Fabricating An Ionic Conductive-okra Based Hydrogel For Chronic Wound Healing

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Abstract

It has been reported that nearly 6.5 million people in the United States suffer from at least one chronic wound in their lifetime. One of the community's are affected by it are people with diabetes mellitus. Hydrogel wound dressing presents a promising option for due to its biodegradability, adhesivity, ability to retain moisture, and wound healing promotion. Furthermore, in literature, electrical stimulation has been mentioned to promote wound healing as well. Thus, we propose to design a device that accelerates wound healing. This project is divided into phases and phase 1 comprises synthesizing the ionic conductive hydrogel patch. Phase 2 comprises of the design and fabrication of the triboelectric nanogenerator (TENG), and phase 3 comprises of executing in vivo and in vitro studies. In this phase, a polyacrylamide (PAM) hydrogel with various concentrations (0,5,10,15,20,30%) of LiCl was synthesized. Furthermore, another batch of PAM/LiCl were synthesized incorporating Okra mucilage. Both batches were compared. Conductivity and swelling properties were measured. Results showed that the LiCl concentration increases, the conductivity increases. However, interestingly, the swelling ratio did not increase as the LiCl concentration increased. This may be due to the solvent in which it was submerged.

Background

Hydrogels are water-insoluble, 3D networks of hydrophilic polymer chains capable of swelling in water and holding large amounts of water while maintaining its geometry due to the crosslinking of individual polymer chains. Hydrogels also contain a degree of elasticity or flexibility. Hydrogels can be categorized in many ways such as preparation, ionic charge, type, crosslinking, response, or properties. The overall components to synthesize a hydrogel involve a monomer, crosslinker, and initiator. In this case, acrylamide was the base polymer used, because of its properties such as chemical inertia, mechanical properties, high swelling degree, and optical transparency.

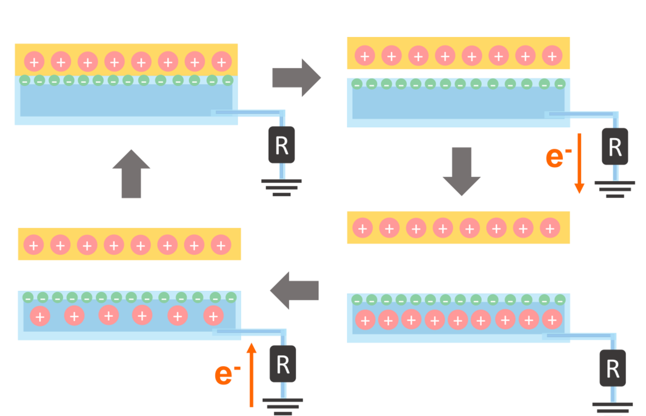


Figure 1 – Schematic of TENGs working mechanisms

Figure 2 – Applications of Hydrogels

Figure 3 – (A) PAM/LiCl Hydrogels (B) PAM/LiCl/OKRA Hydrogel (C) PAM/LiCl hydrogels with different LiCl concentration

