Exploring Solutions to Fast Fashion: Development of Sustainable Fabrics Made from Bacterial Cellulose Grown in a Novel Seaweed-Based Medium

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INTRODUCTION & BACKGROUND

Fast fashion is cheap, trendy, and destructive. It's time to slow it down.

Figure 1: Fast fashion brands. Source: Pacific Standard Magazine

Nowadays, fast fashion brands produce about 52 "micro-seasons" a year or one new "collection" a week leading to massive amounts of consumption and waste.[1]

What Really Happens to Unwanted Clothes?[2]

- ✓ The EPA reports that Americans generate 16 million tons of textile waste a year, equaling just over 6% of total municipal waste
- ✓ On average, 700,000 tons of used clothing gets exported
- ✓ 2.5 million tons of clothing are recycled
- ✓ Over 3 million tons are incinerated
- ✓ A staggering 10 million tons get sent to landfills

Potential Solution: Moving Toward a Circular Fashion Economy[3]

Bacterial Cellulose (BC) Biotextiles

- ✓ Produced by bacteria (*e.g., Gluconacetobacter Xylinus*) and other microbial species at the interphase air-medium
- ✓ Gelatinous film consisting of a 3D nanofibrillar arrangement of pure cellulosic fibers

Advantages:

- * High crystallinity
- * High degree of polymerization
- * High absorption
- * Excellent biodegradability
- * Requires little arable land, no pesticides and less water during production
- * Free of lingin, hemi-cellulose and pectin

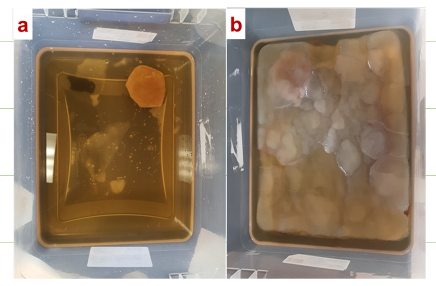

Figure 2: Bacterial cellulose growth at Movil's Lab. (a) after zero days, and (b) after 3 weeks

Main Disadvantage:[4]

- ✓ Typical fabrication method requires food-derived precursors like green tea and sugar.
- ✓ Food crisis affecting millions of people around the world makes unattractive the use of food to produce biomaterials.
- ✓ BC production process is costly, owing to the low productivity of known strains and the use of extremely expensive fermentation medium.
- ✓ For BC production, the medium represents around 30% the total cost. This fact becomes an obstacle for expanding into large scale production and further applications.

Figure 3: Bacterial cellulose film produced at Movil's Lab

Sargassum, the big problem that is taking over the Caribbean can be used as a feedstock to solve this problem

- ✓ Sargassum powder as a substitute of green tea (N source) and sugar (C source) to produce BC
- ✓ Hypothetically, carbohydrates from Sargassum can be transformed into reducing sugars using the same acidic solution (diluted acetic acid)
- ✓ Using Kombucha as a seed to grow cellulose-producing bacteria into the medium

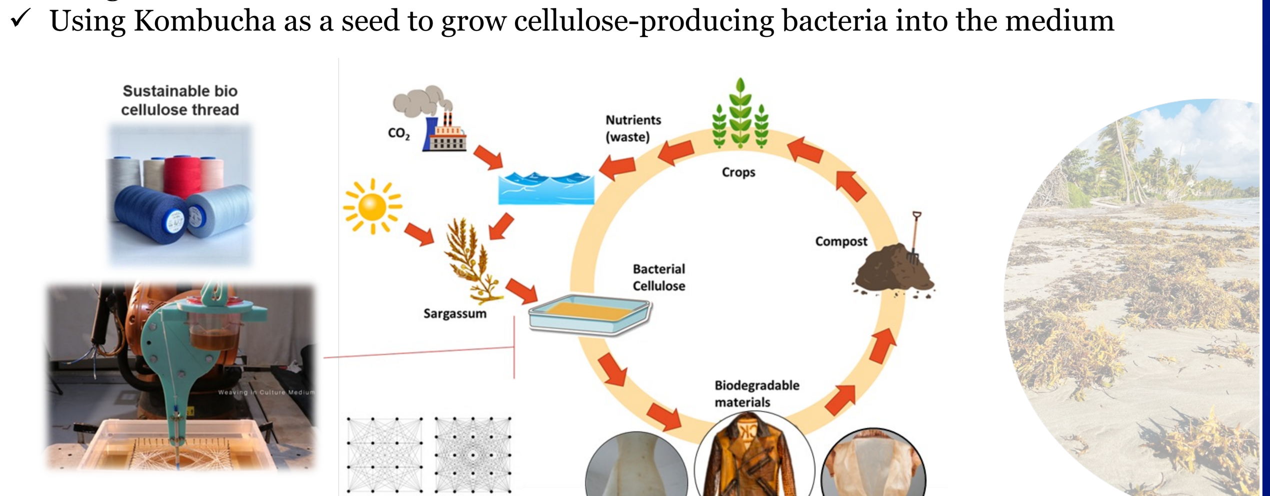

Figure 4 : Proposed Approach

GOAL & OBJECTIVES

GOAL: Evaluate the viability of using Sargassum to produce BC and BC-based fabrics

