Chemistry for Chefs

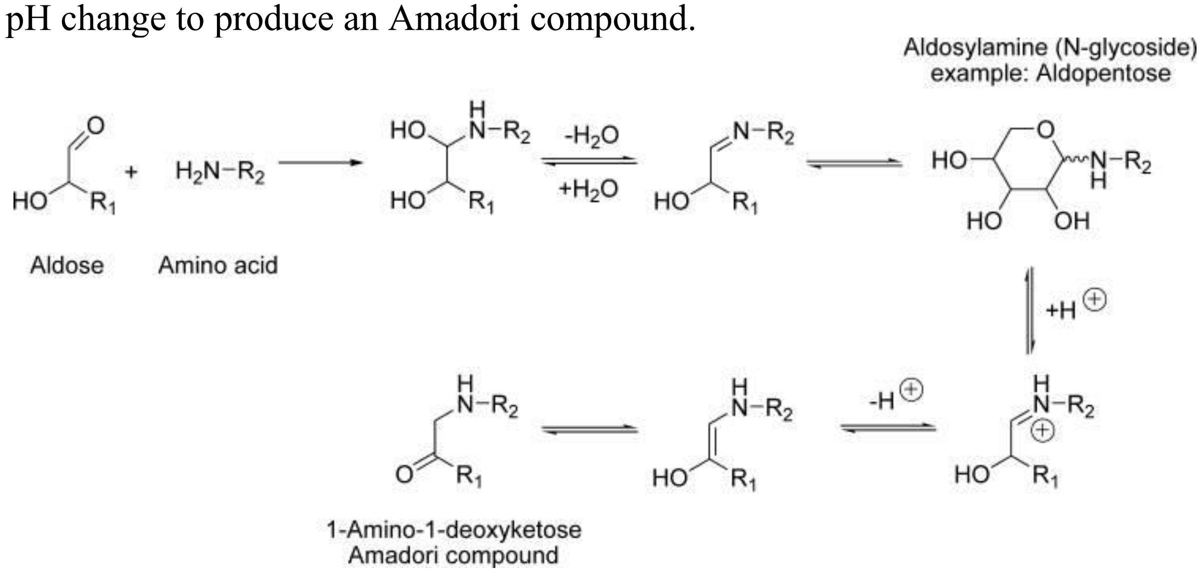
Are chem-chefs happier than chief chemists?

If I think about the chemistry of cooking while I'm in the kitchen, it may distract me from eating my next monsterpiece before it's actually served. In general it will---hopefully for my wife's sake---get me to spend more time at the stove and convert monsterpieces into masterpieces.

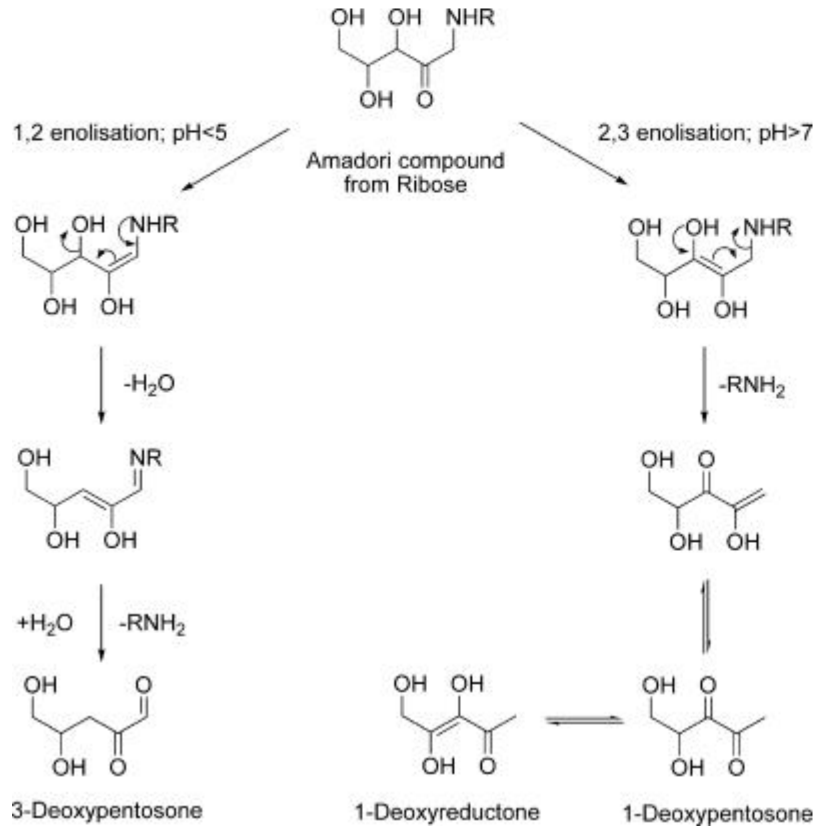
The first set of common reactions that caught my fancy are of the Maillard type. With the addition of heat, the amino group (NH_2) of amino acids attacks the carbonyl group (C=O) of a reducing sugar eventually leading to a range of brownish and appetizing compounds. Do you have to worry the notorious acrylamide produced at higher temperatures if you cook in a cool kitchen?
Here are some examples of baking and cooking products that include compounds from Maillard reactions:

