



Evaluation of hydrolytic degradation of Poly(lactic acid) (PLA) matrices in compression molded Flax/PLA composites

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Sustainable Composites Meeting Series

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Polymer composites for aviation



Increased sustainability by reduction in weight



Composite weight ratio in aircraft has increased from 4% in the 1970s to over 50% as of 2023.



Majority of composites used in aviation are thermoset resins

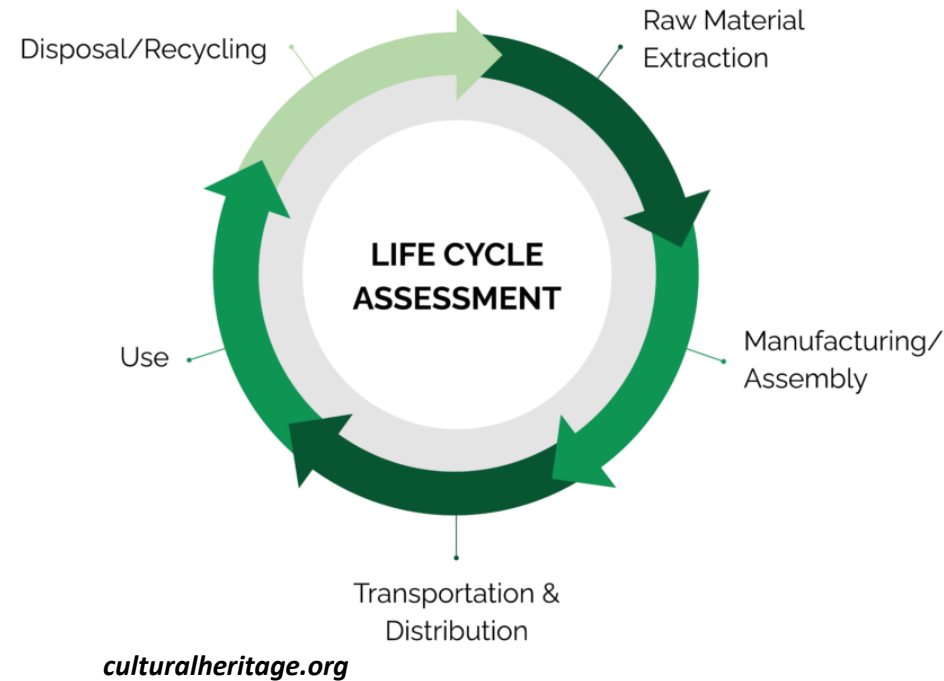


Thermoplastic composites can further increase sustainability

- Easier to process
- Able to be recycled
- Increased chemical and impact resistance and lower density
- Welding techniques available for complex part production

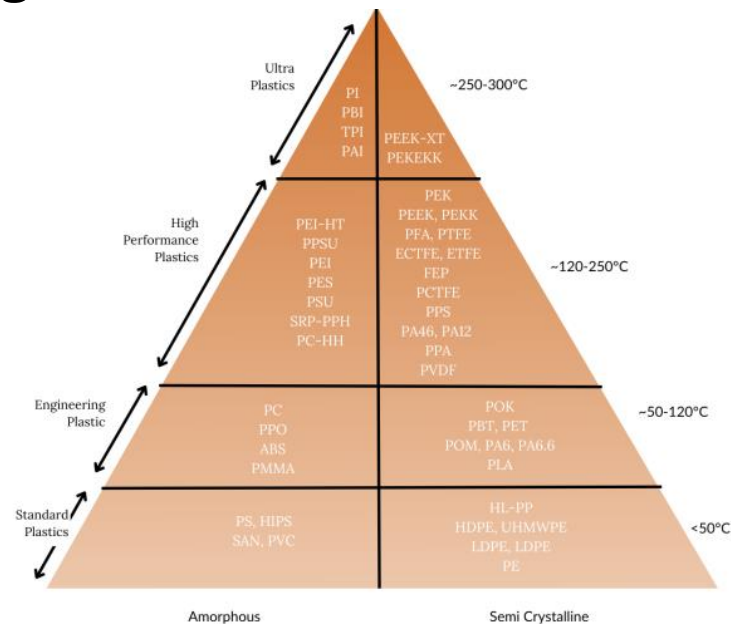
Natural thermoplastic composites

- Can we use natural fibers and bio-based resins to create composites for aviation?
 - **Improved sustainability**



Natural thermoplastic composites

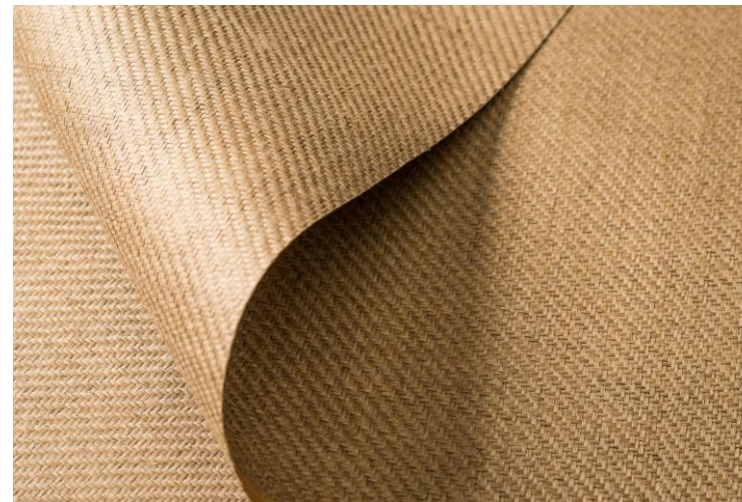
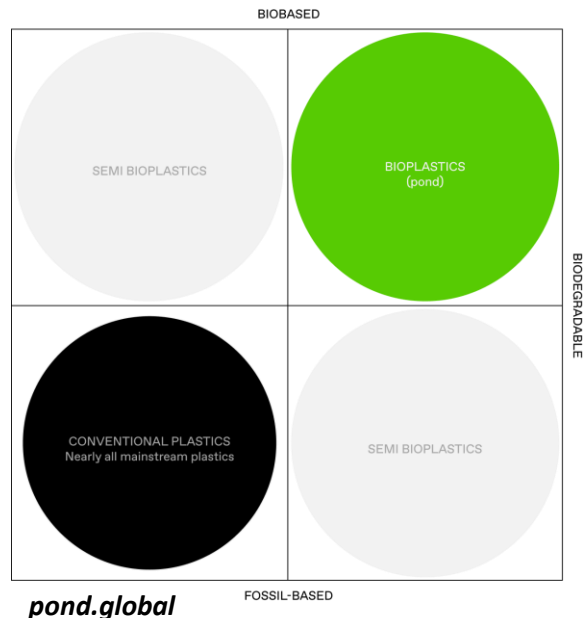
- Can we use natural fibers and bio-based resins to create composites for aviation?
 - Improved sustainability
 - **Unique set of challenges with natural materials**



