Ek Laboratories Response to (RFI) DE-FOA-0001615: Cellulosic Sugar and Lignin Production Capabilities

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EK Laboratories (EK) is the Research and Development center supporting the scale-up and optimization of the patented Cellulose-to-Sugar (CTS) conversion process invented by Dr. Richard G. Blair. The 10,000 sq. ft. Longwood, FL facility has a team of scientists and engineers that have demonstrated the CTS process at laboratory, bench and pilot scale. The facility has demonstrated production of lignocellulose sugar and lignin from over 110 different feed stocks. The laboratory and office areas are outfitted with the latest technology for characterizing incoming feedstock, determining process metrics, and ensuring product quality. EK has also provided laboratory analysis on many feed stocks for many clients.

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

We are willing to sell to any entity whether they are university researchers, national labs, or private industry.

Question 2: What are the maximum and minimum quantities of lignocellulosic sugar you are willing and able to sell (kg)?

We can supply quantities as small as a few milligrams to as large as 1 metric ton.

Question 3: What is the sugar concentration in your product?

The final product is dry solid consisting of 100% C6 and C5 sugars. We can supply solids or solutions at concentrations required by the customer.

Question 4: What physical form do you sell your sugars (e.g., solid or liquid)?

We have the capability to sell solid sugars or solutions of any concentration, depending on customers' needs. We prefer to sell solids or high concentration solutions (>70%) to minimize microbial degradation during shipping.

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

Current customers have requested solutions. Samples are packaged in plastic containers ranging from small jars to 5-gallon plastic buckets. Larger samples will be packaged in 55-gallon food-grade plastic drums. We can ship large quantities by freight.

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

We have produced sugar from many sources including those targeted as potential cellulose sources for cellulosic sugars. A portion of the feedstock we can process are listed in Appendix A.

Question 7: What process do you use to produce lignocellulosic sugar?

We use our patented CTS process to produce the lignocellulosic sugar. The CTS process is a green mechanochemical process developed by Dr. Richard Blair. It operates by solid/solid interactions (solid catalyst and cellulose) which, along with water, hydrolyze the glycosidic linkages in saccharide polymers. CTS is the most energy-efficient process for the hydrolysis of recalcitrant biomass.

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

We have successfully demonstrated our CTS process from gram to kilogram scale at our current facility in batch mode. Most feedstocks are efficiently converted in 15 to 30 minutes. The 10,000 square foot facility can easily process 2.5 tons of feedstock in a day. We have collected data at this scale and have modeled commercial scale implementation including energy requirements and rate of production.

Question 9: What is the typical composition of your sugar stream (e.g., glucose, galactose, mannose, xylose, arabinose) and what is the purity?

The sugar stream composition varies from feedstock to feedstock. The principle components are in the form of glucose and xylose. Glucose concentrations are highest in cellulose rich, hemicellulose poor plants such as softwoods. For example, coastal hay is rapidly hydrolyzed to produce a product with the following composition:

glucose, 92.240%; xylose, 5.125%; cellobiose, 1.791%; other sugars, <1%; HMF, ND

Analysis was performed in-house by EK using LC-RI-MS and validated by a third party (CSCS LLC).

Question 10: Do you routinely test your cellulosic sugar for consistency within and between lots and between feedstocks (if applicable)?

We have a formal quality protocol for evaluating sugar content. All lots are checked for consistency.

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

Impurities present in our final product are low, but typically consist of water soluble minerals (<1%) and silicates (<1%). Chemical impurity levels are measured using a high sensitivity and rapid laboratory analysis with Direct Analysis in Real Time Accurate High Resolution Time of Flight Mass Spectrometry (DART). Inorganic impurities are analyzed via ion selective electrode and ashing.

Question 12: Does your process include a purification step?

A dry flowable powder is produced from the reaction that contains the hydrolyzed biomass, remaining biomass and catalyst. No unwanted side products are produced. Purification is achieved though solubilization of sugars, centrifugation to remove solids, and drying.

Question 13: What is the highest concentration in grams/Liter you can provide?

Since our final product is a solid we can provide solutions up to 811 grams/liter.

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?

A dry product or a solution with a concentration >70% is indefinitely stable. We have been able to keep products on the shelf without change for 6 years. Dilute samples must be refrigerated or frozen. Shelf life for these samples is at most 3 months.

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.

The product composition is mostly monomers with a small fraction of dimers. No larger oligomers or dehydration products are produced. The catalyst does not interfere with fermentation and our product has been tested successfully for fermentability.

Question 16: Into what markets do you typically sell your lignocellulosic sugar? What is a typical application for your lignocellulosic sugar?

Our product is mostly sold for fermentation. The sugar could also be isolated and purified for fine chemical production.

Appendix A

Feedstocks utilized and the quantities of lignin and lignocellulosic sugars recovered as a percentage of initial mass. Hydrolyzed percentage is representative of holocellulose conversion efficiency in a single pass and increases with recycle streams.

Feedstock	Lignin	Hydrolyzed
Algae *Nannochloropsis*	6%	69.20%
Bamboo *Bambusa multiplex*	28%	75.10%
Coastal hay *Cynodon dactylon*	8%	78.40%
Cobs Flint *Zea mays indurata*	18%	81.50%
Spent Coffee Grounds *Coffea arabica,*	27%	45.20%
Big Bluestem Grass, *Andropogon gerardi*	7%	50.10%
Elephant Grass, *Miscanthus giganteus*	26%	64.70%
Switch Grass *Panicum virgatum*	17%	57.90%
Little Bluestem Grass *Schizachyrium scoparium*	8%	48.90%

Feedstock	Lignin	Hydrolyzed
Sweet Cherry *Prunus avium*	50%	95.70%
Stover Flint, *Zea mays indurata*	18%	52.10%
Nictotine-free Tobacco	16%	88.20%
Maple Wood *Acer saccharum,*	24%	72.00%
Red Cedar Wood, *Juniperus virginiana*	31%	74.00%
Tulip Poplar Wood, *Liriodendron tulipifera*	23%	66.90%
Douglas Fir Wood, *Pseudotsuga menziesii*	29%	71.10%
Water Oak Wood *Quercus nigra*	26%	68.50%
Yellow Pine Wood *Pinus taeda*	27%	65.30%

Bahia Grass *Paspalum notatum*	6%	92.50%	Apricot Shell *Prunus armeniaca*	49%	56.83%
Oat Kernel *Avena sativa*	2%	90.30%	Almond Fruit Husk, *Prunus dulcis*	13%	92.37%
Flint Corn Kernel *Zea mays indurata*	1%	93.40%	Almond Wood, *Prunus dulcis*	5%	84.34%
Banana Leaf *Musa acuminate*	30%	52.00%	Dry distiller grain (DDG)	3%	78.24%
Vidalia Onion *Allium cepa*	22%	87.50%	Sugarcane Bagasse *Saccharum officinarum*	5%	51.28%
Paper, newsprint	0%	54.70%			