Biofabrics: Harnessing Sodium Alginate for Sustainable Seaweed-Based Fabrics

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Theme: Sustainable Development and Waste- Management

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NATURE OF THE WORK

Novel solution/ indigenous design to a problem/ challenge

RATIONALE

The textile industry is one of the largest contributors to environmental pollution, with traditional methods of production resulting in excessive waste, high carbon emissions, and reliance on non-renewable resources. In addition to the direct environmental impact, a significant portion of textiles produced globally ends up in landfills, contributing to the growing waste crisis. The harmful chemicals and non-biodegradable synthetic fibers used in textiles further exacerbate pollution, especially microplastics that pollute oceans and land.

In response to these challenges, this project seeks to advance the development of biofabrics using sodium alginate derived from brown seaweed. Sodium alginate, a biodegradable and non-toxic biopolymer, presents a promising alternative to conventional synthetic textiles. The growing demand for sustainable and eco-friendly solutions in the textile industry forms the core rationale for this project. By utilizing natural, renewable resources, such as seaweed, the project aims to reduce the industry's reliance on harmful materials and contribute to reducing pollution and waste.

Although traditional biofabrics made from plant-based materials are gaining traction, they still rely on industrial agriculture and petrochemical-based processes that contribute to environmental degradation. By exploring the potential of sodium alginate from marine algae, this project aims to create a more sustainable, scalable, and biodegradable textile alternative. The biofabrics developed in this study have the potential to reduce the environmental footprint associated with conventional textile manufacturing, including water and energy usage, chemical waste, and carbon emissions.

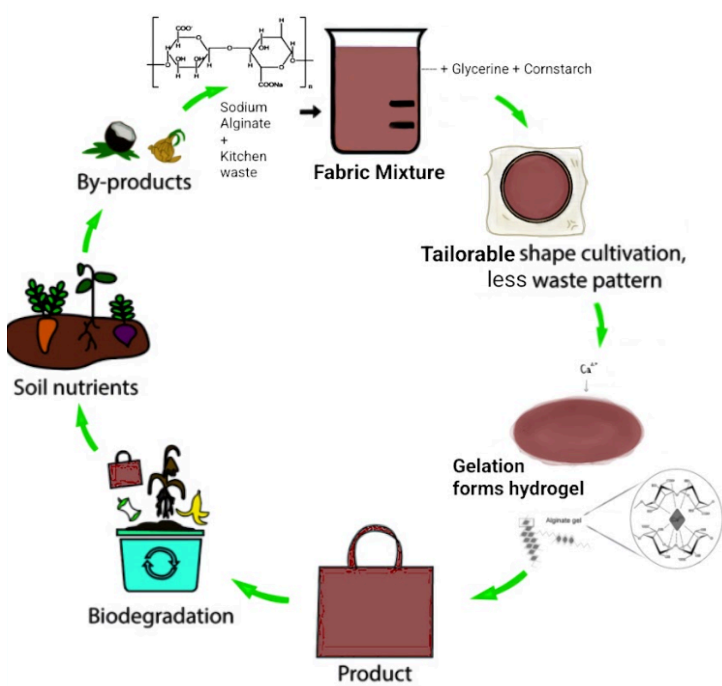
Furthermore, the project’s use of innovative approaches such as combining organic materials like beetroot, tea, and fruit peels with alginate will expand the scope for sustainable fabric production, making it possible to tailor biofabrics to specific applications across various industries, from fashion to medical textiles. This study represents a significant step forward in the integration of green chemistry and biofabrication, fostering a circular materials economy while providing viable solutions to the textile industry's environmental challenges.

SCIENTIFIC PRINCIPLES/CONCEPTS

1. **Biopolymer Chemistry and Gelation:**
   Sodium alginate, a natural polysaccharide derived from brown seaweed, plays a central role in this biofabrication process. Alginate molecules consist of long chains of repeating units of mannuronic acid and guluronic acid, which are hydrophilic (water-attracting).

   Gelation occurs when the alginate interacts with divalent cations, such as calcium ions (Ca^{2+}). In the presence of calcium chloride ($CaCl_2$) solution, the calcium ions crosslink the alginate molecules, forming a stable network structure. This process of crosslinking is fundamental to the creation of the biofabric, providing it with mechanical strength, flexibility, and the ability to hold its shape.

