Biopolymeric Blenda Scaffolds with Incorporation of an Organic Compound with Potential Pharmacological Activity for Application as a Wound Dressing

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Cutaneous wounds caused by trauma, burns, or chronic diseases are challenges that tissue engineering seeks to address through innovative strategies to accelerate healing, using various resources and techniques such as hydrogels and 3D bioprinting. Among the materials used in this field, GelMA (methacrylated gelatin) stands out for its biocompatibility, biodegradability, and non-immunogenicity. Therefore, this study focused on GelMA at different concentrations (5%, 10%, and 15%) to evaluate its properties. Mechanical tests showed that higher concentrations increase the material's strength by enhancing its molecular bonds, resulting in greater tension required for rupture of the dressing. Fourier-transform infrared spectroscopy (FTIR) confirmed the methacrylation reaction. The next step of the study is to evaluate infill patterns and biological properties, aiming to enhance the effectiveness of the dressings in wound healing.
Keywords: 3D Bioprinting. Dressing. GelMA. Tissue Engineering.

Skin wounds can be caused by different factors, such as acute trauma, burns, and surgical procedures, and can be worsened by other comorbidities like diabetes. Treating these wounds depends intrinsically on the interaction between cellular factors and the surrounding extracellular matrix [1]. Tissue engineering recognizes these challenges and seeks strategies to accelerate wound treatment through various techniques, such as the use of hydrogels with different compositions or 3D bioprinting for tissue printing to provide patient-specific substitutes [2].

Gelatin is one of the most commonly used materials in tissue engineering, due to its favorable properties like biocompatibility, biodegradability, and non-immunogenicity. Gelatin-based hydrogels used in 3D bioprinting have proven important for discoveries of various chemical, biological, and mechanical functionalities in this research area [2]. It is possible to produce dressings from hydrogels like gelatin that adhere to the skin, offering protection from the external environment, and which may have antibacterial properties through the addition of other materials, while also delivering drugs that accelerate the tissue regeneration process [3].

This study aims to investigate further the mechanical and physicochemical properties of methacrylated gelatin hydrogel (GelMA) used in 3D bioprinting, by conducting mechanical, chemical, and biological tests to determine how increased concentration affects its properties and evaluate its applicability as a wound dressing.

Materials and Methods

To produce GelMA, 10 grams of gelatin were dissolved in 100 mL of ultrapure water in a magnetic stirrer for 1 hour. Then, 0.14 mL of methacrylic anhydride (MA) was added per gram of dissolved gelatin and kept under constant stirring for at least 2 hours. After this period, an additional 100 mL of ultrapure water was added to stop the reaction. The solution was then centrifuged for 10 minutes at 5000 RPM at 25 °C to remove part of the unreacted MA. Next, the solution was dialyzed in ultrapure water to remove residual MA, with daily water changes for 5 days. Afterward, the solution was removed from the membrane, frozen at -80 °C, and lyophilized for hydrogel production.

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The hydrogel was prepared at three concentrations (5%, 10%, and 15%) using lyophilized GelMA in phosphate-buffered saline (PBS), stirred magnetically at 40 °C. Lithium phenyl-2,4,6-trimethylbenzoylphosphinate (LAP) was used as a photoinitiator at 0.5% to cure the scaffold after printing. The hydrogels were printed using a 3D bioprinter, model Octopus by 3D Biotechnology Solutions, following the parameters shown in Table 1. They were stored and sealed with paraffin for 1 day to allow complete photocuring before mechanical property evaluation.

Table 1. Printing parameters.

Parameter	Value
Scaffold size	15x80x1 mm
Printing speed	150 mm/min
Layer height	1 mm
Nozzle diameter	1 mm
UV exposure time	5 min
Number of walls	5
Infill pattern	Rectilinear
Infill percentage	60%

Gelatin and GelMA were characterized by Fourier-transform infrared spectroscopy (FTIR) using attenuated total reflectance (ATR), model Nicolet Is10 (Thermo Scientific, Massachusetts, USA). The range used was 4000–500 cm^{-1} with a resolution of 4 cm^{-1}.

Mechanical behavior was analyzed by tensile testing of the stress–strain curve for each scaffold at different concentrations, using a Brookfield CT3 texture analyzer, to evaluate how increasing GelMA concentration affects mechanical resistance. The test was conducted at a speed of 0.1 mm/s.