Maximum Operating Temperatures

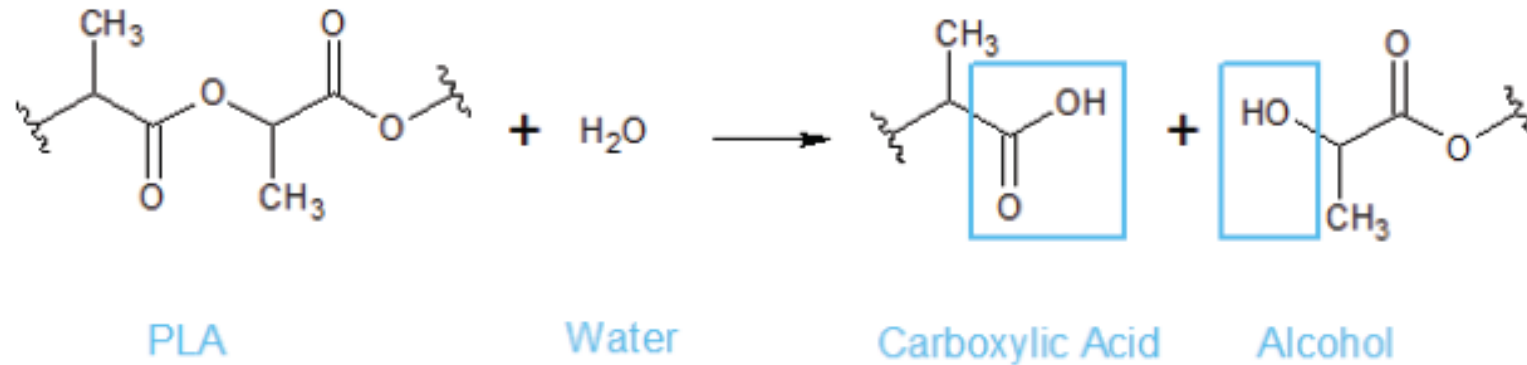
Natural thermoplastic composites

- Can we use natural fibers and bio-based resins to create composites for aviation?
 - Improved sustainability
 - **Unique set of challenges with natural materials**
 - **PLA and Flax Fibers**



