Novel foaming technology applying gas hydrate slurries and its application for foods and upcycled biomass waste streams

SEDIVA Z. (1), WINDHAB E. (1)
1 ETH Zrich, Zrich, Switzerland

A novel technology for foaming viscous food matrices is introduced. The process involves crystalline gas hydrate dispersions as a functional foaming ingredient. Gas hydrates are crystalline inclusion structures consisting of hydrogen-bonded, three-dimensional cages from water molecules, entrapping gas molecules. Main challenges of using gas hydrates as foaming agent are (i) their elevated pressure narrow phase stability domains and (ii) their crystal connectivity favoring aggregate formation (e.g. in pipes/nozzles). Foaming with gas hydrates involves three steps: (i) forming a gas hydrate slurry (GHS), (ii) dosing the GHS into an un-foamed pressurized product stream and (iii) inducing foam formation by expanding the gas hydrate/product mix. Gas hydrate slurries were characterized in terms of gas storage capacity, rheology and expansion behavior. A thermodynamic model for ternary systems was developed for quantitative analysis of the gas distribution in the multiphase system. Homogeneously flowable CO_2 hydrate slurries with an average of 14 vol% hydrate solids and foaming capacities of up to the ca. 160-fold volume of the hydrate crystal volume were successfully processed and applied for foaming of food systems.

The upscaled (pilot scale) technology consists of (i) an in-house (ETH) built gas hydrate formation reactor designed for up to 450 bar operational pressure and (ii) a high-pressure mixing homogenizing unit such as an extruder and/or (iii) a surface-scraped heat exchanger. The pressure range covers the stability region of most gas hydrate formers. We focused on the formation of single-gas CO_2(formation pressure 15-55 bar), mixed gas CO_2/N_2 (formation pressure 15-450 bar) and single gas N_2 (formation pressure 130-450 bar) hydrate crystalline slurries.

The new technology is expected to offer great potential in facilitating micro-foam formation, in most highly viscous matrix fluid systems since the gas hydrate crystals can be used as a "foaming ingredient" (propellant) which can be well dispersed before their gas load release is activated by pressure and/or temperature adaptation. First steps have also been taken in applying the novel gas hydrate-based foaming technology for the valorization of highly abundant cereal and fruit biomass waste streams into foamed biomaterials for fast disposables such as protective packaging and biodegradable foams for plant substrates.