2. **Sustainability and Circular Economy:**
   A key aspect of this project is the concept of a **circular economy**, which emphasizes reducing waste and reusing resources in a sustainable loop.



   The biofabric production process utilizes **waste materials**, such as fruit and vegetable peels (e.g., beetroot, tea, and fruit extracts), which are typically discarded but can be repurposed to add unique properties to the fabric, like color, texture, and aroma. By repurposing these organic waste products, the project decreases the environmental footprint of textile manufacturing. The alginate-based Biofabrics are biodegradable and naturally decompose after use, contributing to the reduction of textile waste in landfills.

3. **Biodegradability:**
   The ability of the biofabric to break down naturally is another crucial scientific principle.

The alginate-based biofabrics are designed to be fully biodegradable, reducing the environmental footprint when the fabric is disposed of. This biodegradability is enhanced by the use of non-toxic, plant-based additives such as glycerine and organic waste materials, further contributing to the fabric's environmental sustainability. Unlike synthetic fabrics that persist in landfills for decades, the biofabric decomposes naturally, leaving behind no harmful residues and aligning with circular economy principles.

MATERIALS USED

1. INGREDIENTS
    a. Sodium Alginate
    b. Calcium Chloride ($CaCl_2$)
    c. Glycerine
    d. Cornstarch
    e. Organic Waste Materials (e.g., Beetroot Juice, Tea, Fruit and Vegetable Peels)
    f. Distilled Water

2. APPARATUS
    a. Canvas Cloth
    b. Beaker
    c. High-speed Blender
    d. Refrigerator
    e. Spray Bottle
    f. Stitching Loop
    g. Paper Towels
    h. Clean Spoon

METHOD

Theory

The process of biofabrication using sodium alginate relies on the principle of gelation, which occurs when alginate molecules form a cross-linked network in the presence of divalent cations, such as calcium ions. When calcium chloride ($CaCl_2$) solution is introduced to the sodium alginate solution, the calcium ions bond with the carboxyl groups of the alginate molecules, resulting in the formation of a stable, gel-like structure. This crosslinking process imparts mechanical strength, flexibility, and the ability to maintain shape, which is essential for fabric formation. Additionally, organic waste materials such as beetroot juice, tea, and fruit peels are incorporated into the process, providing natural colors, textures, and potential functional properties to the fabric, while promoting sustainability by repurposing waste.

Method of Preparation:

Step 1: Preparation of Liquid Base:

1. Select the organic waste material (e.g., beetroot, tea, etc.).
2. Extract the liquid by juicing or soaking the material in water to obtain a concentrated base.
   Mixing Sodium Alginate:
3. Measure 100 mL of the prepared liquid base and transfer it into a clean beaker.
4. Add 2 g of sodium alginate to the liquid base.
5. Blend the mixture using a high-speed blender until the sodium alginate is completely dissolved, forming a homogeneous solution.
   Incorporating Cornstarch:
6. Add 2 g of cornstarch to the solution and blend again to ensure an even distribution. The cornstarch will enhance the fabric's texture and improve its tensile strength.
   Adding Glycerine:
7. Add 4 g of glycerine to the mixture and blend once more. Glycerine helps retain moisture in the biofabric, preventing brittleness and improving comfort.
   Degassing the Solution:
8. Transfer the blended solution to a refrigerator and allow it to rest overnight. This step removes any air bubbles trapped within the solution, ensuring a smooth, even texture in the final biofabric.

Step 2: Preparation of Calcium Chloride Solution

9. In a separate spray bottle, mix 100 mL of distilled water with 10 g of calcium chloride.
10. Shake the bottle vigorously until the calcium chloride is fully dissolved, creating a calcium chloride solution for the gelation process.

