Hong Kong Student Science Project Competition 2022

Team Number: SABC163

Project Title: Adhesive double-layer egg albumen hydrogel bandage with antibacterial properties

Project Type: Invention

To our best knowledge and after thorough literature research, as at 5/3/2023 , there are similar works. If there are, the reference links are as below:

https://www.mdpi.com/2073-4360/14/23/5116
https://www.sciencedirect.com/science/article/abs/pii/S014296122200045X
https://www.sciencedirect.com/science/article/abs/pii/S0142961205003194
https://pubs.acs.org/doi/abs/10.1021/acs.chemmater.0c02823
https://www.sciencedirect.com/science/article/abs/pii/S0141813020340708
https://link.springer.com/article/10.1007/s10856-012-4730-3

The enhancement our project has made for the existing related products or research is summarized as below:

The current wound healing hydrogels are made from chitosan, alginate or gelatin, we chose to use egg albumen as it is easily extracted while holding properties essential to wound healing. We also enhanced the hydrogel bandage by cross-linking it with copper ions and calcium ions, where the former is antibacterial, which was not done in previous studies.

I. Background

Hydrogels are suitable as a bandage as they are flexible, provide a moist environment, and can hold additional substances that promote wound healing. Biodegradable hydrogels are environmentally friendly, and prevent secondary tissue damage as removal is unnecessary. Egg albumen hydrogels are particularly attractive due to their simple fabrication and inherent wound-healing properties. In the study by Duan et al., egg albumen hydrogels for bone tissue engineering are made from the gelation of egg albumen with sodium hydroxide, further cross-linked with solutions of various concentrations of calcium ions.

However, there is currently no recorded fabrication of egg albumen hydrogels as bandages for minor skin wounds and cross-linked with copper or zinc ions, widely recognised as antibacterial, essential trace minerals. Therefore, we created a double-layered egg albumen hydrogel bandage suitable for healing minor wounds, with a hydrogel cross-linked with antibacterial metal ions in its interior, surrounded by simple egg albumen hydrogels. This structural design ensures an antibacterial adhesive bandage will be formed. Tests are then done on its properties to determine the most suitable cross-linking agent. This product also has a wide audience and benefits all who have acute minor skin wounds.

II. Objectives

Through discovering the most suitable cross-linking agent for egg albumen hydrogels with wound healing applications, we aim to create an adhesive hydrogel bandage with antibacterial properties, providing a cost-effective solution to minor wound care, and attain our goal of discouraging the use of plastic-based bandages, thus alleviating plastic pollution.

III. Methodology

First, filtered fresh egg albumen was poured in small molds and mixed with sodium hydroxide solution dropwise, such that thin egg albumen hydrogel pieces were formed after just a few minutes. Exposed to strong alkali, denaturation of the egg albumen occurs. The proteins unfold and reveal amino acid side chains that were once in their interior. They then aggregate by non-covalent interactions, and intermolecular disulphide cross-linking. The first cross-linking of the egg albumen proteins happens. Hydrogels were then unmolded.

