3. Results and Discussion

This section details the experimental outcomes regarding the synthesis, characterization, and property evaluation of the novel poly(ethylene glycol) diacrylate (PEGDA)-based hydrogels. The data presented herein confirms the successful polymerization and provides insights into the influence of crosslinking density and monomer concentration on the resulting material properties. All experiments were conducted in triplicate, and reported values represent the mean ± standard deviation.

3.1. Synthesis and Initial Characterization of PEGDA Hydrogels

The synthesis of the PEGDA hydrogels was successfully achieved via UV-initiated free-radical polymerization. A typical reaction yielded a transparent, highly crosslinked network. The primary monomer, PEGDA (Mn=700 g/mol), was combined with varying concentrations of the photoinitiator, Irgacure 2959 (0.1% to 0.5% w/w relative to monomer). Polymerization was initiated by exposure to UV light (365 nm) for 120 s. The gelation time was observed to decrease significantly with increasing photoinitiator concentration, ranging from 15 s at 0.5% to 45 s at 0.1%.

Gravimetric analysis of the dried hydrogels indicated a high conversion rate, with polymer yields consistently above 95%. FTIR spectroscopy confirmed the disappearance of the characteristic acrylate C=C stretch at approximately 1630 cm−1 and the appearance of a broad O-H stretch around 3300 cm−1 (due to absorbed water), indicating successful polymerization. The absence of unreacted monomer peaks in the FTIR spectra further supported the high conversion efficiency of the reaction.

3.2. Swelling Behavior and Water Content

The equilibrium swelling ratio (Qeq) of the hydrogels was determined in deionized water at 25◦C. Hydrogels prepared with lower PEGDA concentrations (e.g., 10% w/v) exhibited a significantly higher Qeq of 12.5±0.8, compared to hydrogels with higher PEGDA concentrations (e.g., 20% w/v), which showed a Qeq of 6.2±0.4. This inverse relationship is attributed to the increased crosslinking density at higher polymer concentrations, restricting water uptake into the network.

The water content of the swollen hydrogels was also quantified. For the 10% w/v PEGDA hydrogels, the water content was determined to be 92.0±0.5%, while the 20% w/v PEGDA hydrogels exhibited a water content of 83.8±0.7%. These values highlight the hydrophilic nature of the PEGDA polymer and its capacity to absorb substantial amounts of water, making it suitable for various biomedical applications requiring high

hydration.

3.3. Mechanical Properties: Tensile Strength and Modulus

Tensile tests were performed on the synthesized hydrogels to evaluate their mechanical integrity. The tensile strength of the 20% w/v PEGDA hydrogel was measured at 0.15±0.02 MPa, which was notably higher than that of the 10% w/v PEGDA hydrogel (0.05±0.01 MPa). This increase in strength is directly correlated with the higher polymer content and, consequently, the increased number of crosslinks per unit volume.

The Young's modulus (E) also followed a similar trend, with the 20% w/v hydrogel exhibiting a modulus of 0.08±0.01 MPa, compared to 0.02±0.005 MPa for the 10% w/v hydrogel. These results demonstrate that the mechanical properties of the PEGDA hydrogels can be tuned by adjusting the initial monomer concentration, offering a pathway for designing materials with specific mechanical requirements for tissue engineering scaffolds or drug delivery systems.

3.4. Thermal Stability Analysis via TGA

Thermogravimetric analysis (TGA) was employed to assess the thermal degradation behavior of the PEGDA hydrogels. All samples exhibited a two-stage degradation profile. The first stage, occurring between 50◦C and 150◦C, corresponded to the loss of absorbed water, with a mass loss of approximately 10–15%. This observation aligns with the high water content measured in the swelling studies.

The primary degradation of the polymer backbone occurred between 300◦C and 450◦C, with a significant mass loss of 70–80%. The onset of degradation for the 20% w/v PEGDA hydrogel was slightly higher (315◦C) compared to the 10% w/v hydrogel (305◦C), suggesting a marginal improvement in thermal stability with increased crosslinking density. The residual char content at 600◦C was typically less than 5%, indicating a relatively complete thermal decomposition of the organic polymer.

In summary, the results demonstrate the successful synthesis of PEGDA hydrogels with tunable swelling and mechanical properties by varying the initial monomer concentration. The observed trends in swelling ratio, tensile strength, and thermal stability are consistent with the formation of a crosslinked polymer network, where higher polymer content leads to increased crosslinking density, reduced swelling, and enhanced mechanical integrity.