Improving the Properties of Banana Pseudo-stem Fiber LDPE Composites by Chemically and Thermally Treating the Fibers

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Background

- Interested in developing fiber reinforced polymeric composites whose source is sustainable
- Led to working with natural fibers
- This project examines the fibers made from the pseudo-stem of banana plants
- They will be embedded in LDPE polymers
Banana plant production
Banana pseudo-stem

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- MIDRIB
- LEAF
- INFLORESCENCE
- PSEUDO-STEM
- LEAF SHEATH
- CORM
- ROOT
Banana fibers

- Significant number of voids (30-60% by volume)
- Absorbs water
- Voids about 10 μm (10^{-6}m) in diameter, and not likely to be filled with polymer
- Does not bond well with many polymers, such as LDPE (used in this study)
- Since it is a natural material, great variability in individual fiber properties and dimensions
Cross-section of typical banana fiber
Chemically treating the fibers

- **Alkali treatment (NaOH used in this study)**
  - Some lignin and hemicellulose is removed and the cellulose is depolymerized through disruption of hydrogen bonding
  - Surface roughness is increased.

- **Silane treatment**
  - Hydrogen bonds with the hydroxyl groups of the fiber
  - Fiber forms covalent bonds with the organic polymeric matrix
Chemically treating the fibers

- **Maleic anhydride**
  - Grafted co-polymer which forms ester linkages with the hydroxyl groups of the fiber
  - Forms entanglements with the polymeric matrix.
  - Does not affect internal structure of the fibers, as the two previous treatments did

- **Peroxide Treatment**
  - Organic peroxides decompose into free radicals
  - React with hydrogen group of matrix and cellulose fibers
Thermally treating the fibers

- Fibers stored in a temperature and humidity controlled environment
- Determine safe temperature range
- Determine optimum drying temperature
- Explore the effects of drying wetted, peroxide treated fibers
- Explore possible effects of idle time on peroxide treated fibers
Thermally treating the fibers

- Graph shows the effect of temperature on the mass of the fibers.
- Degradation is seen at temperatures above about 200°C.
Thermally treating the fibers

- Effect of low temperature drying on the mass of the fibers
- Higher temperatures dry more quickly
Thermally treating the fibers

- Wet fibers have 3 to 4 times the mass of dry fibers.
- Peroxide treated fibers do not absorb as much water as the untreated ones.
- Wetted fibers were soaked in water, while the initial ones were not.
Thermally treating the fibers

- Idle time refers to how long the fibers were in a humidity controlled environment after treatment.
- The more quickly the tests were done after treatment (less idle time) the more water was removed during drying.
Single Fiber Tensile Test

- Tensile tests were performed to determine the effects of chemical treatments on the strength and stiffness of individual fibers.

- For alkaline and silane treatment, tests were performed using an Instron Testing Machine at a constant rate of extension of 20 mm/min.

- For peroxide treatment, tests were performed using a TA Dynamic Mechanical Analyzer machine at a constant rate of extension of 0.5 mm/min.
Tensile Test Results

- Alkali and silane were tested at 20 mm/min
- Peroxide was tested at 0.5 mm/min
Test results for tests done at 20 mm/min

- For alkaline and silane treatment, strength decreases as a result of the treatment
- Not surprising as the surfaces of the fibers are degraded
- As will be seen later, the bonding of the fibers and matrix is improved as a result of either the rougher surface or change in chemical bonding between fiber and polymer
Test results for tests done at 0.5 mm/min

- For peroxide treatment, tests were performed using a TA Dynamic Mechanical Analyzer machine at a constant rate of extension of 0.5 mm/min.
- Strength of the treated fibers is greater than that of the polymeric resin.
- This is not what was anticipated and further work in this area will be done.
Tensile Test Results

- Idle time is the time the samples were kept in a humidity controlled environment after the chemical treatment.
- The longer the idle time, the lower the strength.
Schematic of Pull Out Test
Mechanical Test System
Pull out test results

- Pull out tests were performed with fibers partially embedded in an LDPE matrix.
- Load was slowly applied to one end of the fiber at a constant extension rate.
- Maximum load measured prior to de-bonding was used to calculate the interfacial shear strength.
Interfacial Shear Strength: Treatment Comparison

Error Bars = 95% Confidence Interval (SEM)
Results

- Chemical treatment of the fibers by NaOH or silane improved the interfacial bonding
  - But also decreased the tensile strength of individual fibers (to be reported elsewhere)
- Maleic anyhdroide did not affect the structure of the individual fiber while dramatically increasing interfacial bonding
- Peroxide treatment appears to increase the fiber strength, and probably the interfacial bonding as well
Work in progress

- Work to be done
- Deal with great statistical variability of the data because natural fibers are not uniform
- Composite properties
  - Strength
  - Toughness (delamination)
  - Impact toughness
Questions?