Step 3: Fabric Preparation:

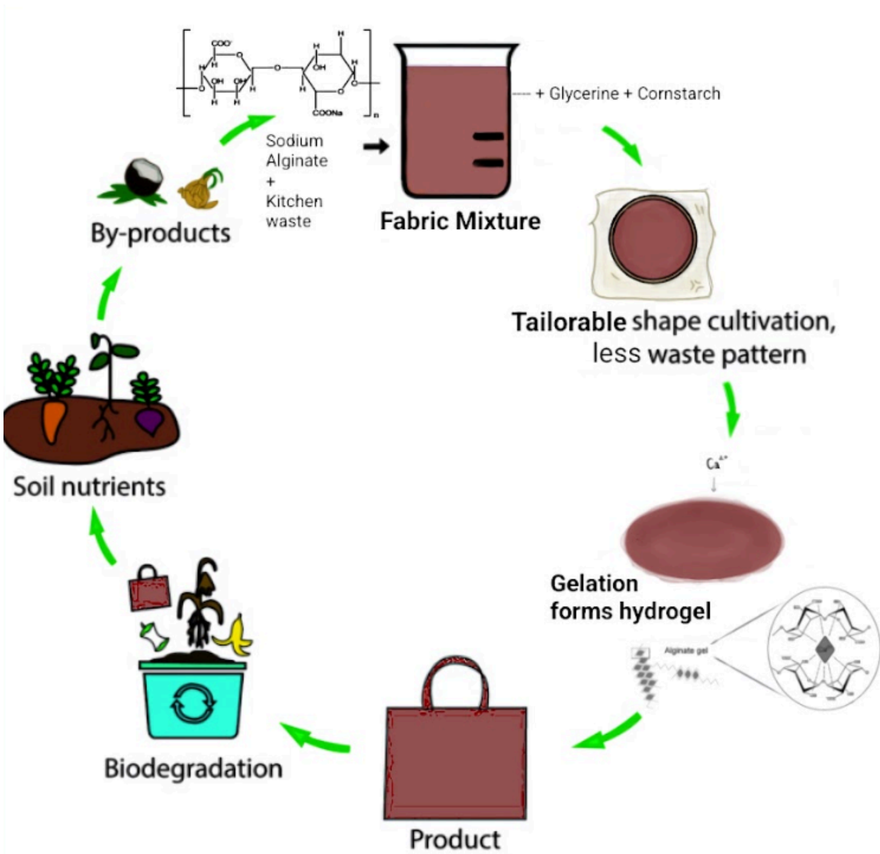
11. Choose a canvas cloth and secure it in a stitching loop to create a stable surface for the biofabric application.
12. Spray the surface of the canvas with the prepared calcium chloride solution. This helps facilitate the gelation of the alginate solution once applied.
13. Carefully pour the prepared alginate-glycerine-cornstarch solution onto the sprayed canvas, ensuring an even distribution across the surface.
14. Lightly mist the top of the poured solution with additional calcium chloride solution.
15. Use a paper towel to gently absorb any excess moisture, ensuring optimal gelation and reducing excess liquid.

Step 4: Setting the Biofabric:

16. Allow the treated fabric to rest in a dry, well-ventilated area for 3-4 days (depending on thickness and material used) to dry and solidify the biofabric.
17. Once completely dried, gently peel the biofabric away from the canvas substrate. The fabric should retain its shape and possess the desired mechanical strength and flexibility.

Drying Process: The drying time for the biofabric can vary depending on the type of organic material used. Thicker layers of liquid solution will require longer drying times to ensure that all moisture is evaporated. The process should be conducted in a well-ventilated, dry area to avoid overheating, which can cause brittleness.

Picture: Drying Biofabrics



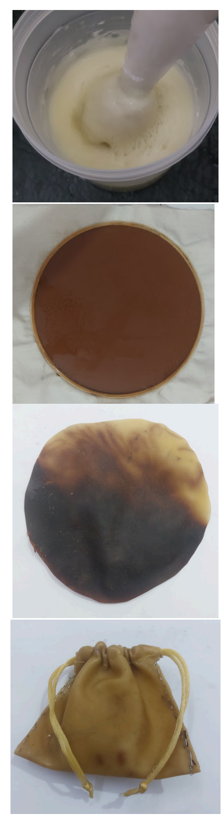


Diagram: Life cycle of a Biofabric

RESULT

The biofabrics produced through this process exhibited notable characteristics and performance attributes:

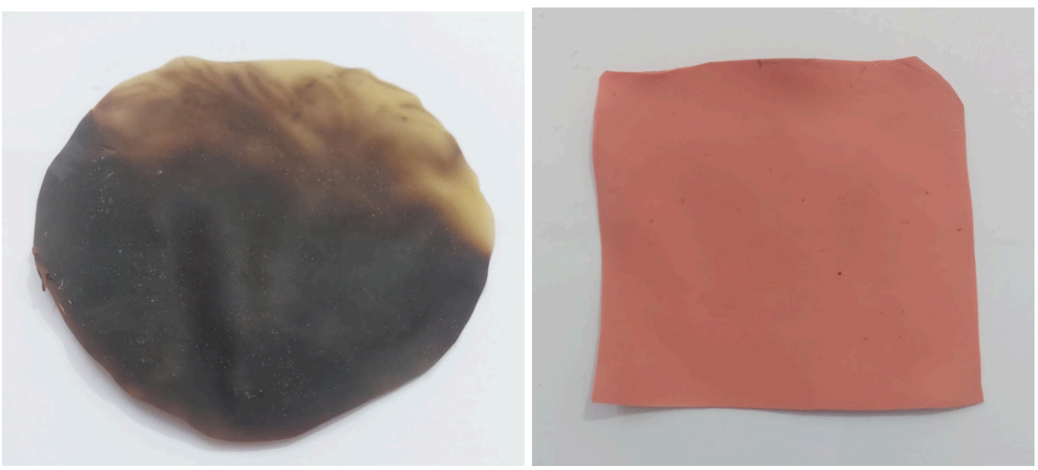
1. **Mechanical Properties:**
    a. **Tensile Strength:** The biofabrics demonstrated significant tensile strength, which varied depending on the organic material used. Fabrics derived from tea and beetroot exhibited good flexibility and resilience, while those made from fruit peels showed a slightly more rigid structure.
    b. **Elasticity:** The biofabrics were moderately elastic, retaining their shape and withstanding some stretching. However, the biofabrics produced from thick liquid waste displayed slightly more rigidity compared to others.
2. **Texture and Appearance:**
    a. The fabric's texture was smooth and flexible, with noticeable variations depending on the base material. For example, beetroot-based biofabric had a soft and smooth texture, while tea-based biofabric was slightly rougher.
    b. The color of the biofabrics mirrored the hues of the organic material used, with beetroot producing a vibrant red-pink shade, while tea imparted a darker brown color to the fabric. Other materials such as fruit peels contributed subtle shades, enhancing the aesthetic appeal of the fabric.
3. **Moisture Retention:**
    a. The addition of glycerine significantly improved the biofabric's ability to retain moisture, ensuring that it did not dry out or become brittle over time. This moisture retention also contributed to the fabric's comfort and durability.
4. **Biodegradability:**
    a. The biofabrics demonstrated complete biodegradability, decomposing naturally without leaving harmful residues. The use of plant-based additives like glycerine and cornstarch further supported this biodegradable property.
5. **Porosity:**
    a. The porosity of the biofabrics varied with the material used. Tea-based and coffee-based biofabrics exhibited higher porosity, which could be advantageous for specific applications like breathable medical textiles. Milk-based biofabrics, however, were denser and less porous, which may limit their breathability but enhance strength.
6. **Durability:**
    a. The biofabrics showed moderate durability, but their lifespan was shorter compared to conventional synthetic fabrics. However, their biodegradability ensured that once they reached the end of their useful life, they would naturally break down without causing

long-term environmental harm.

7. **Aesthetic and Sensory Qualities:**
    a. The biofabrics retained the distinct characteristics of their source materials. For instance, the tea-based biofabric maintained a light, earthy aroma, while beetroot-based fabrics retained their naturally vibrant color, which could be advantageous in applications where aesthetic qualities are important.

Overall, the biofabrics exhibited promising characteristics for a variety of applications, especially in the fields of sustainable fashion, medical textiles, and eco-friendly alternatives to traditional synthetic materials. The use of organic waste materials in their production further enhances their environmental value.

PRODUCED BIOFABRICS AND BIOFABRIC PRODUCTS



Picture: Two sample Biofabrics. (From left) First one made out of tea leaves, second one made out of water given out by filter as waste.

Picture: Products made from Biofabrics.