Enzymatic Hydrolysis of Forage Cell Walls

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The forage plant cell wall is a complex and fascinating biological structure. It is made up from polymers of cellulose and other noncellulosic polysaccharides, such as xylans and pectins in association with lignin, proteins, ions, and water. Cellulose is a highly ordered linear polymer of glucose linked by $\beta$-1,4-bonds. Xylans are linear polymers of xylose linked by $\beta$-1,4-bonds, substituted by varying numbers of arabinose, mannose, rhamnose, or glucuronic acid oligosaccharide side chains, as well as O-acetyl and esterified ferulic and $p$-coumaric acids. Other xyloglucans and $\beta$-1,3-and $\beta$-1,3-$\beta$-1,4-glucans are also present in the fraction defined as noncellulosic polysaccharides. Pectin is a complex group of polysaccharides composed of arabinans, arabinogalactans, galactans, and rhamnogalacturonans. These components are held together by various noncovalent and covalent interactions between plant cell wall polymers. Covalent interactions between plant cell wall polysaccharides strengthen the plant cell wall and may occur directly between polysaccharides or by a covalently linked bridging molecule. Polysaccharides may be linked to other polysaccharides by direct glycosidic cross-links or phenolic acid dimers and may be attached to lignin by glycosidic cross-links, ether cross-linkages, ester cross-linkages, or cinnamic acid bridges (Lam et al., 1990). This organization is an important property of the plant cell wall that leads to rigidity and tensile strength. A detailed review of plant cell wall chemistry and organization is provided in other chapters of this volume.

Ruminants depend on the indigenous bacteria, protozoa, and fungi present in the rumen to digest plant cell wall components. These microorganisms are faced with a recalcitrant substrate. The spatial orientation of cellulose and xylan in primary and secondary plant cell walls, the extensive side chain substitution of xylans, and the evidence that lignin is covalently linked to the noncellulosic polysaccharides can be considered major limitations to plant cell wall hydrolysis. Clearly, numerous enzyme types and specificites are required to hydrolyze the plant cell wall to its constituent monomeric components. This discussion will attempt to integrate the hydrolysis of the