IOCG 2025 Conference

The 1st International Online Conference on Gels

03–05 December 2025 | Online

MDPI

# Microstructural, textural and rheological properties of edible bigels designed for 3D food printing

**Zampouni, K., Biza, T., Morfidou, D., Moschakis, T. and Katsanidis E.**

*Department of Food Science and Technology, School of Agriculture, Faculty of Agriculture, Forestry and Natural Environment, Aristotle University of Thessaloniki, Thessaloniki, Greece*

***presenting author: zampounik@agro.auth.gr**

## INTRODUCTION

Three-dimensional (3D) food printing is an emerging technology in food processing, offering high flexibility and customization to meet the growing demand for personalized nutrition and innovative product designs [1]. Bigels, semi-solid systems composed of a hydrogel and an oleogel, present a promising approach as edible inks for extrusion-based 3D food printing due to their structural and functional properties [2].

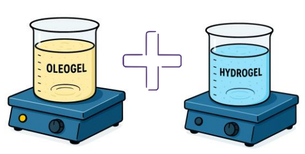
## AIM

**This study aimed to develop and characterize edible bigel inks with optimized properties for 3D food printing applications. Bigels were prepared by blending beeswax–monoglycerides sunflower oil oleogels with gelatin–guar gum hydrogels at varying ratios. Their microstructural, textural, and rheological characteristics were evaluated to assess printability and structural integrity.**

## METHODS

### 1. Preparation of bigel inks

*Sunflower oil*
*Monoglycerides*
*Beeswax*




*Water*
*Gelatin*
*Guar gum*

Mixing at Ultra-Turrax homogenizer *(IKA, Staufen, Germany)* for 2 min 10.000 rpm at 75 °C.


Storage at 4 °C for 24 h before analysis

*Table 1. Composition of bigel inks with different oleogel-to-hydrogel ratios.*

| Bigel inks | Oleogel (%) | Hydrogel (%) |
|---|---|---|
| HG | 0 | 100 |
| BG10 | 10 | 90 |
| BG20 | 20 | 80 |
| BG30 | 30 | 70 |
| BG40 | 40 | 60 |
| BG50 | 50 | 50 |
| OG | 100 | 0 |

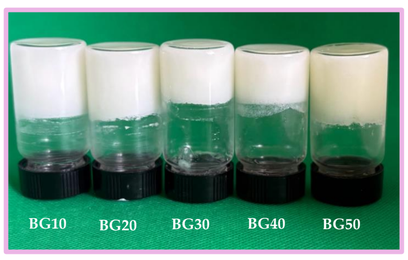



*Fig. 1. Bigel inks.*

### 2. Characterization of bigel inks

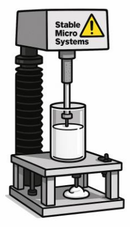
**Microstructural analysis**

Conducted using optical microscopy *(Olympus BX43, Olympus Optical Co. Ltd., Tokyo, Japan)* and confocal laser scanning microscopy *(Leica Microsystems GmbH, Wetzlar, Germany).*

**Forward extrusion analysis**

- Extrudability

*Texture analyzer (XT Plus, Stable Micro Systems, Godalming, Surrey, UK).*




**Rheological analysis**

- Flow curve
- Three interval thixotropy test (3ITT)
- Amplitude sweep test

*(Anton Paar MCR302e, Graz, Austria)*

## RESULTS & DISCUSSION

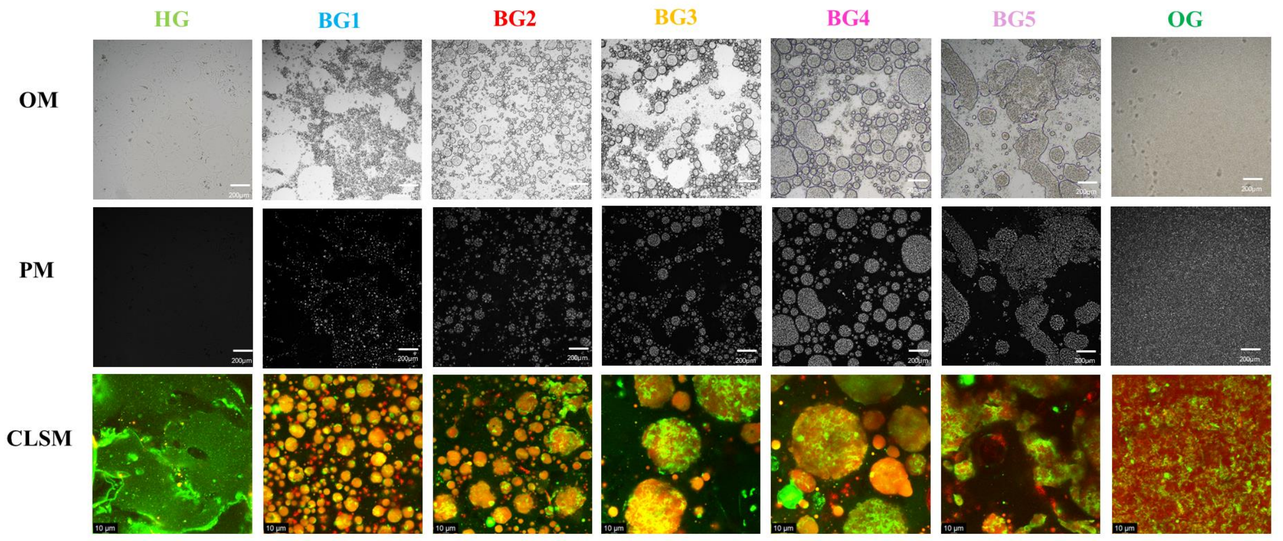



*Fig. 2 Microstructural characterization of bigel inks.*

*Optical microscopy (OM), polarized light microscopy (PM) and confocal laser scanning microscopy (CLSM) images.*

