



Fabrication and Evaluation of Curcumin and Rutin-loaded Gellan Gum Hydrogel as Bioactive Wound Dressings

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Abstract

Appropriate wound dressings play a pivotal role in accelerating the wound healing process and enhancing patients' quality of life. Gellan gum (GG), a naturally derived polysaccharide, has gained increasing attention as a wound dressing material due to its excellent biocompatibility. In this study, GG hydrogels crosslinked with gallium(III) nitrate were successfully fabricated via ionic gelation, incorporating various concentrations of curcumin (CUR) and rutin (RU) phytochemicals.

The resulting hydrogel scaffolds were systematically characterized using Fourier-transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), gel fraction analysis, swelling behaviour, degradation kinetics, antibacterial and antioxidant assays, *in-vitro* drug release profiling, and cytocompatibility evaluation. **FTIR** revealed presence of all key functional groups in hydrogel scaffolds. Presence of gallium(III) ions, CUR and RU were seen in **SEM**. Gallium crosslinking significantly enhanced the **gel fraction**, achieving a 70% improvement compared to non-crosslinked GG formulations. **Swelling analysis** revealed an initial rapid uptake of fluid, with GG hydrogels reaching up to 2535.5% swelling before stabilizing over 24 hours. **Degradation rates** were inversely correlated with CUR and RU concentrations, indicating improved structural integrity with higher phytochemical loading.

Antibacterial testing demonstrated that the Ga-GG/C-0.5-R-0.5 hydrogel achieved a logarithmic reduction value (LRV) of 1.34 against *Methicillin-resistant Staphylococcus aureus* (MRSA, ATCC 43300) and 1.41 against *Pseudomonas aeruginosa* (ATCC 27853). All formulations exhibited superior antibacterial efficacy against the gram-negative *P. aeruginosa*.

Antioxidant analysis showed that Ga-GG/C-2-R-1 possessed the highest radical scavenging activity, with a DPPH inhibition rate of 67.34%, comparable to 0.003 mg/mL of ascorbic acid.

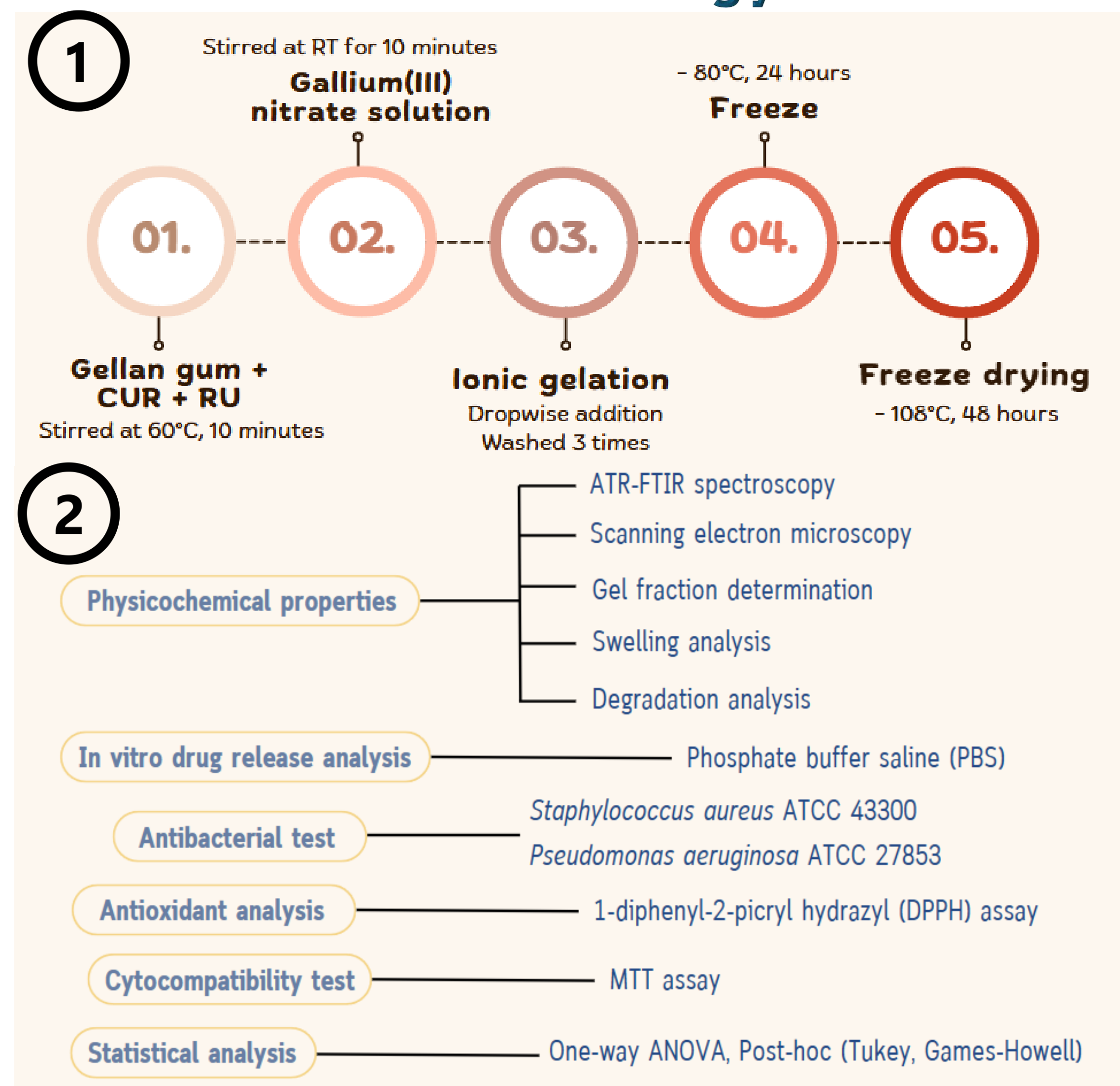
In phosphate-buffered saline (PBS, pH 7.4), the Ga-GG/C-0.5-R-0.5 hydrogel **released 9.17% of CUR and 82.23% of RU** over 168 hours, indicating differential release kinetics. **Cytocompatibility** assays revealed that gallium(III) ion incorporation enhanced cell viability, with the Ga-GG formulation achieving up to 125.7% viability at a scaffold-soaked medium concentration of 0.188 mg/mL, suggesting a proliferative effect on cells. Collectively, the Ga-GG/C-R hydrogel systems exhibit promising potential as alternative wound dressing platforms, offering multifunctional properties that support antibacterial and antioxidant activities, controlled drug release, and enhanced biocompatibility.