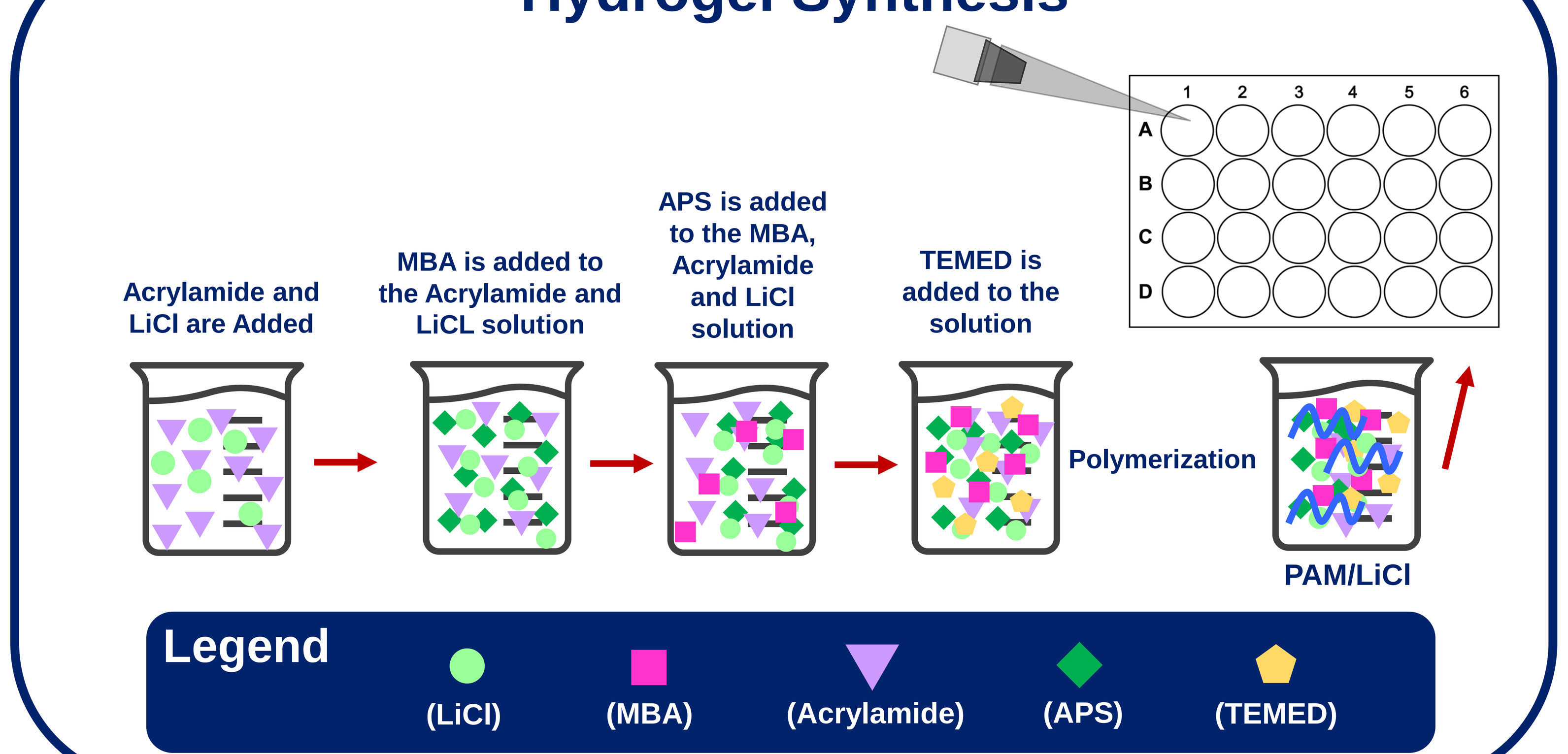
Furthermore, polyacrylamide (PAM) is one of the most used polymers for the fabrication of triboelectric nanogenerators (TENGs) due its biocompatibility and elasticity. A TENG is self-power device that generates energy through coupling contact-electrification and electrostatic induction. Hydrogels have many applications. In this case, we focused on using conductive hydrogels for wound healing. Chronic wounds affect around 1-2% of communities in developed countries. Hydrogel dressing has multifunctional properties that aid in accelerating wound healing. Coupling this with electrical stimulation the healing rate may be much faster.

