BioLab Route Sheet

Development of a Cacao-Based Biomaterial Using a 3D Printed TPU Train Mold

Project / Assignment	Fab Academy 2026 - Week 17 Wildcard Week
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Process area	Biofabrication / biomaterials / flexible mold casting
Final object	Train-shaped biomaterial sample
Mold fabrication	3D printed TPU 95A mold, Bambu Lab X1E
Document purpose	Professional route sheet for reproducing the BioLab process

Process summary. This route sheet describes the design and fabrication of a flexible TPU mold and the preparation of a cacao-based biomaterial made from distilled water, corn starch, unflavored gelatin, glycerin, cacao powder and powdered cacao husk. The process includes material weighing, thermal mixing, viscosity characterization, casting, controlled dehydration and demolding.

1. Objective

Develop a moldable biomaterial using a biopolymeric matrix composed of corn starch, unflavored gelatin, glycerin and cacao-derived fillers. The material is cast into a flexible TPU mold produced by digital fabrication and then dehydrated under controlled conditions to obtain a solid train-shaped sample.

2. Safety and Good Laboratory Practice

This process uses heated liquids, laboratory equipment and food-derived powders. The work must be performed in a clean, ventilated laboratory area using gloves, a lab coat and eye protection when necessary. Avoid touching hot beakers or heated plates directly. Keep the workbench clean and label materials during the process.

Risk / consideration	Control measure
Hot mixture and heated plate	Use heat-resistant handling practices and avoid direct contact with glassware immediately after heating.
Powder handling	Avoid inhaling fine cacao husk particles during grinding and weighing. Keep containers closed when not in use.
Electrical laboratory equipment	Check that cables and instruments are dry and placed away from spills.
Biomaterial contamination	Use clean containers and tools to maintain repeatability and reduce contamination.
Waste and cleanup	Dispose of residues according to local laboratory rules. Clean molds and glassware after use.

3. Equipment and Tools

Equipment / tool	Purpose
Analytical balance	Precise measurement of ingredients in grams.
Digital balance	General weighing support during preparation.
Glass beaker	Container for the liquid mixture during heating and stirring.
Powder measuring container	Container for starch, gelatin and cacao-derived powders.
Magnetic stirrer with heating	Controlled heating and continuous agitation.

Equipment / tool	Purpose
Blender	Reduction of cacao husk particle size before incorporation.
Flexible TPU mold	Train-shaped mold cavity for casting the biomaterial.
Industrial dehydrator	Controlled dehydration after casting.
Viscometer	Measurement of apparent viscosity before casting.
Refrigerator	Cooling or temporary stabilization support when needed.

4. Mold Design and Digital Fabrication

The train mold was designed in Autodesk Inventor. The train geometry was divided into two halves to simplify casting and demolding. A negative cavity was created from one half of the train, and the opposite half was obtained through a mirror operation. This strategy makes it possible to compare two biomaterial formulations while maintaining the same design language as the Fab Train final project.

Parameter	Specification
CAD software	Autodesk Inventor
Mold strategy	Two-part train mold, negative cavity generated from the train geometry
Volume reference	Approximately 31 mL per train half
Printer	Bambu Lab X1E
Mold material	TPU 95A
Wall thickness	2 mm
Infill	15%
Reason for TPU	Flexible mold behavior improves demolding and reduces stress on the dehydrated biomaterial.

Design note: The measured mold volume is used to calculate the approximate amount of biomaterial needed. Preparing the material by volume and weight helps reduce waste and improves repeatability.

5. Biomaterial Formulation

The formulation was prepared for an approximate final volume of 35 mL. Two filler variants were tested: cacao powder and powdered cacao husk. Cacao powder produced a dark brown tone, while cacao husk produced a more reddish brown tone.

Ingredient	Quantity	Function
Distilled water	35 g	Solvent and base liquid for the mixture.
Corn starch	4 g	Biopolymeric structure through gelatinization.
Unflavored gelatin	2 g	Gel-forming component that supports matrix formation.
Glycerin	3 g	Plasticizer that improves flexibility and reduces brittleness.
Cacao powder OR powdered cacao husk	1 g	Natural filler and colorant.

Important: Measure all ingredients by weight. Small variations can change viscosity, drying behavior, flexibility and demolding quality.

6. Preparation of Raw Material

Cacao powder test. Cacao powder is used directly as a natural filler and colorant in the biomaterial. It gives the material a dark brown color.

Cacao husk test. Cacao husk must be reduced in particle size before use. Fine particles improve dispersion and reduce the risk of blocking details inside the mold.

