Composite materials: New opportunities for bio-based products

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The use of renewable resources in applications such as building materials requires the establishment of a sustainable infrastructure for collection and storage of biomass, conversion of raw material and fabrication of products, and end-use application. The BioComposites Group at Iowa State University has been working toward this end by conducting research and technology transfer in three key areas of biomass utilization, i.e., fiber, renewable adhesives, and composite materials. Our goal is to provide a research base from which the needed infrastructure may be developed to establish and maintain viable bio-based initiatives in our State and region.

Collection and storage challenges

Many biomass resources, particularly agricultural crops, present significant challenges for effective harvest, storage, and processing. The materials are generally bulky, subject to degradation in storage, and often available through only one annual harvest. Effective storage technology is thus essential to expanded use of agricultural biomass feedstocks in composite materials. Current storage methods that rely predominantly on dry storage to minimize biological decomposition are nevertheless subject to other hazards, primarily fire. Our research group is investigating wet storage or ensilage and its effects on long-term fiber quality in conjunction with a new company that is developing means to harvest and process corn and soybean stover for use in fiber-based products. Current efforts include the study of ensilage methodology to store fiber with minimal degradation, the investigation of composting technology to pre-treat and dry fiber prior to further industrial processing, and the incorporation of other fiber resources (e.g., recycled paper sludge) and bio-materials (e.g., protein by-products of biotech industries) into this system.

Renewable adhesives

Most of our group's effort over the past few years has been devoted to the development of soybean-based adhesive resins for the wood composite materials industry [1]. This system consists of defatted soybean flour cross-linked with synthetic phenol formaldehyde, the former typically at a ratio of 70% by weight of the adhesive resin . The use of soy flour (containing protein and carbohydrate) as opposed to soybean isolate (purified soy protein) is a distinct shift from previous research and one which could make this technology competitive on a cost basis. Testing on various laboratory-fabricated panels (primarily hardboard, medium density fiberboard, and flakeboard) has shown that the adhesive has performance characteristics that are generally intermediate between the two most-commonly used synthetic resins in the wood industry, i.e., urea formaldehyde and phenol formaldehyde resins [2, 3]. Products bonded with the soy resin emit very little formaldehyde (0.08 ppm or less in a standard desiccator test, or essentially background level). Pilot plant evaluations and an industrial mill trial for use of this resin in the manufacture of hardboard and medium density fiberboard have been conducted. We are currently working with a start-up company in an effort to commercialize this technology for certain applications within the wood-using industry.

Conversion, fabrication, and end-use application

We believe that the best use of agricultural biomass residues for the manufacturing of composites will be with materials refined to fiber or flour form [4]. This level of processing is necessary to render the materials in a state that is easier to bond with conventional and soy adhesives. Many current industrial enterprises that are manufacturing ag-based panels are experiencing business challenges, in part due to the necessity of using expensive and somewhat process-unfriendly isocyanate adhesives. This necessity results from the presence of the calcitrant cuticle layer on particulate material generated from whole agricultural plant stalks. Conversion (i.e., providing a means to break down the cuticle layer) of such biomass through either bio-treatment, conventional industrial processing, or some combination thereof appears to be necessary to optimize the use of these materials in "wood-like" building materials. Fiberized material may be readily used for making products such as hydromulch, molded products such as packing materials, or for building materials such as hardboard or medium density fiberboard. Reduction of biomaterial such as switchgrass or fescue to fine flour makes it amenable to use as a filler in thermoplastics [5]. Our work shows that switchgrass flour performs comparably to commercially used wood flour as a filler in high-density polyethylene. Wood-filled plastics are used increasingly in products ranging from plastic lumber to automotive parts and consumer goods. Depending on the end-use, such fiber/plastic composite materials may contain 20 to 60 percent or more by weight of the natural fiber material. Fiber benefaction (e.g., extraction of low molecular weight soluble carbohydrates) may also render a fiber more amenable to use as a filler in thermoplastics, while simultaneously providing raw material for input to biomass-to-chemicals processes. End-use application of these materials (fiber, panel products, and fiber/plastic composites) is generally similar to current wood-based materials. While we are not advocating the abandonment of the use of wood as an industrial and building material, it is evident that better use of agricultural biomass may be made in order to conserve and extend valuable wood resources. Continuing research on collection and storage, renewable adhesives, and conversion and fabrication into products will lead to new composite bio-based products.

References

[1] Kuo, M.l., and D.D. Stokke. 2000. Soybean-based adhesive resins for composite products. Pages 32-33 in Wood Adhesives 2000 Extended Abstracts. Proceedings No. 7260 (EA), Forest Products Society, Madison, WI.

[2] Kuo, M.l., D. Adams, D. Myers, D. Curry, H. Heemstra, J.L. Smith, and Y. Bian. 1998. Properties of wood/agricultural fiberboard bonded with soybean-based adhesives. Forest Products Journal 48(2):71-75.

[3] Stokke, D.D., and M.-l. Kuo. 1999. Composite products from juvenile hybrid poplars bonded with crosslinked soy adhesives. Pages 132-136 in S.-Y. Wang and M.-C. Yeh, eds. Timber and Wood Composites for the Next Century: Proceedings of ICEUPT'99, International Conference on Effective Utilization of Plantation Timber, His-Tou, Taiwan. The Forest Products Association of the Republic of China, Bulletin No. 16. 643 pages.

[4] Kuo, M.-l., and D.D. Stokke. 1999. Composite panels from agricultural residue bonded with soybean-based resins. Proceedings of the 1999 Ag Fiber Technology Showcase, Memphis, TN. Published on the Ag Fiber Technology CD-ROM 2000. AgroTech Communications, Cordova, TN.

[5] Stokke, D.D., M.l. Kuo, D.G. Curry, and H. Gieselman. 2001. Grassland fiber/polyethylene composites. 6th International Conference on Fiber/Plastic Composites, May 15-16, 2001, Madison, WI.