Objectives

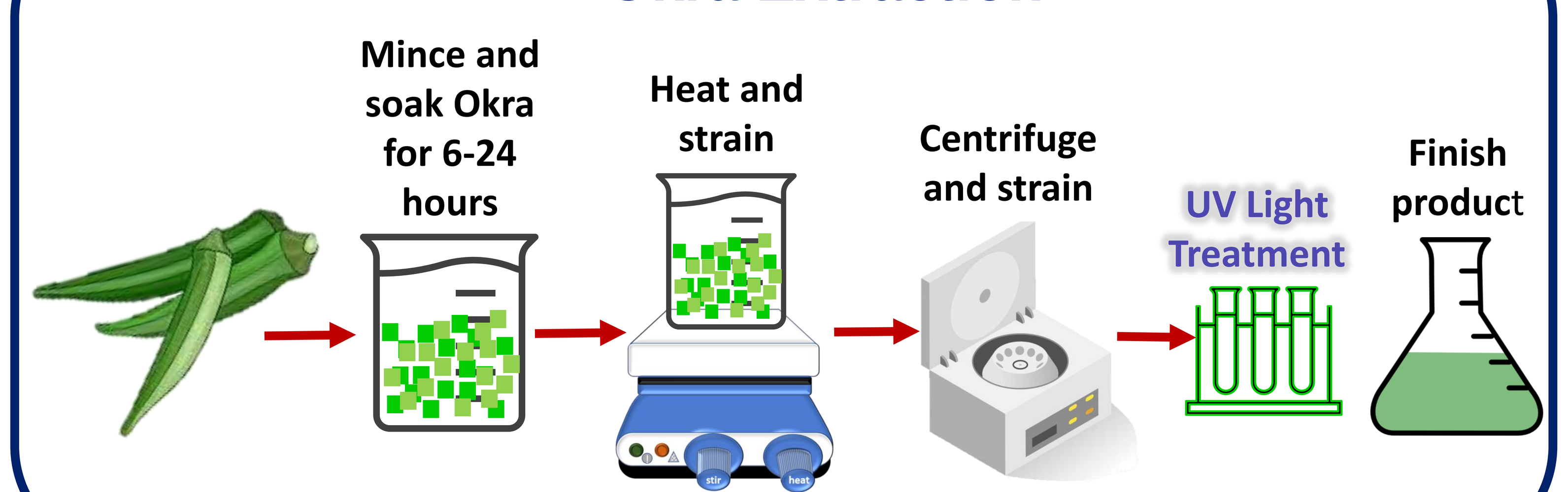
- Synthesize an ionic polyacrylamide hydrogel containing lithium chloride.
- Measure the conductivity and mechanical properties of the hydrogel.
- Compare the measure with polyacrylamide hydrogel w/o LiCl.
- Synthesize the PAM/LiCl incorporating okra to determine if it shows antibiotic properties.
- Measure the mechanical, swelling, FTIF-SPEC, and electrical properties of the okra PAM/LiCl.

Methodology

Hydrogel Synthesis



Okra Extraction



Results

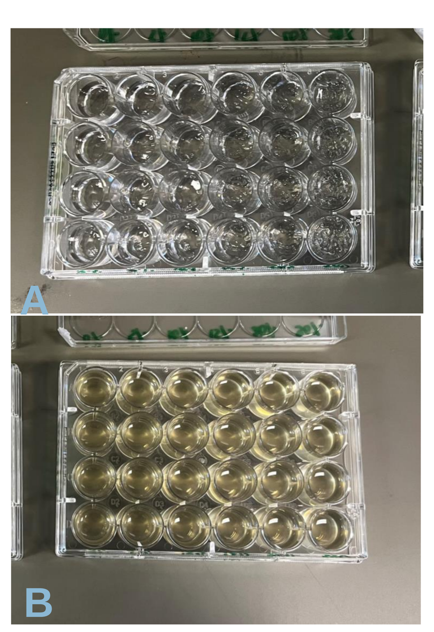


Figure 4 – (A) PAM/LiCl (0,5,10,15,20, 30%) Hydrogels (B) PAM/LiCl/OKRA (0,5,10,15,20,30%) Hydrogels

TABLE 1 – Swelling Ratio test of PAM/LiCl (0,5,10,15,20, 30%)

