Jun 06, 2025

Producing Plant-Based Leather from Coffee Grounds and Yerba Mate remains (Eco-friendly alternative to leather)

DOI
https://dx.doi.org/10.17504/protocols.io.rm7vzqz7xvx1/v1

Joseph shenekji[1,2], kamar shayah[1], Miray Mobayed[1], Marie-Nour Noubarian[1], Alaa Alabd[1], Luna Mannaa[1]

[1]department of biotechnology engineering, faculty of technical engineering, university of Aleppo;
[2]Coordinator of Biotechnologysy.org

Joseph shenekji: PhD in Biotechnology Engineering - josephshenekji94@gmail.com;
kamar shayah: PhD in Biotechnology Engineering
Miray Mobayed: Graduation student
Marie-Nour Noubarian: Graduation student
Alaa Alabd: Graduation student
Luna Mannaa: Graduation student

Joseph shenekji
department of biotechnology engineering, faculty of technica...

DOI: https://dx.doi.org/10.17504/protocols.io.rm7vzqz7xvx1/v1

Protocol Citation: Joseph shenekji, kamar shayah, Miray Mobayed, Marie-Nour Noubarian, Alaa Alabd, Luna Mannaa 2025. Producing Plant-Based Leather from Coffee Grounds and Yerba Mate remains (Eco-friendly alternative to leather). **protocols.io** **https://dx.doi.org/10.17504/protocols.io.rm7vzqz7xvx1/v1**

Protocol status: Working
We use this protocol and it's working

Created: June 06, 2025

Last Modified: June 06, 2025

Protocol Integer ID: 219726

Keywords: plant-base leather, vegan leather, coffee grounds, yerba mate, eco-friendly , leather alternative, leather from coffee ground, friendly alternative to leather, traditional leather, based leather, gelling properties of sodium alginate, formation of the biopolymer matrix, leather, biopolymer matrix, using coffee ground, gelling property, sodium alginate, coffee ground, applications in textile, textile, primary biomass

Abstract

This protocol outlines a method for producing plant-based leather using coffee grounds or yerba mate remains as primary biomass, combined with sodium alginate and other reagents. The process leverages the gelling properties of sodium alginate in the presence of calcium chloride to form a flexible, leather-like material. The protocol details the preparation, mixing, and curing steps, with an emphasis on the molecular mechanisms driving the formation of the biopolymer matrix. This eco-friendly approach repurposes household daily waste into a sustainable alternative to traditional leather, with applications in textiles and material science.

Materials

For Coffee-Based Leather

- **Sodium alginate: 8 g**
- **Coffee grounds (dried, finely ground): 8 g**
- **Olive oil (lampante olive oil or pomace olive oil): 8 g**
- **Glycerin: 20 g**
- **Distilled water: 132 ml**
- **Calcium chloride ($CaCl_2$, anhydrous): 7 g**

For Yerba Mate-Based Leather

- Sodium alginate: 8 g
- Yerba mate (dried, finely ground): 8 g
- Olive oil: 8 g
- Glycerin: 20 g
- Distilled water: 132 ml
- Calcium chloride ($CaCl_2$, anhydrous): 7 g

Equipment

- Analytical balance (0.01 g precision)
- Glass beakers (250 mL, 2 units)
- Magnetic stirrer with hotplate
- Spatula or stirring rod
- Flat, smooth, non-porous surface (e.g., glass or silicone mold)
- Spray bottle (for $CaCl_2$ solution)
- Drying oven (optional, set to 40°C)
- pH meter (optional, for quality control)

Introduction

1 **This protocol transforms household coffee grounds (*Coffea* spp.) and yerba mate (*Ilex paraguariensis*) into plant-based leather, mitigating traditional leather's environmental impact (15,000 L water/kg). Globally, 10.5M metric tons of coffee (2020) produce ~5.25M tons of grounds; households generate 2–4 kg yearly. In Argentina, 90% of households consume 5.9 kg mate/person, yielding 16.5–18.9 kg waste/household. Syria imports 26,000 tons (2023), producing 2.8–6.4 kg/household. Using sodium alginate cross-linking, this biodegradable leather reduces landfill methane (1.5–2.0 tons CO_2/ton) and taps the $73.4B vegan leather market (2023), fostering sustainable economies.**

Objectives

- **To repurpose coffee grounds and yerba mate into a sustainable leather alternative.**
- **To elucidate the molecular interactions driving biopolymer formation.**
- **To provide a reproducible protocol for laboratory and industrial applications.**

Protocol of making plant-based leather

3d 0h 20m

2 **Step 1: Preparation of Dry Components**

Weigh 8 g of sodium alginate and 8 g of dried coffee grounds (or dried remains of yerba mate) using an analytical balance. Combine in a 250 mL beaker.

weighing dry components, dried remains of yerba mate, sodium alginate, dried coffee grounds

Molecular Mechanism: Sodium alginate, a linear copolymer of β-D-mannuronic acid (M) and α-L-guluronic acid (G) residues, provides a scaffold for the biopolymer matrix. Coffee grounds and yerba mate contribute lignocellulosic fibers (cellulose, hemicellulose, and lignin), which enhance tensile strength and texture. The dry mixing ensures uniform distribution of the biomass within the alginate matrix, preventing clumping during hydration.

