the cost can be significantly reduced. The nutrients include a food product, e.g., a grain or vegetable; a residue of a food product, e.g., a residue of a crop product such as rice bran, or a residue of a meat product, e.g., stock, renderings, bouillon or extract of beef, chicken, pork ~~or the like~~; or mixtures thereof. These will be referred to collectively herein as "food-based nutrient sources." Because food-based nutrient sources are used, nutrients can be supplied to the fermentation process at relatively low cost, reducing the overall cost of a product produced by the process. The food-based nutrient source can be low in sugar content, since the material is being used primarily or solely as a nutrient source, rather than as a fermentation feedstock. Thus, materials can be used that are not valued as a sugar source.

In some implementations, the food-based nutrient source is delivered as part of a nutrient package, which may include one or more additional ingredients. In some preferred implementations, the nutrient package further includes a nitrogen source, e.g., urea, ammonia, ammonium sulfate, and mixtures thereof.

In one aspect, the invention features a method that includes combining a feedstock, comprising a carbon-containing material, such as a cellulosic or lignocellulosic material and/or a saccharified cellulosic or lignocellulosic material, with a microorganism

In some preferred implementations, the mixture further comprises an enzyme system selected to release nutrients, e.g., nitrogen, amino acids, and fats, from the food-based nutrient source. For example, the enzyme system may include one or more enzymes selected from the group consisting of amylases, proteases, and mixtures thereof. In some cases, the enzyme system comprises a protease and an amylase.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, suitable methods and materials are described below. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only ~~and not intended to be limiting~~.

Other features and advantages of the invention will be apparent from the following detailed description, and from the claims.

DESCRIPTION OF DRAWINGS

FIG. 1 is a flow diagram illustrating conversion of a feedstock to ethanol via production of a glucose solution.

FIG. 2 is a schematic diagram of an ethanol manufacturing facility.

FIG. 3 is a diagram illustrating the enzymatic hydrolysis of cellulose to glucose.

DETAILED DESCRIPTION

Using the methods and nutrient packages described herein, carbon-containing materials such as cellulosic and lignocellulosic materials and their saccharified derivatives can be bioprocessed, e.g., using fermentation, to produce useful intermediates and products such as those described herein.

The inventors have found that by adding low levels of a food product and/or a food residue to the fermentation batch, efficient fermentation can be obtained, resulting in relatively high concentrations of ethanol, e.g., up to 10%, 15%, 20%, 25%, or even up to 30% or more. In some cases, concentrations can be, for example, from about 0.1 to 80

After the last increment of feedstock was added, at 27 hours, the batch was allowed to continue to saccharify to a total of 70 hours from the beginning of the process. At this point the glucose concentration was 90 g/L.

The saccharified mixture was transferred to a BioFlow® 115 bioreactor for fermentation. The parameters were then changed, and the mixture inoculated, to initiate fermentation. Mixing was performed with a Rushton impeller at 250 rpm, with air provided at 0.025 wm, and the pH was adjusted to about 5.0. The temperature was reduced to about 30°C. pH control was provided using 1M H_3PO_4 (acid control) and 1M NaOH (base control). Inoculation was based on the following ratio: 1 mg of Superstart™ yeast to 1 g of glucose. The yeast was added directly to the mixture as a freeze dried inoculum.

After 20 hours of fermentation under these conditions, the concentration of ethanol in the mixture was about 50 g/L, and the concentration of glucose had dropped to about 0 g/L. This was only slightly lower than ethanol concentrations obtained by fermenting 150 g/L glucose and 40 g/L xylose in a medium containing 1.7 g/L YNB, 2.27 g/L Urea and 6.6 g/L soy peptones under the same processing conditions.

OTHER EMBODIMENTS

A number of embodiments of the invention have been described herein, which illustrate. ~~Nevertheless, it will be understood that various modifications may be made without departing from~~ the spirit and scope of the invention.

~~For example, while~~ While it is preferred for cost reasons that the nutrient packages disclosed herein include only food-based (and in particular vegetable and/or grain) nutrient sources, if desired the nutrient package can include mixtures of these nutrient sources with other non-food based or non-grain/non-vegetable food sources.

Accordingly, other embodiments are within the scope of the following claims. It is intended that the scope of the invention be defined by the following claims and their equivalents:

WHAT IS CLAIMED IS:

1. A method comprising

combining a feedstock, comprising a cellulosic or lignocellulosic material and/or a saccharified cellulosic or lignocellulosic material, with a microorganism and a nutrient package comprising 2% to 5% by volume weight of a food-based nutrient source that is not derived from the feedstock to form a mixture, the microorganism utilizing the feedstock to produce a product or intermediate;

wherein the food-based nutrient source is used primarily or solely as a nutrient source for the microorganism; and

wherein the mixture further comprises an enzyme system comprising one or more enzymes selected to release nutrients from the food-based nutrient source.

2. The method of claim 1 wherein the food-based nutrient source is selected from the group consisting of grains, vegetables, residues of grains, residues of vegetables, residues of meat products, and mixtures thereof.

3. The method of claim 1 or 2 wherein the product comprises a fuel selected from the group consisting of hydrogen, alcohols, organic acids, hydrocarbons, and mixtures thereof.

4. The method of claim 1, 2 or 3 wherein utilizing comprises fermentation.

5. The method of claim 4 wherein the microorganism comprises a yeast.

6. The method of claim 4 wherein fermentation is conducted at a pH of 4.8 to 5.2.

7. The method of any one of the above claims wherein utilizing comprises saccharification.

8. The method of claim 7 wherein the microorganism comprises an enzyme.

9 The method of claim 8 wherein the enzyme comprises a hemicellulase or a cellulase.