Introduction



- Wound healing requires dressings that maintain moisture, allow gas exchange, absorb exudates, and are biocompatible—criteria unmet by traditional dressings (1).
- Hydrogels like gellan gum (GG) offer biocompatibility and drug encapsulation but lack antibacterial activity and mechanical strength (2).
- Incorporating curcumin (antibacterial), rutin (antioxidant), and Ga³⁺ (crosslinking, antimicrobial) can address these limitations (3,4)
- This study develops a CUR–RU-loaded, Ga³⁺-crosslinked GG hydrogel with enhanced physicochemical, antimicrobial, and wound-healing potential.

Methodology



Research question

What is the effect of CUR and RU on the physicochemical properties, antioxidant activity, antibacterial activity and biocompatibility of GG hydrogels?

Research objectives

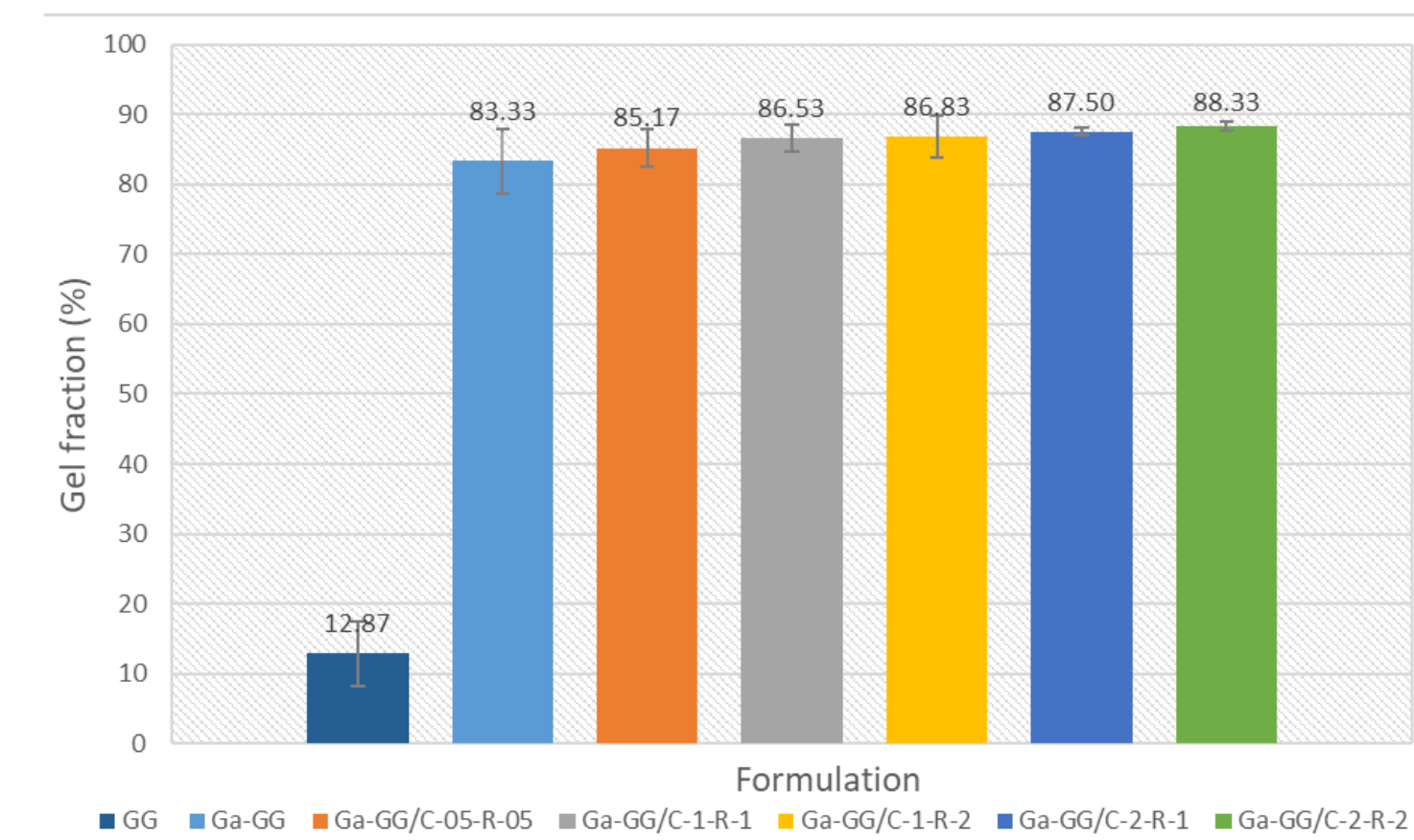
- To prepare GG hydrogels containing CUR and RU via ionic gelation and lyophilisation.
- To examine the physicochemical properties, antioxidant activity, antibacterial activity and biocompatibility of GG hydrogels containing CUR and RU.

