Evaluation of poly(lactic acid) and agricultural coproducts as green composite materials

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Agenda

- Challenge
- Materials
- Preparation
- Evaluation
  - Thermal Properties
  - Mechanical Properties
  - Microscopy
  - Acoustic Emission
- Summary

Challenge

- Utilize agricultural "coproducts" from industrial feed streams
  - Pulp from sugar production from beets
  - Pulp from apple orchards & cider production
  - Residue from oilseed harvest
    - Pressed seedcake
    - Cellulose, pectin, oil, protein, etc

Materials

- Poly(lactic acid) - PLA
  - Commodity plastic
  - Polymerized from lactic acid
  - Lactic acid is a chemical feedstock from the ethanol fermentation process
  - Desirable mechanical properties
  - Biodegradable
- Sugar Beet Pulp
- New Oilseed Crops
  - Cuphea, Lesquerella & Milkweed

Alternate Oilseed Crops

- Cuphea
- Lesquerella
- Milkweed
  - Harvested for its floss
  - Seeds contain oil and can be harvested

Preparation

- Dry & grind coproduct (300 μm particle size)
- Melt PLA in twin-screw extruder.
- Incorporate coproducts in varying amounts.
- Chop compounded material
- Injection mold each sample into tensile bars
- Condition samples at standard temperature & humidity

PLA Composite Materials

- Modify the properties of PLA
  - Fiber reinforcement
- Reduce the cost of the product
  - Fillers
- GREEN

PLA Thermal & Mechanical Properties

- Density = 1.25 g/ml
- Molecular Weight = 100K-300K (daltons)
- T_g = 50-80 °C
- T_m = 140-180 °C

	PLA	PS	PET
Tensile (MPa)	**50 - 85**	55 – 82	275
Elongation (%)	**5 - 10**	3 – 40	50 – 150
Modulus (GPa)	**2.1 – 3.0**	3.0 – 4.0	7.0 – 9.0

General results

- SBP
- Cuphea
- Lesquerella
- Apple
- Milkweed
- Plasticized SBP

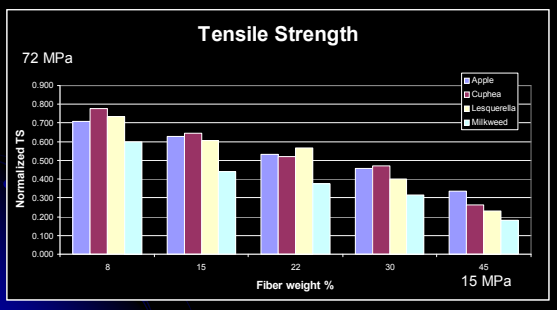
Thermal properties of PLA composites

- T_g = 58 °C
- T_m = 155 °C (onset around 141 °C)

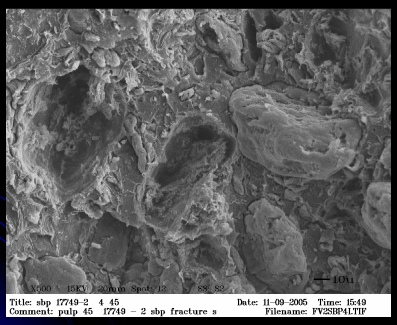
45%	T_g (°C)	T_m (°C)
Apple	53	151
Milkweed	54	154
Lesquerella	51	151*
Cuphea	53	149*

* Dual peak

Mechanical properties



SEM fracture surfaces



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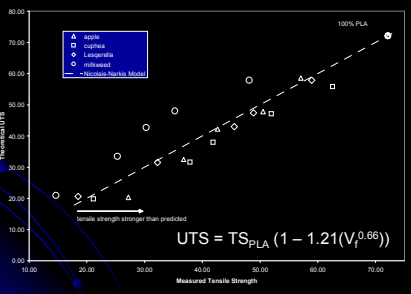
Predicted vs. Actual Strength



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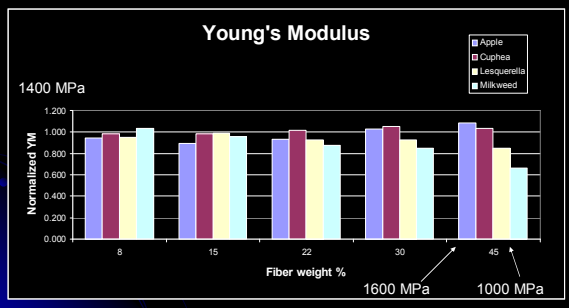
Mechanical properties



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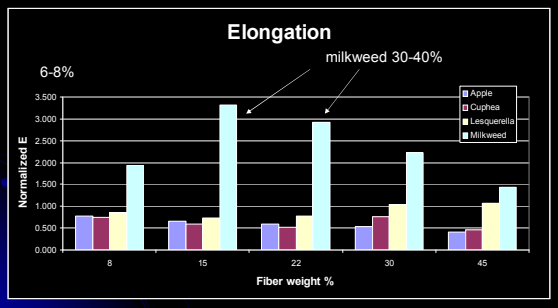
Mechanical properties