Material variant	Expected visual result
Cacao powder	Dark brown color
Powdered cacao husk	Reddish brown color

7. Experimental Procedure

Stage	Step	Action
Preparation	1	Weigh 35 g of distilled water.
Preparation	2	Add 4 g of corn starch.
Preparation	3	Add 2 g of unflavored gelatin.
Preparation	4	Add 1 g of cacao powder or powdered cacao husk.
Preparation	5	Mix until the formulation is visually homogeneous.
Gelatinization	6	Place the mixture on the magnetic stirrer with heating.
Gelatinization	7	Heat to 90 degrees C for 6 minutes with constant agitation.
Gelatinization	8	Observe the progressive increase in viscosity due to starch gelatinization and gelatin activation.
Plasticization	9	Add 3 g of glycerin.
Plasticization	10	Continue stirring for 2 additional minutes.
Plasticization	11	Obtain a homogeneous fluid-viscous mixture suitable for casting.

8. Viscosity Characterization

Before casting, the mixture is characterized with a viscometer. The successful mixture reached an apparent viscosity of approximately 5,000 cP. This viscosity allows the material to flow into the TPU mold while maintaining enough body to form a gel-like structure before dehydration.

Parameter	Value / observation
Apparent viscosity	Approx. 5,000 cP
Casting behavior	Adequate flow during pouring
Mold filling	Able to fill mold cavities
Post-cooling behavior	Initial gel-like structure before dehydration

9. Mold Release and Casting

Step	Action
1	Apply a thin layer of vegetable oil or release agent to the internal surface of the TPU mold.
2	Pour the hot biomaterial into the mold while it is still fluid-viscous.
3	Distribute the mixture evenly until the available mold volume is filled.
4	Allow initial cooling and gel formation before moving the mold to dehydration.

10. Controlled Dehydration

The loaded mold is dehydrated in an industrial dehydrator. The goal is to reduce moisture content, increase dimensional stability and transform the initial hydrogel into a solid biomaterial sample.

Condition	Successful value
Temperature	50 degrees C
Time	10 hours
Process goal	Moisture reduction and dimensional stabilization
Expected result	Solid train-shaped biomaterial that can be removed from the TPU mold

11. First Trial and Corrective Action

The first trial did not produce a stable result. The dehydration was performed at 40 degrees C for 4 hours, and the material did not reach sufficient structural integrity. During demolding, the piece broke and the geometry was not preserved correctly.

Problem observed	Correction applied
Insufficient drying and weak structure	Increase dehydration to 50 degrees C for 10 hours.
Piece broke during demolding	Use flexible TPU mold and a thin release layer.
Poor process repeatability	Measure all ingredients precisely by weight and use volume reference from CAD.
Unstable viscosity	Use controlled heating at 90 degrees C for 6 minutes and add glycerin after gelatinization.

12. Expected Final Result

The expected result is a biodegradable biomaterial with biocomposite characteristics, capable of reproducing the train-shaped TPU mold geometry and maintaining structural stability after dehydration. The cacao powder version should appear darker brown, while the cacao husk version should appear reddish brown.

13. Quality Control Checklist

Control point	Acceptance criterion
Ingredient weighing	All ingredients measured according to formulation.
Particle size	Cacao husk reduced to fine particles before mixing.
Heating profile	90 degrees C for 6 minutes with constant agitation.
Glycerin addition	Added after gelatinization and mixed for 2 minutes.
Viscosity	Approx. 5,000 cP or visually fluid-viscous behavior.
Mold release	Thin and even release layer applied.
Dehydration	50 degrees C for 10 hours.
Demolding	Piece removed without major breakage.
Geometry	Train shape visible and details preserved.

14. Reproducibility Notes

The most critical variables are formulation accuracy, temperature, time, viscosity and dehydration. If any of these variables changes significantly, the final biomaterial can become too brittle, too wet, too soft or difficult to demold.

Variable	Why it matters
Water content	Controls fluidity, drying time and final shrinkage.
Starch and gelatin ratio	Defines matrix formation and mechanical integrity.
Glycerin	Controls flexibility and brittleness.
Cacao filler	Changes color, texture and dispersion behavior.
Heating temperature	Required for gelatinization and viscosity increase.
Dehydration time	Required to stabilize the final object.
TPU flexibility	Reduces damage during demolding.

15. Version Record

Version	Description
Trial 01	Lower dehydration condition: 40 degrees C for 4 hours. Result broke during demolding.
Trial 02	Improved process: 90 degrees C heating, glycerin after gelatinization, 50 degrees C dehydration for 10 hours. Result acceptable.

16. Route Sheet Summary

This route sheet combines digital fabrication and biomaterial processing. The digitally fabricated TPU mold provides shape and repeatability, while the biomaterial formulation demonstrates how cacao-derived materials can be explored as fillers in a biodegradable matrix. The process supports experimentation with local by-products, sustainable material exploration and Fab Academy Wildcard Week documentation.

Prepared for Week 17 - Wildcard Week. This document is intended as a reproducible BioLab route sheet and should be used together with the mold design file, process photos and final assignment documentation.