Advanced Methacrylated Gelatin (GelMA) Hydrogel Scaffolds for Wound Care Applications

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Tissue engineering is an area of research that has been advancing with the implementation of new technologies to create scaffolds that can aid in regenerating damaged tissues. Among these technologies, bioprinting has gained prominence due to the diverse range of hydrogels that can be used as scaffolds and dressings for tissue regeneration. Gelatin methacrylate (GelMA) has been studied for its potential use as a dressing for skin regeneration. This study aimed to evaluate the properties of scaffolds with different concentrations of 3D-printed GelMA for application as wound dressings. The degradation rate and tensile strength of these scaffolds were assessed. Results showed that with increasing GelMA concentration, there was a decrease in the degradation rate and swelling while the maximum tensile stress increased. The next phase of this study will involve incorporating drugs to evaluate their influence on the properties of the scaffolds.

Keywords: Scaffolds. Gelatin. 3D Bioprinting. Wound Dressing.

Hydrogels are hydrophilic polymers whose chemical and mechanical properties vary based on the selected polymer and concentration. Several hydrogels are used in bioengineering to produce scaffolds for regenerative medicine, such as bandages. These structures serve as extracellular support to assist in cell proliferation, thereby accelerating tissue regeneration [1]. Various hydrogels, including hyaluronic acid, gelatin, alginate, and chondroitin sulfate, are studied for tissue regeneration due to their properties, such as water retention, porosity, and degradation [2]. This work aimed to produce and evaluate scaffolds' tensile properties and degradation rate based on methacrylate gelatin hydrogel (GelMA) for application as dressings to aid in the regeneration of skin injuries.

Materials and Methods

To produce GelMA, 10 grams of gelatin from pig skin was dissolved in 100 mL of ultrapure water using a magnetic stirrer for 1 hour. Then, 0.14 mL of methacrylate anhydride (MA) was added for each gram of gelatin dissolved, and the mixture was left 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 divided into Falcon tubes, with 25 mL of the solution in each tube, and subjected to centrifugation for 10 minutes at 5000 RPM at 25ºC to remove part of the byproducts. After centrifugation, the solution was transferred into membranes for dialysis with ultrapure water to remove the remaining MA. The water immersed in the membrane was changed daily for 5 days. After dialysis, the solution was removed from the membrane, frozen at -80ºC, and lyophilized to produce the hydrogel. The hydrogel was prepared in three concentrations (5%, 10%, and 15%) using lyophilized GelMA. To do that, 10 mL of phosphate-buffered saline (PBS) was added to the lyophilized GelMA on a magnetic stirrer at 40ºC to dissolve the gelatin completely. Lithium phenyl-2,4,6-trimethylbenzoylphosphinate (LAP) was added as a 1% photoinitiator to cure the scaffold after bioprinting. The bioprinted bandages, with dimensions of 15x80x1.5 mm, were printed using an Octopus model bioprinter from 3D Biotechnology Solutions at a speed of 300 mm/minute with 80% fill through a 1-millimeter diameter needle with a layer height of 0.7 mm.

Received on 17 February 2024; revised 28 May 2024.
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J Bioeng. Tech. Health 2024;7(2):121-123
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After printing, the dressings were exposed to 375 nm UV light for 10 minutes and then subjected to testing and evaluation of their properties. The degradation test was conducted using portions of the bioprinted dressings, with each dressing separated into three samples for each concentration. These samples were weighed and placed in a 12-well plate filled with PBS. The plates were then incubated in an oven with agitation and air circulation at 37ºC. The samples were weighed every three days over a total of 15 days. During the first week, the PBS was not changed, while in the second week, the PBS was changed at each weighing to evaluate the swelling of the scaffolds. For mechanical analysis, the stress-strain behavior of each scaffold at different concentrations was analyzed using a Brookfield CT3 texturometer to evaluate how increasing the concentration of GelMA affects mechanical resistance. This test was conducted at a speed of 0.05 mm/s.