		Batches					
Day 1 07/26/2023	Measurements	0%	5%	10%	15%	20%	30%
	Size (D) Height (H) Weight (W)	D: 4.7cm H:0.6cm W:4.78g	D:4.71cm H:0.6cm W:5.52g	D:4.71cm H: 0.6cm W: 5.75g	D:4.7cm H:0.6cm W:5.90g	D:4.7cm H:0.6cm W:5.39g	D:4.7cm H:0,6cm W:5.67g
Day 2 (24hours)	Size (D) Height (H) Weight (W)	D: 7cm H:0.7cm W:17.46g	D: 7cm H:0.6cm W:17.13g	D: 6.5cm H: 0.5cm W:17.78g	D:6.5cm H:0.7cm W:16.41g	D:6.9cm H:0.7cm W:15.99g	D:6.4cm H:0.8cm W:15.8g
Day 3 (48 hours)	Size (D) Height (H) Weight (W)	D: 7.2cm H:0.7cm W:20.6g	D:7.5cm H:0.8cm W:20.61g	D:7.5cm H:0.6cm W:20.67g	D:7.5cm H:0.7cm W:22.72g	D:7.3cm H:0.7cm W:19.36g	D:6.9cm H:0.6cm W:16.84g
Day 6 (96hours)	Size (D) Height (H) Weight (W)	D:7.3cm H:0.7cm W:19.71g	D:7.5cm H:0.7cm W:21.88g	D:7.5cm H:0.7cm W:21.08g	D:7.7cm H:0.8cm W:27.55g	D:7.4cm H:0.8cm W:20.20g	D:7.1cm H:0.7 cm W:17.6g
Day 8 (144 hours)	Size (D) Height (H) Weight (W)	D:7.3cm H:0.7cm W:19.93g	D:7.5cm H:0.8cm W:21.60g	D:7.6cm H:0.8cm W:21.86g	D:7.6cm H:0.8cm W:25.95g	D:7.6cm H:0.8cm W:21.45g	D:7.2cm H:0.7cm W:17.10g

