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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 2: Lignin**

Question 1: To which types of research entities are you willing and able to sell or otherwise provide your lignin (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 lignin? NREL provides lignin to all research entities, provided the material is used only for research purposes and is not provided to other parties, without prior arrangement. For the solid lignin product, if a proprietary enzyme is used in the conversion process, 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 lignin that you are willing and able to sell (kg)? NREL can supply any amount from several kilograms to thousands of kilograms of solid or solubilized lignin.

Question 3: In what units do you sell your lignin and is it packaged (e.g., super sacks), or sold in bulk? The solid (kg) and liquid (L) product is supplied in any appropriate shippable container.

Question 4: How do you ship lignin? Material is shipped via common carriers.

Question 5: What is the lignin concentration in your product? The concentration of lignin in the solid product is estimated at 60–80% (w/w dry basis) lignin, the balance consisting primarily of residual cellulose and insoluble ash. The moisture content of the material ranges from 70% (as produced) to near 5% if dried.

There are currently no rigorous analytical methods available for accurately quantifying all of the aromatic compounds in the soluble product. However, the estimated dissolved solids content ranges from 2–15% depending on processing conditions. This number accounts for all aromatic compounds, acids, and mono- and poly-saccharides.

Question 6: What type(s) of biomass do you use in your process? NREL can use any type of biomass, but product quality and composition will vary with biomass type. 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 that produces lignin (dilute acid, ammonium fiber expansion (AFEX), hot water, organosolv, etc.)? Solid lignin is the residual material remaining after pretreatment and enzymatic hydrolysis of the raw biomass and is produced as described in Question 7 in the lignocellulose sugar section.

Soluble lignin is produced by treating biomass with a dilute caustic solution at an elevated temperature and is contained in the liquor fraction. It is recovered by pressing and/or filtrating the treated slurry. The severity of the treatment conditions (caustic loading, temperature and residence time) influences the quality and amount of soluble lignin recovered.

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

Question 9: Do you measure the typical composition of your lignin? If so, what method do you use? How consistent is the composition of your lignin? The lignin (Klason) composition of solid product is measured using NREL standard analytical procedures developed for lignocellulosic biomass (<http://www.nrel.gov/bioenergy/biomass-compositional-analysis.html>). The same methods are used to measure other components (cellulose, hemicellulose) in the solid lignin product.

Conventional analytical methods are currently inadequate for fully characterizing the soluble lignin product. A total dissolved solids measurement provides an estimate of the concentration of all soluble compounds present in the material. A spectroscopic method is used to provide semi-quantitative information on the amount of aromatic compounds in the liquor. Methods (GC-MS and GPC) are under development that will provide better information on aromatics in the future. The consistency of both products is influenced by feedstock and production process variabilities.

Question 10: Do you routinely test your lignin for consistency within and between lots? The composition of each lot of material produced is individually measured and tracked.

Question 11: What impurities are present in your lignin and what testing do you perform to determine the presence of impurities? For the solids product, see answers to questions 5 and 9. The amount of mono- and poly saccharides and acetic acid in the soluble lignin product are measured by HPLC.

Question 12: Does your process include a purification or filtration step? No other processing is done on the solid lignin product. Residual solid particulates are removed from the soluble lignin product by additional filtering, if desired, but no purification is typically performed.

Question 13: What is the typical concentration in g/L you can provide? For the soluble lignin product, typical concentration range is ~20-150 g/L.

Question 14: Have you examined the impacts of transport and storage on lignin? If so, can you please provide any relevant (non-proprietary) details of these impacts? No.

Question 15: What additional information are you willing and able to provide to the research community about the lignin? Please provide any non-proprietary 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.

Question 16: Into what markets do you typically sell your lignin? What is a typical application for your lignin? NREL provides lignin to a number of different industries for evaluation.