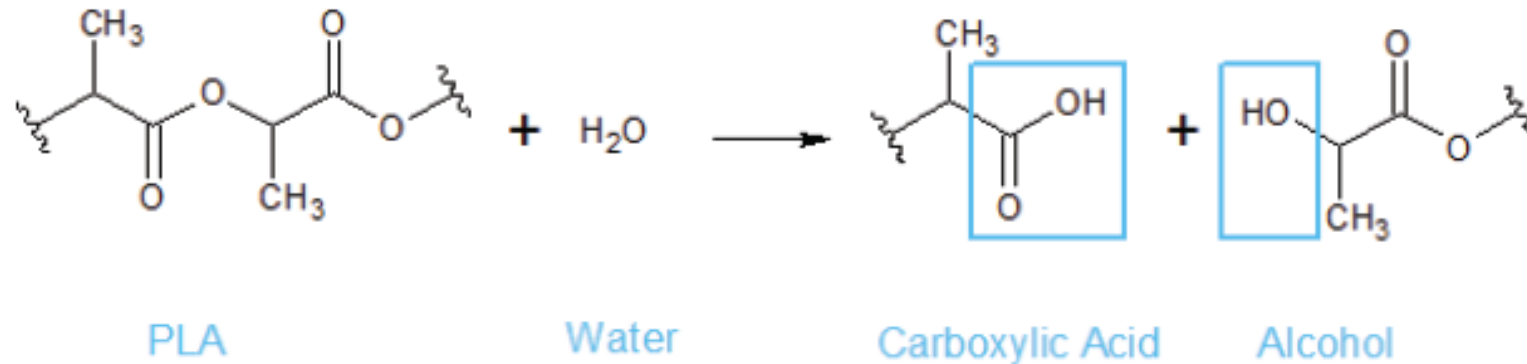
Bcomp.com/amplitex

Hydrolytic degradation of PLA



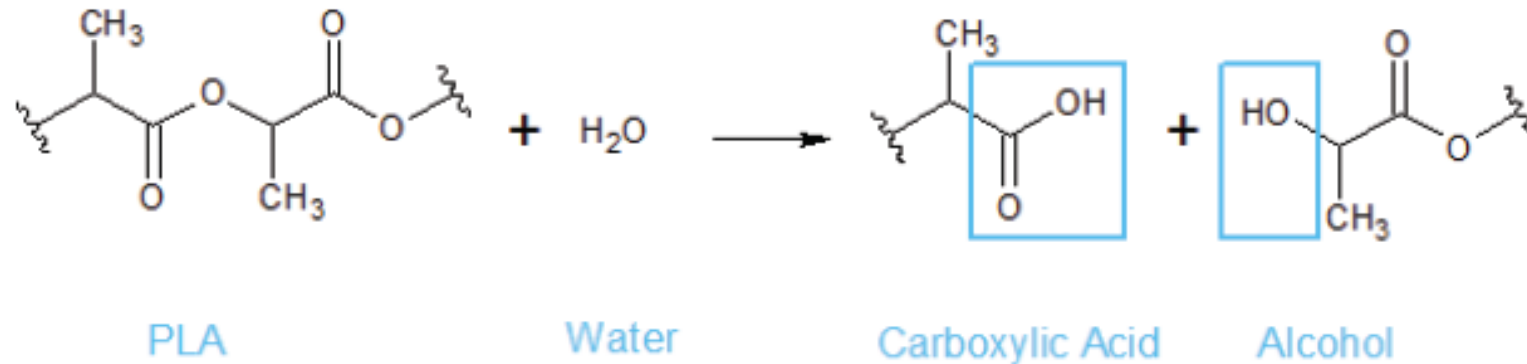
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Hydrolytic degradation of PLA



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- **Flax fibers can store up to 5% weight of water**
 - **Does the residual moisture in flax accelerate PLA hydrolysis in composite production process?**

Hydrolytic degradation of PLA



- Leads to decrease in mechanical performance
- Flax fibers can store up to 5% weight of water
 - Does the residual moisture in flax accelerate PLA hydrolysis in composite production process?
- **Crystallinity, molecular weight, and temperature are some of the factors effecting hydrolysis kinetics**

Processing considerations for manufacturing

Processing parameters:

- Varied processing times
- Varied drying procedures
- Varied cooling profiles

PLA and Flax Fibers

- Terre de Lin flax, braided at A&P Technology Inc.
- 4 Plies, 4" x 4"

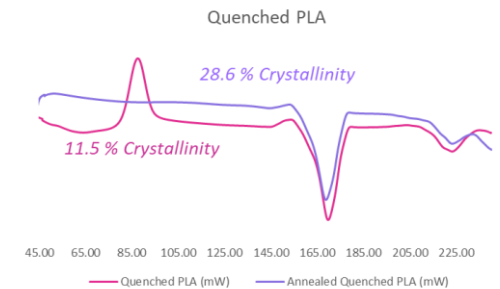


PLA and Flax Fibers

- Terre de Lin flax, braided at A & P technologies
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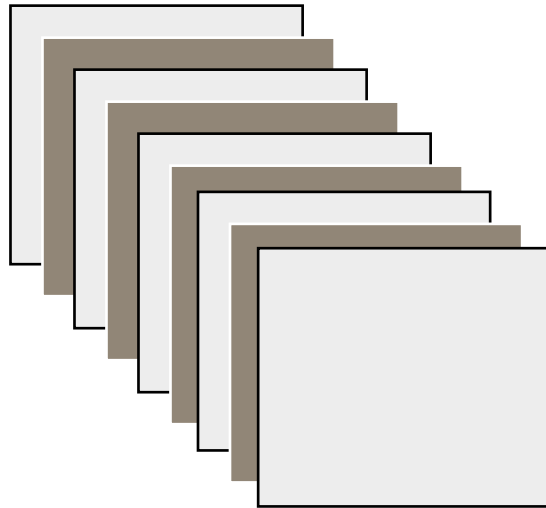


- Semicrystalline granules pressed & cut into 4" x 4" sheets
- 1:1 w/w with flax



Compression Molding Composites

→
Drying Procedure



Layup of PLA (gray) and Flax
(brown)

-
1. Preheat: 182C, 15 min, 0 psig
 2. Heat & press: 182C, *x min*, 600 psig
 3. *Cooling profile*



Composite characterization
with Fourier Transform
Infrared Spectroscopy (FTIR)
& Dynamic Mechanical
Analysis (DMA)