Results and Discussion

The tensile test (Figure 1) indicated that increasing GelMA concentration is associated with a higher maximum stress sustained by the material before rupture. Although the supported tension increased, the observed strain remained similar across the three tested concentrations. The increased mechanical strength can be attributed to the greater amount of GelMA in the formulation. Higher GelMA concentrations promote stronger molecular bonding within the dressing structure, thereby requiring greater force for rupture [4].

Figure 2 shows the FTIR spectrum of pure gelatin and GelMA. In the 1200 to 1750 cm^{-1} range, band stretching associated with C=H and C=O amino groups is observed. In the 2800 to 3400 cm^{-1}

Figure 1. Stress *vs*. strain curve of GelMA at 5%, 10%, and 15% concentrations.

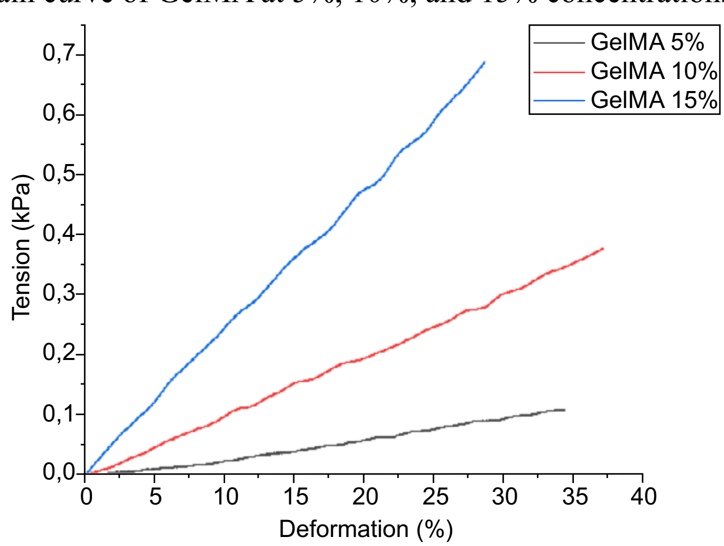
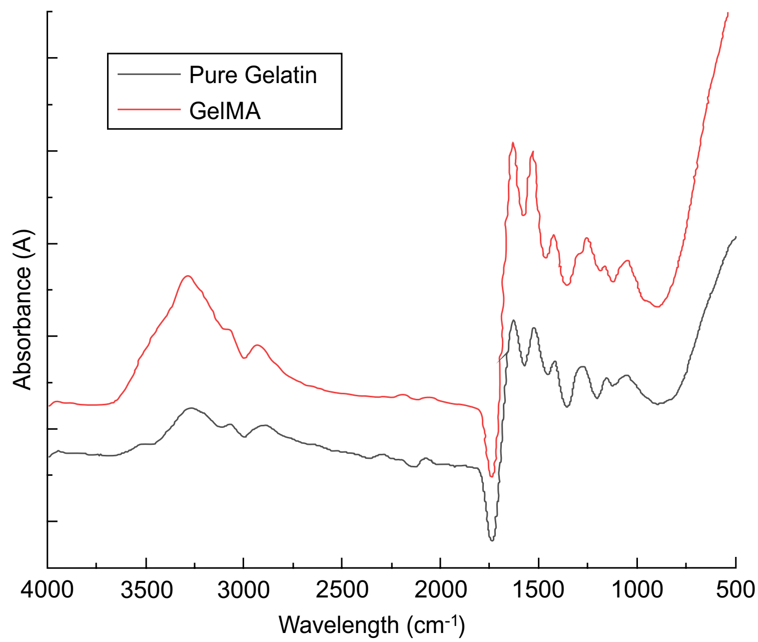


Figure 2. FTIR spectrum of pure gelatin and GelMA.



range, stretching is seen for OH groups and N-H peptide bonds [4,5].

Conclusion

According to the results, it was possible to characterize and observe stretching of certain functional group bands in GelMA compared to pure gelatin, and to verify the influence of concentration increase on the stress required to rupture the printed dressing. Future tests will be necessary to evaluate the influence of the dressing's infill pattern, as well as the incorporation of new materials to achieve additional properties. In addition to mechanical analysis, it will also be essential to investigate the biological properties, focusing on cellular compatibility and the potential for drug incorporation in the dressing to aid wound healing.

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