1) Bread crust
2) Boiling of maple syrup
3) Roasting of almonds, coffee or cocoa nuts
4) Beer-making (where's the heat you may wonder? It's the heat of fermentation.
5) Cookie baking

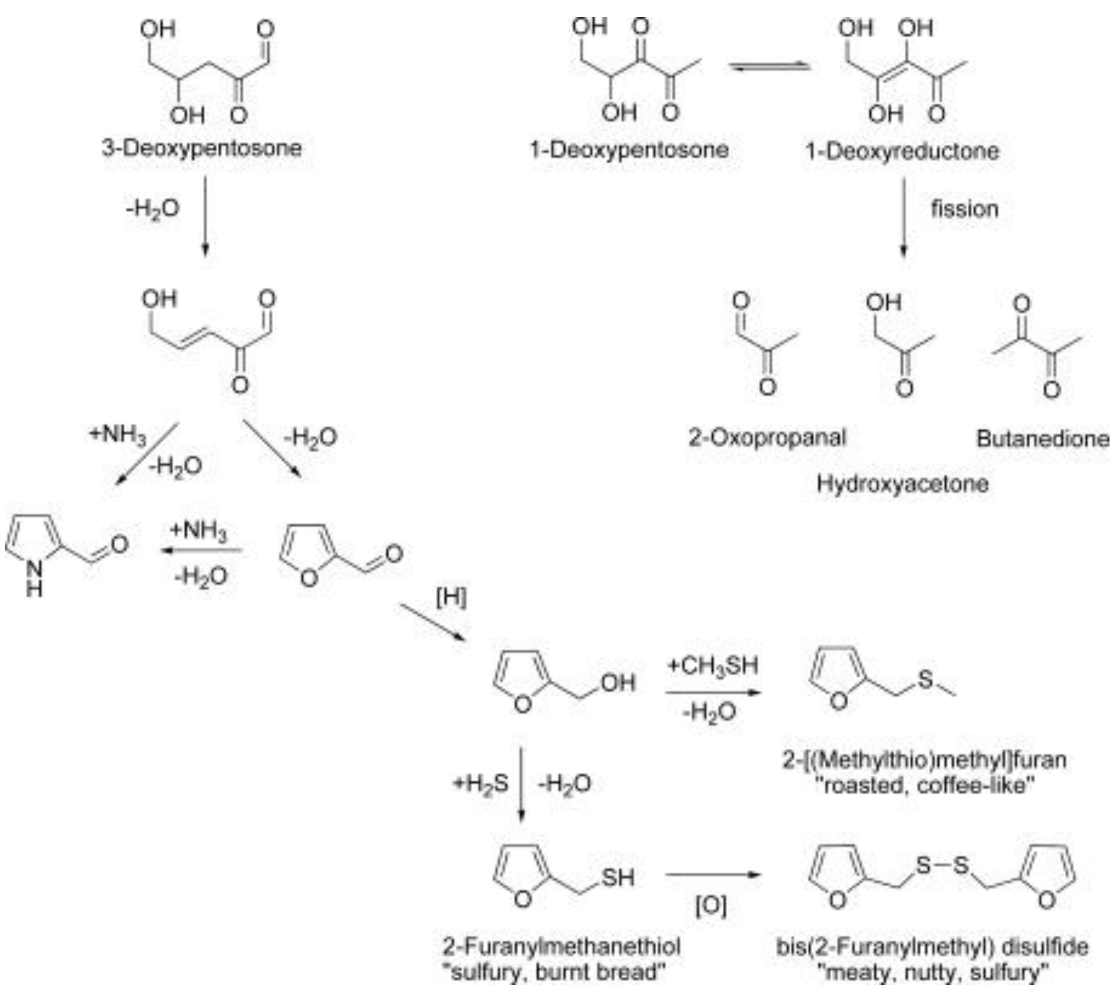
The first compound formed from the amino attack is an N-substituted glycosylamine.(see aldo pentose example in the diagram) But the hexagonal ring of this molecule then breaks up, undergoes another rearrangement with the help of a pH change to produce an Amadori compound.