The lignocellulosic components in coffee grounds (approximately 40–50% cellulose) and yerba mate (similar composition) act as fillers, increasing the mechanical strength of the final material. Sodium alginate's anionic carboxyl groups are critical for subsequent cross-linking with calcium ions.

3 **Step 2: Preparation of Liquid Components**

In a separate 250 mL beaker, combine 132 g distilled water, 20 g glycerin, and 8 g olive oil. Stir using a magnetic stirrer at 300 rpm for 00:05:00 to form a homogeneous mixture.

mixing olive oil with water and glycerin

Molecular Mechanism: Glycerin acts as a plasticizer, reducing intermolecular forces within the alginate matrix to enhance flexibility. Olive oil, rich in triglycerides (e.g., oleic acid), serves as a hydrophobic agent, improving water resistance and adding suppleness to the material. Water hydrates the alginate, enabling dissolution and gel formation.

Glycerin's hydroxyl groups form hydrogen bonds with alginate's carboxyl and hydroxyl groups, reducing brittleness. Olive oil's non-polar nature minimizes water penetration, enhancing the material's durability in humid conditions.

4 **Step 3: Combining Dry and Liquid Components** 10m

Gradually add the liquid mixture to the dry mixture while stirring continuously for 00:10:00 to achieve a uniform, viscous paste.

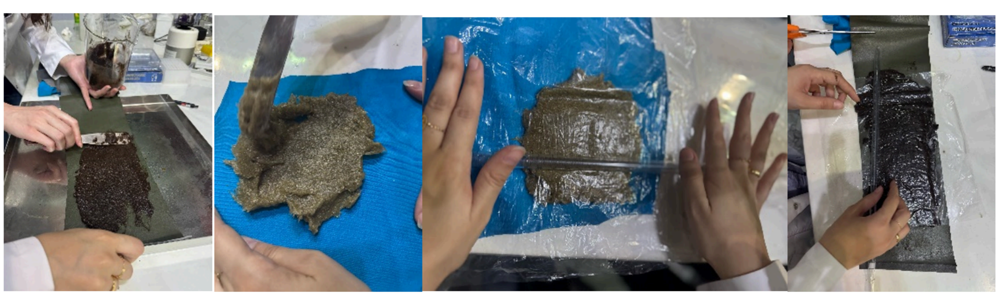
mixing liquid and dry components

Molecular Mechanism: Hydration of sodium alginate results in the dissociation of Na^+ ions, exposing negatively charged carboxyl groups. The lignocellulosic fibers from coffee grounds or yerba mate become embedded in this viscous matrix, forming a composite material.

The viscosity of the mixture (typically 1000–5000 cP, depending on shear rate) ensures proper dispersion of fibers. Overmixing should be avoided to prevent air bubble incorporation, which could weaken the material.

5 **Step 4: Forming the Leather Sheet**

Spread the mixture evenly onto a smooth, non-porous surface (e.g., glass or silicone mold) to a thickness of 2–3 mm using a spatula, cover it with a plastic bag and roll it to have a consistent appearance.



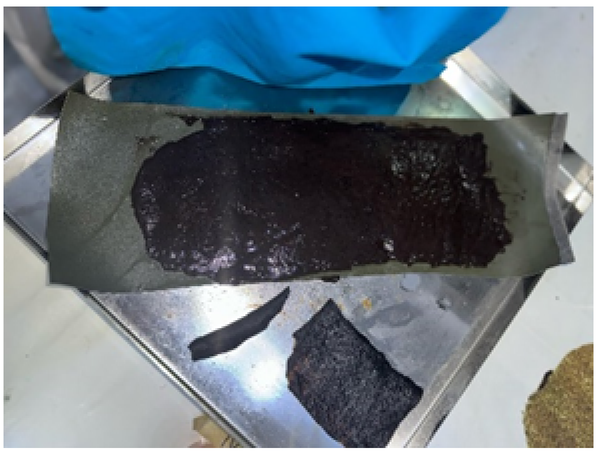
forming leather sheet of coffee grounds, and yerba mate remains

Molecular Mechanism: The uniform spreading ensures consistent cross-linking in the subsequent step. The lignocellulosic fibers align randomly within the alginate matrix, contributing to isotropic mechanical properties.

The thickness of 2–3 mm is optimal for balancing flexibility and strength. Thinner layers may be too fragile, while thicker layers may require extended drying times.

6 **Step 5: Cross-Linking with Calcium Chloride** 10m

Dissolve 7 g of calcium chloride in 50 mL of distilled water to prepare a 14% (w/v) solution. Spray the solution evenly over the spread mixture using a spray bottle. Allow it to sit for 00:10:00 .



after spraying the leather on both sided with cacl2 it will give this appearance

Molecular Mechanism: Calcium ions (Ca^{2+}) interact with the guluronic acid (G) blocks of sodium alginate, forming an “egg-box” structure through ionic cross-linking. This creates a stable, three-dimensional hydrogel network that traps the lignocellulosic fibers.