Results and Discussion

Figure 1 shows the stress-strain curves of the scaffolds. An increase in stress proportional to the concentration is observed, with strain varying between 20% and 60%. The scaffold with a concentration of 15% GelMA exhibited the highest tensile stress, approximately 980 KPa, almost 10 times greater than the maximum stress obtained by the scaffold with 5% GelMA.

Figure 2 shows the degradation curves of the scaffolds with different concentrations of GelMA over 15 days. A noticeable difference in the degradation rate of each scaffold is observed. For scaffolds with 5% GelMA, the weight loss was almost 50%, representing the highest degradation rate among the scaffolds. As the GelMA concentration increased, the degradation rate progressively decreased. From the sixth day onwards, the ability of PBS to degrade the scaffolds diminished significantly, leading to absorption and, consequently, a mass gain. Lower concentrations of GelMA absorbed more PBS than higher concentrations due to their greater affinity with the solution.

Discussion

The behaviors observed in Figures 1 and 2 can be explained by the concentration of GelMA in each scaffold. According to the study by Xu and colleagues (2023) [3], increasing the concentration of GelMA enhances mechanical properties and decreases the scaffolds' degradation and swelling rate. Additionally, lower concentrations of GelMA demonstrate higher rates of degradation and swelling and lower tensile values, corroborating the results of this study.

Figure 1. Stress x Deformation curves of the GelMA dressing at 5%, 10% and 15%.

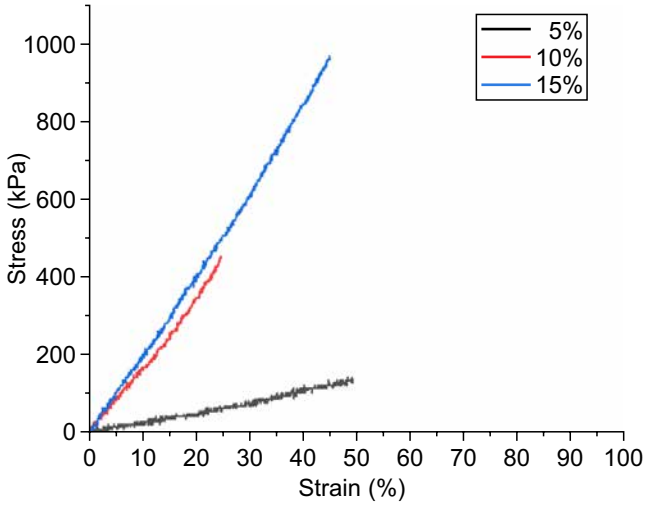
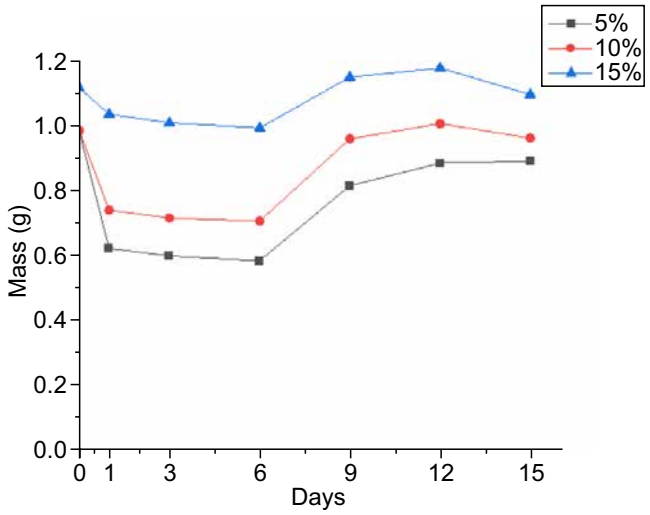


Figure 2. Degradation curve of 5%, 10% and 15% GelMA dressings.



Conclusion

The results of the tensile and degradation tests were promising for the subsequent stage of drug incorporation, aimed at improving tissue regeneration capacity. Cell viability tests must be conducted to enhance this study to verify cytotoxicity. The tensile test results are crucial for determining the optimal GelMA concentration.

Acknowledgments

The authors thank CNPq, CAPES, and FIOCRUZ for the scholarship opportunity, SENAI CIMATEC for providing the infrastructure, and the team for their assistance in carrying out this work.

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