OBJECTIVES:

- ✓ Fabricate and characterize BC and bacterial nanocellulose (BNC) films fabricated using traditional materials (Sugar + Green tea)
- ✓ Evaluate the effects of using Sargassum (as the source of nitrogen and carbon) on the yield and materials properties of the obtained BC and BNC films
- ✓ Establish the process conditions to fabricate BC-based composite fabrics using commercial natural threads as the supporting material and evaluate their material properties

METHODOLOGY

Task 1. Fabrication of BC via a traditional method

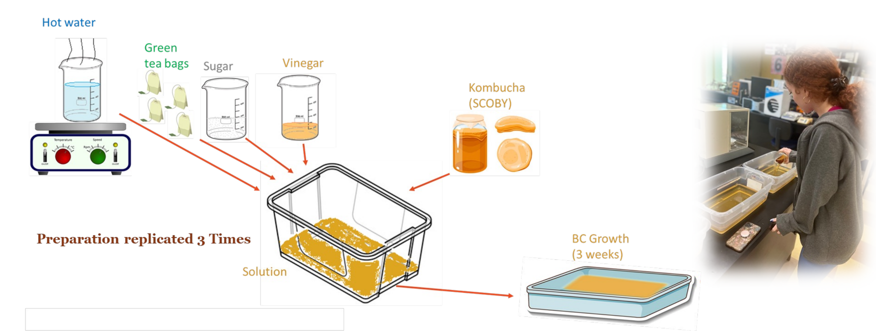

Figure 5 : Medium preparation using sugar + green tea

Task 2. Transformation of the BC pellicle into BNC dispersed fibers

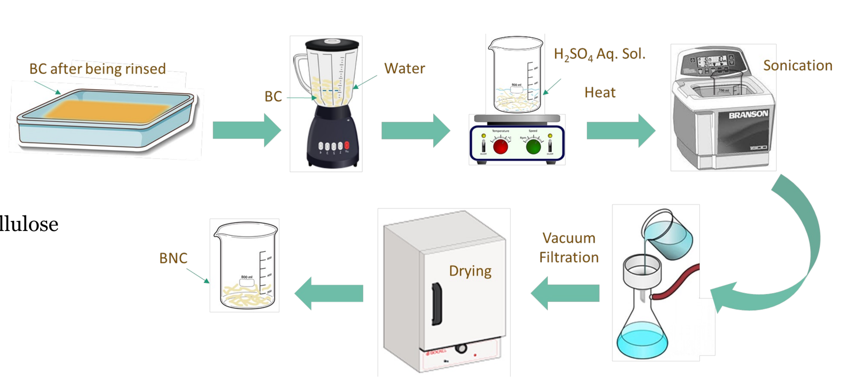

Figure 6 : Bacterial nanocellulose processing