Research hypotheses

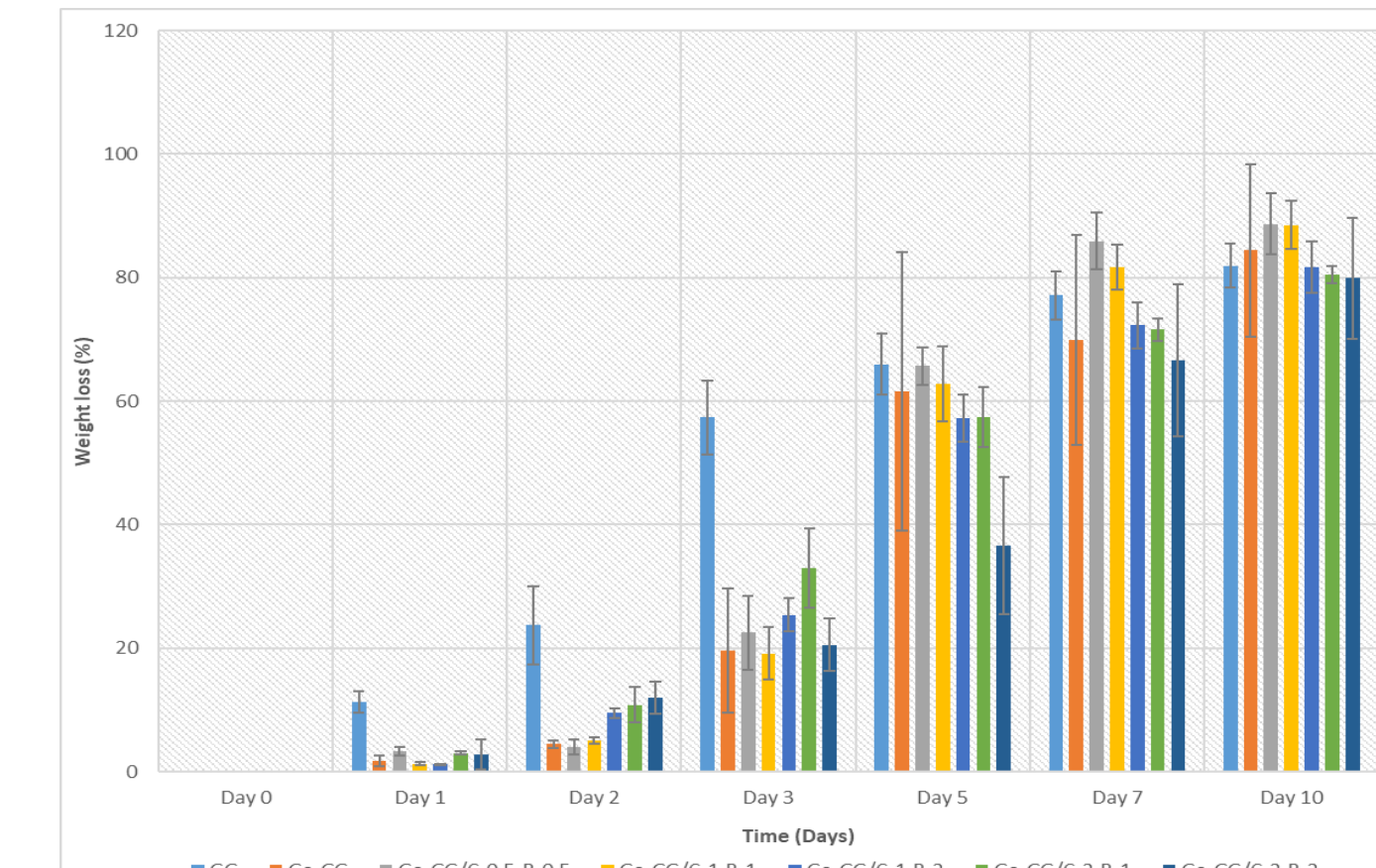
H₀: There is no significant difference in the physicochemical properties, antioxidant activity, antibacterial activity and biocompatibility of GG hydrogels before and after loading with CUR and RU.

