Sodium Alginate-Infused Hydrogels: A Treatment Approach for Managing Chronic Wounds in the Skin

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Abstract:

Climate change has increased the growth and dispersal of Sargassum algae across the Atlantic Ocean, posing significant environmental challenges, especially in the Caribbean. However, from Sargassum, sodium alginate, a polysaccharide with gel-forming abilities, is extracted and presents as a valuable resource for various applications. Chronic wounds, affecting approximately 6.5 million patients annually in the USA, require advanced treatments due to their complex healing processes. Hydrogels, known for their biocompatibility, moisture retention, and oxygen diffusion capabilities, offer an ideal solution for wound dressings. This research explores the synthesis and potential of sodium alginate-infused hydrogels for chronic wound care in the skin. Their efficacy in promoting *Saccharomyces cerevisiae* cell proliferation and inhibiting bacteria *Escherichia coli* and *Staphylococcus epidermidis* bacteria was tested through tests based on the disk diffusion method. Their swelling ratio was tested through a water retention test. The findings indicate that the sodium alginate-infused hydrogels successfully promoted significant proliferation of *Saccharomyces cerevisiae* cells, demonstrating their potential to accelerate the healing process. Additionally, the hydrogels exhibited substantial antibacterial activity, effectively inhibiting the growth of *Escherichia coli* and *Staphylococcus epidermidis*. The swelling tests revealed that the hydrogels have an excellent capacity to absorb and retain water over the observed time, which is essential for maintaining a moist wound environment conducive to healing. These results confirm the hydrogel's functionality in promoting cellular regeneration and preventing infections while also ensuring an adequate moisture environment for wounds.

Background:

Hydrogels are three-dimensional hydrophilic polymers capable of retaining large amounts of water due to their chemical properties, where hydrogen atoms attract oxygen atoms, creating a network that holds water throughout the polymer chain. This water retention and biocompatibility make hydrogels valuable in medical applications, particularly for drug delivery. Hydrogels can be natural, synthetic, or a combination of both, with studies showing that mixed hydrogels yield optimal results for medical use. Sodium alginate, a biodegradable and biocompatible biopolymer with hydrophobic properties, forms gels through ionotropic gelation with calcium ions and has been effective in targeting deep wounds, bones, blood vessels, and muscles. When infused into hydrogels, sodium alginate may enhance cell growth and bacterial inhibition, making it a promising component for treating chronic wounds. Combining synthetic polyacrylamide with sodium alginate could result in a hydrogel that maximizes these therapeutic benefits.

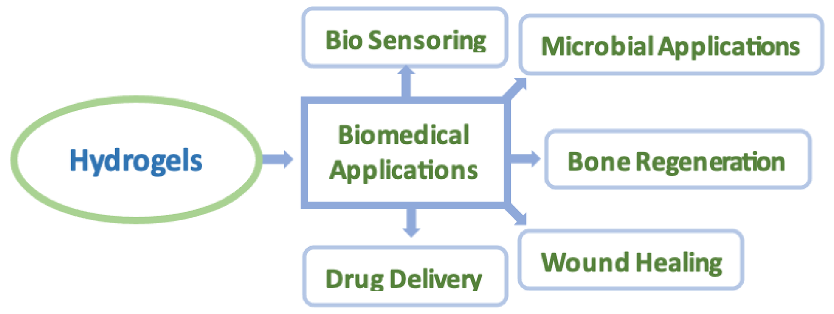

Figure 1-Biomedical Applications of Hydrogels (Díaz, 2024)

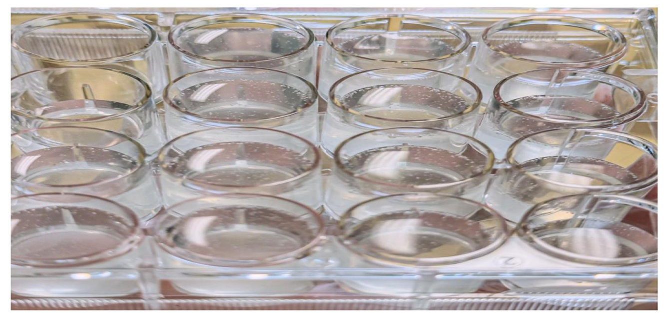

Figure 2-Sodium Alginate-Infused Hydrogels (Díaz, 2024)

