Pickering Emulsions and Their Role in The Food Sector

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Introduction

Emulsions are a dispersion system made of two incompatible liquids, a mixture of one liquid in the form of microscopic droplets scattered in another liquid. Since an emulsion is a thermodynamically unstable system, an emulsifier is essentially needed to attain desired stability. It is employed to prevent, or at least postpone, the separation which may eventually cause emulsions to break down thus making emulsions kinetically stabilize (Berton-Carabin & Schroën, 2015, Chen *et al*., 2020). Pickering emulsion is a type of emulsion that uses solid particles or colloidal particles (Pickering particles) as emulsifiers rather than surfactants to adhere at oil-water interface. It has the superior ability to withstand droplet aggregation, flocculation, and Ostwald ripening. 'Surfactant-free' character makes them attractive over conventional emulsions (Rayees *et al*., 2024)

Mechanism

- The theory of solid particle interface film: due to the capillary force, the partially wetted solid particles in two phases can be adsorbed on the interface to form a dense single-layer or multi-layer particle film offers physical hindrance.
- The three-dimensional viscoelastic particle network mechanism: formation of a 3D network structure between particles and particles, and between particles and droplets under van der Waals force (Chen *et al*., 2020).

Key parameters governing emulsions' stability

The main governing parameters of the formation of Pickering emulsion are, surface wetting properties, dimension of Pickering particles, interfacial tension of emulsion and surface charge. The long-term stability mainly depends on the formulation, but the process also matters since the droplet size is often governed by the shear rate of the emulsification process (Chevalier & Bolzinger, 2013, Low *et al*., 2020).

Preparation methods

Solid particles are initially pre-dispersed in one of the phases, typically the aqueous phase, to ensure adequate wetting. This preparatory step is critical for facilitating the subsequent adsorption and uniform distribution of particles at the oil-water interface. The final properties, such as droplet size, stability, and rheology, are fine-tuned by adjusting particle concentration and type, oil-to-water ratio, and mixing conditions. The preparation methods for Pickering emulsions are diverse and include several techniques (Chen *et al*., 2020; Cheng *et al*., 2024; Gauthier & Capron, 2021; Pandita *et al*., 2024):

High-energy processes:

1) Ultrasonication
2) High-pressure homogenization
3) Rotor-stator homogenization
4) Microfluidic technology
5) Membrane emulsification

Low-energy methods:

6) Spontaneous emulsification
7) Vapor condensation

2) Classification

Pickering emulsions can be systematically classified based on various criteria which includes:

1) Particle type: Stabilizers for Pickering emulsions can be inorganic nanoparticles, organic polymers, or natural biological materials.
2) Volume Fraction: High Internal Phase Emulsions (HIPEs) and low Internal Phase Emulsions (LIPEs).
3) Functional properties: Temperature-Responsive, pH-Responsive and photo response.
4) Type of emulsion: oil in water and water in oil emulsions.

Cheng *et al*., 2024)

Stabilising particle

A large variety of emulsifying particles have been successfully demonstrated as effective Pickering emulsifiers. The choice of particles as emulsifiers is a vital step for the fabrication of stable and functional Pickering emulsions. There is more focus on production of edible emulsions considered as "completely natural" and "clean label" (Jacinto Almeida *et al*., 2024). The core of food-grade Pickering emulsions is food-grade particle. In recent years, as a research hotspot, a large

number of food-grade particles have been discovered, which can be divided as:

1) Polysaccharide particles
2) Protein-based particles
3) Composite particles
4) Microorganism
5) Food-grade wax
6) Fat crystals
7) Agri-food by product

(Meng *et al.*, 2024; Xia *et al.*, 2021)

7) Modification methods

Functional performance of individual natural biopolymer particles is often limited and naturally there are not in particulate form that can be used to form and stabilize emulsion. Consequently, there has been interest in extending their performance by using different modification methods to fine tune the properties of particle to have desired stability. It includes physical, chemical and enzymatic methods (Cui *et al.*, 2021; Zhang *et al.*, 2021).

8) Advantages

- Superior stability
- Stable during spray-drying
- Stimuli-responsiveness
- Fantastic carrier of essential oils
- Easy and simple to prepare
- Intrinsic versatility
- Freeze thaw stability

(Pandita *et al.*, 2024; Rayees *et al.*, 2024; Wu & Ma *et al.*, 2016)

Potential Applications in food industry

- Low-fat products
- Detergents
- Encapsulation and controlled release
- 3D printing technology
- Food preservation and packaging
- Functional foods

(Cheng *et al.*, 2024; Zhang *et al.*, 2023)

- **Challenges**
- Particle Selection and functionalization
- Scalability
- Regulation
- Stability

Future prospectives

- To address scalability issues and commercialization of the Pickering based products.
- Conduct more in vivo and clinical studies to confirm the in vitro results of food grade particles and controlled release of functional compounds.
- Making it affordable as it is more expensive technology than molecular surfactants.
- Need of novel green technologies to modify the particles to have utmost performance.

Conclusion

- Emulsion plays a crucial role in the production of various food products, such as beverages, seasonings, condiments, pastes, desserts, sauces etc. Thus, there is concern for development of safe and food-grade emulsions which can be meet by Pickering emulsions.
- They have enhanced stability and environmental friendliness compared to conventional emulsions which meets the demand of the present world striving for sustainable and healthy products.
- It has significant potential for innovation and enhanced functionality in food and nutraceutical technology. Hence, opening new possibilities through emulsion technology.
- Use of biodegradable and biocompatible stabilizers of natural origin, presents a promising future for the development of Pickering emulsions.

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