H_a: There is significant difference in the physicochemical properties, antioxidant activity, antibacterial activity and biocompatibility of GG hydrogels before and after loading with CUR and RU.

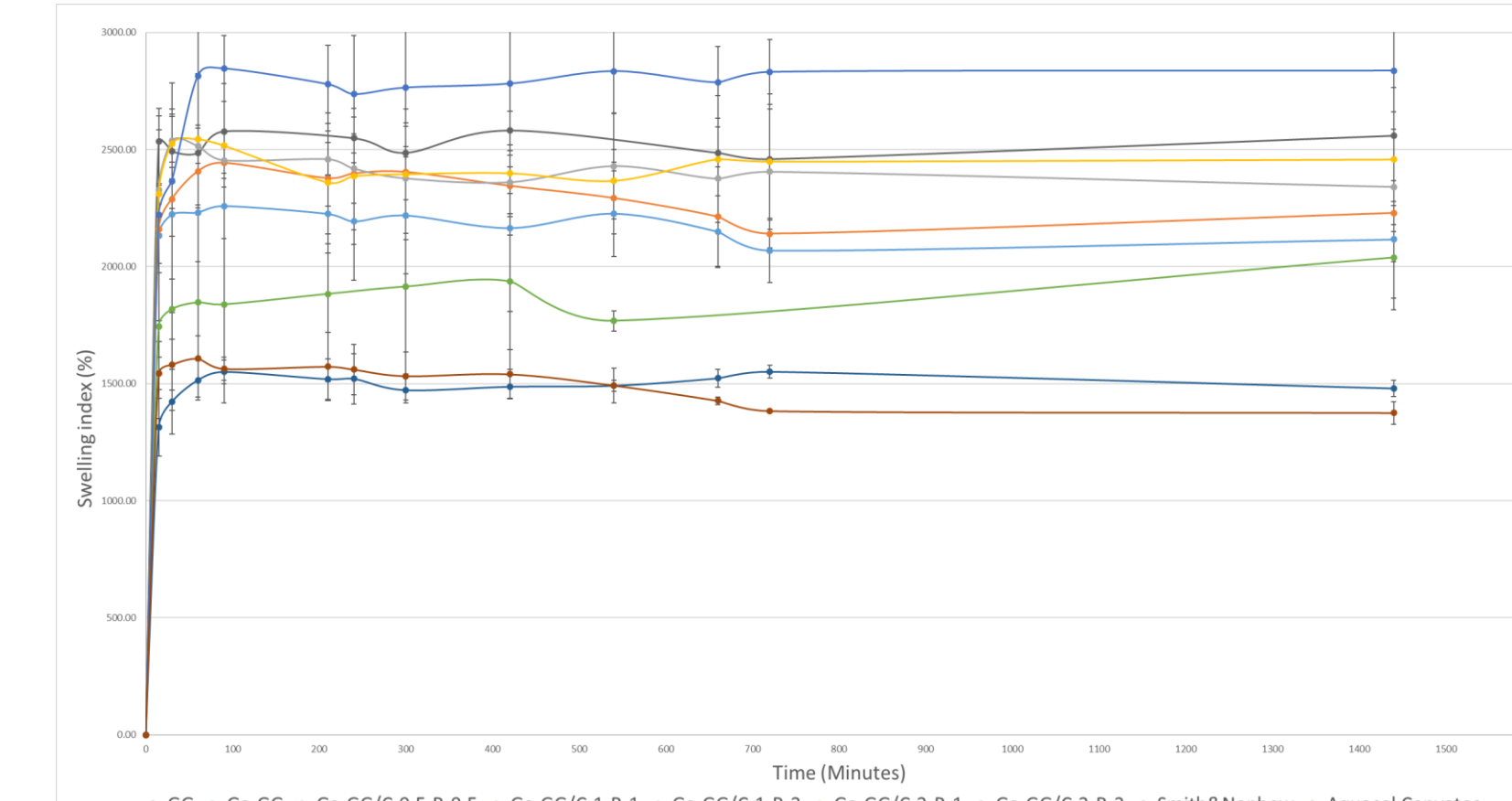
