Alex Iacob

Prof. Lanzafame

CHMG 142

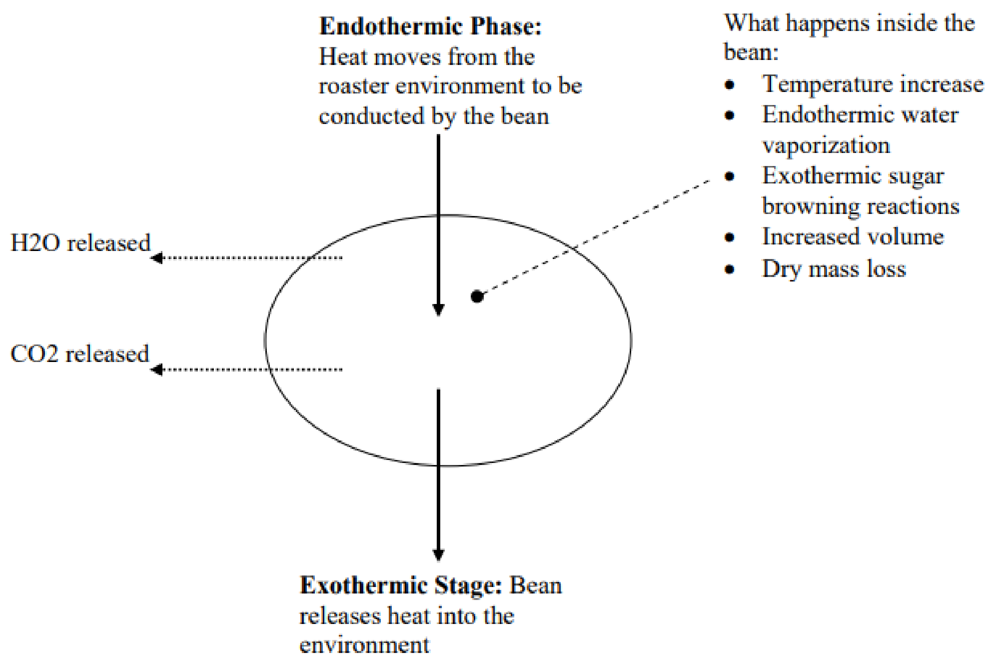
April 27, 2021

The Maillard Reaction

The Maillard reaction is a reaction that nearly every cook uses to make their food taste good. This is often described as caramelization or the “browning” of foods. More specifically, this is a chemical reaction between the food’s amino acids and reducing sugars. This reaction leads to the distinctive flavors of seared meat, fried potstickers, bread, toasted marshmallows, and many more. This reaction was initially described by French chemist Louis Camille Maillard in 1912 while attempting to reproduce protein synthesis. This discovery leads to further discussions in the food sciences about the said reaction.

The Food Lab describes the reaction as “many small simultaneous chemical reactions that occur when the proteins and sugars in and on your food are transformed by heat, producing new flavors, aromas, and colors.” The strength of this reaction is often based on the food itself. Each food has a different ratio of protein, sugar, and water. A steak, for example, is a muscle, which is mostly protein and water with little sugar. This high protein concentration leads to a Maillard reaction that yields more flavor molecules and less aromatic ones. In contrast, a cookie is mostly sugar. This high concentration of sugar leads to a Maillard reaction that yields more aromatic molecules than flavor ones.

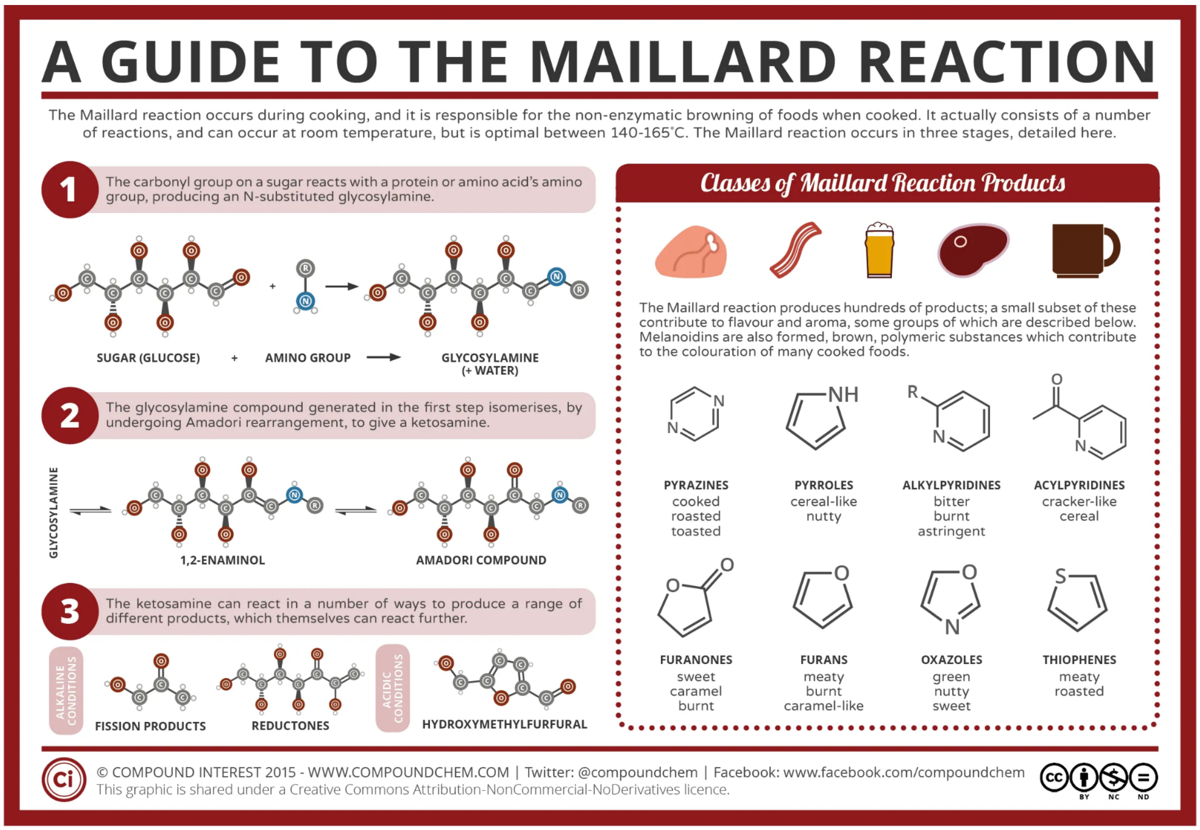
In the Maillard reaction, the thermodynamics of the reaction can be described as the temperature and energy of food once it begins cooking. When any form of cooking happens, food is brought to contact with a degree of heat. The transfer of heat then proceeds to start the cooking process in the food itself. For coffee beans, the visual example for thermodynamics is the roasting of the bean itself. When a coffee bean is inside a roaster, the heat in the environment and the system are taken into account when creating a roast. While being roasted, the coffee bean begins an endothermic phase, where the bean absorbs heat from the roaster environment. While this is happening, H_2O and CO_2 are being released from the environment. Inside the coffee bean itself, the internal temperature increases, there is dry mass loss, increased volume, water vaporization, and sugar browning (Image below).



