Microbubble powders using freeze-dried Pickering emulsions

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Microbubbles are a widely used material in food formulations, as well as in various biomedical and pharmaceutical applications. Typically, microbubbles stabilized by surfactants and proteins tend to coalesce, break, and coarsen quickly. In contrast, microbubbles stabilized by solid nanoparticles, known as Pickering-stabilized microbubbles, can exhibit significantly better stability. Such microbubbles are often produced by directly dispersing gas into a nanoparticle dispersion and allowing the dispersed nanoparticles to adsorb at the air-liquid interface. However, the yield of such a process is low, as a significant amount of gas is lost. In addition, the resulting bubbles are often rather large with a wide size distribution, which decreases the shelf life through Ostwald ripening [2]. To improve the yield and stability of microbubbles, we present an alternative method here. First, we create an oil-in-water (O/W) emulsion, which is known for its high stability and uniform size distribution [3]. After this step, we remove water by freeze-drying, leaving a microbubble powder behind.
In this work, we investigated the potential of different nanoparticles and different volatile oils to prepare stable microbubbles. When hydrophobic silica nanoparticles were used, the produced microbubbles remained stable for up to a week, both in water and solutions with enhanced osmotic pressure. As a more sustainable alternative to silica particles, we also used modified hydrophobic calcium carbonate ($CaCO_3$) nanoparticles. Surprisingly, we achieved a series of even more stable microbubbles that remained intact for over a month. Also, the type of oil used influenced the properties of the microbubbles. This work highlights that the Pickering emulsion template method proves to be an excellent approach for preparing microbubbles, and that the properties can be tuned using different particles and oils. Also, food-grade microbubbles can be prepared.

Keywords:
Microbubble, Pickering-stabilized, hydrophobic nanoparticles, freeze-drying

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