Gel Fraction Determination



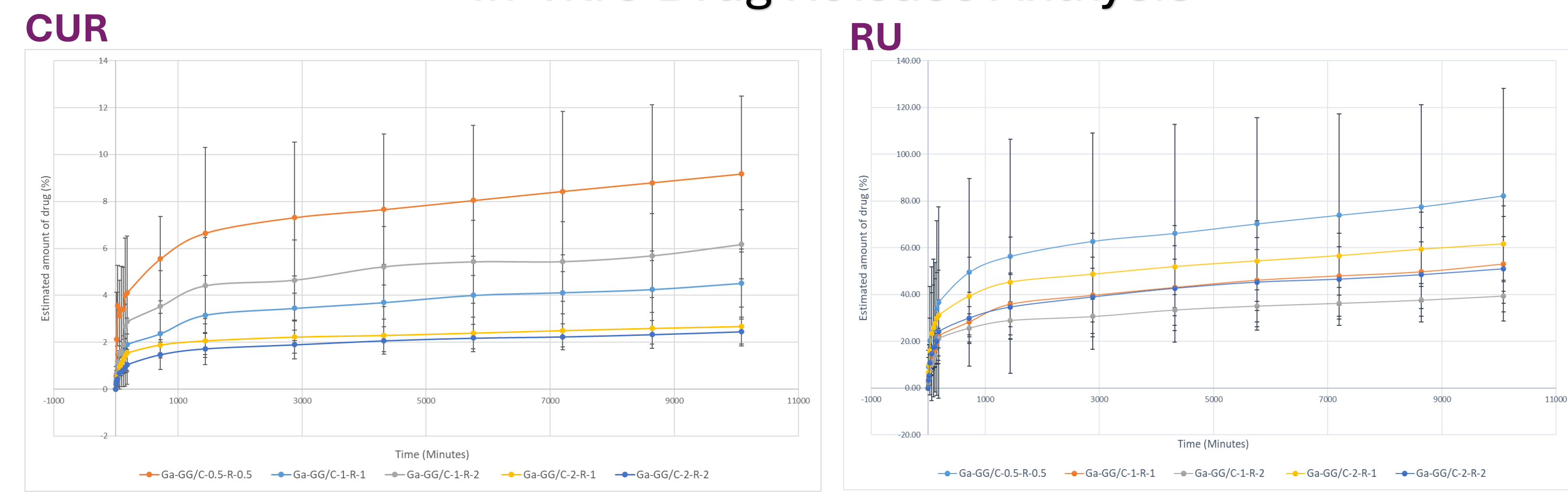
Degradation Analysis



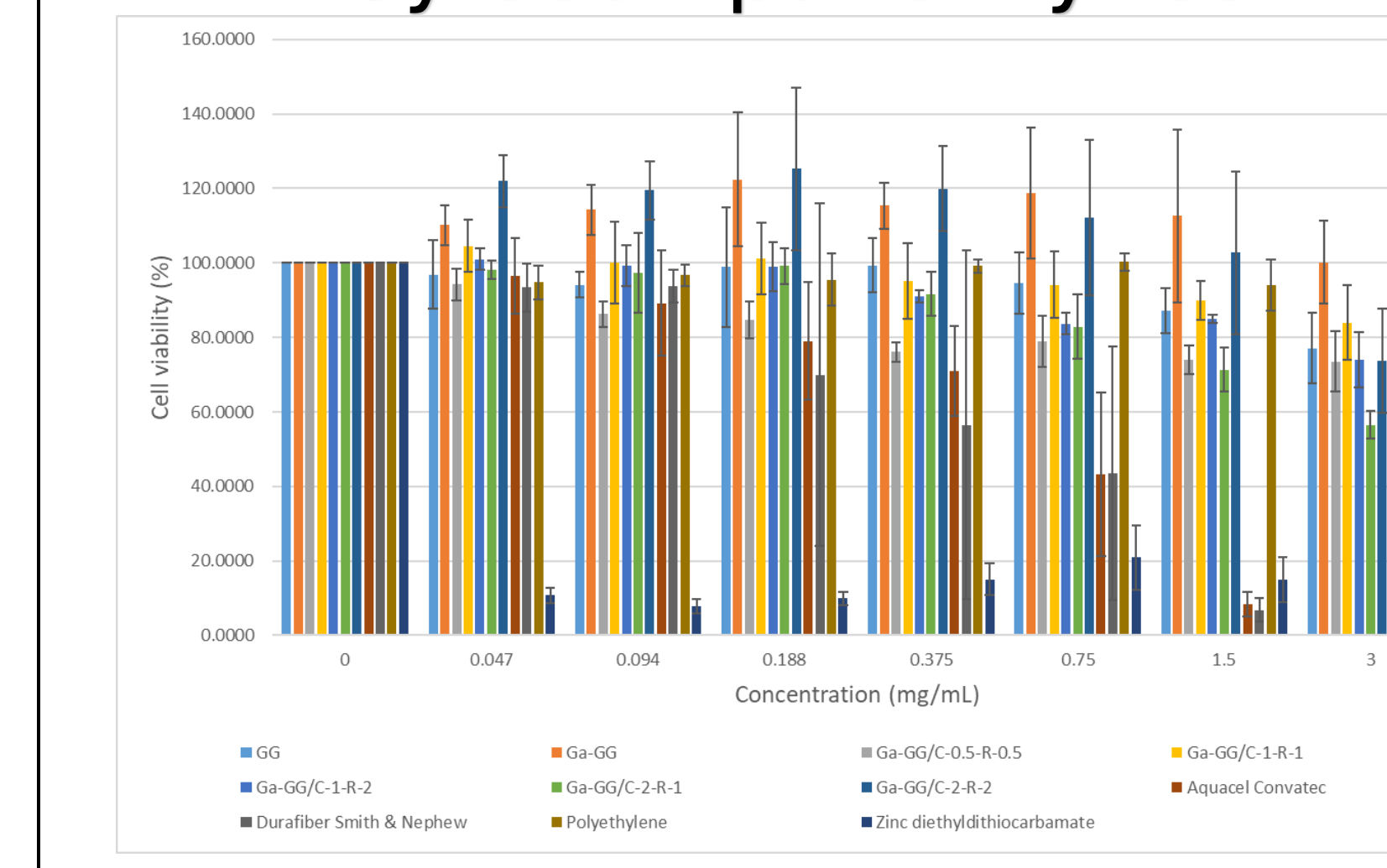
Swelling Analysis



In-vitro Drug Release Analysis

