José Andrés argued that spherification is perhaps the most beautiful modern example of gelation. Besides its culinary significance, the physical process that leads to spherification is analogous to many other more common processes in cooking.

Gelation

Gelation occurs when a critical number of cross links occurs in a polymeric material. There are two different types of molecules that commonly crosslink in cooking: (i) Proteins: A protein unfolds, exposing its hydrophobic amino acids, which then stick to hydrophobic amino acids from other unfolded proteins to form a gel. (ii) Carbohydrates: these usually involve some type of binding agent to stick the different carbohydrate molecules together. In spherification, the binding agents are ions which have doubly positive charges (e.g. Ca^{2+}).

A great innovation in modern culinary practice has been the ability to use a wide variety of different gelling agents. These gelling agents are natural ingredients, deriving from plants, sea weed, bacteria, etc. But they can have a vast array of physical properties which effectuate many different qualities in foods – e.g. hot jello, hot ice cream, and Heston Blumenthal's ice tea recipe.

Spherification

Spherification occurs when (negatively charged) alginate, a polymer of sea weed, is dissolved in a droplet of food and placed in a calcium bath. The divalent calcium ions serve as cross links for the alginate polymers. The gel forms from the outside of the droplet – the calcium ions move inwards and cross link the alginate to form a gel. The thickness of the gel layer depends on how long you wait for the gel to form.

The second kind of spherification is called *inverse spherification*. Here we place a droplet containing calcium in an alginate bath. This is natural when using milk product, which naturally contain calcium. A gel layer still forms on the outside, exactly as in direct spherification. But now when the droplet (containing calcium) is removed from the bath the gelation reaction stops – so the gel layer keeps constant thickness.

Diffusion

The physical process that describes the motion of the calcium ions is called diffusion. This involves a motion of the ions that scientists call the *random walk*. The ions randomly switch directions – but on average make net progress over time. The equation characterizing their progress is

$$L = \sqrt{4Dt},$$

where L is the distance the ions move and t is the time elapsed. If L is measured in cm and t in seconds, then the diffusion constant D has units cm^2/sec. The diffusion constant of a calcium ion in water is $8 \times 10^{-6}\ \text{cm}^2/\text{sec}$. We use this equation to predict the thickness of a spherification shell. Another important example of diffusion in cooking is osmosis, where the molecule diffusing is the solvent (usually water).

Additional materials available online

- Derivation of $L = \sqrt{4Dt}$ (Advanced)
- ATK video on scrambled eggs
- Critical bond fraction for gelation (Advanced)

Science Review Questions

1. Which of the following has an underlying physical process analogous to spherification:
   (a) Ricotta cheese
   (b) Cooking a steak
   (c) Making Jell-O
   (d) Sautéeing an onion

2. The solution to the problem of the random walk was discovered by
   (a) Albert Einstein
   (b) Carl Pearson
   (c) Isaac Newton
   (d) Henri Poincaré
   (e) Louis Bachelier

3. José Andrés showed us a remarkable example of spherifying an egg made of parmesan cheese. Suppose he placed the droplet of cheese containing calcium in an alginate bath for 3 minutes. Using the equation of the week, $L = \sqrt{4Dt}$, calculate the thickness of the resulting shell. (The diffusion constant of calcium is $D = 8 \times 10^{-6}$ cm^2/sec.)

4. Suppose that Jose forgot to start his stopwatch when he put the spherified egg in the bath. After getting it out of the bath, he decided that the recipe was perfect and he needed to figure out how long he left it in. He measures the thickness of the shell to be 3 mm. How long did he leave the spherified egg in the bath?

5. True or False. If you sautée a salted onion, it will have a higher water content after you are done than if you didn't salt the onion beforehand.