



SCIENCE of COOKING

Biochemistry and Biotechnology 100 - Dragon Core Area 4 with Lab



Why Foods Brown – The Maillard Reaction



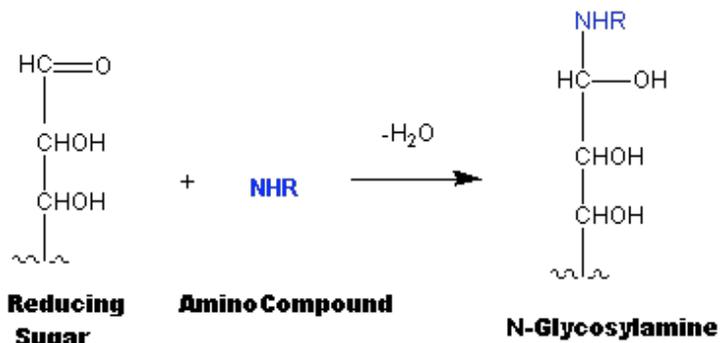
Chicken breast with carrots cooked at 200oF



Chicken breast with carrots cooked above 300oF

The Maillard Reaction (also known as browning) is a type of non-enzymatic browning which involves the reaction of simple sugars (carbonyl groups) and amino acids (free amino groups). They begin to occur at lower temperatures and at higher dilutions than caramelization.

Browning, or the Maillard reaction, creates flavor and changes the color of food, the taste and color to baked bread and even the turning of beer brown. Maillard reactions generally **only begin to occur above 285°F (140°C)**. Until the Maillard reaction occurs meat will have less flavor. Shown above are two identical dishes cooked (left) below (140°C) and right at much higher temperatures. Both caramelization and the maillard reaction only occur on the right producing the noticeable brown color.



The **Maillard reaction** is a chemical reaction between an amino acid and a reducing sugar, usually requiring the addition of heat. The reactive sugar interacts with the amino group of the amino acid, and an interesting but poorly characterized odor and flavor molecules result. This process accelerates in an alkaline environment because the amino groups do not neutralize. This reaction is the basis of the flavoring industry, since the type of amino acid determines the resulting flavor.

In simple terms, certain foods contain carbohydrates in the form of sugars, while others contain amino acids in the form of proteins. These sugars and amino acids often exist side-by-side, as in the case of raw meats. They may also be blended together, as in the case of bread dough. As long as there is no outside catalysts, or cause for change, the meat remains red and the bread dough remains white.

The Maillard reaction is the catalyst for change, primarily by the addition of heat. When bread dough or meat is introduced to a hot oven, a complex chemical reaction occurs on the surface. The carbon molecules contained in the sugars, or carbohydrates, combine with the amino acids of the proteins. This combination cannot occur without the additional heat source. The end result of this chemical recombination is the Maillard reaction. The surface of the heated bread dough is now brown, as is the outer layer of the roasted meat.



SCIENCE of COOKING

Biochemistry and Biotechnology 100 - Dragon Core Area 4 with Lab



Not only do the combined sugars and amino acids change the appearance of the food, but they change the flavor as well. The Maillard reaction is responsible for the savory flavor of roasted meats, as well as the toasted flavor of baked breads. When bread is placed in a toaster, the Maillard reaction causes the outer layer of carbohydrates and proteins to combine. The result is a piece of browned toast. Recipes containing both eggs, which contain protein, and flour, which contains carbohydrates, benefit from the Maillard reaction to achieve a pleasing browned appearance.

AMINO ACIDS - Amino acids called lysine gives most of the color to browning reactions. This amino acid is naturally occurring and because it has an amino group in its side chain, is able to react well with the sugars producing a rich color and taste. Thus those foods rich in lysine will brown nicely. Whey is a lysine rich protein and when used as a food additive can help brown the food. Breads also brown well due to the content of lysine in flour.

SUGARS – Some sugars react better than others. Ribose, a simple sugar found in beef, pork, salmon, and chicken as well as mushrooms react the most with amino acids. Glucose, another simple sugar found in pasta, cereals and rice will brown but not as well as ribose. While lactose (the milk sugar) doesn't react well at all with amino acids and is why milk sugars burns rather than browns.

Although used since ancient times, the reaction is named after the chemist Louis-Camille Maillard who investigated it in the 1910s as he was working on protein synthesis.

Products with Maillard reactions

The Maillard reaction is responsible for many colors and flavors in foodstuffs:

- caramel made from milk and sugar
- the browning of bread into toast
- the color of beer, chocolate, coffee, and maple syrup
- self-tanning products
- the flavor of roast meat
- the color of dried or condensed milk
- 6-acetyl-1,2,3,4-tetrahydropyridine is responsible for the biscuit or cracker-like odor present in baked goods like bread, popcorn, tortilla products.
- 2-acetyl-1-pyrroline flavours aromatic varieties of cooked rice. Both compounds have odor thresholds below 0.06 ng/l.