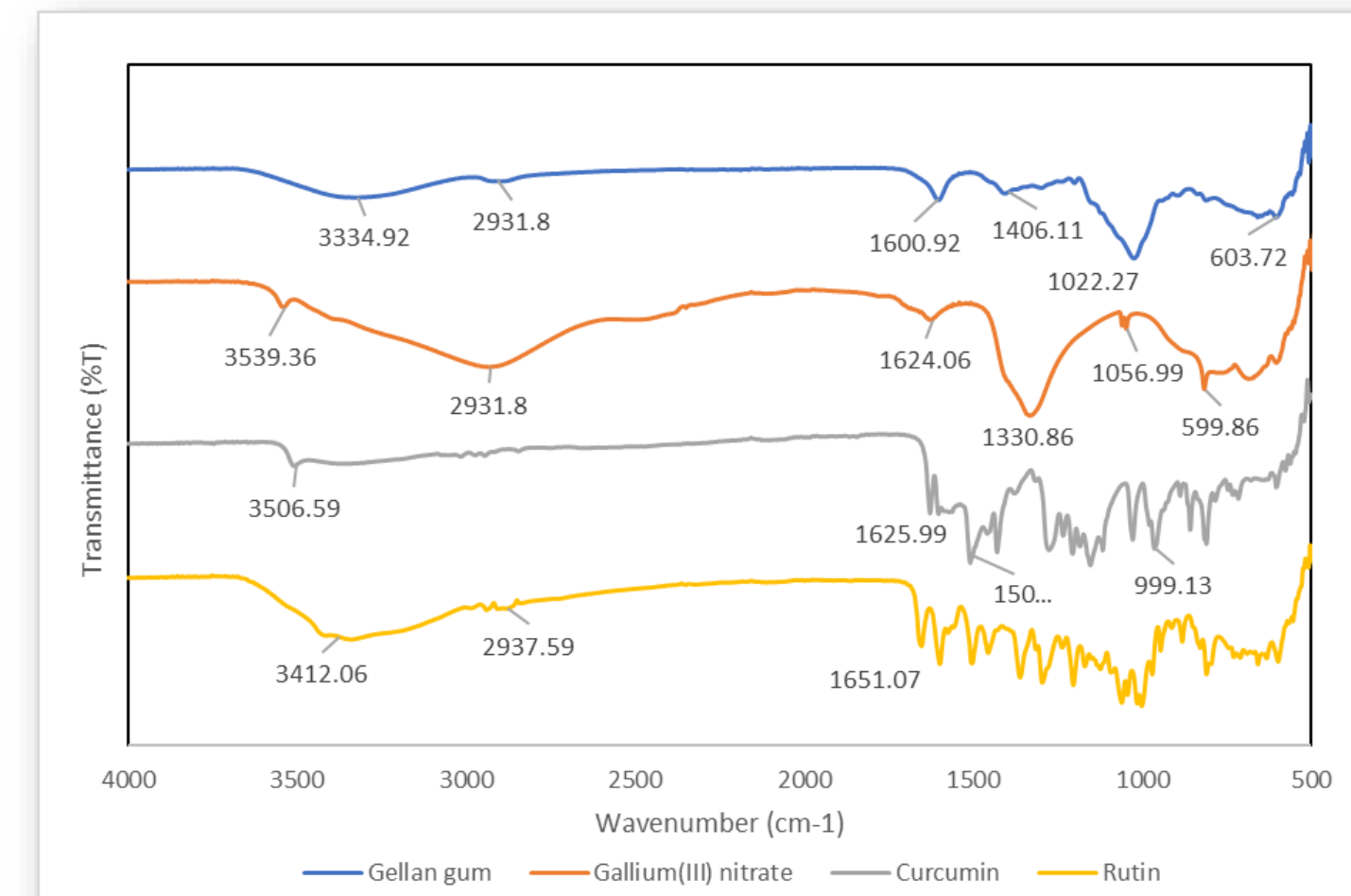


Cytocompatibility Test

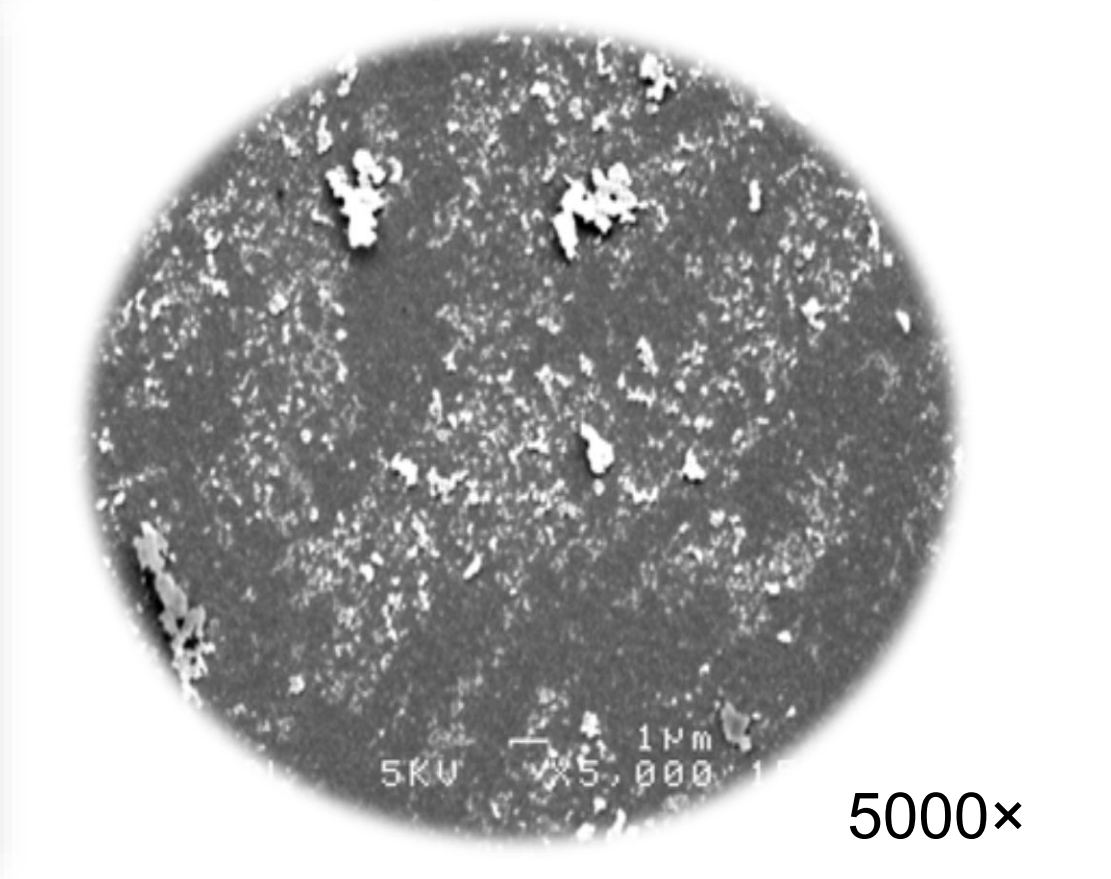


Results

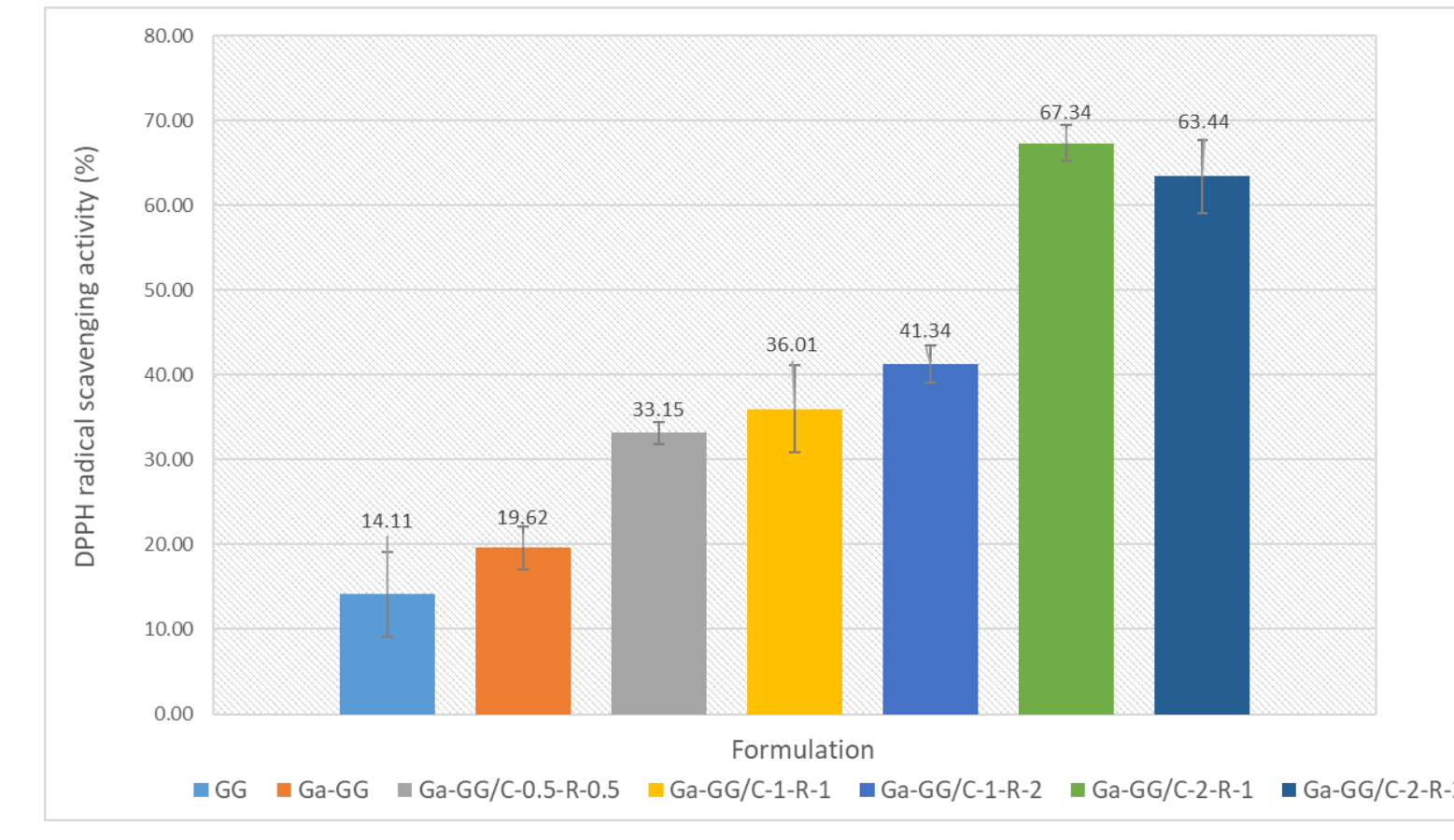
FTIR



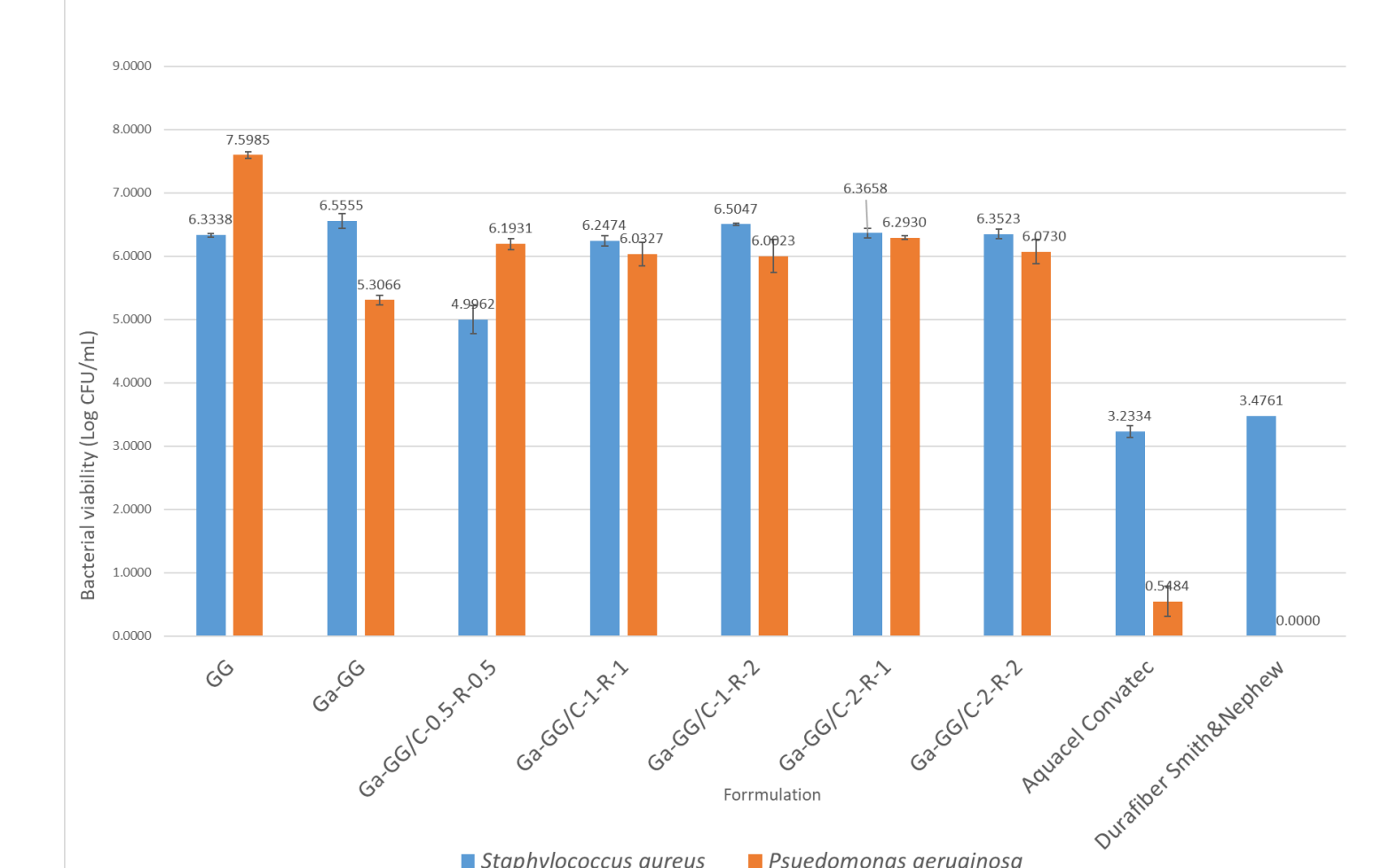
SEM



Antioxidant Analysis



Antibacterial Test



Conclusion

GG hydrogels containing CUR and RU were successfully fabricated via ionic gelation and lyophilisation. Incorporation of CUR and RU into GG hydrogel improves the physicochemical properties, antioxidant activity, antibacterial activity and biocompatibility. Thus, the null hypothesis is rejected, and the alternative hypothesis is accepted.



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