

Sustainable Synthesis of Epoxy Resin from Hemp Oil and Hemp Lignin

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Abstract

This paper presents a sustainable and scalable protocol for producing epoxy resin from hemp oil and hemp lignin. The process combines in-situ epoxidation of unsaturated fatty acids in hemp oil with lignin-based polyol crosslinking. Hemp lignin acts as a reactive aromatic biopolymer that enhances the mechanical, thermal, and biodegradation properties of the epoxy network. This innovation contributes to the development of fully organic composite systems for sustainable industrial applications.

1. Introduction

Epoxy resins are thermosetting polymers widely used in coatings, adhesives, and composites. Conventional epoxies are typically derived from bisphenol-A and epichlorohydrin, raising environmental and health concerns. Hemp oil, rich in unsaturated fatty acids, and hemp-derived lignin, an aromatic polymer byproduct of biomass processing, offer a viable and renewable alternative. By integrating both, we create a hybrid bio-epoxy system with enhanced sustainability and performance.

2. Materials and Reagents

Chemicals.

- Hemp seed oil (cold-pressed, filtered)
- Hydrogen peroxide (30% solution)
- Acetic acid or formic acid
- Sulfuric acid (catalyst)
- Sodium bicarbonate
- Magnesium sulfate

- Hemp lignin (organosolv or alkali-extracted)
- Optional: maleic anhydride or propylene oxide (for lignin modification)
- Curing agent (e.g., triethylenetetramine or acid anhydrides)

Equipment.

- Three-neck round-bottom flask
- Reflux condenser
- Mechanical or magnetic stirrer
- Dropping funnel
- Separatory funnel
- FTIR and NMR spectrometers
- Oven or thermal curing press

3. Methodology

3.1. 1. Epoxidation of Hemp Oil.

1. Add 100 mL hemp oil and 100 mL acetic acid to a 3-neck flask.
2. Heat to 50 °C with stirring.
3. Add 70 mL of 30% hydrogen peroxide dropwise over 1 hour.
4. Add 1 mL sulfuric acid as catalyst.
5. Maintain at 60 °C for 4–6 hours.
6. Monitor epoxidation via FTIR (epoxy peaks at 820–860 cm^{-1}).
7. Cool, wash with sodium bicarbonate and brine, dry over magnesium sulfate.

3.2. 2. Preparation of Hemp Lignin.

1. Use dried hemp lignin (organosolv preferred for high reactivity).
2. (Optional) React lignin with maleic anhydride or propylene oxide to increase hydroxyl content and solubility.
3. Dry under vacuum and sieve to fine powder.

3.3. 3. Formulation and Curing.

1. Mix epoxidized hemp oil (EHO) with hemp lignin powder in 70:30 or 80:20 weight ratio.
2. Add curing agent (e.g., triethylenetetramine) at stoichiometric ratio.
3. Stir at room temperature or mild heat (60 °C) to ensure homogeneity.
4. Pour into mold or substrate.
5. Cure for 24–48 hours at room temperature or 80–150 °C for 2–6 hours.

4. Characterization

Fourier Transform Infrared Spectroscopy (FTIR).

- Confirmation of epoxy groups at 820–860 cm^{-1}
- Disappearance of olefinic C=C peak at 3010 cm^{-1}

Thermal and Mechanical Testing.

- TGA for degradation onset temperature
- DSC for glass transition temperature (T_g)
- Tensile and flexural strength via ASTM D638

NMR Spectroscopy.

- ^1H and ^{13}C spectra to confirm disappearance of alkene protons and appearance of oxirane rings.

5. Discussion

The integration of hemp lignin into epoxy systems derived from hemp oil increases thermal stability and modulus due to lignin’s rigid aromatic structure. Proper lignin modification or solvent blending can overcome miscibility issues. With optimized ratios and curing systems, the resulting bio-epoxies show excellent potential in coatings, organic composites, and biodegradable packaging materials, especially when used in tandem with fiber-reinforced systems like Seshat’s Composites.

6. Conclusion

This method provides a feasible path for developing fully bio-based epoxy resins using hemp-derived raw materials. Hemp lignin functions both as a polyol and reinforcement agent, while hemp oil provides the reactive base for epoxidation. This aligns with the goals of the Organic Revolution and the Universal Declaration of Organic Rights in promoting non-toxic, sustainable materials.

References

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