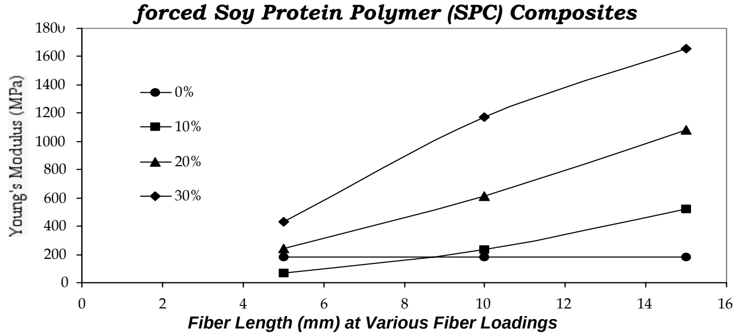
"Green" Composites from Cellulose Fabrics & Soy Protein Resin

Anil N. Netravali (Cornell)

Using short and continuous plant-based fibers and soy protein polymer, we have developed fully degradable composites with sufficient mechanical properties.

Fiber-reinforced composites have been used for many applications from sporting goods to automotive parts. Most commercial fiber-reinforced composites are made from petroleum based synthetic fibers and resins that are non-degradable. Our goal is to develop fully degradable and environment-friendly 'Green' composites using cellulose fibers/yarns/fabrics as reinforcement and soy protein as resin and to understand the fiber/soy protein interaction.

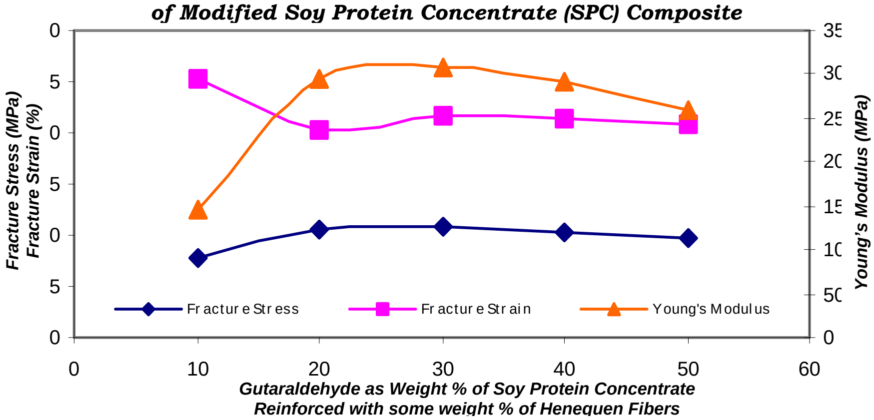
Effect of Fiber Length on Young's Modulus of Ramie Reinforced Soy Protein Polymer (SPC) Composites



Using plant-based short and continuous cellulosic fibers in soy protein polymer resin, we have successfully developed fully-degradable, environment-friendly, 'Green' composites. The random short fiber composites have moderate mechanical properties and can be used in non-structural applications. The unidirectional continuous fiber composites have tensile properties close to steel. However, at a typical steel-to-composite density ratio of about 6, these 'Green' composites are significantly superior to steel on a per weight basis and may be used for indoor structural applications in housing and transportation, such as in automobiles.

Soy protein polymer (SSP) is commercially available in two grades; soy protein isolate (SPI) containing 90% protein and soy protein concentrate (SPC) containing 70% protein, in addition to the soy flour (defatted). We have used both SPI and SPC as resins and also modified them to obtain improved mechanical properties. Because of highly polar groups on both cellulose and soy protein polymer, the fiber/resin interface is strong.

