Project 1.1 Emerging Feedstock Core R&D
Task 1.1.1.1 Harvesting, Collection and Preprocessing

<u>Classification & Application of Biomass Physical Properties in Harvesting & Preprocessing Systems</u>

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## Purpose and Scope:

Chopping, grinding, chipping, billeting, and other operations in harvesting and preprocessing systems are highly dependent on the physical and mechanical properties of the biomass feedstock. Fundamental to these processes is the mechanical behavior characteristics of shear strength, tensile strength, Young's modulus, and rigidity modulus. These mechanical characteristics can change between crop varieties, crop maturity; and in addition, are greatly affected by environmental conditions (i.e., moisture). The lack of understanding of these characteristics in cellulosic feedstocks is a limiting factor in economically collecting and processing crop residues, including wheat and barley stems and corn stover. Several testing methods, including compression, tension, and bend have been investigated to increase the understanding of the biomechanical behavior of cellulosic feedstocks. Biomechanical data from these tests are needed to provide input into numerical models being developed to advance harvesting, handling, and processing techniques. In addition, integrating the models with the complete data set from this study could identify potential tools for manipulating the biomechanical properties of plant varieties in such a manner as to optimize their physical characteristics to produce higher value biomass and more energy efficient harvesting practices.

## Key results:

Harvested biomass was collected and tested to determine the modulus of elasticity and ultimate strength of the internodal steam regions of two varieties of wheat and barley straw and four cultivars of corn. The varieties were chosen for their abilities to present a range of physical characteristics for evaluation. The varieties of wheat straw included Amidon, a standard height hard spring wheat with moderate resistance to lodging and a semi-solid stem structure, and Westbred 936, a semi-dwarf, hollow-stemmed variety with strong lodging resistance. Bowman, and its fragile stem mutant, *fst 1.d*, barley varieties were selected due to their varying lodging resistance, breakage properties, and closely tied genetic make-up. Bearclaw 7998, Dekalb 611, Garst 8550, and Iowa 550473 were the corn varieties evaluated. These particular cultivars were chosen based upon relative variances in field standability, apparent strength when handled, and internodal stalk length.

Several testing techniques, including compression, tension, bend, and torsion were used to determine the mechanical characteristics of the varieties. These methods were conducted using load frames that had been specially configured to accommodate these specimens. Video imaging techniques were employed for the in-situ examination and documentation of the various load test measurements. Microscopic analyses were also conducted before and after testing to elucidate changes in structural components as a function of the various test parameters. Seven samples from each variety were tested in order to provide a statistically-significant representation of the properties.

## Conclusions:

The testing and evaluation determined that there were differences in the modulus of elasticity; and consequently, the mechanical properties, of the two varieties of wheat and barley and four corn cultivars. These differences could be correlated with differences in the physical structures and chemical compositions of the varieties. These material differences were anisotropic, consistent with the behavior of composite structures.

The ability to track and develop modeling techniques to predict significant differences between the varieties and their individual structural and compositional components provides a path forward for tailoring harvesting, handling and processing operations. In particular, the insight provided by appropriately designed and validated models will help determine how particular biomechanical properties affect the energy relationships associated with harvest and post-harvest handling. They may also eventually lead to improved tools for manipulating the biomechanical properties of the plant varieties for the production of higher value biomass.

## Recommendations:

The project proposes to now apply this basic understanding of the material properties of crop residue to actual harvesting and processing systems. In particular, the biomechanical loadings and material failure database developed in FY-04 for grain stover will be correlated with biomass materials collected during various phases of the harvesting and milling processes. This analysis will in turn allow the determination of the role a particular biomechanical characteristic, shear strength for example, might play in a particular processing step. This step-by-step correlation can then be used to estimate the energy consumption, power requirements, and efficiency of the process as a function of the physical properties of the biomass. The ultimate goal is to develop models that can be used to predict the efficiency of a particular harvesting system configuration and type and variety of biomass.