

Experimental Protocol: Interfacial Engineering of All-Hemp Nanocomposites for High-Performance Biocomposites

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1 Abstract

This protocol details the synthesis and mechanical validation of a 100% bio-based nanocomposite utilizing carbon nanosheets (CNS) derived from hemp bast as a reinforcing phase within an epoxidized hempseed oil (EHSO) matrix. The system is crosslinked using **Seshat's Lignin (QF-MHL)**. To optimize load transfer, three surface functionalization strategies (Silanization, Acylation, and Grafting From Polymerization) are proposed to bridge the hydrophilic-hydrophobic gap between the reinforcement and the bio-resin.

2 Hypothesis-Driven Objectives

- **H1:** Covalent bonding via 3-Glycidyloxypropyltrimethoxysilane (GPTMS) will enhance the interfacial shear strength (IFSS) by $\geq 35\%$.
- **H2:** Surface acylation with palmitoyl chloride will permit CNS loading up to 7 wt% without significant agglomeration in the EHSO matrix.
- **H3:** The integration of QF-MHL as a crosslinker will provide a rigid aromatic backbone, elevating the glass transition temperature (T_g) of the total system.

3 Materials and Reagents

Component	Material/Reagent	Source/Specification
Matrix	Epoxidized Hempseed Oil (EHSO)	Landry Industries / In-house
Reinforcement	Hemp Carbon Nanosheets (CNS)	Derived from Industrial Hemp
Crosslinker	Seshat's Lignin (QF-MHL)	Modified Kraft Lignin Derivative
Functionalization	APTES / Palmitoyl Chloride	Sigma-Aldrich (Moncton Lab Supply)
Catalysts	DMAP / Tin(II) octoate	Laboratory Grade

4 Theoretical Framework

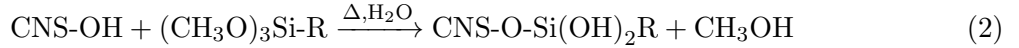
The predicted composite modulus (E_c) is modeled using the modified Halpin-Tsai equation for 2D nanoplatelets:

$$E_c = E_m \left[\frac{1 + \xi \eta \phi_f}{1 - \eta \phi_f} \right] \quad (1)$$

Where:

- $\eta = \frac{(E_f/E_m)-1}{(E_f/E_m)+\xi}$
- $\xi = 2(w/t)$ (The aspect ratio of the hemp nanosheets).

The chemical attachment of silane to the CNS hydroxyl groups is represented by:



5 Standard Operating Procedure (SOP)

5.1 CNS Production and Functionalization

1. **Activation:** Subject hemp bast to hydrothermal carbonization (180°C), followed by KOH activation at 800°C under Argon. 2. **Silanization:** Disperse CNS in ethanol/water (95/5 v/v). Add 2% v/v GPTMS. Stir for 6h at 60°C. Filter and dry.

5.2 Composite Formulation

1. **Mixing:** Use high-shear dispersion to integrate functionalized CNS (1 – 5 wt%) into EHSO for 30 minutes. 2. **Crosslinking:** Add QF-MHL lignin in a 1:1 epoxide-to-hydroxyl equivalent ratio. 3. **Curing:** Degas under vacuum. Pour into ASTM-standard molds. Cure at 80°C (2h) then 140°C (4h).

6 Regional Collaboration and Funding

This project is strategically positioned for the **New Brunswick Innovation Foundation (NBIF)** Innovation Voucher.

- **Primary Lab Partners:** Université de Moncton (Microscopy); UNB NCM Lab (Mechanical Testing).
- **Economic Impact:** Transitioning NB agricultural waste (hemp/lignin) into high-value aerospace-grade biocomposites.