Response to Request for Information DE-FOA-0001615

Cellulosic Sugar and Lignin Production Capabilities

Iowa State University

Contact: Ryan Smith
515-294-6244
rgsmith@iastate.edu

Category 1: Lignocellulosic Sugars

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)? Are there any types of research entities to whom you are not willing and able to sell your lignocellulosic sugar?

Iowa State University (ISU) is willing and able to sell cellulosic sugar to any type of research entity, including universities, national laboratories and private entities. A standard rate will be developed to recover costs incurred for the production and shipment of the sugars.

2. What are the maximum and minimum quantities of lignocellulosic sugar you are willing and able to sell?

There will be no minimum quantity of sugars that can be provided, however, a minimum fee will be applied to ensure recovery of fixed costs. The maximum quantity of sugar that can be provided will be dependent on equipment availability and throughput, as well as personnel availability. Currently production of concentrated cellulosic sugars is constrained at approximately 5 kg/day from woody biomass, and 2 kg/day from herbaceous biomass.

3. What is the sugar concentration in your product?

As-produced, the product is a solution of organic products. Total organics concentration is nominally 200 g/L, with 80 g/L C6 sugars, 30 g/L C5 sugars, 40 g/L sorbitol and 50 g/L other compounds (phenolics, furans, acids, and aldehydes). This solution can be concentrated using a proprietary purification process, resulting in nominal concentrations (dry weight basis) of 52% C6 sugars, 28% C5 sugars, 10% sorbitol, and 10% other volatile compounds (primarily furans and acids). Finally, a proprietary process can be used to generate crystalized high-purity cellulosic sugar. This product is >98.5% levoglucosan with the balance being cellobiosan. Any of these sugar streams can be reduced using acid hydrolysis, resulting in xylose and glucose from C5 and C6 sugars, respectively.

4. What physical form do you sell your sugars?

As described above, the sugars can be provided as solutions, as concentrated solutions, or in crystalline form.

5. How do you package your lignocellulosic sugars for shipping? Do you ship in bulk?

Currently, sugar samples that have not been concentrated are shipped in bottles on dry ice to prevent microbial breakdown. Concentrated and crystalized samples are shipped without dry ice.

6. What type(s) of biomass do you use to produce lignocellulosic sugar?

Currently woody biomass (e.g. red oak and pine) and herbaceous feedstock (e.g. corn stover and switchgrass) are used to produce cellulosic sugars.

7. What process do you use to produce lignocellulosic sugars?

Iowa State University utilizes an autothermal bubbling fluidized bed pyrolysis system to thermally deconstruct lignocellulosic biomass. To achieve autothermal operation, the bed is fluidized using 100% air. This system processes up to 1 ton of woody biomass or 0.6 ton of herbaceous biomass per day. Pyrolysis vapors are collected as stage fractions with distinct physical and chemical properties using pairs of condensers and electrostatic precipitators (ESP).[1] The heavy fractions collected in the first condenser and ESP are then mixed with water to recover the water soluble sugars.[2] A proprietary purification step is then used to remove phenolic compounds present in the stream. The sugars can be concentrated using evaporation or reduced to glucose and xylose using acid hydrolysis.

8. What details of the scale of your process are you willing to share (e.g. batch and/or continuous/ volumetric productivity)?

The autothermal pyrolysis and fraction collection are continuous processes that produce concentrated sugar quantities at rates of approximately 5 kg/day from woody biomass, and 2 kg/day from herbaceous biomass. Separation of water soluble sugar from heavy fractions is currently done in 1 liter batches. The sugar purification step is a continuous, 1-2 liter per hour process. Production of high purity levoglucosan crystals is a batch process completed in 30 minutes that produces up to 100 g per batch. Acid hydrolysis to glucose and xylose is a batch process requiring one hour. Approximately 1 liter of concentrated sugar solution can be reduced per batch.

9. What is the typical composition of your sugar stream and what is the purity.
Purity levels are described in response to question #3.

10. Do you routinely test your cellulosic sugar for consistency within and between lots and between feedstocks?

Sugar quantification is completed for each batch using HPLC methods for hydrolysable and water soluble sugars.[3] Volatile contaminants are identified and quantified using GC/MS/FID. Total phenolics are quantified using the Folin-Ciocalteu method.[4] Organic acids are quantified using Ion Chromatography.

11. What impurities are present in your lignocellulosic sugar process and what testing do you perform to determine the presence of impurities?

Impurity descriptions and testing methods are described in responses to questions #3 and #11.

12. Does your process include a purification step?

Optional purification steps are described in responses to questions #3 and #8.

13. What is the highest concentration in grams/liter you can provide?

Liquid samples without concentration or crystallization typically have total sugar concentrations of 150-200 g/L.

14. Have you examined the impacts of transport and storage on sugar degradation?

We have observed a reduction in sugar content when samples are stored at room temperature for two weeks. This breakdown in sugars is slowed by removing water from the samples and storing at cold temperatures.

15. What additional information are you willing and able to provide to the research community about your lignocellulosic sugar?

Sugar samples have been successfully fermented with *E.coli* by researchers at ISU and by an industrial collaborator.

[1] A. S. Pollard, M. R. Rover, R. C. Brown, *Journal of Analytical and Applied Pyrolysis* **2012**, *93*, 129-138.

[2] M. R. Rover, P. A. Johnston, T. Jin, R. G. Smith, R. C. Brown, L. Jarboe, *Chemsuschem* **2014**, *7*, 1662-1668.

[3] P. A. Johnston, R. C. Brown, *Journal of Agricultural and Food Chemistry* **2014**, *62*, 8129-8133.

[4] Z. Y. Chi, M. Rover, E. Jun, M. Deaton, P. Johnston, R. C. Brown, Z. Y. Wen, L. R. Jarboe, *Bioresource Technol* **2013**, *150*, 220-227.