Task 3. Fabrication of BNC films via filtration assembly

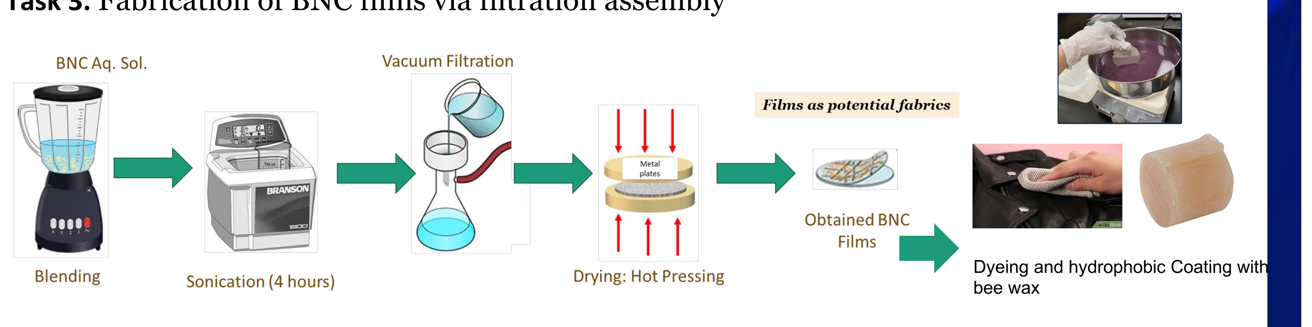

Figure 7 : BNC film processing

Task 4. Fabrication of BC using Sargassum + Sugar

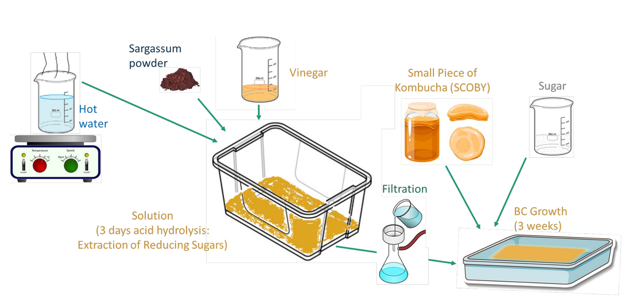

Figure 8 : BC synthesis using Sargassum + sugar

Task 5. Fabrication of BC using ONLY Sargassum

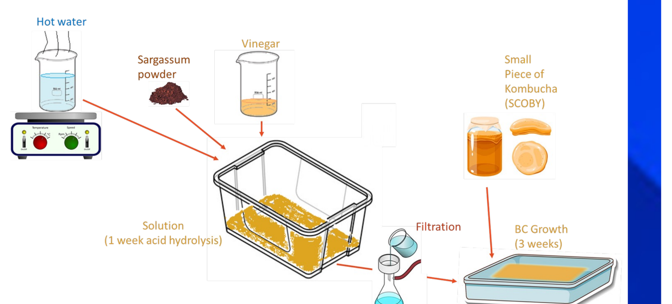

Figure 9 : BC synthesis using Sargassum

Task 6. In-situ Fabrication of BC-based Composite Fabrics

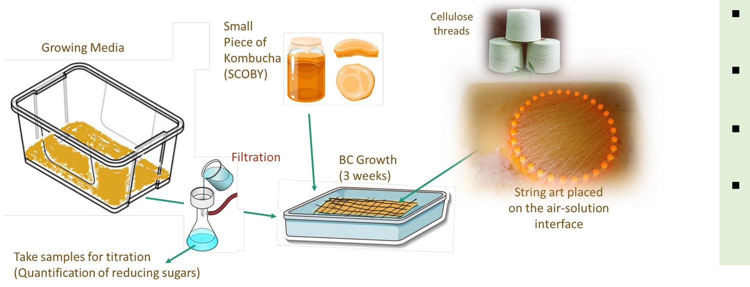

Figure 10 : Synthesis of BC composite fabrics

Task 7. Materials Characterization

- FTIR (Chemical Characterization)
- Contact Angle (hydrophobicity)
- SEM (microstructure)
- Yield will be calculated as: Produced BC (grams)/ Growing media volume (L)