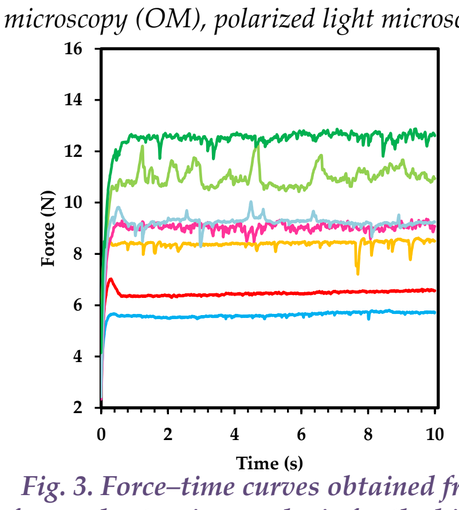



*Fig. 3. Force–time curves obtained from the forward extrusion analysis for the bigel inks.*

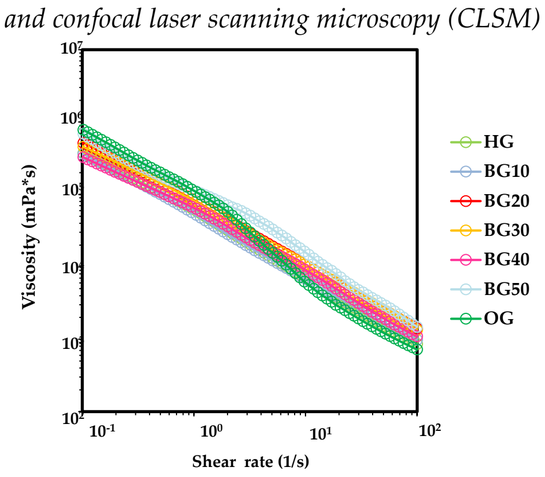



*Fig. 4. Flow curves showing shear-thinning behavior of bigel inks.*

- Microscopy showed that modifying the oleogel ratio formed different bigel microstructures, from oleogel-in-hydrogel to bicontinuous networks.
- Forward-extrusion tests confirmed that all bigel inks can be extruded well under 3D-printing–like conditions.
- All formulations exhibited elastic dominance (G′ > G″) and strong shear-thinning properties, supporting smooth extrusion and stable shape retention after deposition.

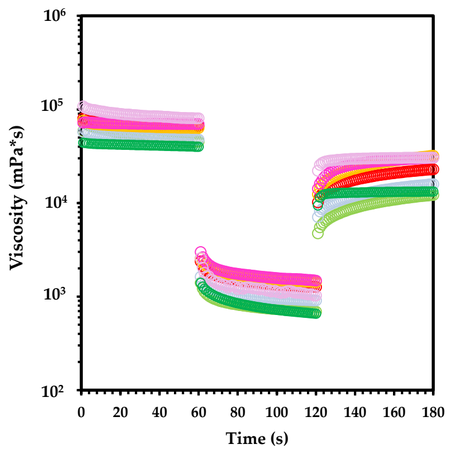



*Fig. 5. Time-dependent viscosity at different shear rates, demonstrating structural recovery.*

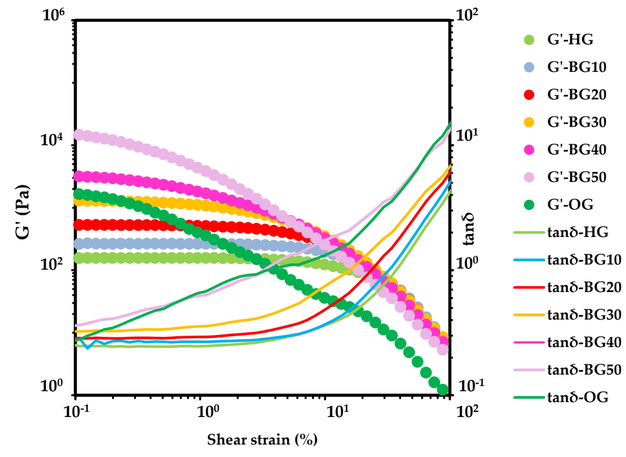



*Fig. 6. Amplitude sweep showing the changes in storage modulus (G′) and damping factor (tan δ) with increasing strain.*

## CONCLUSION

**The oleogel–hydrogel phase ratio in the bigel inks determines their microstructure, rheological behavior and printability.**

## REFERENCES

[1] Gupta, S., & Sharma, S. (2026). 3D printing of functionalized biopolymers: design, processes, and applications. In *Functionalized Biopolymers* (pp. 199-226). Elsevier.

[2] Zampouni, K., Dimakopoulou-Papazoglou, D., & Katsanidis, E. (2024). Food-grade bigel systems: Formulation, characterization, and applications for novel food product development. *Gels*, *10*(11), 712.