PacifiCan-MMRI Accelerating Circular Economy (ACE) TechBrief Report

Project title: Antibacterial foam using agricultural waste

Industry partner(s): Advanced BioCarbon 3D Inc.

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Introduction & Background:

In recent times, plastic pollution ha sbecome a major concern leading to the research in the field of biodegradability and recyclable foam and packaging. Recently, researchers have focused on utililsing agricultural waste (hemp) based material for replacing plastic in packaging industries and other applications[1]. Polymer based foams are utilised in different applications like packaging and thermal insulations in construction field[2]. These foams are hard to degrade and often contribute to pollution. Utilizing hemp-based cellulose from waste plants can help in developing biodegradable foam. In real world application, these foams are susceptible to various microorganism thus, making it vulnerable and limiting its application in real world applications[3]. This research focuses on developing cellulose (Hemp) -based foams with enhanced antibacterial acitivity properties enabling it for real world applications and commercialization. The objective of this research is to develop novel antibacterial foam using hemp cellulose fiber and test them using UTM machine for compression strength and modulus (ASTMD 1621), water absorption (ASTM E96) and antibacterial activity.

Relevance to Circular Economy:

This research will be leading footstep towards providing a sustainable solution to the present polymer-based foams commonly used in different industries such as packaging and thermal insulations. This research will provide recyclable foam based on upcycling plant-based biomaterial with antibacterial properties thus, helping in circular economy. This would also result in reducing the current need for polymer-based foams.

Methodology:

This research focuses on preparing foam from agricultural waste, focusing on a long-term goal of commercialization. Until now, we have prepared lab scale sample for such agricultural waste-based foams. Different crosslinker and modification were tried for fabricating foams using hemp-based bio-waste. We received bleached hemp fiber (BHF) from ABC3D company. All other chemicals (Polyether Imine (PEI), Terephthaldehyde (TA), Lithium chloride (LiCl) and Dimethylacetamide (DMAc) were obtained from sigma Aldrich.

Initially, as received BHF were further processed into cellulose fiber(CF) by salt 2 wt% (Lithium Chloride) in DMAc impregnation and mechanical stirring for 24 h at room temperature. Thus, obtained CFs were washed and dried. In second step, these dried (1 gm) CFs were mixed with aqueous 20 mL (5 wt%) PEI solution for 12 h ensuring proper coating of fibers with PEI. Further, the obtained solutions were mixed with TA (200 mg) dispersed in ethanol. The solution starts gelation at room temperature after few minutes. Before gelation, the solution was poured into desired mold. These molded samples were freeze dried to obtain porous foam like structure.

These aerogels were prepared into different shapes as per ASTM for different sample analysis. The polymer formation mechanism is represented in figure 1.

Thus, obtained aerogels were characterized for mechanical and thermal properties. Further these aerogels will be analyzed for antibacterial properties. For practical world applications, other properties like water absorption and flammability will be accessed.

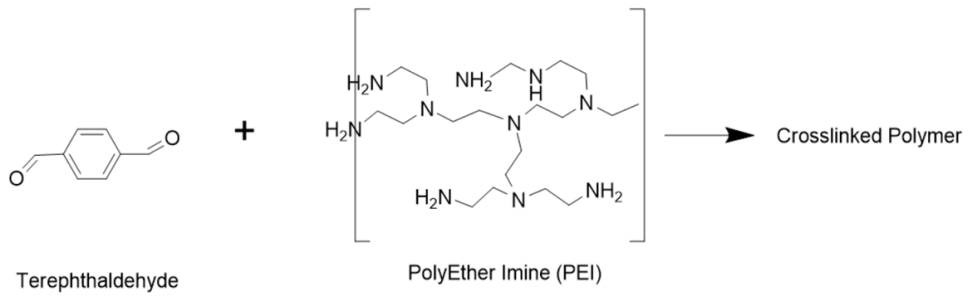
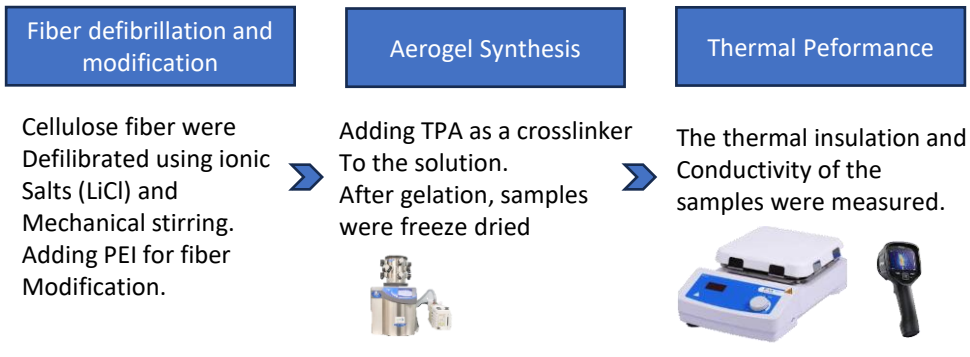