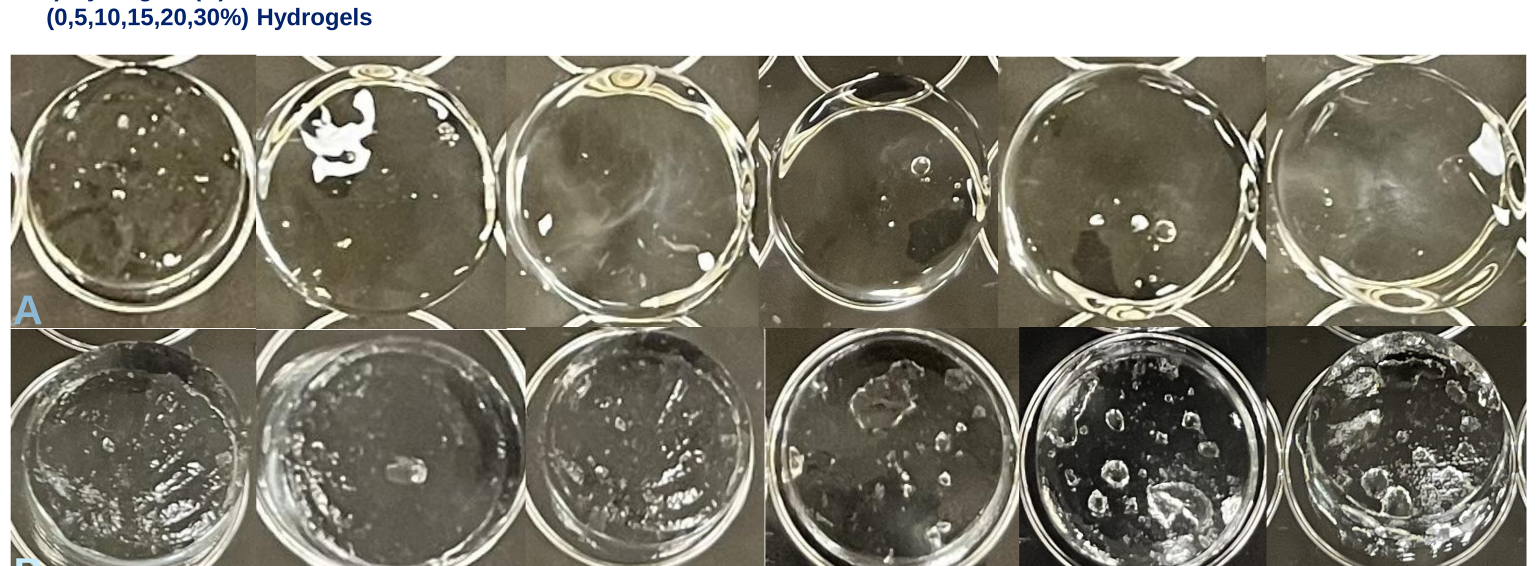


Figure 5 – (A) Left to right PAM/LiCl/OKRA (0,5,10,15,20,30%) Hydrogels & (B) Left to right PAM/LiCl (0,5,10,15,20,30%)

Analysis

FTIF-SPEC

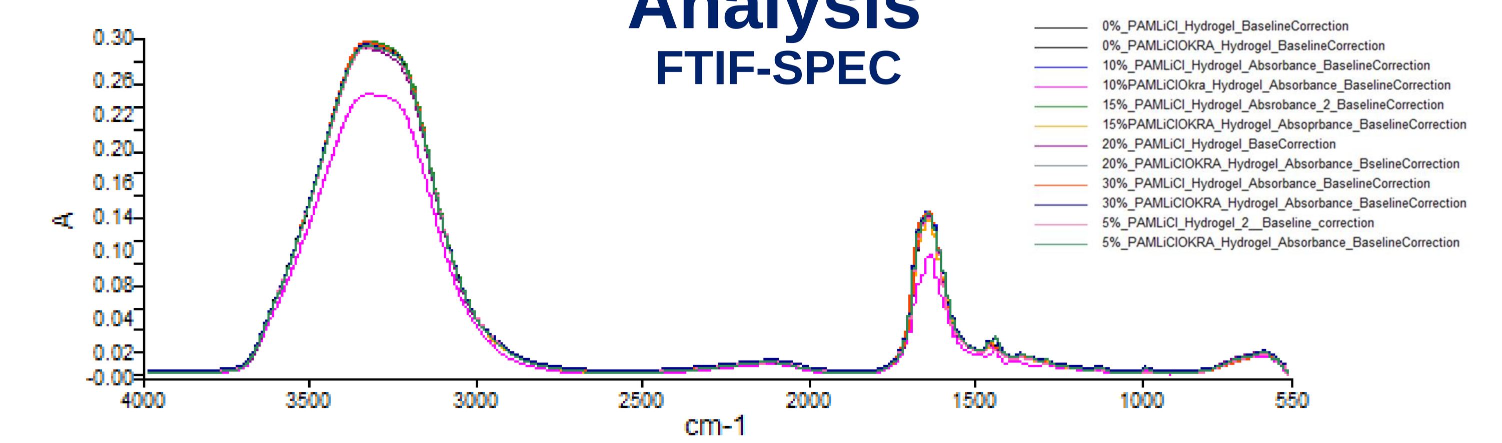


Figure 6 – FTIR Spectroscopy of the PAM/LiCl and PAM/LiCl/OKRA in various concentrations (0,5,10,15,20,30%)