Objectives:

- Synthesize sodium alginate-infused hydrogels with cell growth abilities and germicidal properties to potentially assist in the healing of chronic skin wounds.
- Demonstrate the sodium alginate-infused hydrogel's ability to show significant proliferation in *Saccharomyces cerevisiae* cells.
- Demonstrate the sodium alginate-infused hydrogel's present germicidal effects on *Escherichia coli* and *Staphylococcus epidermidis* bacteria.
- Demonstrate the sodium alginate-infused hydrogel's ability to swell while evaluating water absorption capacity and structural integrity.
- Measure the sodium alginate-infused hydrogel's swelling ratio.

Methodology:

The synthesis of the hydrogel will be realized using the free radical method; this method aims at the free radical copolymerization of acrylamide-based monomers with a chemical cross-linker N, N'-methylenebisacrylamide (MBA) in the presence of a free radical initiator system (APS and TEMED) inside an aqueous solution.

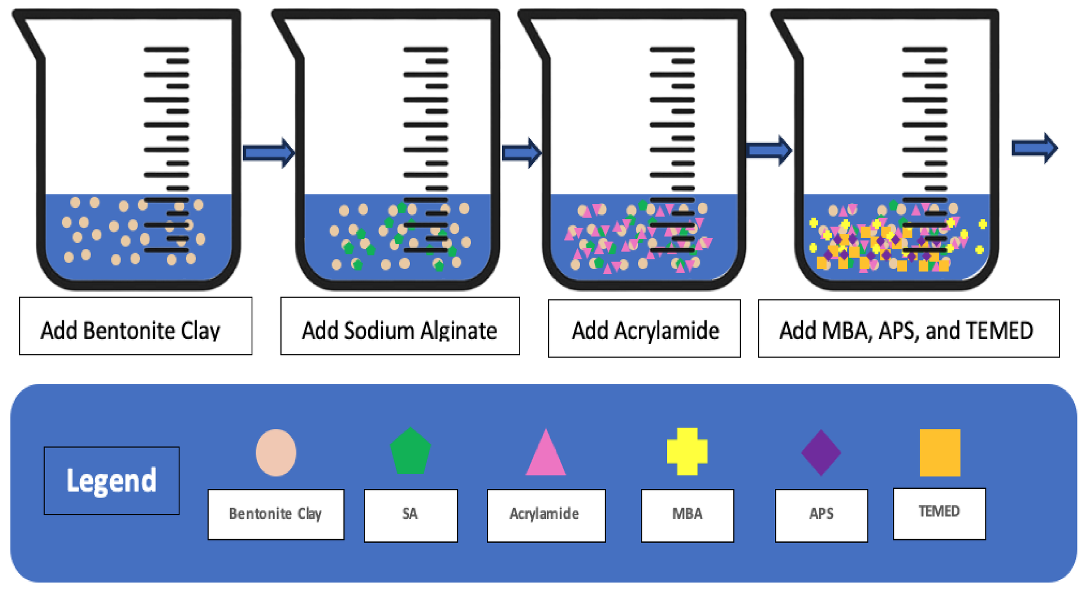

Figure 3-Sodium Alginate-Infused Hydrogels (Díaz, 2024)

The cell growth test for the synthesized hydrogels will be conducted using the disc diffusion method to evaluate biocompatibility in yeast cells. The germicidal test for the synthesized hydrogels will also be conducted using the disc diffusion method to evaluate their antimicrobial properties against *Escherichia coli* and *Staphylococcus epidermidis*. The swelling ratio test for the synthesized hydrogels will consist of submerging the gel in water for specific intervals and recording its weight.

