Use of Manuka Honey and Oregano Essential Oil as antibacterial coatings for 3D-printed alginate/PVA/45S5 Bioactive Glass scaffolds

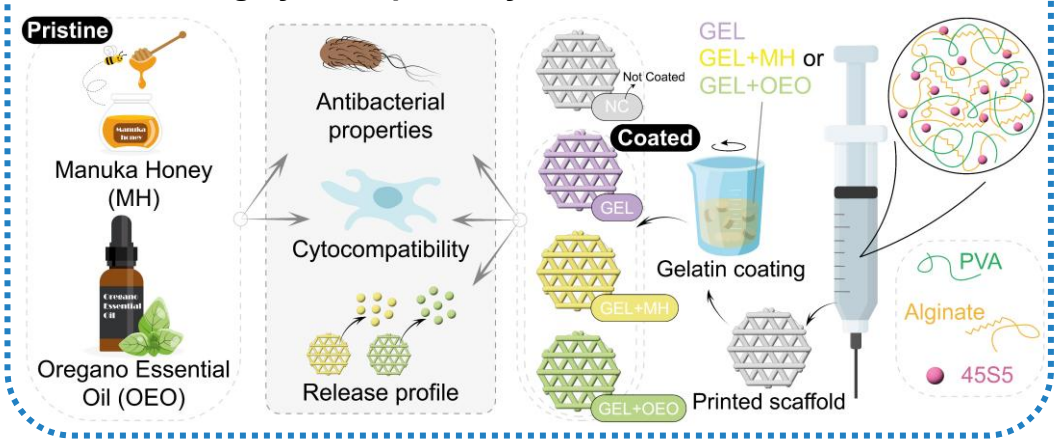
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Introduction

- **Bacterial infections** remain a major challenge in bone tissue engineering, highlighting the need for biomaterials combining **regenerative properties** with **local antibacterial activity**;
- **3D-printed alginate/PVA/45S5** bioactive glass scaffolds provide a promising platform for bone regeneration, while **gelatin coatings** offer an effective strategy for **incorporating bioactive compounds**;
- This study investigated the incorporation of **manuka honey (MH)** and **oregano essential oil (OEO)** into gelatin coatings to impart **antibacterial properties** to 3D-printed composite scaffolds while **maintaining cytocompatibility**.



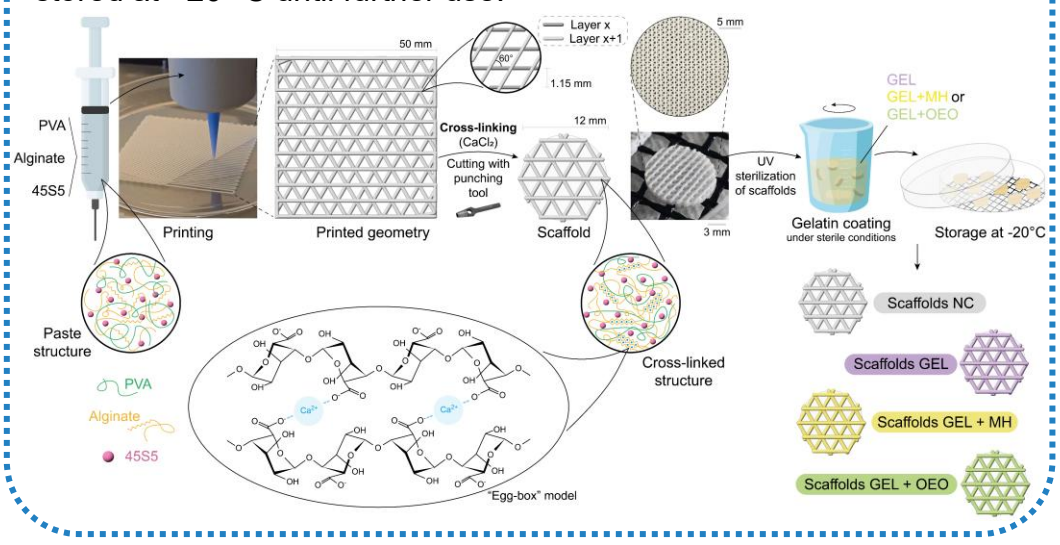
Materials and Methods

3D Printing of Alginate/PVA/45S5 Scaffolds

PVA (6% w/v) was dissolved in DPBS at 80 °C for 30 min. Separately, 45S5 bioactive glass (30% w/v) was dispersed in DPBS by ultrasonication for 10 min. The PVA solution was combined with the bioactive glass suspension, followed by the gradual addition of sodium alginate (10% w/v) under stirring at 37 °C. The resulting paste was transferred into cartridges, centrifuged (3500 rpm, 30 min) for bubble removal, and stored overnight. Scaffolds were fabricated by robocasting (410 µm nozzle) and ionically cross-linked in 1 M $CaCl_2$ for 12 h. The printed structures were cut into 12 mm-diameter discs and UV-sterilized (1 h per side).

