Synthesis of a Novel Flame-retardant Hydrogel for Skin Protection Using Xanthan Gum and Resorcinol Bis(diphenyl phosphate)-coated Starch

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Firefighters suffer from burns annually; in 2018, 2835 U.S. firefighters received burn injuries. Existing heat-resistant fabrics have noncontiguous areas, and facemasks are often removed in operations due to discomfort and inconvenience, all failing to provide sufficient protection. Solutions to this include applying superabsorbent polymer (SAP) on skin, but this cannot withstand prolonged burns as it only relies on water's large specific heat. This research reports the synthesis of a hydrogel specifically for skin protection based on principles of Intumescent Flame Retardant systems. We synthesized the said gels using various biodegradable materials' combinations, and used flammability assessments on sheepskin to determine the optimal formulation: 2.5 wt.% resorcinol bis(diphenyl phosphate) (RDP)-coated xanthan gum/10 wt.% RDP-coated starch. Further tests were conducted on chicken skin. In thermal protection performance tests with constant thermal radiation, compared with Stoll Criterion, the gel displayed a protection time of 103 s, outperforming commercial SAP by 94%. Under open flame, its protection time, given by thermal images and modeling with Henriques Equation, exceeded that of the SAP by 46%, reaching 145 s. Tissue residue covered by the gel maintained an intact skin layer, while that by the SAP had the entire muscle layer damaged. Mechanism studies showed that hydrogel reduced heat propagation mainly via intumescent charring with endothermic processes of dehydration and transesterification. In-vitro cell tests, thermalgravimetric analysis, rheology tests, and goniometry respectively confirmed the hydrogel to be nontoxic, thermally stable, easily spreadable, and adhesive, all proving this research's value as a protective measure for firefighters worldwide.