Varied Processing Times



10 min

20 min

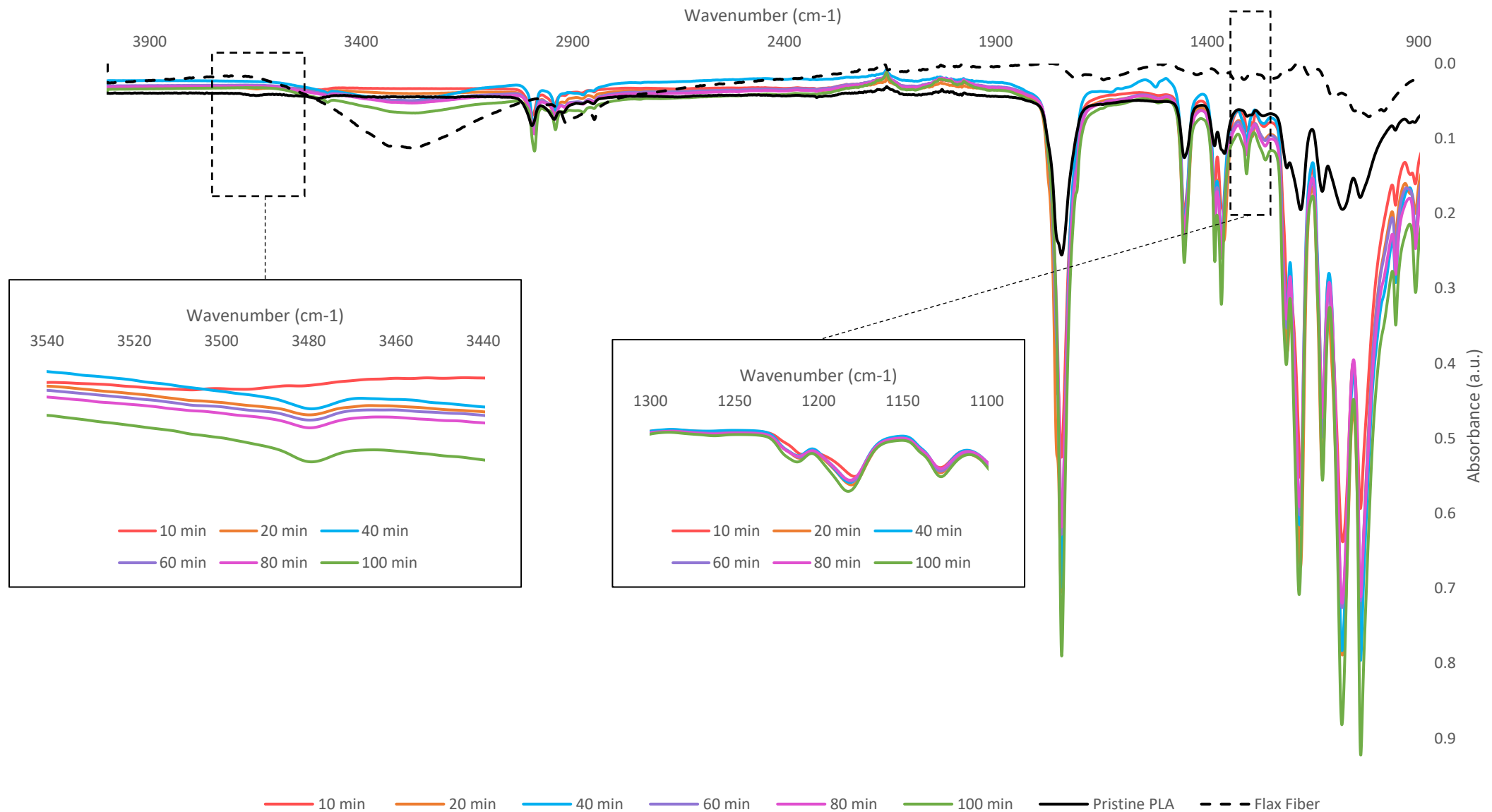
40 min

60 min

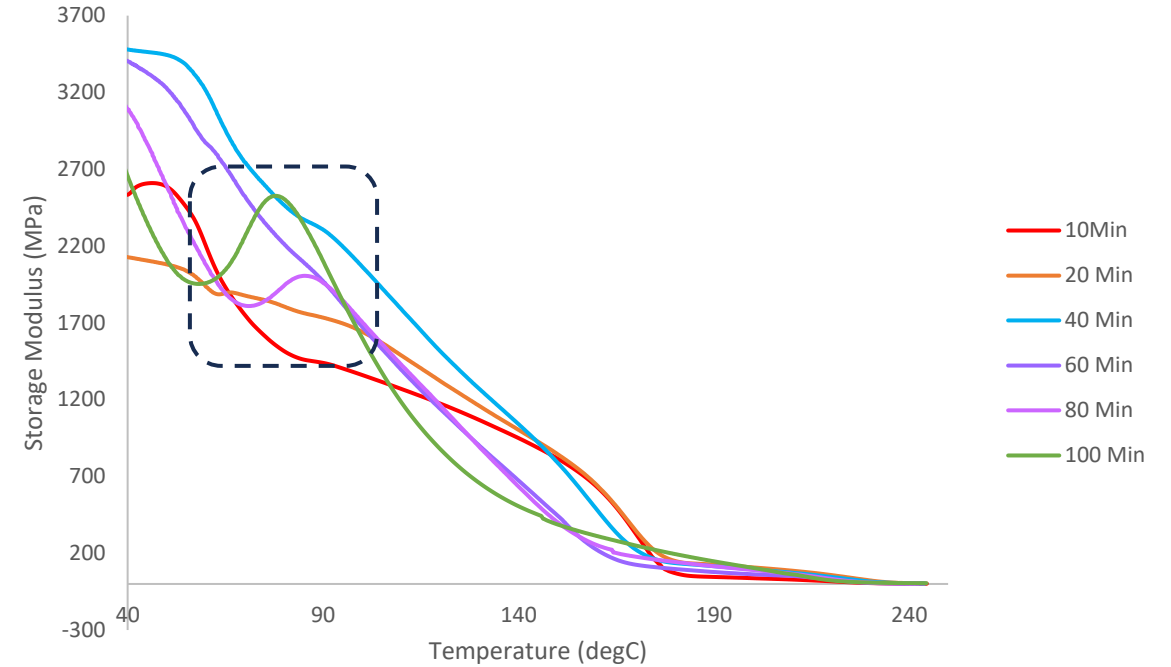
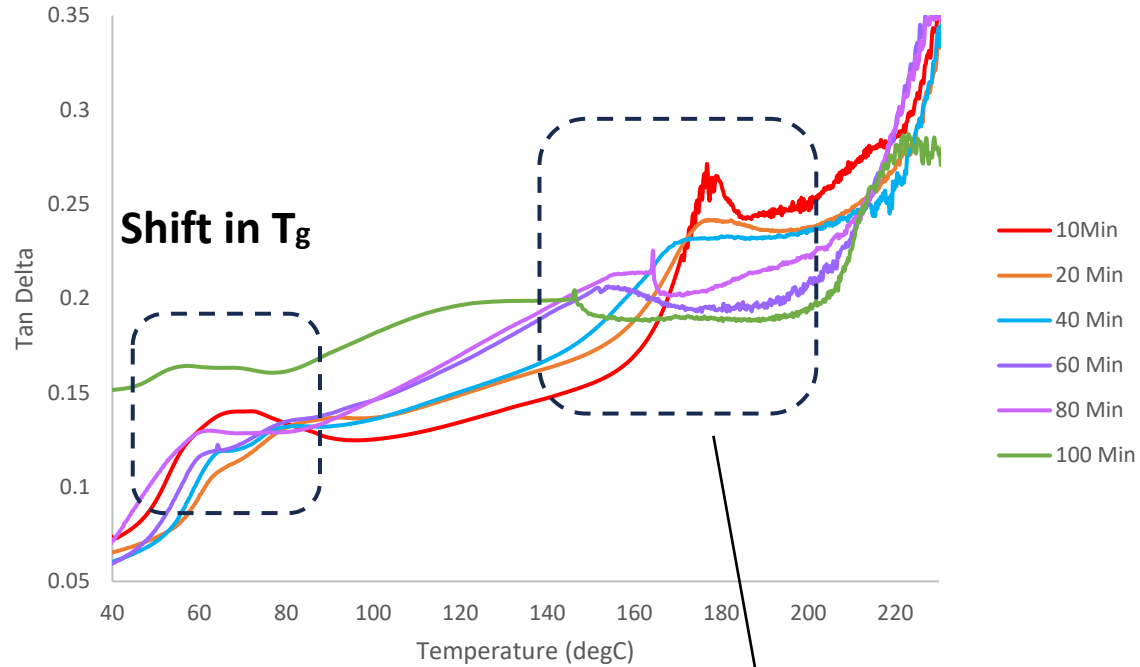
80 min

