Development of Conductive Gels for Biomedical Applications

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Abstract

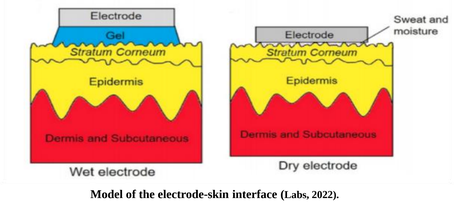
Conductive gels are essential in biomedical applications, particularly in electroencephalography (EEG), but they often cause skin irritations and evaluation interruptions as they dry out. This research explores the formulation of conductive gels using Hydroxyethyl Cellulose (HEC), a polymer derived from natural plant cell walls. This natural polymer aids in developing a less irritating alternative with comparable efficiency to commercially available electrode gels like Signagel®. The gels were formulated using varying Hydroxyethyl Cellulose (HEC) concentrations, sodium chloride as an ionic solute, propylene glycol as a humectant, and water as a solvent. Key parameters such as viscosity, pH, and conductivity were measured. The results indicate that HEC-based gels, particularly the 2.5% HEC formulation, exhibit properties matching those of Signagel®, with a pH of 6.42, viscosity of 11,530 cP, and conductivity of 120.3 mS. This study demonstrates that HEC is a viable option for creating conductive gels that minimize skin irritation and maintain the physiochemical properties required for EEG tests.

INTRODUCTION

Conductive gel is a water-based, chemically neutral, electrolytic substance applied in non-invasive neuroimaging techniques such as EEG tests, which is the focus of this study.

EEG uses electrodes placed on the scalp to record the brain's electrical activity. The conductive gel serves as an interface between EEG electrodes and the scalp, reducing the skin's impedance and enabling the conversion of tissue ionic potentials into electrical potentials recorded in an electrogram.

A persistent challenge in EEG is maintaining stable and consistent electrode-skin contact, directly affecting the recorded data's quality and reliability. This issue is primarily due to the adhesiveness and durability of the conductive gel. Current gel formulations often fail to provide the desired adhesivity, leading to suboptimal data quality, the need for repeated electrode repositioning, and skin irritation. While some researchers have attempted to eliminate conductive gel by using dry electrodes, this method increases the cost and complexity of the procedure due to additional cables and equipment.



Model of the electrode-skin interface (Labs, 2022).

OBJECTIVES

- Formulate a conductive gel using Hydroxyethyl Cellulose
- Evaluate viscosity, pH, conductivity, and non-irritating reagents
- Identify that HEC is a viable natural polymer for conductive gels

METHODOLOGY

PHASE 1: Preparation

Lab equipment and safety measures

Installation of ViscoQC 300-R

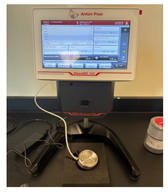
PHASE 2: Formulation

Chemical Reagents

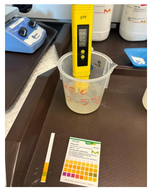
ANALYTICAL REAGENT GRADE CHEMICALS
Distilled water
Hydroxyethyl cellulose (HEC)
Methylparaben
Propylene glycol
Propylparaben
Sodium chloride

Table 1. Materials

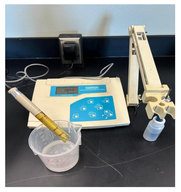
PHASE 3: Comprehensive Characterization



Viscosity test using ViscoQC 300-R



pH test



Conductivity test using Oakton pHCon Meter

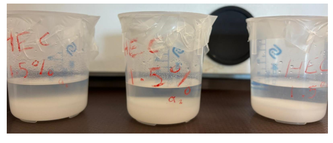
PHASE 4 : Final Testing and Validation

GEL FORMULATION BY HEC CONCENTRATION	1.5%	2.0%	2.5%	3.0%
Hydroxyethyl cellulose	1.5 g	2.0 g	2.5 g	3.0 g
Distilled water	80 mL	80 mL	80 mL	80 mL
Propylene glycol	10 mL	10 mL	10 mL	10 mL
Sodium chloride	4 g	4 g	4 g	4 g

Table 2. Refined formulations based on characterization results

- **Adjustments**

Parabens were discarded from the gel formulations because they proved to be incompatible with the HEC solution. They did not dissolve properly, leading to sedimentation and the formation of conglomerates which would make the gel unsuitable for the intended application in EEG tests.



