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Technical Report

Title: Lignin as Pellet Binder

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Publication Series: Technical Report

Publication Number: 03-20251209

Lignin is a complex, irregular, three-dimensional aromatic polymer found in the cell walls of plants, where it functions as both a natural adhesive and a key structural support material. Chemically, lignin is composed of phenylpropane units derived from three primary monolignols: p-coumaryl alcohol, coniferyl alcohol, and sinapyl alcohol. These monomers polymerize through radical coupling reactions, forming a highly crosslinked network containing a variety of ether (C–O–C) and carbon–carbon (C–C) linkages. The polymer is rich in aromatic rings, hydroxyl groups (–OH), methoxy groups (–OCH_3), and phenolic structures, which give lignin both rigidity and chemical reactivity. This structural diversity creates a heterogeneous macromolecule capable of forming strong hydrogen bonds, undergoing oxidative or thermal crosslinking, and exhibiting thermoplastic behavior when heated.

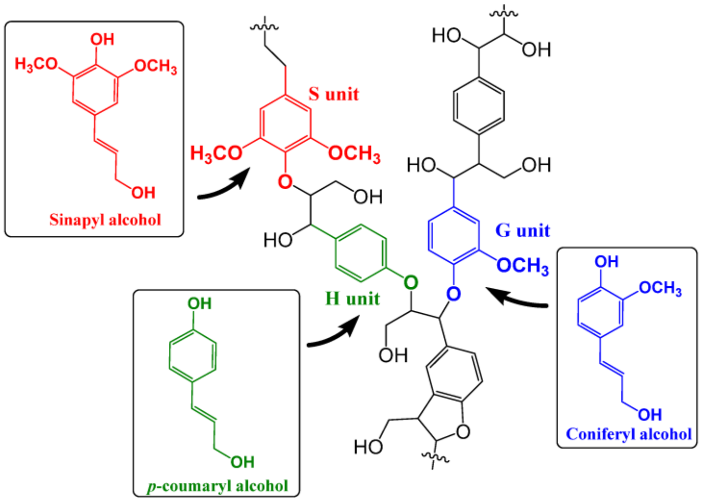

Figure 1. Representative chemical structure of lignin. Adapted from [1]

When incorporated into a substrate and subjected to the pelleting process, lignin acts as an effective natural binding agent. Its binding mechanism is both thermo-mechanical and chemical. Lignin behaves as a thermoplastic polymer [2] that becomes activated by the heat and moisture applied during conditioning. When steam is introduced, the temperature of the mash rises and moisture acts as a plasticizer, allowing lignin to soften and pass through its glass transition temperature. In this softened state, lignin (especially in the form of lignosulfonates) becomes a viscous, tacky film. As the mash is compressed through the die under high pressure, this molten lignin flows, coats the feed particles, and fills inter-particle voids. Once the pellet exits the die and cools, the lignin resolidifies and forms a strong, resilient matrix that physically locks the feed ingredients together [3]. In addition to its thermoplastic behavior, lignin provides excellent chemical binding. Because lignin is rich in polar functional groups—particularly hydroxyl groups—it can form strong hydrogen bonds and adsorptive interactions with hydroxyl, carboxyl, and amino groups on the surfaces of starch, cellulose, and protein particles in the feed [4]. These interactions significantly increase inter-particle adhesion and contribute to the high mechanical durability of the final pellet. Furthermore, research shows that lignin can undergo self-crosslinking under heat and pressure, increasing its molecular weight, improving its adhesive strength, and enhancing the water resistance of the pellet [4,5].

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