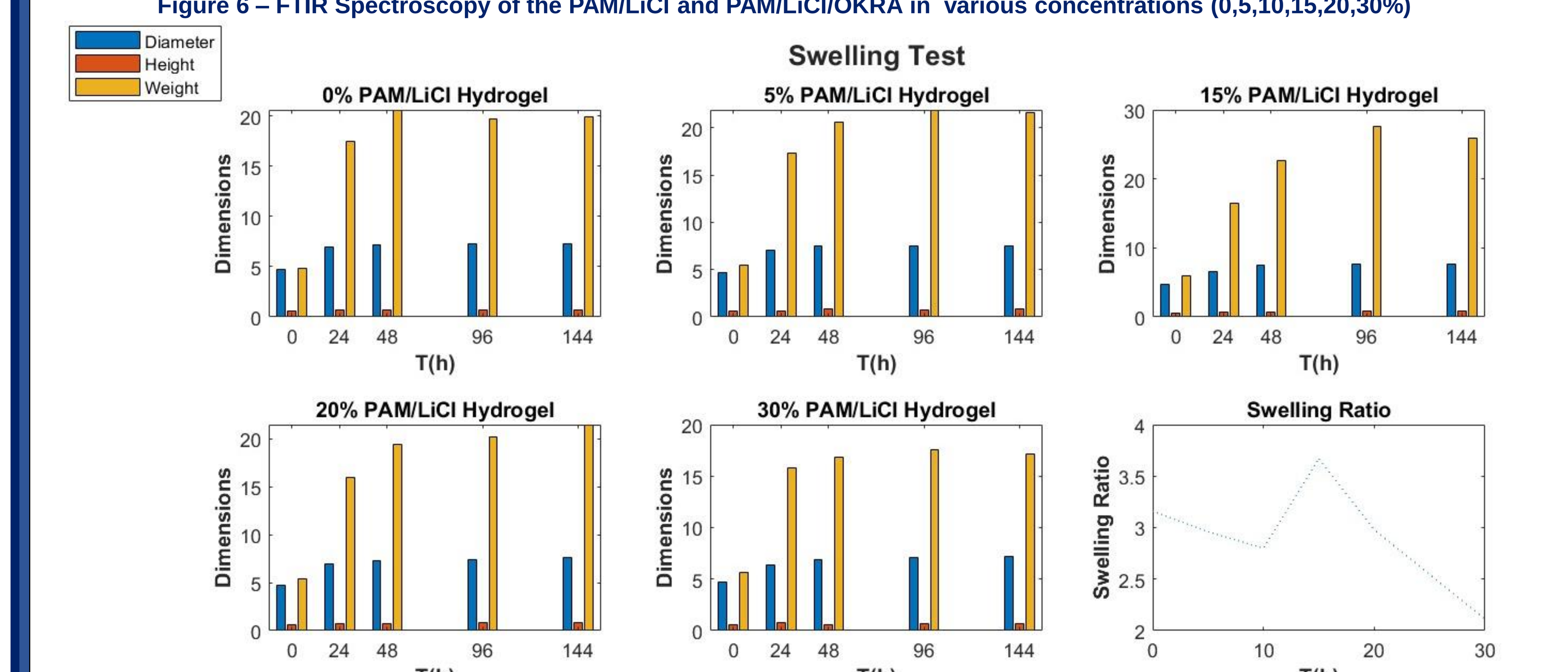


Figure 7 – Swelling Test of PAM/LiCl Hydrogel with concentrations ranging from 0,5,10,15,20,30%

