ECP 2025 Conference

The 4th International Electronic Conference on Processes

20–22 October 2025 | Online

MDPI

Progress in particle engineering to improve the overall quality and functionality of bioactive compounds in functional drinks

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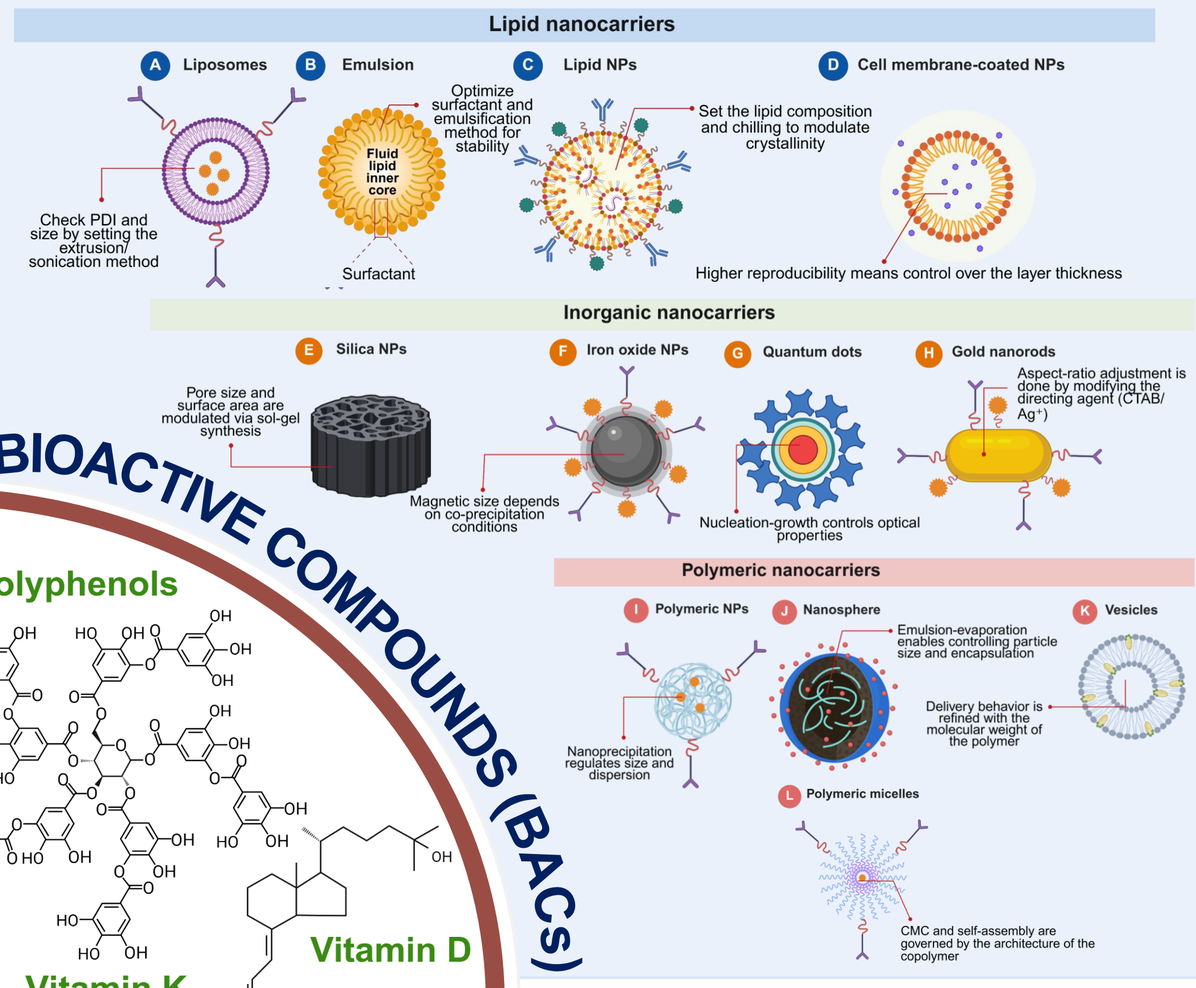
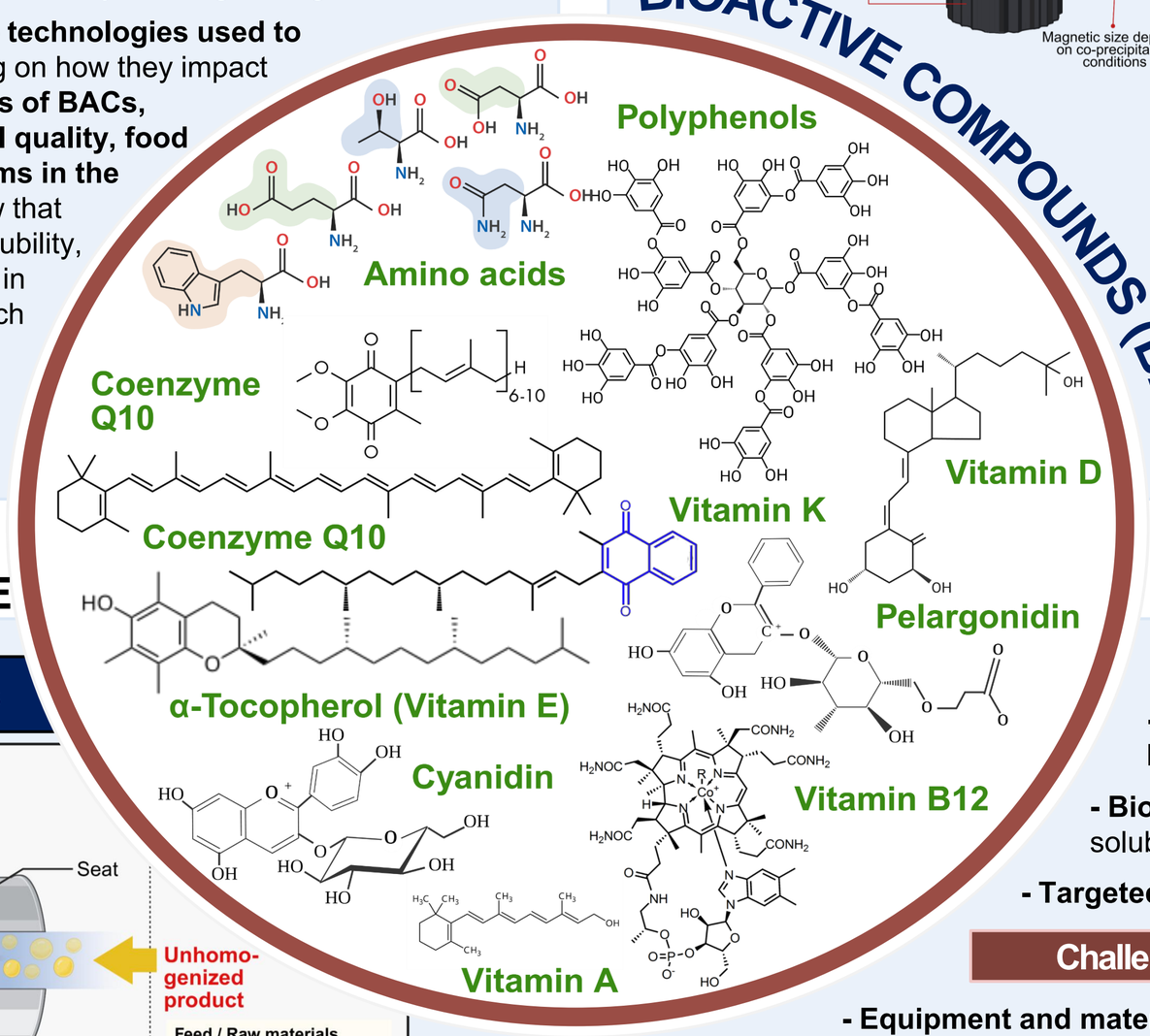
1. INTRODUCTION & OBJECTIVES