The “egg-box” model involves Ca^{2+} ions coordinating with oxygen atoms in the carboxyl and hydroxyl groups of adjacent G blocks, forming a rigid gel (Draget et al., 2006). The 14% $CaCl_2$ concentration ensures rapid gelation without excessive ion residue, which could affect texture.

7 **Step 6: Washing Excess Calcium Chloride**

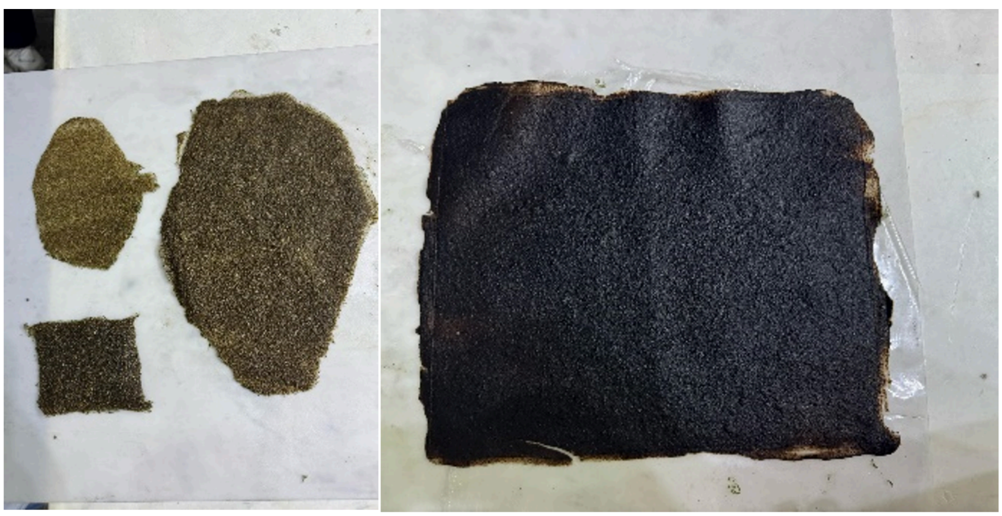
Rinse the gelled material with distilled water to remove excess calcium chloride. Gently pat dry with a lint-free cloth.

Molecular Mechanism: Excess Ca^{2+} ions not incorporated into the alginate matrix are removed to prevent surface crystallization, which could compromise flexibility. The rinsing step also removes unbound sodium ions and residual coffee or yerba mate particles.

Over-rinsing should be avoided to prevent leaching of glycerin, which could weaken the material's flexibility. The pH of the rinse water should be neutral (pH 6.5–7.5) to avoid disrupting the alginate matrix.

8 **Step 7: Drying the Material** 3d

Allow the material to air-dry at room temperature (20–25°C) for 72:00:00 or use a drying oven at 40°C for 24 hours.



final appearance of plant-based leather from coffee grounds and yerba mate remains.

Molecular Mechanism: Evaporation of water during drying consolidates the alginate matrix, reducing pore size and increasing density. The glycerin retains residual moisture, preventing excessive brittleness.

Drying at higher temperatures (>50°C) may cause cracking due to rapid water loss. The lignocellulosic fibers contribute to dimensional stability during drying, minimizing shrinkage.

Expected Results

9 The resulting material is a flexible, leather-like sheet with a thickness of 1–2 mm (post-drying), exhibiting a slightly textured surface due to the embedded coffee grounds or yerba mate. The material is biodegradable, relatively water-resistant (you can add a layer of hydrophobic spray), and mechanically robust, with potential applications in sustainable fashion and upholstery.

Protocol references

Draget, K. I., Smidsrød, O., & Skjåk-Bræk, G. (2006). Alginates from Algae. In *Polysaccharides and Polyamides in the Food Industry* (pp. 1–30). Wiley-VCH.

Lee, K. Y., & Mooney, D. J. (2012). Alginate: Properties and biomedical applications. *Progress in Polymer Science*, 37(1), 106–126.

Ballesteros, L. F., Teixeira, J. A., & Mussatto, S. I. (2014). Chemical, functional, and structural properties of spent coffee grounds and coffee silverskin. *Food and Bioprocess Technology*, 7(12), 3493–3503.

Sánchez, M. L., & Laca, A. (2020). Yerba mate as a source of biopolymers for sustainable material development. *Industrial Crops and Products*, 155, 112791.

ICO. (2020). Coffee Market Report. https://www.ico.org/documents/cy2020-21/cmr-1220-e.pdf

INYM. (2023). Yerba Mate Sales in Argentina. https://www.inym.org.ar/estadisticas/

UN Comtrade. (2024). Yerba Mate Exports. https://comtrade.un.org/data/

NextMSC. (2025). Vegan Leather Market. https://www.nextmsc.com/report/vegan-leather-market