For those biochemists in the crowd (*the rest of this reading is not required for the science of cooking class*) - An outline of the Maillard reaction is given in the figure above. Maillard reactions have three basic phases. The initial reaction is the condensation of the carbonyl group of a [reducing sugar](#) (aldose) with a free amino group of a protein or an amino acid, which loses a molecule of water to form N-substituted glycosylamine (Step A). This is unstable and undergoes the "Amadori rearrangement" to form "1-amino-1-deoxy-2-ketoses" (known as "ketosamines") (step B). The ketosamine products of the Amadori rearrangement can then react three ways in the second phase. One is simply further dehydration (loss of two water molecules) into reductones & dehydro reductones (step C). These are essentially "caramel" products and in their reduced state are powerful antioxidants. A second is the production of short chain hydrolytic fission products such as diacetyl, acetol, pyruvaldehyde, etc (step D). These then undergo "Strecker degradation" with amino acids to aldehydes (step E) and by condensation to aldols, or they may react in the absence of amino compounds, to give aldols and high molecular weight, nitrogen-free polymers (step F). A third path is the Schiff's base/furfural path. This involves the loss of 3 water molecules (step C), then a reaction with amino acids and water. All these products react further with amino acids in the third phase to form the brown nitrogenous polymers and copolymers called **melanoidins** (step G). These can be off flavours (bitter), off aromas (burnt, onion, solvent, rancid, sweaty, cabbage) or positive aromas (malty, bread crust-like, caramel, coffee, roasted). Step H in Figure 1 illustrates a direct route to fission products from N-substituted glycosylamines, without the formation of an ARP (Amadori rearrangement product)

In the process, hundreds of different flavor compounds are created. These compounds in turn break down to form yet more new flavor compounds, and so on. Each type of food has a very distinctive set of flavor compounds that are formed during the Maillard reaction. It is these same compounds that flavor scientists have used over the years to



SCIENCE of COOKING

Biochemistry and Biotechnology 100 - Dragon Core Area 4 with Lab



create artificial flavors.

The process

1. The carbonyl group of the sugar reacts with the amino group of the amino acid, producing N-substituted glycosylamine and water
2. The unstable glycosylamine undergoes Amadori rearrangement, forming ketosamines
3. There are several ways for the ketosamines to react further:
 - Produce 2 water and reductones
 - Diacetyl, aspirin, pyruvaldehyde and other short-chain hydrolytic fission products can be formed
 - Produce brown nitrogenous polymers and melanoidins

Key Factors

- Pentose sugars react more than hexoses, which react more than disaccharides.
- Different amino acids produce different amounts of browning.
- Since the Maillard reaction produces water, having a high water activity environment inhibits the reaction.

References *An Expedient, High-Yielding Construction of the Food Aroma Compounds 6-Acetyl-1,2,3,4-tetrahydropyridine and 2-Acetyl-1-pyrroline* Tyler J. Harrison and Gregory R. Dake *J. Org. Chem.*; **2005**; 70(26) pp 10872 - 10874; (Note) DOI: 10.1021/jo051940a [Abstract](#)

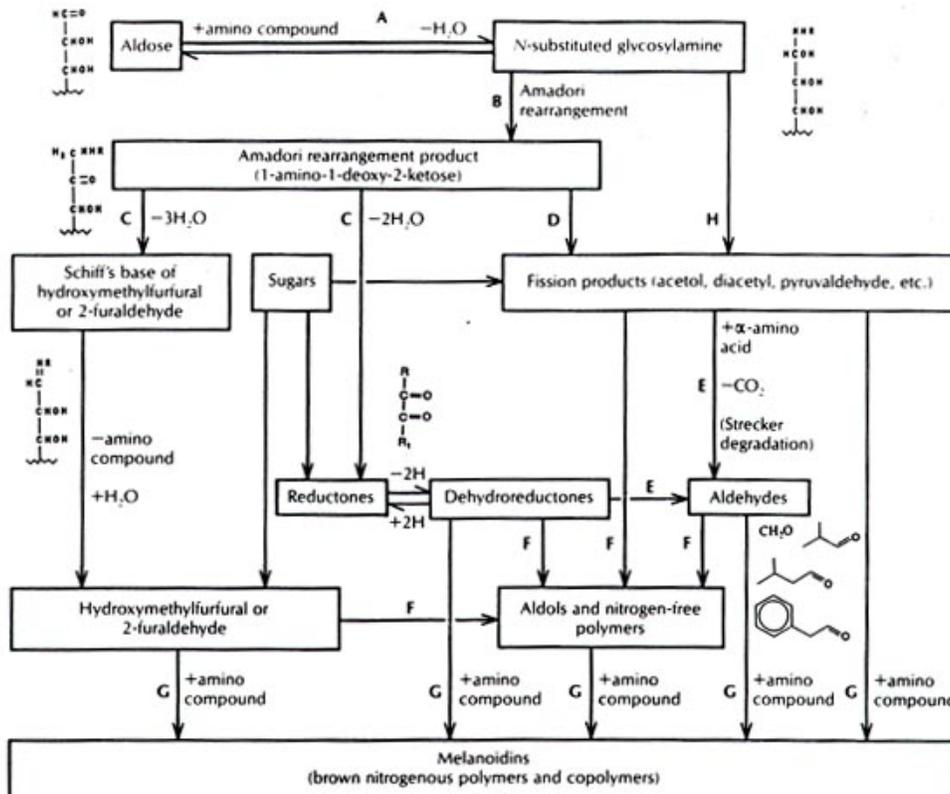


Figure 1: An outline of the Maillard reaction

Taken from http://www.edinformatics.com/math_science/science_of_cooking/maillard_reaction.htm Oct 24, 2010