Considering this form of roasting, the most accurate model for this system is the Second Law of Thermodynamics, which states that heat flows in one direction, from a hotter system/environment to a colder system/environment. Many factors play into how fast this transfer can happen; however, one of the most prominent factors is the difference in temperature between each system/environment. When the coffee bean is being roasted, many changes occur to the bean due to its thermodynamics. The first change occurs within the coffee bean while it is being heated up. The surface moisture begins to vaporize, which is an endothermic reaction. While this vaporization occurs, the Maillard reaction can begin. The reaction starts when the coffee bean's internal temperature is around 160ºC. This signifies the gradual move of an endothermic to an exothermic reaction. The activation energy for the exothermic reaction begins when the sugars reach 175ºC, and the Maillard process can begin.

The nitrogen within the amino acid bonds to the carbon chain gives off one single molecule of water. This changes the structure of the chain then reacts again into one of three compounds: a compound that loses more water molecules to create caramel molecules, break down into shorter chain molecules like diacetyl to develop foods with a buttery flavor, or break down into more amino acids. Each of these reactions can further break down into molecules named melanoidins. These molecules are known for their "roasted, amity, bready, bitter, and burned flavors." While the coffee bean is being roasted, the change in the internal energy of the roasting system is the sum of the entering heat and the heat being created from the Maillard reaction. As the sugars break down, more heat is added to the system internally. This leads to an internal pressure buildup that then signifies the beginning of the exothermic reaction. This pressure build-up then cracks the bean, which indicates the climax of the exothermic reaction.

The Maillard reaction in coffee beans relies on thermodynamics to roast to develop more profound and more complex flavors. This roasting mainly follows the Second Law of Thermodynamics, which states that heat travels from the warmer system to the colder system. Using this, when coffee beans are heated up, the bean absorbs heat from its environment, then once the internal temperature is high enough, the Maillard reaction can occur. It is responsible for creating the roasted and deep flavors of any deeply roasted coffee. In other foods, different chemicals are released to create different flavor compounds (Image below). For example, when a cut of meat is seared and cooked, the Maillard reaction would create thiophenes and furans. The seared surface is made from the released melanoidins as “formed, brown polymeric substances.”



For learning more about the reaction, I would have liked to find more concise and in-depth articles about the Maillard reaction in more foods. The one that I did find was a research paper about coffee bean roasting. I would have liked to find a report of similar contents about searing various meats. As for the reaction itself, I would have wanted to find something that explained the equilibrium constants or describe the enthalpy/entropy of the system. From there, finding more sources to get a broader understanding of how different chemical compounds can create other unique flavors of coffee.

Sources

- Schulze, Eric. “An Introduction to the Maillard Reaction: The Science of Browning, Aroma, and Flavor.” *Serious Eats*, Serious Eats, 25 Sept. 2019,
- Interest, Post author By Compound, et al. “Food Chemistry – The Maillard Reaction.” *Compound Interest*, 3 May 2015, www.compoundchem.com/2015/01/27/maillardreaction/.
- Songer, Paul, “A Thermodynamic Approach to Roasting Parameters and Stages of Roast” https://www.datocms-assets.com/949/1488852277-a-thermodynamic-approach-to-roasting-parameters-and-stages-of-roast-pdf
- “Second Law of Thermodynamics.” *NASA*, NASA, www.grc.nasa.gov/www/k-12/airplane/thermo2.html.
- “The Maillard Reaction - The Reason Your Coffee Tastes Like Coffee.” *Fellow*, fellowproducts.com/blogs/learn/the-maillard-reaction-the-reason-your-coffee-tastes-like-coffee.