RESULTS

Chemical Characterization of the Fabricated BC via FTIR

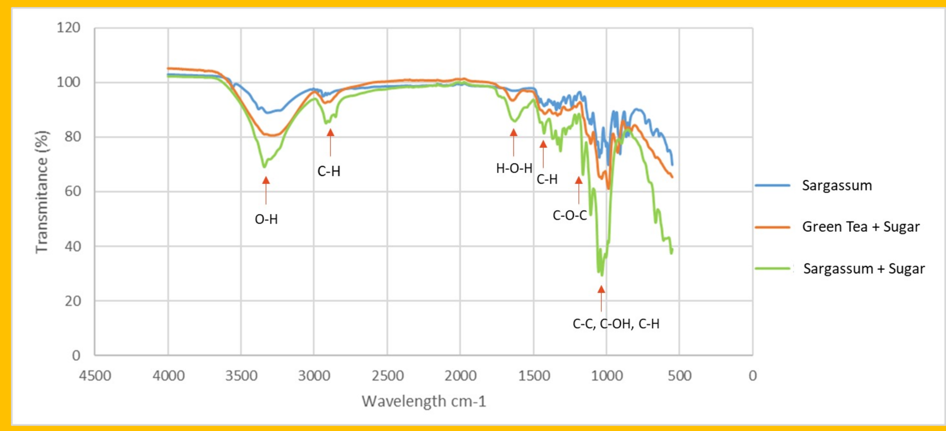

Figure 11 : FTIR analysis of the obtained BC

Morphological Characterization of the fabricated BC via SEM

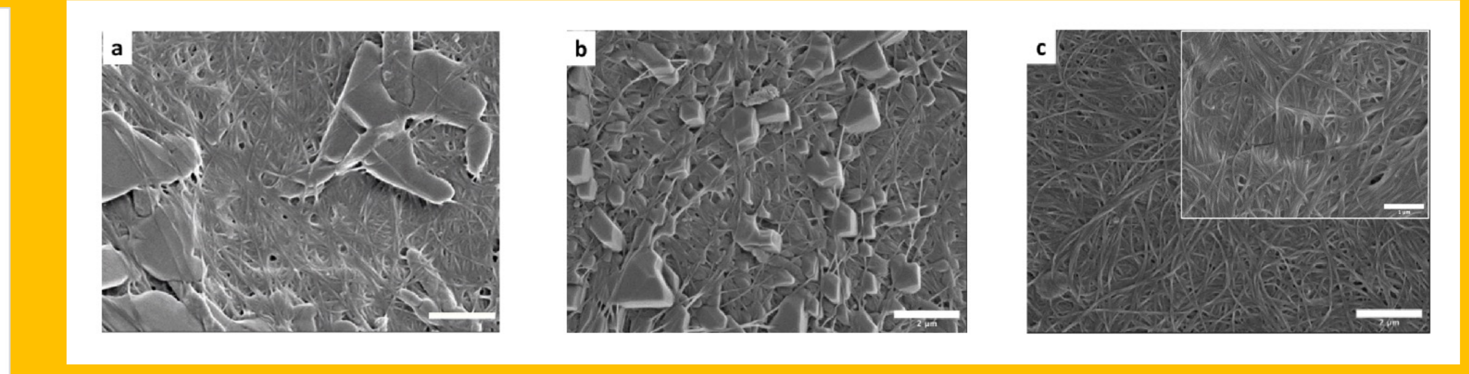

Figure 12 : SEM images of the obtained BC using different growing media. (a) sugar + green tea, (b) sugar + Sargassum extract, and (c) Only Sargassum extract

BC Yield Obtained Using Different Growing Media

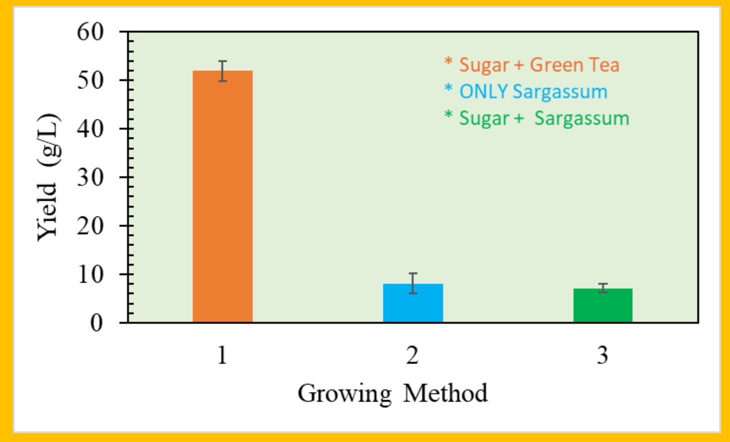

Figure 12 : BC yield using different growing media

Water Content of the Obtained BC

Table 1. Results of the water content experiments

Traditional Method (Sugar + Green Tea)			
	Initial weight (g)	Final weight (g)	% Weight loss
B1-1	5.61	1.00	82.11
B1-2	5.43	0.95	82.32
B1-3	5.42	0.97	81.91
B1-4	5.13	0.93	81.74
B2-1	5.50	1.10	79.98
B2-2	5.11	1.05	79.40
B2-3	5.63	1.15	79.44
B2-4	5.91	1.23	79.02
B3-1	5.82	1.08	81.36
B3-2	5.50	1.05	80.83
B3-3	5.12	0.99	80.57
B3-4	5.24	0.99	80.92
		AVERAGE =	80.80
		STDVA =	1.13