Conclusion:

The potential of sodium alginate-infused hydrogels for chronic wound care in the skin was demonstrated through a series of key tests. Hydrogel batch C, which presented the best physical properties, showed strong biocompatibility by supporting *Saccharomyces cerevisiae* growth and exhibited significant antimicrobial properties against *Escherichia coli* and *Staphylococcus epidermidis*. Additionally, the swelling test confirmed batch C's high water absorption capacity, which is essential for maintaining a moist wound environment. Batch A and B, which presented more unstable physical properties, failed the tests due to drying. These results suggest that batch C could enhance wound healing by promoting cell proliferation and preventing bacterial infections.

Acknowledgment:

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Results:

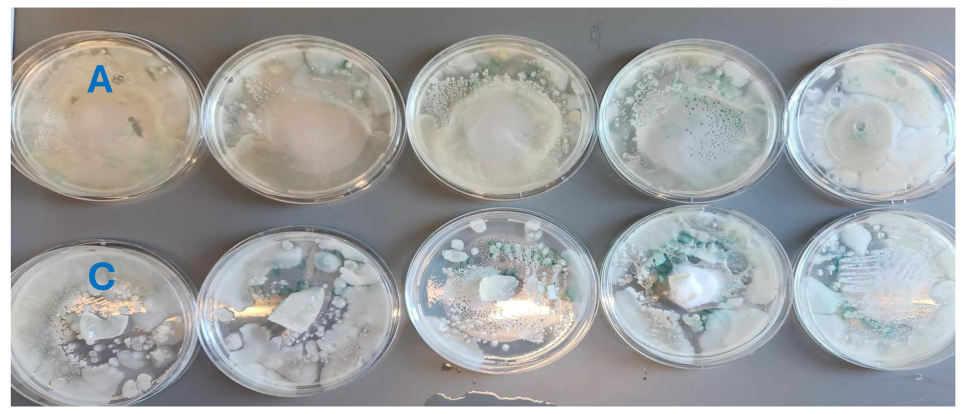

Figure 4-Batches A and C After Cell Growth Test (Faustinelli, 2024)

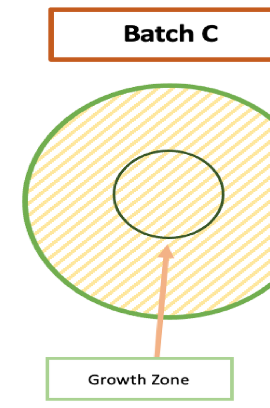

Figure 5-Batch C Growth Zone Representation (Díaz, 2024)

No *Saccharomyces cerevisiae* cell growth was observed under the hydrogel batch A, although it presented peripheral growth. However, batch C presented robust yeast growth beneath and around the hydrogel.

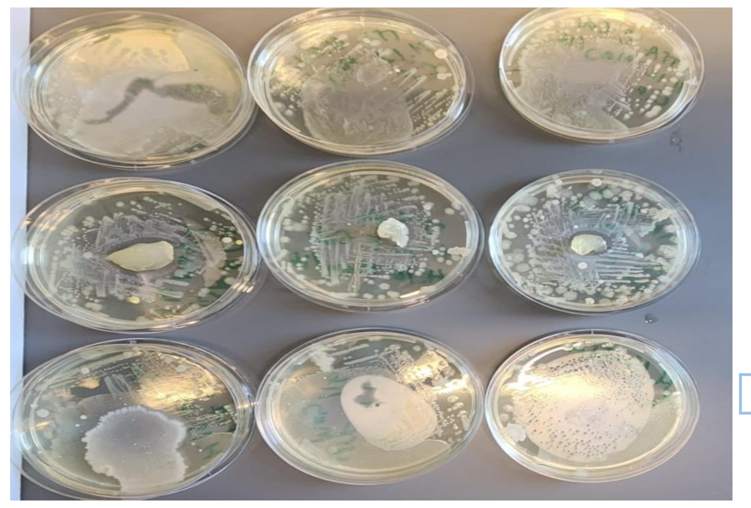

Figure 6-Batches A, B, and C After Germicidal Test (Faustinelli, 2024)

