

Production of Bio-Based Epoxy Resin from Hemp Oil

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Abstract

This document outlines a laboratory-scale method for producing epoxy resin from hemp oil through in-situ peracid epoxidation. The process represents a sustainable and biodegradable alternative to petroleum-derived epoxies, with potential applications in organic composites such as Seshat's Composites. The protocol includes materials, reaction conditions, and curing procedures.

1. Introduction

Epoxy resins are widely used polymers known for their high mechanical strength and chemical resistance. Traditional epoxies are derived from bisphenol-A (BPA), a compound with known endocrine-disrupting properties. In contrast, vegetable oils such as hemp oil offer a renewable and less toxic source for epoxy resin production via epoxidation of unsaturated fatty acid chains. Hemp oil is particularly rich in linoleic and linolenic acids, making it a prime candidate for this transformation.

2. Materials and Equipment

Chemicals.

- Cold-pressed, filtered hemp seed oil
- Hydrogen peroxide (30 % solution)
- Acetic acid or formic acid
- Sulfuric acid or acidic ion exchange resin (catalyst)
- Sodium bicarbonate
- Distilled water and brine solution
- Magnesium sulfate (drying agent)

- Toluene (optional solvent)
- Curing agent: triethylenetetramine or maleic anhydride

Equipment.

- 3-neck round-bottom flask
- Mechanical stirrer or magnetic stirrer
- Thermometer
- Dropping funnel
- Reflux condenser
- Separatory funnel
- FTIR and/or NMR spectrometer
- Fume hood and personal protective equipment (PPE)

3. Methodology

3.1. Step 1: Drying of Hemp Oil. Dry the hemp oil using vacuum distillation or by passing it through molecular sieves to remove moisture. Store in a sealed container until use.

3.2. Step 2: In-Situ Peracid Epoxidation.

1. In a 3-neck flask, add hemp oil and acetic acid (molar ratio oil:acid 1:1).
2. Heat to 50 °C under stirring.
3. Slowly add hydrogen peroxide dropwise to form peracetic acid in situ.
4. Add sulfuric acid (0.5–1 wt%) as catalyst.
5. Maintain temperature at 50 to 60 °C for 3–6 hours.
6. Monitor progress using iodine value or FTIR (epoxide peak at 820–860 cm^{-1}).

3.3. Step 3: Workup and Purification.

1. Cool the mixture and transfer to a separatory funnel.
2. Wash with saturated sodium bicarbonate to neutralize acid.
3. Wash with brine to remove residual water.
4. Dry over magnesium sulfate, then filter and store under nitrogen.

3.4. Step 4: Curing Process.

1. Mix the epoxidized hemp oil with chosen curing agent at stoichiometric ratio.
2. Cast into mold or apply to substrate.
3. Cure at room temperature for 24 hours or at 70–150 °C for accelerated curing.

4. Characterization

- **FTIR Spectroscopy:** Confirm formation of epoxy groups by peaks near 820–860 cm^{-1} .
- **NMR Analysis:** ^1H and ^{13}C NMR can confirm disappearance of olefinic protons and appearance of oxirane signals.
- **Oxirane Oxygen Content:** Determine using titration with hydrogen bromide/acetic acid solution.

5. Applications and Integration

The bio-based epoxy resin derived from hemp oil can be used as a binder in:

- Carbon-fiber composites
- Sustainable coatings
- Biodegradable packaging materials
- Organic defense and aerospace materials (e.g., Seshat’s Composites)

6. Safety Considerations

- Perform all steps involving peroxides and acids in a well-ventilated fume hood.
- Use gloves, goggles, and lab coat at all times.
- Control temperature carefully during peroxide addition to avoid exothermic runaway.

7. References

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