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NREL supplies ton quantities of lignocellulosic sugars and lignin derived from a variety of biomass types to the research community and to various industries (biofuels, bio-chemical, bio-products, petrochemical, and others). Sugars are produced by pretreatment and enzymatic hydrolysis of the raw biomass, which also leaves a residual solid lignin product. Soluble lignin is generated by treating biomass with a caustic solution, creating a heterogeneous mixture of aromatic monomers, high-molecular weight lignin, and acetic acid with smaller amounts of other acids and mono- and poly-saccharides.

Category 1: Lignocellulosic Sugars

Question 1: To which types of research entities are you willing and able to sell your lignocellulosic sugar (e.g., university researchers, national laboratories, industry/private sector)? We provide sugars to all types of research entities, provided the material is used only for research purposes and is not provided to other parties, without prior arrangement. If a proprietary enzyme is used to produce the sugars, then the receiving party must have an appropriate materials transfer agreement with the enzyme manufacturer. Non-proprietary, commercially available enzymes may be used that would negate this requirement.
Question 2: What are the maximum and minimum quantities of lignocellulosic sugar you are willing and able to sell (kg)? We are able to supply any amount of sugar product from several liters to tens of thousands of liters (<kg to 1000's of kgs).
Question 3: What is the sugar concentration in your product? The product is supplied at typical sugar concentrations (~150–200 g/L total sugars) produced during enzymatic hydrolysis of a 20% total solids (w/w), pretreated corn stover slurry. The concentration of the product will vary if other biomass types are used. Sugar concentrations are routinely measured for each lot of product by HPLC methods given on our web site (http://www.nrel.gov/bioenergy/biomass-compositional-analysis.html). We recommend that the sugar solution be concentrated to ~ 400–600 g/L total sugars to better preserve the product.
Question 4: What physical form do you sell your sugars (e.g., solid or liquid)? Sugars are supplied as an aqueous liquid product.
Question 5: How do you package your lignocellulosic sugars for shipping? Do you ship in bulk? Sugar solutions are supplied in any type and size of shippable container (from Nalgene bottles to buckets up to 1,000 L IBC totes) requested by the receiving party.
Question 6: What type(s) of biomass do you use to produce lignocellulosic sugar? We will use any type of lignocellulosic biomass and presorted MSW lignocellulosic material, but some materials respond more readily to pretreatment and enzymatic hydrolysis producing more sugars

per unit mass than other biomass types. Non-domestic biomass (i.e. not from the continental US) can be accepted, but requires prior permitting and storage protocols, per USDA APHIS requirements.

Question 7: What process do you use to produce lignocellulosic sugar? Sugars are produced by a combined pretreatment and enzymatic hydrolysis process. Pretreatment is performed at elevated temperatures using a variety of catalyst (acids or caustics solutions) or using no catalyst (autohydrolysis). Enzymatic hydrolysis is performed on the whole pretreated slurry or on washed pretreated solids after removing the residual liquor. In the case of an acid-based pretreatment process, the hemicellulosic sugars may be recovered prior to enzymatic hydrolysis of the residual cellulosic solids and supplied separately from cellulose derived glucose. Enzymatic hydrolysis is performed using readily available enzyme (cellulase and/or hemicellulose) cocktails.
Other processing options are available for producing cleaner sugar solutions including deacetylation (removing acetyl and some lignin from the biomass) prior to acid pretreatment or mechanical refining in place of the standard pretreatment process. NREL's capabilities for pretreatment and enzymatic hydrolysis are shown on our website at the following link: http://www.nrel.gov/bioenergy/ibrf.html, fermentation capabilities at the following link: http://www.nrel.gov/docs/gen/fy12/53599.pdf, feedstock handling capabilities at: http://www.nrel.gov/docs/gen/fy12/53598.pdf.

Question 8: What details of the scale of your process are you willing to share (e.g. batch and/or continuous/ volumetric productivity)? The available pretreatment reactors range in size from batch 1-L reactors to continuous 900 dry kg/d continuous reactors. Batch low-solids (up to 10% insoluble solids) enzymatic hydrolysis is performed in reactors ranging in size from several liters up to 9,000-L stirred tanks and 10-L, 170-L, 1x 900-L and multiple 4,000-L paddle reactors are available for batch, high-solids enzymatic hydrolysis (insoluble solids concentrations greater than 10%).

Question 9: What is the typical composition of your sugar stream (e.g., glucose, galactose, mannose, xylose, arabinose) and what is the purity? Composition and relative concentration of various sugars in the product will depend on the biomass type used and processing conditions. Typical sugars concentrations in un-concentrated enzymatic hydrolysate produced from corn stover are: glucose, 90–100 g/L; xylose 40–50 g/L; arabinose, 5–10 g/L; and galactose, 5–10 g/L.

Question 10: Do you routinely test your cellulosic sugar for consistency within and between lots and between feedstocks (if applicable)? While we routinely measure sugar concentration in each lot, there may be significant differences in sugar concentrations and yields (e.g., kg of sugar/kg of feedstock) between lots because of feedstock and process variabilities.

Question 11: What impurities are present in your lignocellulosic sugar process and what testing do you perform to determine the presence of impurities? The most common known impurities are sugar degradation products (furfural and 5-hydroxymethlyfurfural (HMF)), acetic acid, and aromatic-type compounds derived from solubilized lignin along with small amounts of polysaccharides. The amount of each compound in the product depends on the feedstock type and pretreatment process. HPLC measurement of furfural, HMF, acetic acid and polysaccharide concentration is routinely performed. Testing for aromatic compounds may be done if needed.

Question 12: Does your process include a purification step? Purification is not routinely performed, but activated carbon treatment may be done if desired.

Question 13: What is the highest concentration in grams/Liter you can provide? See answer to Question 3.

Question 14: Have you examined the impacts of transport and storage on sugar degradation? If so, can you please provide any relevant (non-proprietary) details of these impacts? At typical sugar concentrations (~150–200 g/L total sugars) produced during enzymatic hydrolysis, the sugars are subject to microbial contamination and loss to contaminating microorganism metabolic products. This can be avoided by adjusting the pH to ranges that do not support microbial growth (acidic or basic) or by refrigeration (for up to 2 weeks) or freezing (long term storage). Alternatively, the sugars can by concentrated to a syrup at a total sugar concentration of ~400-600 g/L, which should be stable at room temperature for up to several weeks.

Question 15: What additional information are you willing and able to provide to the research community about your lignocellulosic sugar? Please provide any nonproprietary cost information you are willing to share. There is not a fixed charge ($/kg) for these products. NREL charges for material and labor used to produce these materials and so cost depends on process/equipment used and amount of material produced. NREL can and routinely provides compositional analyses services (http://www.nrel.gov/bioenergy/biomass-compositional-analysis.html) related to the production of lignocellulosic sugars.

Question 16: Into what markets do you typically sell your lignocellulosic sugar? What is a typical application for your lignocellulosic sugar? Not applicable to NREL.