RFI Category 1 – LIGNOCELLULOSIC SUGARS

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Introduction:
American Science and Technology Corporation (AST) is an R&D service provider with pilot plant capabilities that can process various lignocellulosic biomass and produce cellulosic sugar from a few grams to couple of tons per week. Over the years, AST has developed two patented Organosolv-based fractionation technologies that can extract lignin from lignocellulosic materials and produce pulp and bio based chemicals such as furfural, butyl acetate, etc. AST pulp is enzymatically hydrolyzed and produces food grade sugar that can be used for various applications.

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?
AST sells its sugar worldwide to any entity that may need it for any purpose (unless it is prohibited by US laws). So far, AST's sugar (in form of food grade sugar) have been shipped to various domestic universities, national labs, as well as public and private companies. As long as it is not prohibited by any US laws, we impose no restrictions and no limitations for selling our cellulosic sugar to any one or any entity worldwide.

Question 2: What are the maximum and minimum quantities of lignocellulosic sugar you are willing and able to sell (kg)?
AST has the capabilities to produce cellulosic sugar from a few grams per batch (in our laboratories) to about 200 Kg per batch using our pre commercialization pilot plant. If necessary, AST pilot plant can process four batches per day to produce about ¾ to one ton of sugar per day.

Question 3: What is the sugar concentration in your product?
AST sugar is produced by enzymatic Hydrolysis of AST pulp and it can be dehydrated to whatever our customer requests. Usually AST sugar is dehydrated to about 50 brix or more to avoid spoilage. But delivering at a higher brix, all the way to solid sugar, is possible as well.

Question 4: What physical form do you sell your sugars (e.g., solid or liquid)?
We can ship our sugar usually in liquid form. However, if necessary, AST sugar can be dehydrated all the way to a solid form as well.

Question 5: How do you package your lignocellulosic sugars for shipping? Do you ship in bulk?
AST's liquid sugar is usually placed in food grade plastic containers for shipping. Due to our limited production, we have not shipped bulk yet, but certainly for a large order, it is possible to hold the sugar and ship them bulk via truck once a week or so.

Question 6: What type(s) of biomass do you use to produce lignocellulosic sugar?
AST's biorefinery pilot plants can use any type of lignocellulosic biomass to produce pulp and thereafter convert the pulp to sugar. AST's processes to pretreat lignocellulosic biomass, with a minor changes in process parameters, have been successfully tested to fractionate various hardwood, softwood, agricultural wastes such as corn straw, wheat straw, tobacco stalk, etc. and produce pulp that easily converted to sugar by using enzymatic hydrolysis.

Question 7: What process do you use to produce lignocellulosic sugar?
AST uses its proprietary and patented Organosolv process to fractionate lignocellulosic biomass and separate lignin from pulp. In addition, due to its acidic nature, AST's Organosolv process produces more solvents such as furfural and butyl acetate, creating additional revenue streams. The pulp produced by AST's Organosolv fractionation, is washed and hydrolyzed to produce C6 sugar. After hydrolyzing the pulp, the sugar solution is passed through a centrifuge to remove any remaining lignin and unreacted fiber and extract sap. The sap is then passed through granulated activated carbon for further cleaning and from there it is directed to the evaporation process to produce liquid sugar with at least 50 brix.

Question 8: What details of the scale of your process are you willing to share (e.g. batch and/or continuous or volumetric productivity)?
AST's current capabilities are all batch processors and include the following equipment for the fractionation of biomass:

a) Two small 250 ml laboratory PARR reactors that can process about 20 grams of biomass per batch, and each batch from start to end will take about 4 hours. Inside these reactors, biomass and solvent are mixed via a mixer and heated up with an external heater.

b) One 40 gallons pilot reactor with about 15 to 20 kg biomass processing capability per batch. Inside this reactor, we have a perforated basket that holds the biomass. During the process, the biomass is continuously showered with hot solvent from the top of the basket. While traveling from the top of the basket toward the bottom, the solvent washes the biomass and therefore removes the lignin. After exiting from bottom of the basket, the solvent is the collected in the bottom of the reactor and is directed toward a heater to heat up the solvent and maintain process temperature for the duration of our process.

c) One 2000 gallon pilot reactor with about half ton biomass processing capability per batch. In this reactor, first the biomass in loaded via a bucket elevator. After that, hot solvent at process temperature under pressure is injected into the reactor. The reactor is also equipped with a heating jacket that can be used for both heating the materials inside the reactor or to maintain the process temperature during the fractionation period. A high shear mixer continuously mixes the materials inside the reactor. At the end, the materials inside the reactor are directed to a blow tank to further open up the pulps and at the same time cool them down. From the blow tank, the materials are pumped into a screw press to separate pulp from solvent. The resulting pulp is directed to the washing station to remove any remaining volatiles and get it ready for hydrolysis

For sugar production, AST uses commercially available enzymes to hydrolyze its pulp. During the hydrolysis process, AST monitors and control the process temperature and pH of the solution. Currently AST uses the following equipment to produce cellulosic sugar in various amounts:

d) A bio-stat with 1500 ml capacity, with mixer, automatic temperature and pH controls.
e) A 150 liter fermenter fully equipped with mixer, and automatic temperature and pH control
f) A 150 Gallon hydrolysis reactor fully equipped with mixer, and automatic temperature and pH control
g) A 2300 Gallon hydrolysis reactor fully equipped with mixer, and automatic temperature and pH control

Question 9: What is the typical composition of your sugar stream (e.g., glucose, galactose, mannose, xylose, arabinose) and what is the purity?
Depending on the source of biomass (pulp), typical AST sugar has none to very little Arabinose and Mannose (0% to 0.1%), some Galactose (0.1% to 2%), some xylose (1% to 4%), and over 94% glucose.

