SIDEBAR 1: MOLTEN CHOCOLATE CAKE

Molten Chocolate Cake

Ingredients

130 g dark chocolate chips
120 g unsalted butter (1 stick)
2 whole eggs plus 2 egg yolks
100 g sugar
60 g all-purpose flour
Pinch salt

Directions

1. Preheat the oven to 350°F (177°C). Spray 8 ramekins with nonstick baking spray.
2. In a small saucepan, melt the chocolate and butter together over low heat, stirring constantly.
3. In a medium bowl, whisk together the eggs, egg yolks, and sugar.
4. In another bowl, whisk together the flour and salt.
5. Slowly add the chocolate mixture to the egg mixture, whisking constantly.
6. Little by little, add the flour mixture to the wet ingredients and whisk well. Make sure all of the flour is completely incorporated.
7. Fill the prepared ramekins with batter so that they are a little more than half full (1.5 cm to 2 cm from the top).
8. Place the ramekins on the middle rack of the oven and bake for 12 minutes.
9. Serve warm, preferably topped with ice cream!

Molten chocolate cake, lava cake, moelleux au chocolat—regardless of what you call this dessert, the combination of soft cake with the surprise of a gooey center is one that has universal appeal. Molten chocolate cake is actually a cake that has been under-baked so that the center is still a runny batter. For this reason, this cake has been used in the Science and Cooking course since its inception to study heat diffusion. As the cake cooks, the batter around the edges reaches the temperature at which it solidifies and forms a "crumb front" that moves toward the center of the cake. If you were to take temperature measurements during the cooking process, you could calculate the heat diffusion constant of the cake batter. In the course, we use a special thermometer with multiple probes placed at different distances from the cake center.

What does our equation say about how far heat moves in 12 minutes? To find out, we need to put the values for t and D into our equation. The time elapsed is 720 seconds and the diffusion coefficient for heat in water is 0.0014 cm^2/sec. Our equation then shows that the distance heat should have traveled in this time is about 2 cm, which is a pretty reasonable crumb thickness for a molten chocolate cake.

$$L = \sqrt{4Dt} = \sqrt{4 \times 0.0014 \text{ cm}^2/\text{sec} \times 720 \text{ sec}} = 2 \text{ cm}$$

At this point, you should make the chocolate cake and check out for yourself whether it works!

What is truly amazing about our equation for the diffusion of heat is that we can use exactly the same reasoning to find out how long we need to cook a medium steak and how long to fully cook the fish in ceviche. The typical recommendation for a medium steak is to cook it for about 5 minutes on each side. According to our equation, the heat diffuses 1.3 cm in this time. Double the time for both sides and you get a distance that isn't so far from the thickness of a typical steak.

For ceviche, the entity that diffuses is not heat but hydrogen ions, the molecules in lemon juice that are ultimately responsible for cooking ceviche. Hydrogen ions move at a different rate than heat. Our equation remains exactly the same, but the value of the diffusion coefficient changes. For hydrogen ions, it is $D = 0.000005$ cm^2/sec. If we use our equation, we thus find that the hydrogen ions move 0.9 cm in 12 hours. If you have ever cooked ceviche so that the fish cooks all the way through, you know this is pretty accurate. Often, we cut the fish into small pieces

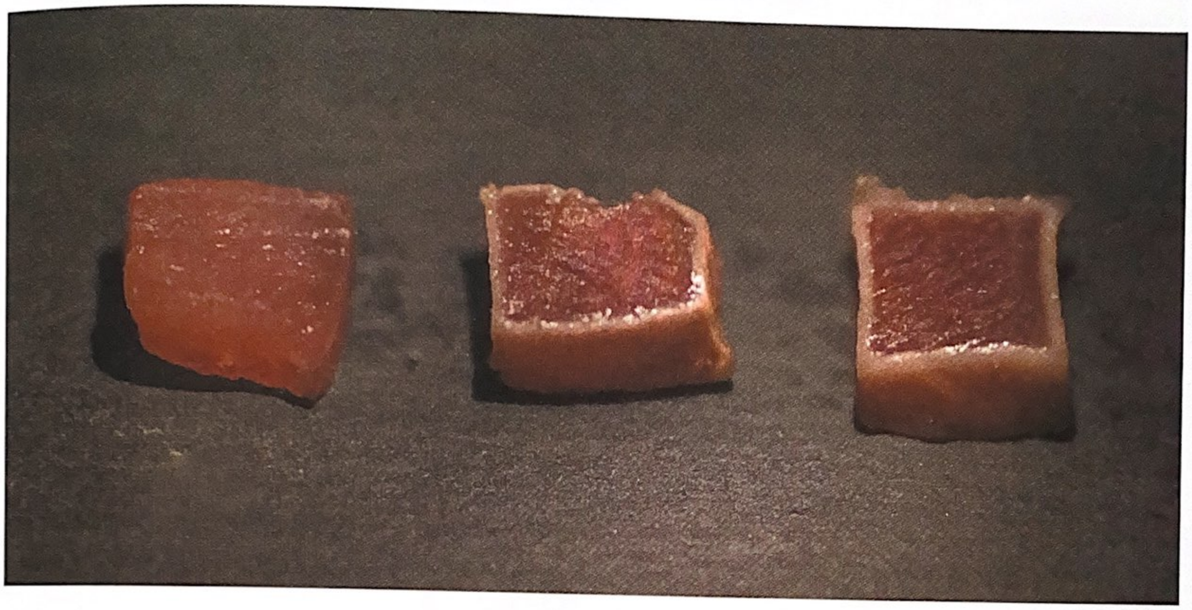

FIGURE 3 The image shows cubes of tuna fish that have been submerged in lime juice for 0 minutes, 30 minutes, and 90 minutes. The flesh is still red in the center. The lime juice has diffused only a short distance, resulting in a "cooked" layer of whiter fish.

before putting it in the lemon juice; this means that the ions have less distance to go and so can get there in a shorter amount of time.

Many recipes these days call for ceviche to be cooked for much shorter times. Chef Virgilio Martínez immerses the fish for less than a minute, which, according to our equation, allows the hydrogen ions to travel only 0.3 mm. They barely get into the fish at all, so the result is a very thin coating of cooked fish, almost like eating sushi.

Spherification Revisited

We described spherification in chapter 3, focusing on Ferran Adrià's recipe and the role that charged calcium ions play in sticking the alginate polymers together. But the gelation of alginate polymers is not the only reason this recipe works. At the very heart of the recipe is, you guessed it, diffusion. In fact, while spherification has lost some of its novelty in the chef community in the last few years, we still love it because it is such a marvelous example of how many different scientific concepts come together. Let's reexamine Adrià's recipe to see how.