BNC Films & Composite Fabrics

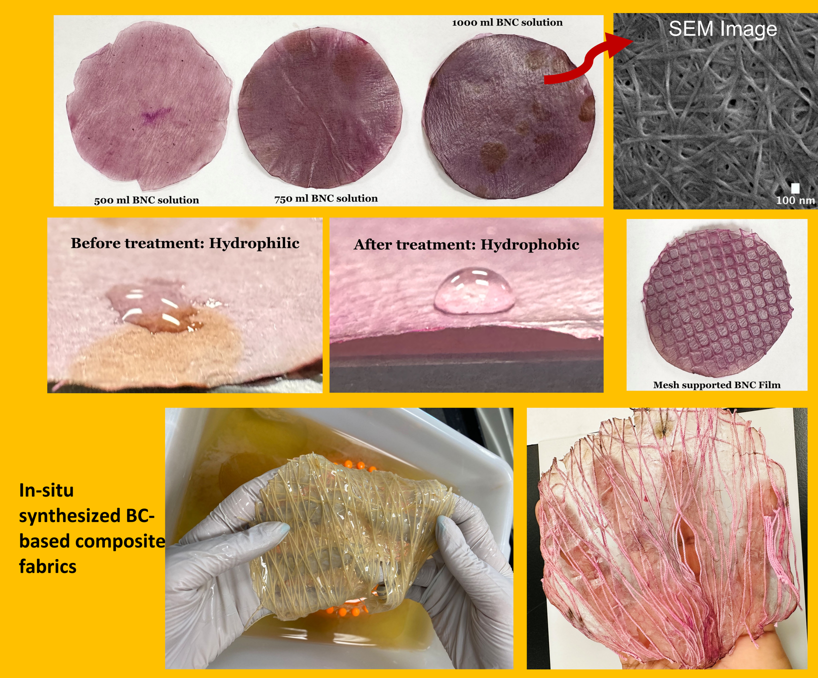

Figure 13 : BNC films and composite fabrics

ONGOING & FUTURE WORK

- ✓ Fabrication of wearable electronics (sensors & circuits) using 3D printing techniques to deposit conductive composite materials onto the fabrics.
- ✓ Design and fabrication of doll clothes using the obtained BNC films.
- ✓ Evaluate the mechanical properties (via tensile test) of the fabricated films before and after being washed using a domestic laundry machine.

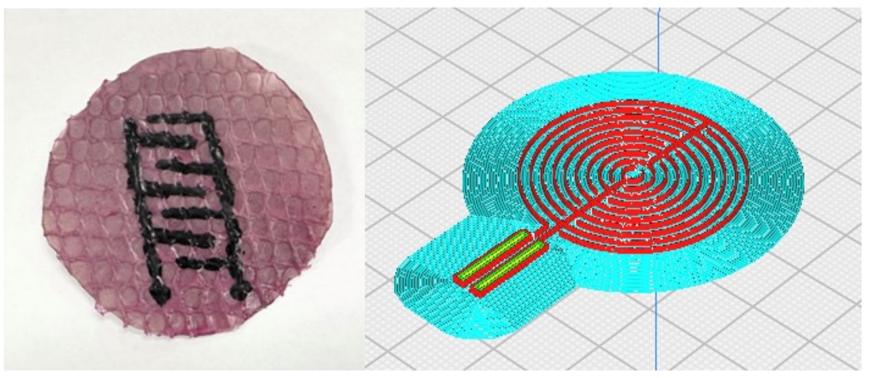

Figure 14: Wearable & flexible electronic. Images of interdigitated electrodes deposited onto a BNC fabric to create a humidity sensor (left) and model (CURA G-code file) of circular interdigitated electrodes to be 3D printed onto a BNC fabric

Figure 15: Doll clothes fabricated with the obtained BNC fabrics

CONCLUSIONS

- ✓ FTIR analysis confirmed the synthesis of BC using three different growing media
- ✓ SEM analysis confirmed the synthesis of BC fibers with nanometric sizes (< 100 nm).
- ✓ SEM images also indicate that BC pellicles obtained using Only Sargassum exhibited less impurities as compared to those obtained using sugar and green tea.
- ✓ BC yields for the traditional method (sugar + green tea) were 5 times higher than those obtained with growing media containing Sargassum.
- ✓ Water content of the obtained bacterial cellulose is ~80%
- ✓ This is most likely because during the hydrolysis of the sargassum with vinegar, most of the extract was compose of a high amount of phenolic compounds, instead of the expected reducing sugars.
- ✓ Phenolic compounds have been reported as stronger antibacterial properties, which could affect the performance of the *Gluconacetobacter Xylinus,* resulting in lower BC yields. Further experiments are required to confirm this hypothesis.
- ✓ Composite fabrics obtained via in-situ fabrication method were extremely thin and fragile.

RECOMMENDATIONS

- ✓ Implement enzymatic hydrolysis to extract reducing sugars from Sargassum. High concentration of reducing sugars could increase the BC yields when using the brown macroalgae.
- ✓ Use glycerol (inexpensive waste product) as a source of carbon and vitamins to promote the BC growing.
- ✓ Scale up the fabrication process to obtain large amounts of BC.
- ✓ Functionalize the BNC fibers with hydrophobic compounds obtained from plants to replace the bee wax.

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