Effect of Gutaraldehyde % on the Tensile Properties of Modified Soy Protein Concentrate (SPC) Composite



Short Random Fiber Composites: Fiber Length

Based on the interfacial shear strength of ramie fiber/SSP composites, we calculated that 2.5mm was the shortest fiber length that could be used for reinforcement. Thus, we prepared short fiber composites from fiber lengths of 5, 10 and 15mm and fiber volume fractions of 10, 20 and 30%. At 5mm fiber length and 10% volume fraction there was no significant increase in tensile strength over pure SPP resin. However, as fiber length and volume fraction increased, composite strength also increased (See Graph at left) and fracture strain decreased. These experimental Young's modulus data were lower than our predicted data, particularly at lower fiber contents and shorter lengths. However, this discrepancy, which was likely caused by voids in the composites and by non-uniform fiber distribution, was smaller for higher fiber loadings and fiber lengths. In addition, at low fiber content, short fibers seem to act like defects, reducing the strength values.

Short Fiber Composites: % Crosslinking

We made short random fiber composites from henequen fibers and soy protein concentrate (SPC) which was modified by adding 10-50% gutaraldehyde by weight, as a crosslinking agent. Adding up to 30% (by weight) gutaraldehyde increased fracture stress and Young's modulus (See Graph below), primarily due to additional cross-linking. Any additional unreacted gutaraldehyde plasticizes the SPC.

Resin Dilution

To make random, short fiber composites, we cut the henequen fibers to 25.4 mm length and dispersed them in water to obtain a randomly oriented fiber mat. We then infiltrated the modified SPC resin in four different ways: no resin dilution, 25% dilution, 50% dilution and two step infiltration of 50% diluted resin. All resins had 10% glycerin as plasticizing agent. All composites contained 55% henequen fiber by weight. The mechanical properties of the henequen/modified SPC composites suggested that the two-step process gave the best mechanical properties. This is believed to be the result of better resin penetration, reduced voids and improved interface. These composites have sufficient mechanical properties for use in packaging, non-structural consumer goods and automotive parts such as door trimmings.

Continuous Fiber Composites

We prepared unidirectional ramie composites with 65% (by weight) ramie fibers in SPC resin plasticized by 30% glycerin. We optimized the curing and postcuring processes for SPI resin to obtain the highest possible mechanical properties (See Table below).

Compared to three commonly used woods (bass, cherry and walnut), tensile and flexural properties were significantly higher in the longitudinal direction than all wood varieties. In the transverse direction, mechanical properties were comparable to wood. These results indicate that it is possible to obtain better properties in both directions by placing laminates at 0 and 90 degrees. Again, in our initial experiments, actual tensile stress and Young's modulus were not as high as the theoretical values, probably because of a loss of fiber alignment during composite formation, voids and resin shrinking during curing.

Mechanical Properties of Ramie/SPC Composites

Materials	Direction in measurement	Tensile stress (MPa)	Fracture strain (%)	Young's modulus (GPa)	Energy to break (J)
Composite	Longitudinal	271.4 (8.6)*	9.2 (18.3)	4.9 (17.3)	3.9 (23.4)
	Transverse	7.4 (27.5)	5.3 (22.5)	0.9 (30.3)	0.1 (37.5)
SPC polymer resin		6.9 (6.7)	30.2 (10.7)	0.1 (4.8)	0.2 (25.0)

**** Numbers in parentheses = % coefficient of variation for each measure***

Contributing Graduate Students: *S. Chabba, Sunghyun Nam, P. Lodha* (Cornell); **Undergraduate Students**: *Cindy Winoto, Ellan Spero* (Cornell)*;* **Visiting Professor**: *H. Takagi*.

Industry Interactions: 2 [Archer Daniels Midland, DuPont]
Other Interactions: Academic:1; Government: 1.

Project Web Address:
http://www.human.cornell.edu/units/txa/research/ntc/F01-CR01-02.pdf

For Further Information:

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Anil N. Netravali, a Professor of Fiber Science at Cornell, joined the faculty in 1987 after a postdoc in Materials Science and Engineering at Cornell. Anil earned his M.S. in textiles in 1973 from Bombay Univ. and an M.S. (1980) and Ph.D. (1984) in fiber and polymer science from NC State. His research interests include high strength fibers, advanced and "Green" composites, fiber/resin interface modification, polymer durability and geotextiles.
F01-CR01
ann2@cornell.edu
(607)-255-1875
http://www.human.cornell.edu/faculty/facultybio.cfm?netid=ann2&facs=1