Figure 1: Synthesis of Polyimine network for preparing aerogel



Results & Discussion

The hemp-based foam like structure prepared using different crosslinking chemical agents with good mechanical stability and comparable density to the traditional foams available for packaging industries. These foams like porous structure have shown good thermal insulation property and mechanical stability. The crosslinking and formation of the polyimine (2940 and 2631 cm^{-1}) representing free amine of unreacted PEI network is confirmed by FTIR analysis. Furthermore, the carbonyl peak (1000 cm^{-1}) is observed signifying the reaction between terephthaldehyde and amine leading to the formation of crosslinked network. To test the thermal behaviour of the aerogel, the aerogel was placed on a hotplate at 280 °C and the surface temperature was observed with IR mapping. The aerogel prepared showed high thermal stability with no degradation for 10 minutes, and there no significant changes in the surface temperatures ensuring efficient thermal insulation as evident by Figure 2 (b).

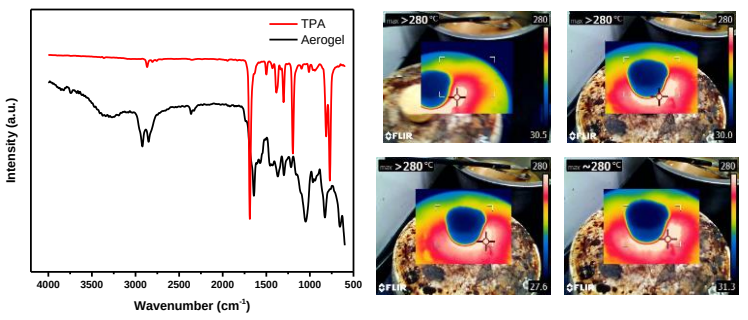


Figure 2: (a) FTIR for hemp aerogel **(b)** Thermal performance of the aerogel sample (S1)

Further, to study the effect of crosslinker on the density of the aerogel different samples were made and analyzed,

S.no.	PEI	TPA	Cellulose	Density
S1	100 mg	100 mg	1g	0.161 g/mL
S2	150 mg	150 mg	1g	0.170 g/mL
S3	200 mg	200 mg	1g	0/185 g/mL

Table 1: List of samples with different crosslinking density

Conclusion & Next Steps

The bio-based foams are gaining interest aiming as a replacement for current packaging industries because of its mechanical strength and ease of biodegradability. In this work we showed the preparation of the hemp-based foam with good mechanical properties and good thermal properties. Also, these foams will be tested for antibacterial properties required for commercial applications. The company partner is working towards upscaling manufacturing and commercializing the material in end-use applications.

References:

1. (Ahmed, Islam et al. 2022)
2. (Di Maio, Iannace et al. 2021)
3. (Tavakolian, Okshevsky et al. 2018)

Further reading:

Polyethylenimine-Grafted Cellulose Nanofibril Aerogels as Versatile Vehicles for Drug Delivery, Jianggi Zhao et. al.

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