100 min

Fourier Transform Infrared Spectroscopy (FTIR)



Dynamic Mechanical Analysis (DMA)



Decrease in T_m as processing times increase due to chain scission

Varied Drying Procedures



PLA + Flax Dried

PLA: 3 h at 88°C

Flax: 1 h at 88°C

PLA Dried

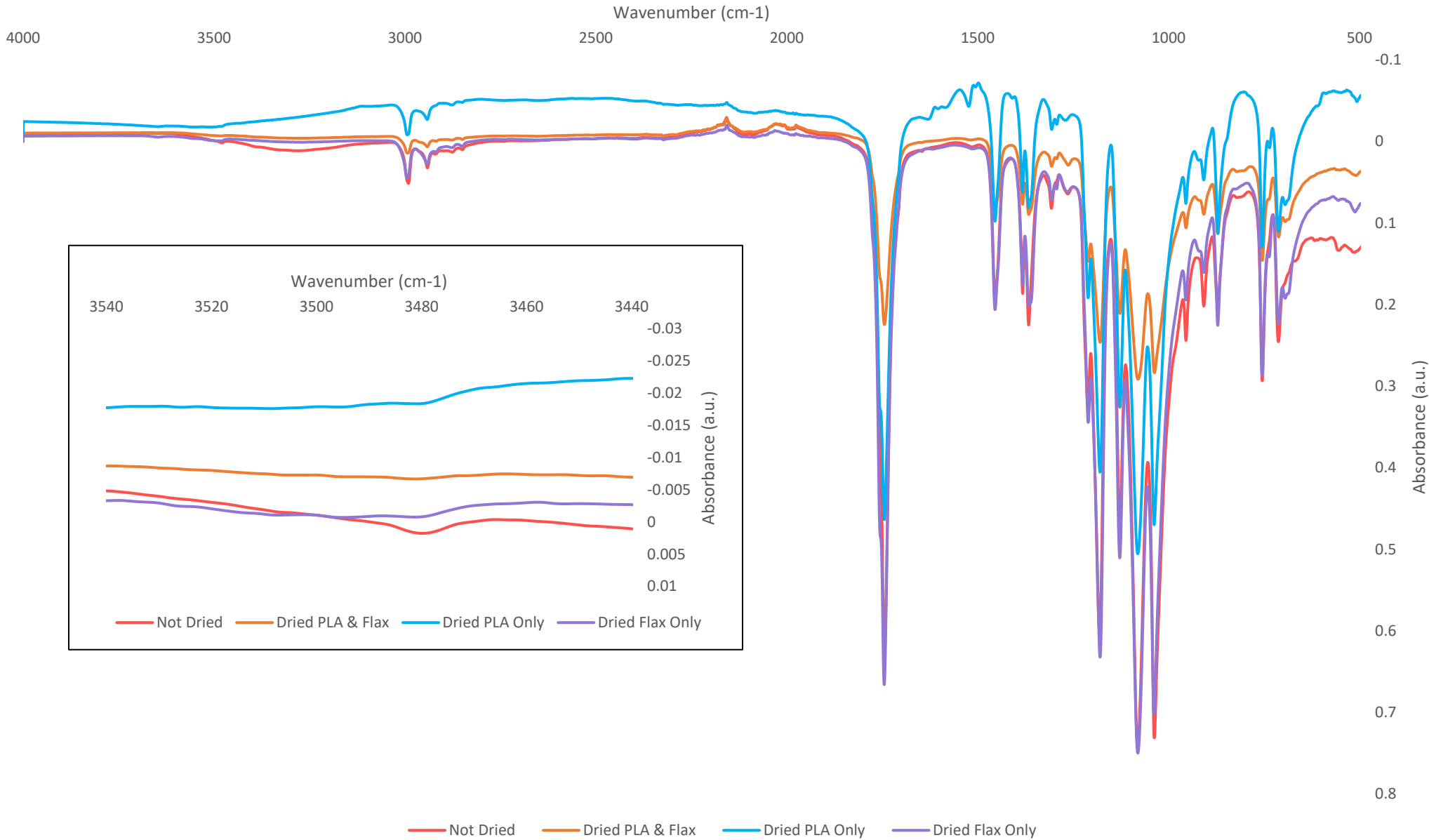
3 h at 88°C

Flax Dried

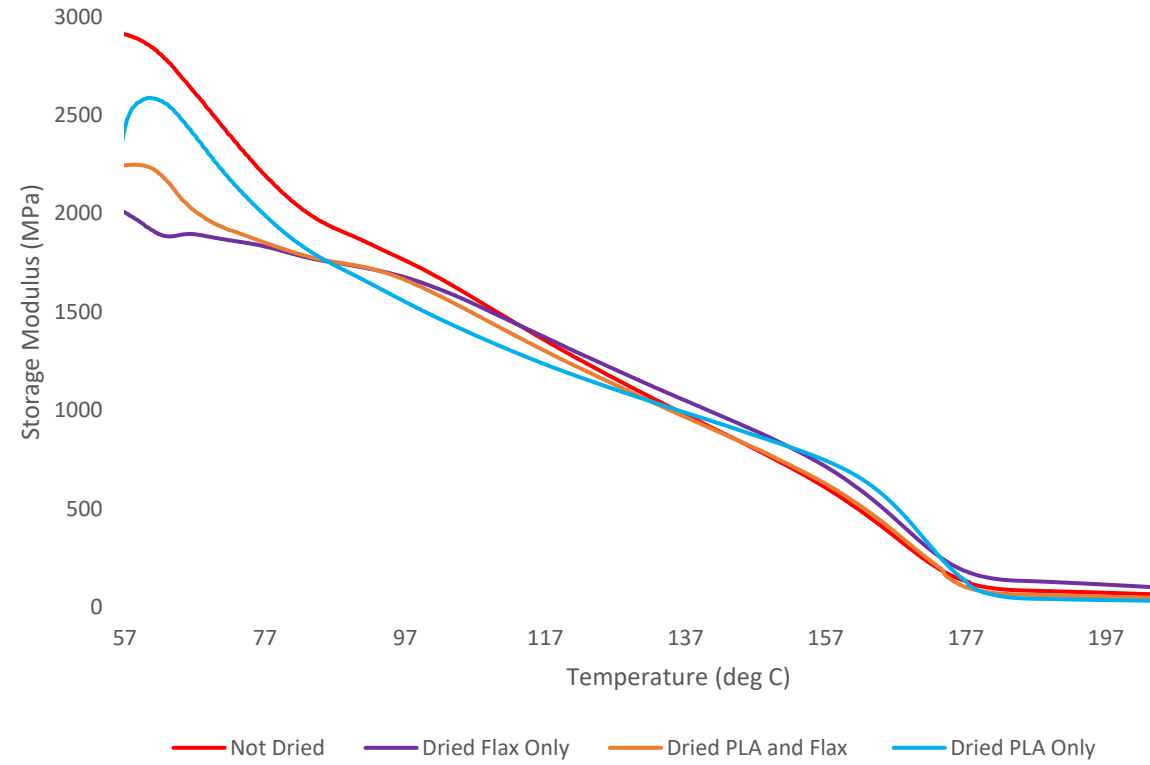
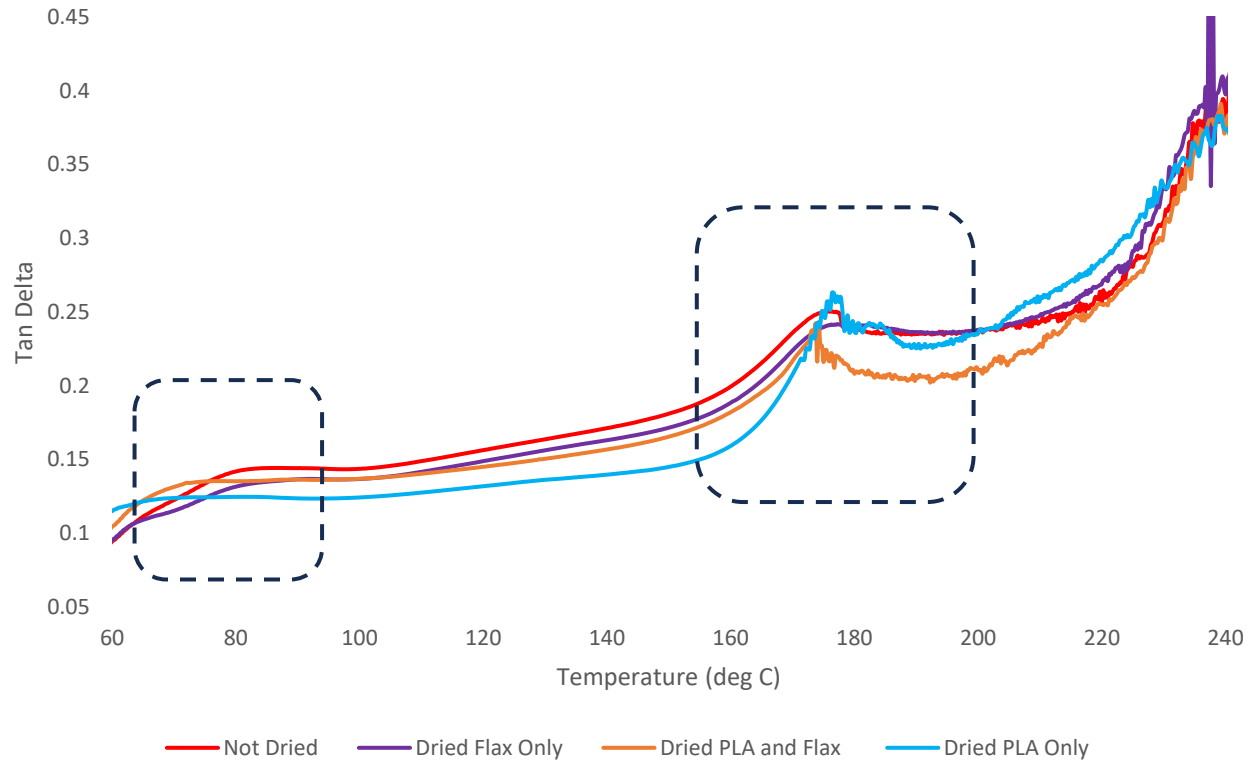
1 h at 88°C

