pH-Responsive Biofilms as Sensors for Smart Management of Complex Wounds

Camacho Pastrana, Sheila Judith (School: Instituto Profesional en la Ensenanza y Formacion Humana S.C Plantel Aeropuerto)

Chronic wounds represent a major public health challenge, with a 24% infection risk and annual healthcare costs of $25 million in the U.S. alone. Conventional treatment based on visual assessment is invasive and painful; furthermore, it fails to provide timely information for medical intervention. This highlights the need for accessible, low-cost monitoring alternatives, which remains the primary limitation of current smart dressings. In this context, exudate pH is a key biomarker: acidic environments (pH 4–6) promote healing, while alkaline values (>7) delay it and are frequently associated with bacterial infection. This study addresses these issues through the development and characterization of sodium alginate and chitosan biofilms enriched with red cabbage anthocyanins as visual pH sensors. The engineered biofilms reported an ultra-thin thickness of 0.262 mm. Results confirmed a visual and quantifiable chromatic response to pH changes: pink tones at pH 3, blue at pH 7, and purple at pH 9. Additionally, a color difference (?E) = 3 was obtained within the CIELAB scale, indicating that the chromatic shift is perceptible to the human eye. Physicochemical tests showed solubility increases in acidic environments (100% at pH 3) compared to neutral or alkaline ones (71.5%), suggesting potential for studying pH-dependent controlled drug release. Furthermore, the swelling capacity (5.6–5.8 times its weight) was comparable to commercial hydrocolloid dressings. The biopolymer combination enhanced tensile strength and elongation, creating a stable, flexible structure. These findings validate the technical viability of the proposed smart sensors for the management of complex wounds and provide a solid foundation for future in vitro and in vivo clinical efficacy trials.

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