

Structuring Algal Oil Nanoemulgels into Gummies via Extrusion-Based 3D Printing for Nutraceutical Delivery

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Abstract

Designing functional food systems for the co-delivery of multiple bioactive components in a single palatable form is a key advancement in personalized nutrition. 3D printing is a transformative approach for engineering customized formulations for tailored and on-demand delivery.

The present study adopts a dual approach to personalized nutrition, integrating a nanoemulgel-based nutraceutical delivery system with 3D printing-driven customization. Algal oil nanoemulsion loaded with cholecalciferol (Vitamin D₃) and magnesium was formulated using an ultrasonication approach. The nanoemulsion exhibited a low mean droplet size ($D_p < 200\text{nm}$), a narrow particle size distribution ($\text{PDI} < 0.2$), and significantly high zeta potential ($\zeta < -35\text{mV}$), indicating good dispersion and electrostatic stability. Further, the nanoemulsion was structured into a nanoemulgel formulation by incorporating in a hydrocolloid matrix using xanthan gum and gellan gum. Rheological properties of the nanoemulgel were tuned to ensure suitability for extrusion-based 3D printing. The nanoemulgel ink was further 3D printed into gummies by optimizing printing conditions such as nozzle diameter, printing speed, and infill properties to obtain good shape integrity.

The developed 3D printed nutraceutical gummies can be customized by varying the bioactive components and their dosages based on the consumer's nutritional requirements. Therefore, the study demonstrates a combined approach of customized nanoformulation design for nutrient delivery, aimed at improved stability and bioavailability.

References

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