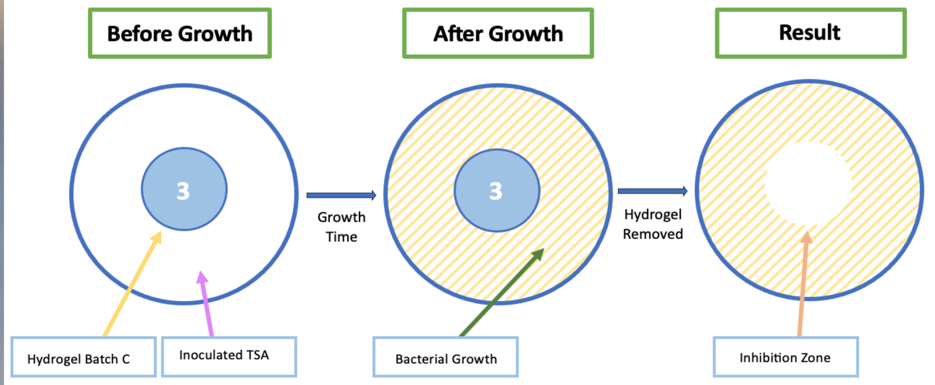

Figure 7-Batch C Inhibition Zone Representation (Díaz, 2024)

Batches A and B presented no inhibition of *E. coli* or *S. epidermidis* growth. Batch C showed significant inhibition zones for both bacteria, demonstrating strong antimicrobial properties.

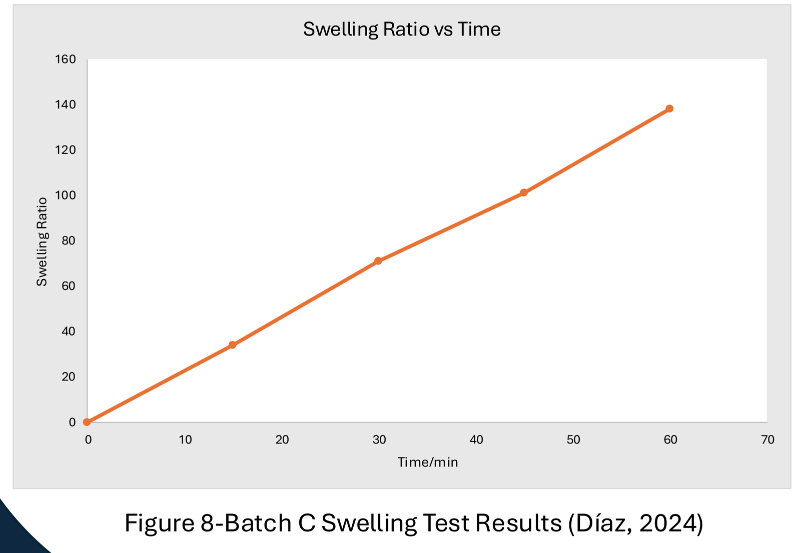

Figure 8-Batch C Swelling Test Results (Díaz, 2024)

Swelling test results on batch C:

- 15 minutes SR: $\frac{2.04-1.52}{1.52} \approx 0.34$
- 30 minutes SR: $\frac{2.60-1.52}{1.52} \approx 0.71$
- 45 minutes SR: $\frac{3.09-1.52}{1.52} \approx 1.03$
- 60 minutes SR: $\frac{3.61-1.52}{1.52} \approx 1.38$

Future Work:

- Testing the SA-infused hydrogels with other cell types, including mammalian cells, to confirm their suitability in clinical applications.
- Further investigation is needed to determine the mechanical properties of the SA-infused hydrogels, such as tensile strength and elasticity, to ensure they can withstand the stresses of a clinical setting.
- Research the potential use of these hydrogels in other medical applications.
- Further, methodologies should be developed to synthesize an SA-infused hydrogel with the proper physical properties for a clinical setting.
- Conduct long-term stability assessments of SA-infused hydrogels under different environmental conditions to evaluate their durability and effectiveness over extended periods in real-world medical scenarios.