There is considerable interest in the use of naturally derived **bioactive compounds (BACs)** in the formulation of **fortified functional drinks** owing to their health benefits. Yet, industrial **scalability raises several challenges,** mainly due to their instability in response to external factors such as pH, light, oxygen, temperature, and sugar content. **BACs such as vitamins, carotenoids, polyphenols, amino acids, coenzyme Q10, and pre-/probiotics are susceptible to degradation during processing and packaging,** which can reduce their effectiveness. **In this context, this systematic review aims to study the use of particle engineering as technological means of optimizing these parameters through techniques including nano- and microencapsulation, and high-pressure homogenization.** The growing demand for **natural products and low-calorie**, healthy functional drinks is driving extensive research on optimizing novel ingredients for these trendy beverage categories.

In conclusion, this study **critically analyzes the technologies used to engineer particles** in functional drinks, focusing on how they impact **the stability, bioavailability, and effectiveness of BACs,** as well as their capacity **to optimize the overall quality, food safety, and commercial viability of these items in the food and nutraceutical markets.** Results show that these methods protect the BACs, boost their solubility, control their release, and preserve their stability in complex liquid matrices. Additionally, factors such as sugar type and quantity, fermentation temperature, and storage time can greatly impact the stability and bioavailability of these compounds.

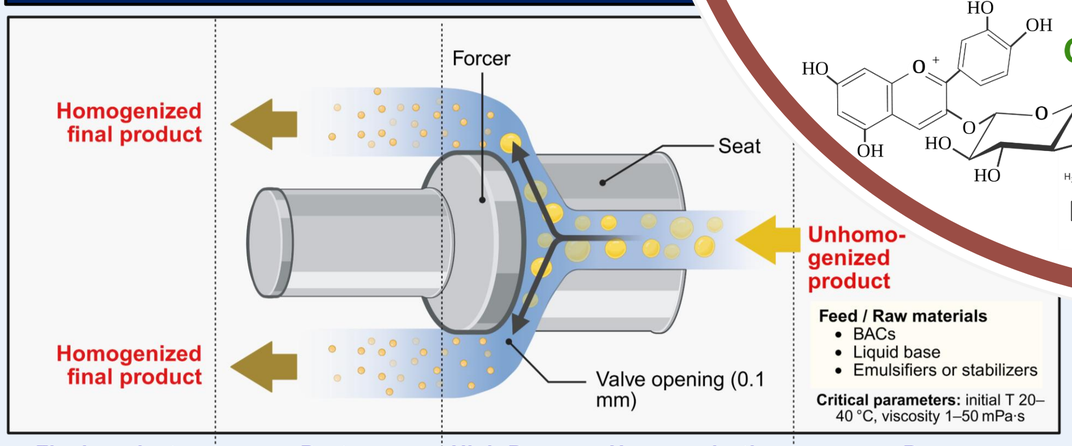
2. NANO- AND MICROENCAPSULATION STRATEGIES





3. HIGH-PRESSURE HOMOGENIZATION TECNIQUE

Technical diagram of the HPH process



4. BENEFITS & CHALLENGES OF PARTICLE ENGINEERING

Benefits

- **Stability Improvement:** Protection from heat, light, pH levels, and oxygen exposure.
- **Bioavailability enhancement:** Improves the solubility and absorption of compounds.
- **Targeted and controlled delivery of ingredients**

Challenges

- **Equipment and materials are highly costly**
- **Production complexity:** Requires specialized know-how and meticulousness
- **Consumer acceptability is affected by changes in taste, mouthfeel, or appearance**

CONCLUSIONS & FUTURE PERPSECTIVES

- **Particle engineering** stabilizes and makes BACs more **bioavailable when added to functional drinks.**
- Nano- and microencapsulation techniques can be used **to protect the BACs during processing, storage, and digestive processes.**
- Further research is still **needed to achieve optimal large-scale industrial applications and sensory quality.**

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ACKNODLEGMENTS

The research leading to these results was supported by Proyectos de Generación de Conocimiento 2023 (PID2023-148814OA-C22) supporting the predoctoral industrial grant for A. Perez-Vazquez (DIN2024-013416) in collaboration with Mercantia Desarrollos Alimentarios S.L; by Xunta de Galicia for supporting the pre-doctoral grant of P. Barciela (ED481A-2024-230). The authors also the EU-FORA Fellowship Program (EUBA-EFSA-2023-ENREL-01) that supports the work of F. Chamorro (INNOV2SAFETY-GA13).