Question 10: Do you routinely test your cellulosic sugar for consistency within and between lots and between feedstocks (if applicable)?
AST routinely tests its cellulosic sugar for its sugar level within and between a large number of various feedstock. In addition, during the hydrolysis processing, AST monitors the pH of the solution as well as the process temperature. And during dehydration process, again, AST monitors sugar concentration until our customer's desired brix is achieve.

Question 11: What impurities are present in your lignocellulosic sugar process and what testing do you perform to determine the presence of impurities?
AST's sugar impurities depend on the source of pulp (biomass), and include various minerals coming from biomass. A typical lab report for impurities of AST glucose made from agricultural wastes, before and after purification, is tabulated below (milligram mineral / kilogram sugar):

Mineral	Al	Ca	Cu	Fe	K	Mg	Mn	Na	Ni	Zn	mg/kg
Glucose	1.7	198.6	0.2	31.5	166.3	546.0	7.4	4669.9	22.9	3.5	5648.0
Purified G	<0.7	25.4	<0.07	1.5	6.3	26.2	0.1	68.7	<0.3	<0.2	128.3

Question 12: Does your process include a purification step?
AST sugar production process does include filtration, and passing through granulated activated carbon to clean the initial solid free enzymatic hydrolysate. In addition, AST has in-house capabilities to further purify its sugar by using various ion exchange columns. AST's final purification is applied per customer's request.

Question 13: What is the highest concentration in grams/Liter you can provide?
Typically, after hydrolysis, AST sugar is about 5% to 6% sugar content. After the filtration of solid free enzymatic hydrolysate, we usually dehydrate the solution to about 50 Brix or whatever the customer requests.

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?
Our past experiences show that at 50 brix or higher, our cellulosic sugar can be stored in cool and dry environments for a long time without degradation. At about 70 brix, it starts to crystallize. AST's cellulosic sugar is being shipped in liquid form (so far). As such, almost half of the product is water which adds to the cost of transportation. Depending on the order size, increasing the sugar concentration can reduce the costs of transportation.

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 heart of AST's cellulosic sugar production is its Organosolv fractionation process. As of now, all of AST pilot plants are for batch processes only. At the end of each batch, the pulp is separated from the solvent by using some form of filtration process such as bag filters, screw press, or decanter centrifuge, or any combination of these equipments. After separation, the pulp is washed to remove any remaining solvent from it. The clean pulp is then hydrolyzed to produce clean sugar for any further applications. Meanwhile after separation, the solvent, that includes organic solvents and water, is directed toward another separation system to further separate the aqueous part from the organic part. The aqueous part usually includes most of the water soluble minerals removed from the biomass, plus some water soluble lignin, and some volatiles (depending on their solubility in water). And the organic part, which has the most valuable products in it, includes whatever solvent that was used at the start, plus any new organic solvent produced during the process (such as furfural, butyl acetate, etc.), lignin that is dissolved in organic solvent, and some water (depending on the solubility of water in the available organic solvent). After separation, the organic part of the solvent goes through another separation distillation system to evaporate the solvent and condense the vapor to recover the initial solvent and any additional solvent made during the processes, and at the end leave the lignin in its solid form. The AST lignin is a black, brittle, and hydrophobic polymer with a melting point of about 120 to 200 C (depending on the process parameters) that when it is at

room temperature, breaks like glass. AST lignin is considered a very pure lignin that is being used as a renewable polymer, as a base for composites, for coating, and many other applications. So, all together, besides making pulp that is being used to make either paper or cellulosic sugar, the AST process also produces organic solvents and lignin. Together all these products can reduce the price of cellulosic sugar for the consumer, if the process is properly scaled up to manufacturing scale.

Since AST is not in the mass production business yet, the prices of AST products are based on a reasonable costs of labor and use rate of the facilities and equipment that are required to perform one batch digestion and the follow up process to make sugar. AST's price list for equipment and labor are listed in AST's web site.

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

So far AST sugars are delivered in small quantities to research institutes as a clean sugar for R&D purposes. In addition, AST has produced and delivered a couple of large orders (about a ton each) food grade sugar in form of glucose and high fructose syrup for industrial R&D. The AST batch process allows cellulosic sugar to be produced from any isolated and specific lignocellulosic biomass for any specific applications. Typical applications reported by AST customers are fermentation to produce bio renewable chemicals, make consumable products such as (beauty creams), use as food additive and pharmaceutical derivatives, making high purity food grade ethanol, etc.