

Suspensions – mixtures of two or more substances that fail to dissolve completely in one another – are found in almost all foods. In a suspension, one or more substances constitute a dispersed phase surrounded by a continuous (usually fluid) phase. At high volume fractions, suspensions increase the viscosity of food or even lend solidity, as demonstrated by our equation of the week:

$$E = \frac{\sigma}{r} (\phi - \phi_c)$$

where r is the radius of the droplets, ϕ_c is the critical volume fraction ($\phi_c \approx 0.64$ for randomly-packed spheres), and σ is the interfacial tension – the energy required to form a given area of interface (units: J/m^2 or, equivalently, N/m). The interfacial tension reflects the fact that water molecules at the phase boundary usually cannot form as many hydrogen bonds as they could if surrounded by other water molecules, so the formation of the interface is unfavorable. In the absence of surfactants, $\sigma = 72 \text{ mN}/\text{m}$ for water-air interfaces and $24 \text{ mN}/\text{m}$ for water-oil interfaces.

As a result of the interfacial tension and curved boundary, the pressure inside round droplets/bubbles is $\Delta p = 2\sigma/r$ higher than the pressure outside. This pressure difference, called the Laplace pressure, makes it difficult to deform small droplets/bubbles against one another when a stress is applied, as conveyed by our equation of the week above.

Four ways that suspensions fail

- Creaming/sedimentation: Separation of phases by gravity due to density differences.
- Coalescence: Bubbles/droplets merge on contact to decrease interfacial energy.
- Phase inversion: The dispersed phase becomes the continuous phase, lowering ϕ .
- Ostwald ripening: Despite an energy barrier, individual molecules from the dispersed phase occasionally dissolve in the continuous phase, through which they can travel to other droplets/bubbles. Over time, there is a net movement of molecules from small bubbles/droplets (where the Laplace pressure is higher) to larger ones.

Strategies for stabilizing suspensions

Surfactants (“surface active agents”) decrease the rate of coalescence and Ostwald ripening. Amphiphilic molecules (those with both non-polar and polar regions), including lipids like lecithin and others found in cell membranes, make excellent surfactants at oil-water interfaces; solid particles like denatured proteins can act as surfactants at both oil-water and air-water interfaces. By coating the surface, surfactants sterically prevent droplets and bubbles from coalescing and hinder individual molecule movement to/from the continuous phase. Some surfactants are also charged, causing active repulsion between droplets/bubbles.

Increasing the viscosity hinders the movement of the dispersed phase through the continuous phase, decreasing the rate of emulsion failure. Changing the temperature can also stabilize an emulsion by altering the viscosity and the solubility of dispersed phase molecules within the continuous phase (potentially limiting Ostwald ripening).