Paraben sedimentation in HEC gels

Conglomerates observed during viscosity test

DATA

The gels were formulated using varying Hydroxyethyl Cellulose (HEC) concentrations, sodium chloride as an ionic solute, propylene glycol as a humectant, and water as a solvent.

The characterization results are summarized in the following table, using Signagel® as the control gel:

CHARACTERIZED GEL	pH	VISCOSITY (cP)	CONDUCTIVITY (mS)
Signagel®	5.4-6.4	180,000-260,000	121.0
HEC 1.5%	6.68	1,457	129.9
HEC 2.0%	6.53	6,477	130.3
HEC 2.5%	6.42	11,530	120.3
HEC 3.0%	6.46	68,510	136.7

Table 3. Characterization results of Signagel® and HEC gels

ANALYSIS & RESULTS

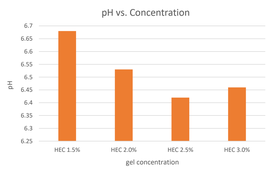


Table 4. pH comparison of HEC gels

The pH values of the gels ranged from 6.42 to 6.68, with a slight decrease as the concentration of HEC increased.

The 2.5% and 3.0% HEC concentration gels have the pH closest to Signagel® values.

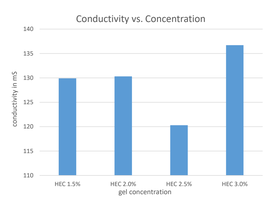


Table 5. Conductivity comparison of HEC gels

Conductivity values were relatively stable across the different gel concentrations.

The 2.5% HEC gel showed a conductivity of 120.3 mS, closely matching the 121.0 mS value of Signagel®.

The 3.0% HEC gel had a higher conductivity of 136.7 mS, which, while still within acceptable limits, may lead to slight discrepancies during EEG tests.

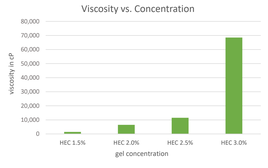
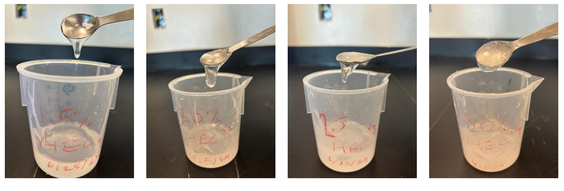


Table 6. Viscosity comparison of HEC gels

The 2.5% HEC gel showed a viscosity of 11,530 cP, significantly lower than the range of Signagel®. However, it has a consistency similar to Signagel®, suggesting that viscosity alone may not be the sole determinant of usability.

The following figures display the HEC gels in concentrations of 1.5% to 3.0%, presented in the same order as described:



Experimental HEC gels of 1.5% to 3.0% concentration

CONCLUSIONS & RECOMMENDATIONS

Formulations with 2.5% to 3.0% HEC concentrations exhibit the most promising properties. Specifically, the 2.5% HEC gel demonstrated a pH of 6.42, a viscosity of 11,530 cP, and a conductivity of 120.3 mS. Although there is a significant difference in viscosity compared to Signagel®, the consistency of the 2.5% HEC gel compensates for this, making it more suitable for EEG applications. Despite showing effective conductivity, 3.0% HEC gel was not chosen due to its paste-like consistency, which could impact the stability and application of the gel during EEG recordings.

Using sodium chloride in the formulation achieves the necessary conductivity while being a biocompatible solute, and propylene glycol provides antimicrobial properties while acting as a non-irritating humectant. Additionally, the 2.5% HEC gel opens the possibility of incorporating additional reagents as additives, potentially improving the gel's performance without relying solely on viscosity adjustments. This flexibility could lead to further study of HEC gels and their biocompatibility.

FUTURE WORK

pH Adjustment	• Decrease the pH using a sodium hydroxide solution.
EEG Testing	• Conduct EEG tests and compare the electroencephalogram results.
Polymer Research	• Explore the use of other polymers such as Sodium Alginate and Carbopol 940.
Chemical Stability Analysis	• Assess the chemical stability of the gels to ensure their long-term effectiveness.

ACKNOWLEDGEMENTS

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