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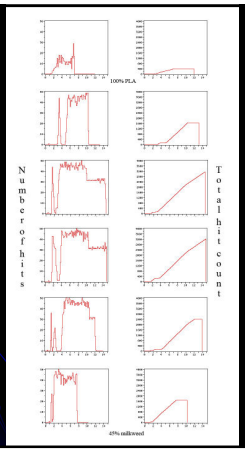
Acoustic Emission

Milkweed



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Plasticized SBP

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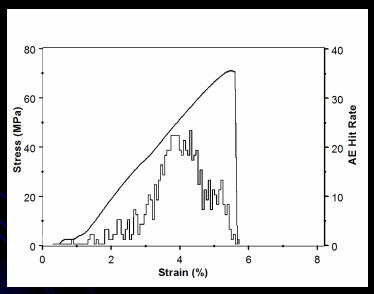
AE and TME for pure PLA



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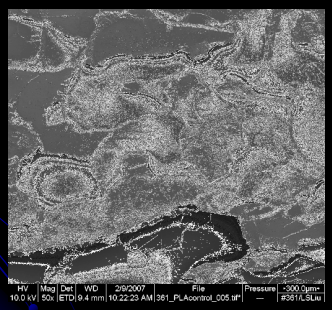
SEM of PLA fracture surface



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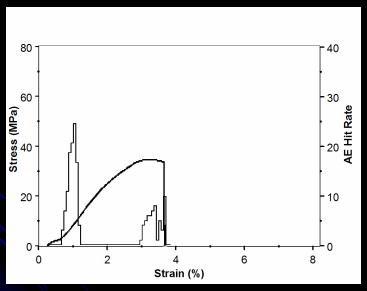
AE and TME for low pSBP



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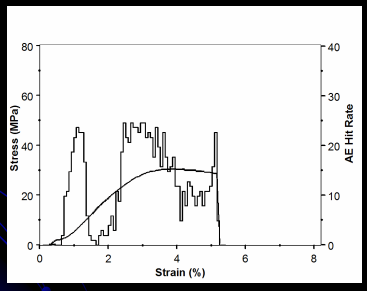
AE and TME for high pSBP



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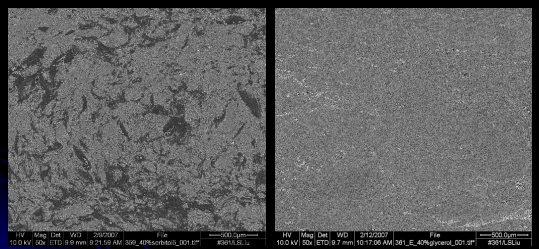
SEM for unplasticized & plasticized SBP in PLA



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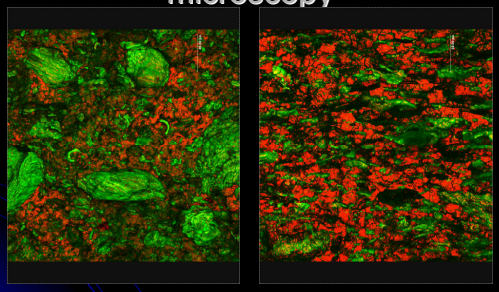
Confocal fluorescence & reflection microscopy



PLA – red (reflection)
SBP – green (500-530 nm @ λ=488 nm)

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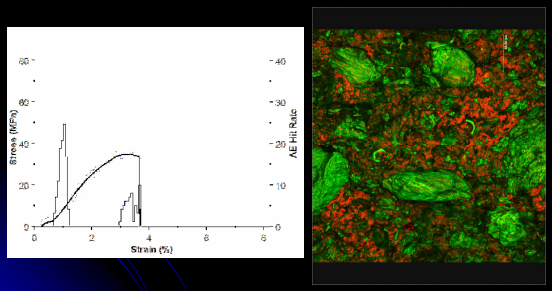
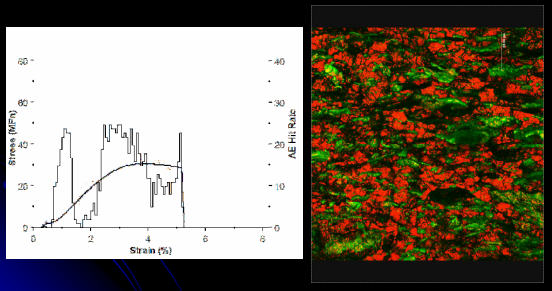
Comparison: SBP-PLA



Comparison: plasticized SBP-PLA



Results

- SBP-PLA composites behave similar to PLA with cuphea, lesquerella and apple.
- All PLA-fiber composites except milkweed exhibited stronger tensile strength than predicted by the model especially at higher levels of fiber content indicating some level of adhesion between the two phases.
- PLA-milkweed composites show unusual elongation accompanied by stress-cracking or whitening. AE confirms ductile response of composite under stress.

Results

- Plasticized SBP-PLA shows ductile behavior and exhibits co-continuous phases.
- It is possible to use agricultural fillers to augment PLA in green composites with some interesting mechanical properties.

Next Steps

- Chemically modify agricultural coproduct to promote reinforcement of polymer matrix by adhesion
- Utilize other commodity plastics
  - PCL
  - PEO

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