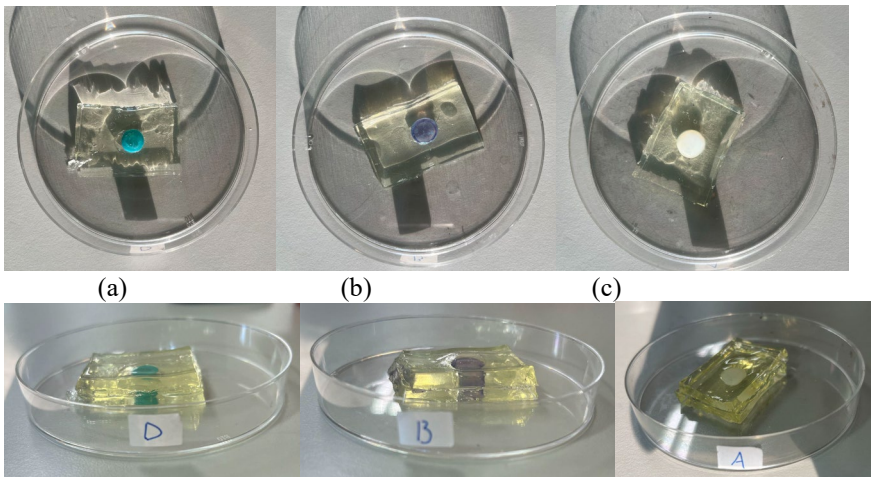
Then, small hydrogel cylinders were cut out from the center of the hydrogels, and were immersed into bivalent antibacterial metal ions solutions. These metal ions attract the negatively charged, deprotonated carboxyl groups of carboxyl side chains in proteins. The second cross-linking of egg albumen proteins occurs. This strengthens the hydrogel and increases its antibacterial activity. Genipin, a naturally occurring cross-linking agent, originally also used, was quickly eliminated as the hydrogel produced was of low strength.

Finally, the dual cross-linked hydrogel cylinders are returned to the center of the original hydrogel, with a second layer of unbored hydrogel adhered on top.

Three tests were performed to determine the physical and antibacterial properties of the hydrogels: Swelling tests were performed in water to determine the extent of cross-linking in the hydrogels, as more cross-linked hydrogels hold less water and are lighter due to denser polymer networks. Tests on the adhesiveness of the hydrogel bandage were done by adhering them on inverted Petri dishes. They were observed at 2 hour intervals. The zone of inhibition test was performed to determine the level of antibacterial activity of the hydrogels due to oxidative stress generated by the metal ions.

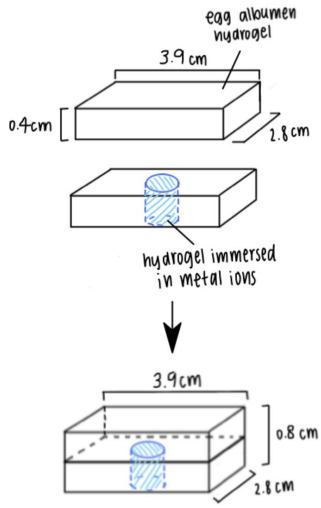
IV. Design of Invention

We observed that the egg albumen hydrogels became less adhesive after being cross-linked twice. Therefore, for an antibacterial yet adhesive hydrogel bandage to be formed, we created a double-layered hydrogel bandage. The lower layer, which will be in contact with the skin, holds a hydrogel cross-linked with antibacterial metal ions in the middle. A second layer of egg albumen hydrogel was adhered on top to keep the cross-linked material in place.



(a) (b) (c)

(d) (e) (f)



(g)

Aerial and side views of the double-layered egg albumen hydrogel bandage with its center cross-linked with (a)(d) copper-calcium (b)(e) copper-zinc (c)(f) calcium metal ions (g) Illustrations of the design of a double-layered hydrogel.

V. Application / Market Need

The egg albumen hydrogel presents itself as a solution to the problem of non-biodegradable plastic medical waste. It is designed to be an alternative for a bandage for acute minor skin wounds, being antibacterial, adhesive, environmentally-friendly, comfortable, and affordable.

A limitation of our current bandage is storability, the hydrogels could only be stored at 4°C, whereas commercial bandages can be stored at room temperature. Finding sustainable storage methods for sizable amounts of hydrogels is crucial towards its development as a commercial product.

VI. Conclusion

Through the series of tests, we determined that the double-layered hydrogel cross-linked with copper and calcium ions in its center is the best formulation for a bandage, as it had satisfying swelling rate, ductility and flexibility. It also exhibits sufficient adhesiveness and the highest antibacterial activity as it adhered on an inverted Petri dish for 3 days, and the clear zone formed around it during the inhibition test was the largest, respectively. Therefore, we have met our objective of forming a biodegradable and low-cost egg albumen-based antibacterial hydrogel bandage.