Not Dried

FTIR



DMA



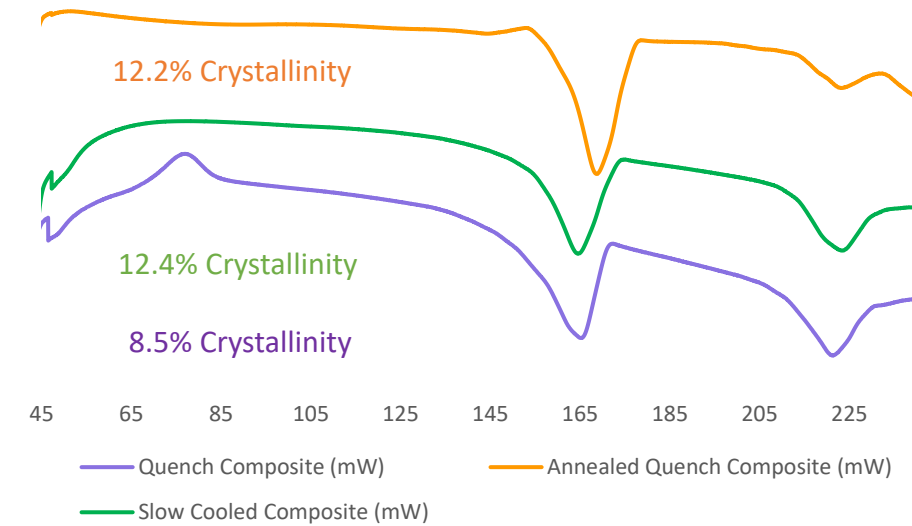
Varied Cooling Profiles



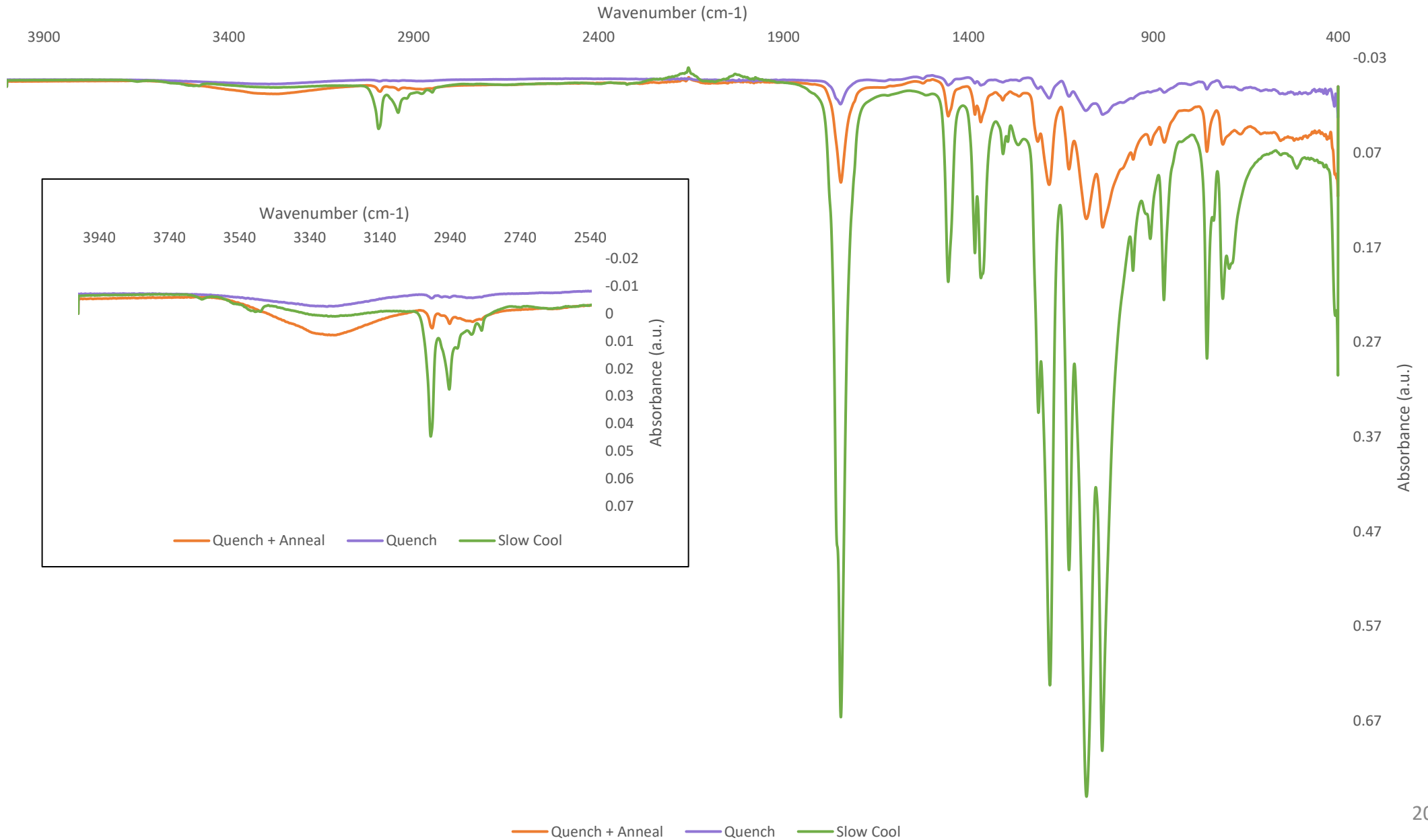
Slow Cool

Quench Cool

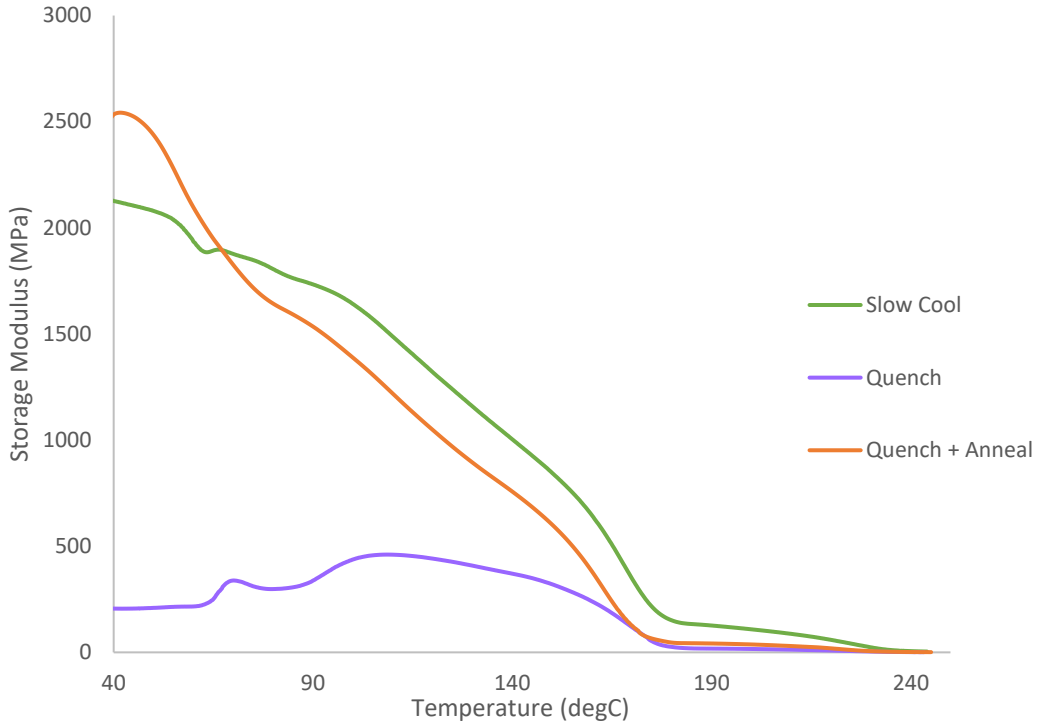
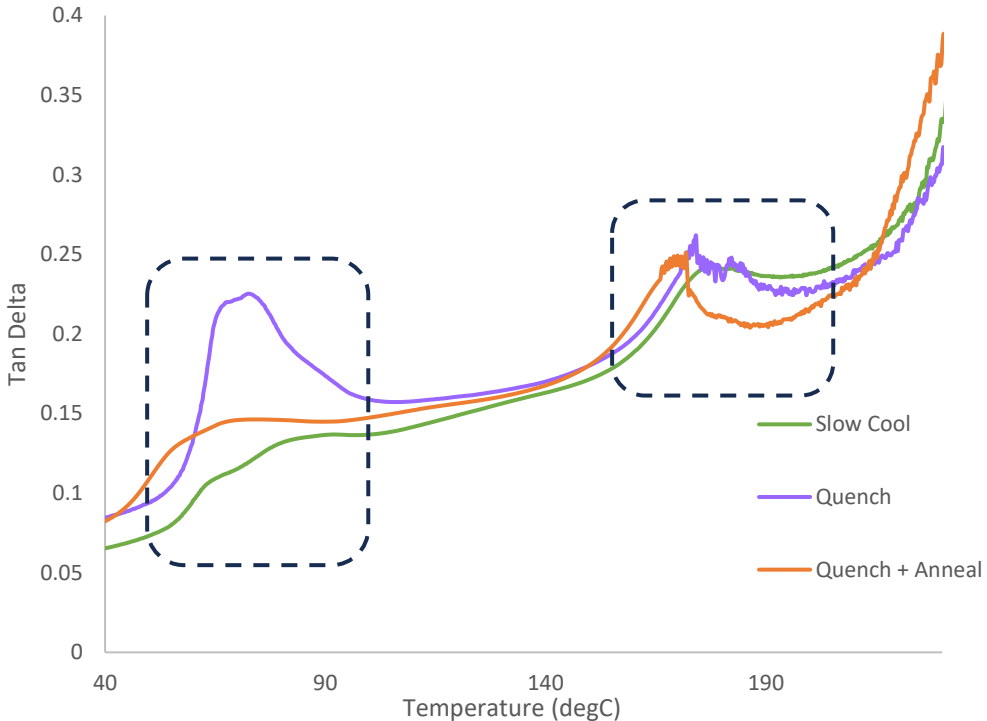
**Quench Cool +
Anneal**



FTIR



DMA



Key Takeaways & Next Steps

- **Hydrolysis of PLA occurs in the manufacturing of composites with natural fibers**
- **Pre-drying the fibers can minimize the effects of hydrolysis by removing excess moisture**
- **Optimizing processing time under pressure can mitigate hydrolysis**

Optimized conditions for manufacturing

- 20 min under pressure
- Pre dry Flax
- Slow Cool

Key Takeaways & Next Steps

- Hydrolysis of PLA occurs in the manufacturing of composites with natural fibers
- Pre-drying the fibers can minimize the effects of hydrolysis by removing excess moisture
- Optimizing processing time under pressure can mitigate hydrolysis
- **Perform optical microscopy to evaluate consolidation**
- **Perform mechanical testing to evaluate performance**
- **Quantify hydrolysis products for quality control**



Questions?

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