Gelatin-Based Coating and Functionalization

Gelatin solution (4.75% w/v) was prepared in HBSS at 50 °C. Microbial transglutaminase (mTG) was used as the cross-linking agent. **Manuka honey (150 µL/mL)** or **oregano essential oil (6.25 µL/mL)** was incorporated into the gelatin solution. Scaffolds were immersed in HBSS for 2 min and subsequently dip-coated in the corresponding gelatin solution for 5 min. Coated scaffolds were stored at −20 °C until further use.



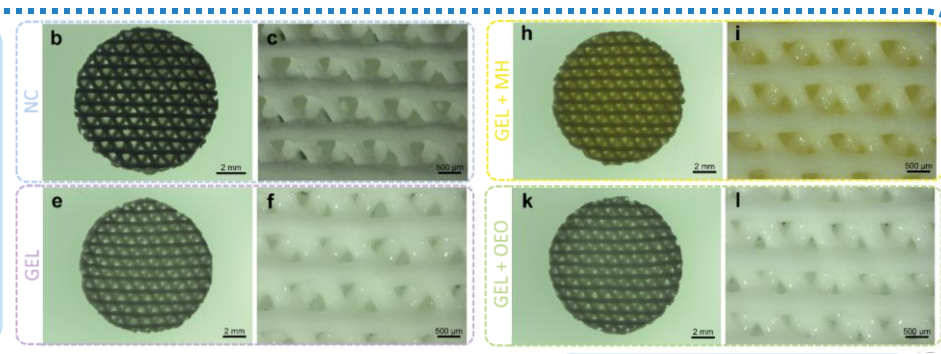
Results

Antibacterial activity of MH

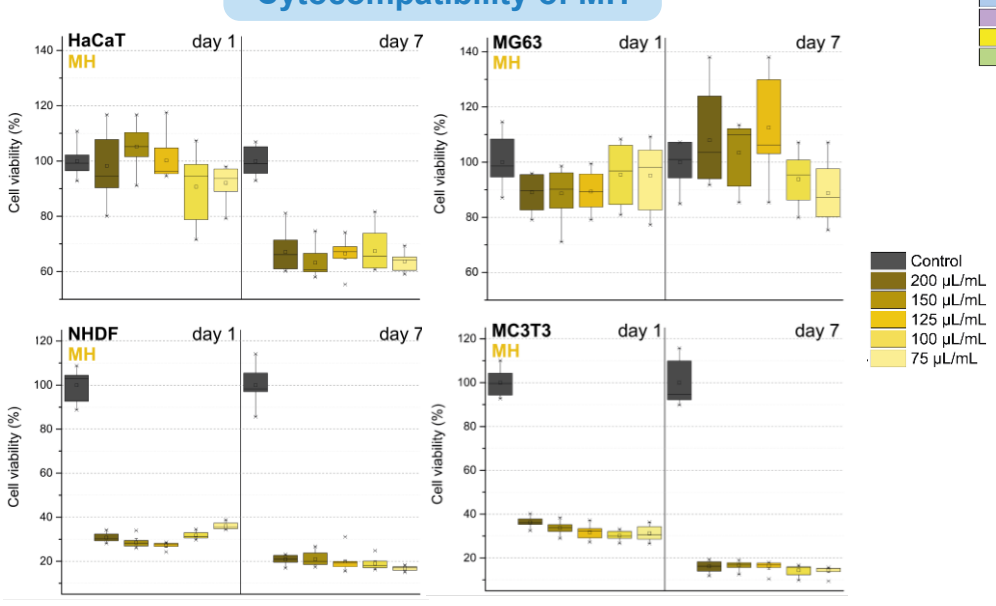


Antibacterial activity of OEO

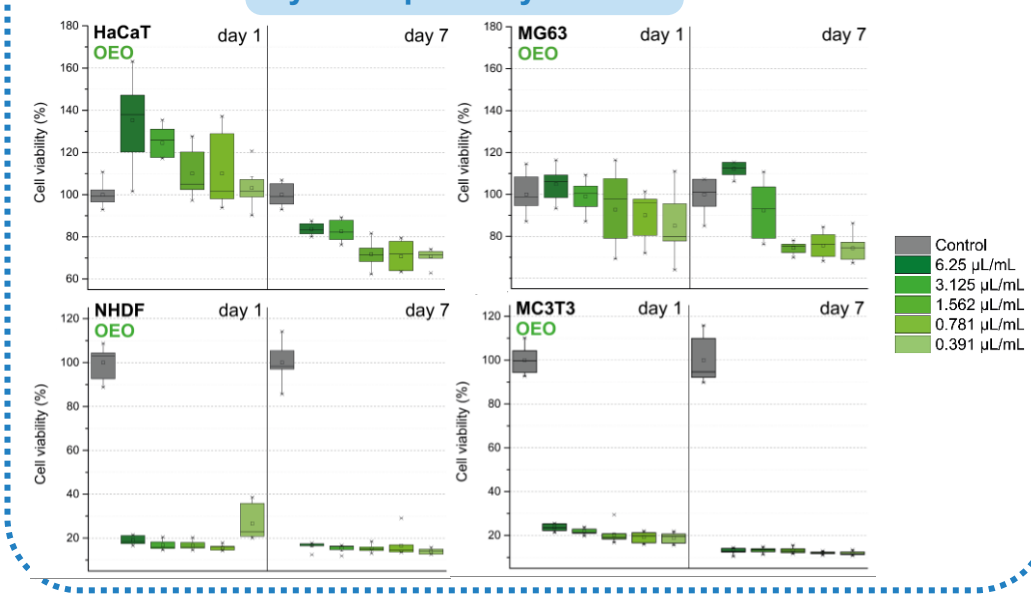
Morphology of the scaffolds



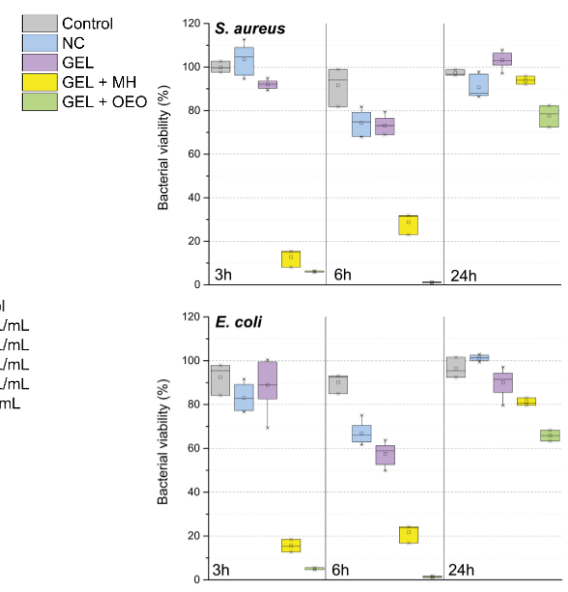
Cytocompatibility of MH



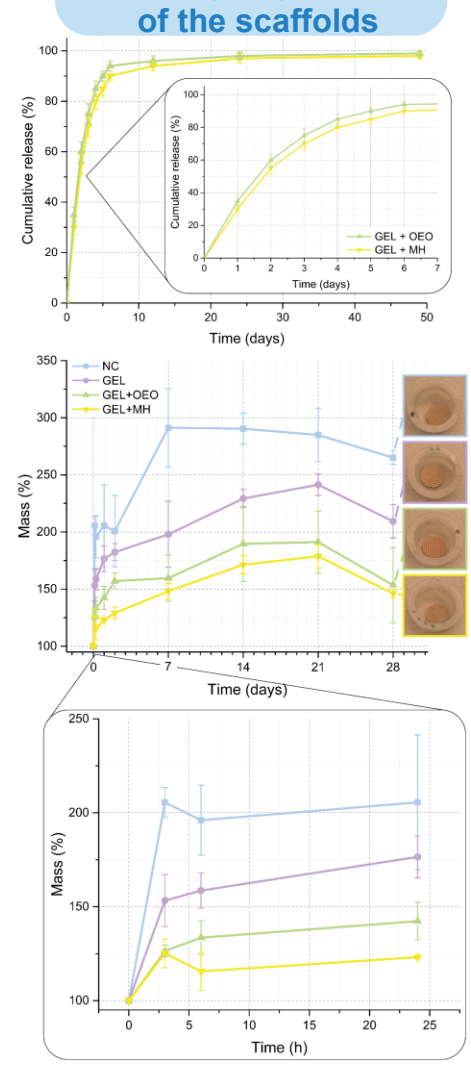
Cytocompatibility of OEO



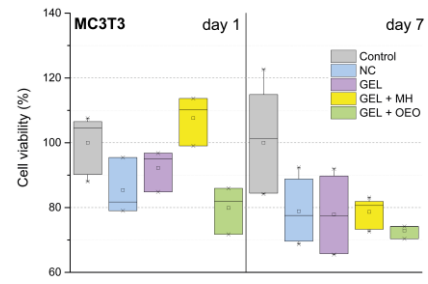
Antibacterial activity of the scaffolds



Release profile and swelling/degradation of the scaffolds



Cytocompatibility of the scaffolds



Conclusions

- Manuka honey (MH) and oregano essential oil (OEO) imparted **antibacterial activity against *S. aureus* and *E. coli*;**
- OEO exhibited **~25-fold higher** antibacterial potency than MH;
- **Gelatin coatings mitigated the cytotoxic effects** of both phytotherapeutic agents;
- Functionalized scaffolds maintained MC3T3 cell viability above 70% over 7 days;
- **Burst release** (~90% released within the first 7 days) enabled **early antibacterial protection** but reduced effectiveness after 24 h;
- The scaffolds show promise for **short-term infection prophylaxis** in bone tissue engineering.

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Acknowledgments

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