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Tinker-Tailoring Lignin

Sandia National Laboratories

A method to generate oxidized lignin with specified carboxylic acid content and molecular weight that can be used in various types of polymer products.

US Patent Pending

Technology Readiness Level 5

The valorization of lignin has faced many limitations due its intricate molecular structure, hydrophobicity, and low molecular weight. Several oxidation methods of lignin tend to increase hydrophobicity and impart chemical functionalities, primarily in the form of carboxylic acid (COOH) groups. However, these oxidation methods need to bear higher yields of COOH content to ensure the proper valorization of lignin. Additionally, there is also a lack of an efficient approach that can effectively tailor the low molecular weight of lignin.

Native lignin exists in a very limited range of molecular weight and have relatively low molecular weights that are further reduced during lignin extraction. This low molecular weight of lignin impacts its specific application and performance in different polymer applications. Hence, overcoming these challenges and enhancing lignin valorization will require an efficient strategy capable of simultaneously increasing lignin's molecular weight while enhancing the COOH content.

Researchers at Sandia National Laboratories have developed an oxidation approach that uses a well-known Fenton chemistry to effectively generate a high COOH content and specified molecular weight of raw kraft lignin stream, the largest supply of lignin in the world. The method involves a pH-dependent oxidation process that capitalizes on the strong differential increase in molecular weight and COOH content at varying pH levels. Initially, the raw kraft lignin stream is treated with hydrogen peroxide in the presence of an iron catalyst at a pH 6 until the desired COOH content is achieved. Subsequently, the pH is increased, and more hydrogen peroxide is applied until the desired molecular weight is attained. Since COOH content only slightly increases at higher pH values, both specific desired values of COOH content and molecular weight can be achieved.

This method has successfully shown to substantially increase the molecular weight of raw kraft lignin and generate COOH contents of greater than 5 mmol COOH/g, which is considerably higher than most conventional oxidation methods that typically yield 2-3 mmol COOH/g. Notably, this approach has also shown to avoid the toxic residual formaldehyde commonly associated with lignosulfonates due to the use of sulfite pulping process. Sandia-generated lignin can be used in most applications where lignosulfonates are commonly employed while providing a safer process. Therefore, Sandia's oxidation method not only ensures specified COOH content and molecular weight, enhancing their chemical functionality and versatility, but also produces raw kraft lignin that are safer than lignosulfonates.

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This paves the way for its valorization and broader utilization in various types of polymers.

Sandia's oxidation method has significant promise in the construction industry where lignin can serve as binders in particleboard flooring, linoleum flooring, roads, and as plasticizers/water reducers, surfactants, and stabilizers in concrete. The technology also has applications in sectors such as agriculture, where lignin can be modified to serve as hydrogels for soil amendments. Lignin can be used in generating stronger coal briquettes, and as a means of biofuel feedstock, binding agents, and dispersants in many industries. The technology is also useful in the food, cosmetics, and pharmaceutical manufacturing industries that have had limitations in using lignosulfates as binders due to the formaldehyde toxicity that sulfite pulping processes bring.

Next Steps

Sandia is seeking partners to develop and commercialize this technology. The intellectual property is available on a non-exclusive licensing basis only.

Technical Benefits

- Produces raw kraft lignin with a high carboxylic acid (COOH) content exceeding 5 mmol COOH/g, significantly improving the typical yield of 2-3 mmol COOH/g seen in most conventional oxidation methods.
- Significantly increases the molecular weight of raw kraft lignin, paving the way for its widespread use in different polymer, concrete, adhesives, and agrochemical applications.
- Avoids the toxic presence of residual formaldehyde that is present in lignosulfates streams due to sulfite pulping.

Industries & Applications

- Construction
- Agriculture
- Chemical Manufacturing
- Pharmaceuticals
- Food Industry
- Cosmetics
- Biofuel Industry

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U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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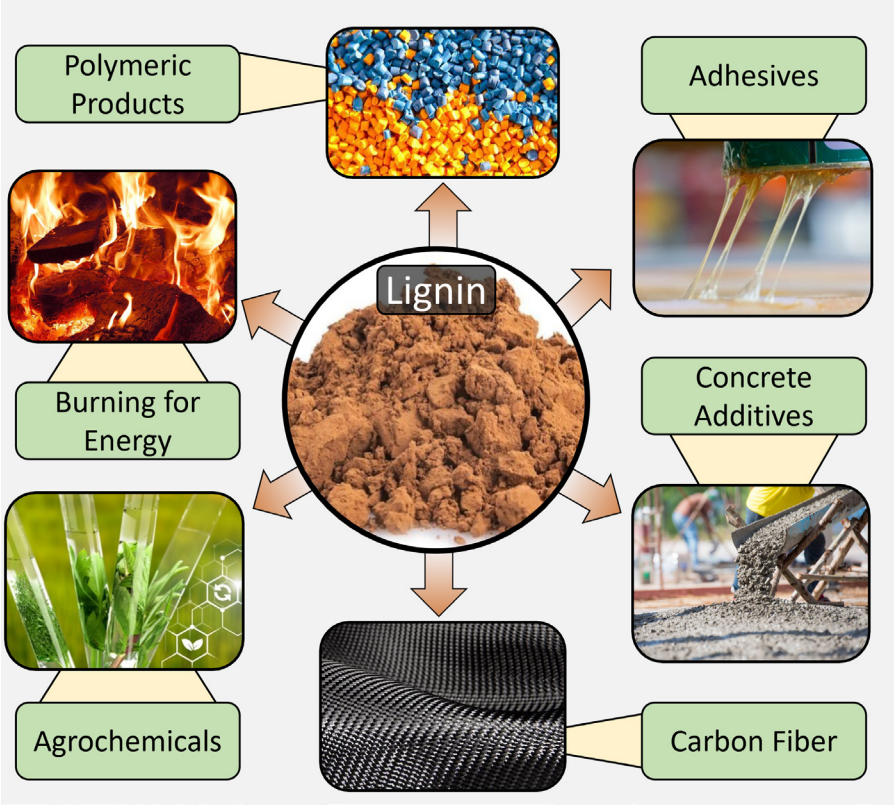

Above: Figure illustrates the diverse range of potential applications that Sandia's raw kraft lignin can be used for.

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