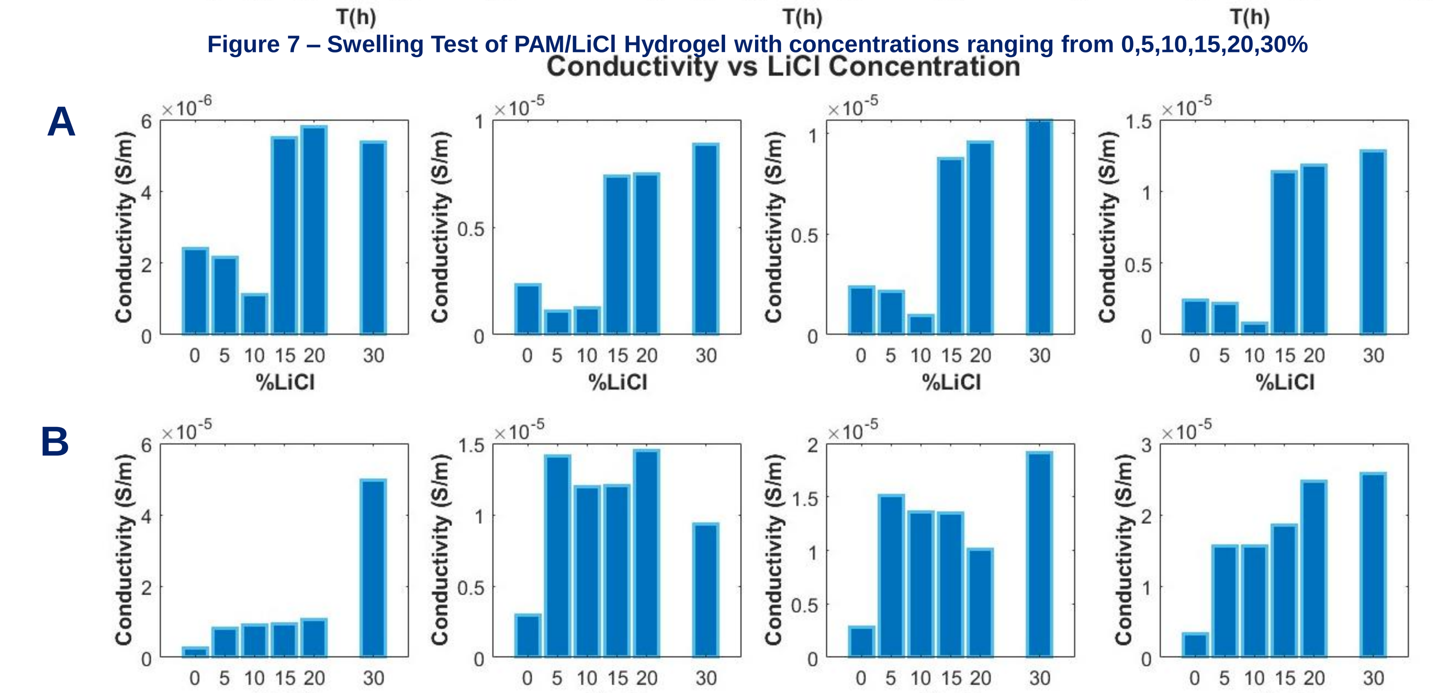


Figure 8 – (A) Conductivity of the PAM/LiCl and (B) Conductivity of PAM/LiCl/OKRA Hydrogels showed an increased as the LiCl concentrations increased.

Conclusion

The synthesis of the hydrogels with different crosslinker ratio exhibit a change in the mechanical properties such as changes in elasticity and viscosity. The synthesis of the hydrogel with different LiCl concentrations was achieved as well as the incorporation of the Okra mucilage. The hydrogel with LiCl and Okra mucilage exhibit higher elasticity and viscosity. Furthermore, it required more time to polymerize in comparison to the PAM/LiCl hydrogel. FTIF-SPEC, swelling, and conductivity test were executed on both batches. Interestingly, the hydrogel with 30% LiCl exhibits a decrease in swelling in comparison with the other concentrations. Conductivity tests exhibit that as the concentration of LiCl increases the conductivity increases.

Future Works

- Work on the ratios for the hydrogel synthesis to improve conductivity and mechanical properties.
- Test the mechanical properties of the synthesized hydrogels.
- Design the TENG and incorporate the conductive patch.
- Test the antibacterial and antifungal properties of H-Okra.
- Test the TENG in vitro and in vivo studies.

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