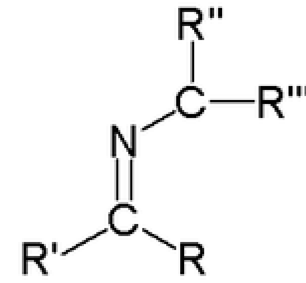
What happens to this typ eof compound depends on pH, but in either case the NH_2 group is lost forming ketones.(A compound with C=O group sandwiched between carbons.)



In the next stage, these compounds are split into some of the brown compounds that we taste and smell. Here are some examples



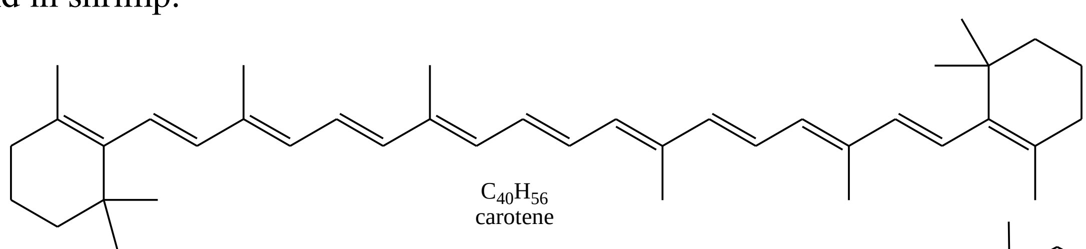
Maillard reactions occur alongside caramelization (bonding of sugars) that also leads to browning. While Maillard reactions are taking place, amino acids can decompose into Schiff bases that eventually produce cereal like flavours and those of roasted nuts, bread and meat.



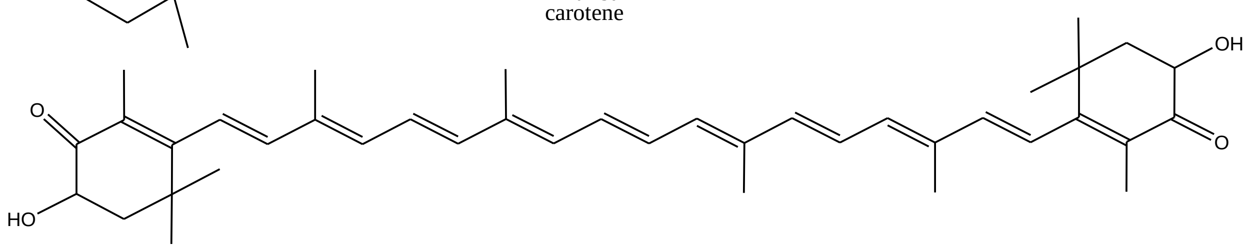
Unless a sweet sauce is added to meat, the browning seen upon cooking is not a Maillard reaction. Rather it results from the oxidation of the Fe^{+2} in myoglobin to the Fe^{+3} state. This is part of the reaction where the myoglobin protein is denatured to hemichrome.

And when a cooked leaf loses its green colour, it is because chlorophyll has lost its Mg^{+2} ion. Like most reactions it depends on enzymes. In this case if you want to maintain the green colour, a little baking soda can be added. (not too much or you'll gain both colour and bitterness) The higher pH from HCO_3^- prevents the enzyme from converting chlorophyll into pheophytin.

If you are non-meat eater, you won't mind me switching the topic from meat to seafood. Astaxanthin is a compound related to the carotene in carrots. It is pink and found in shrimp.



$C_{40}H_{56}$
carotene



astaxanthin$C_{40}H_{52}O_4$

Normally while the shrimp is alive, the pink colour of astaxanthin is not evident because it is bound to a protein, which changes its colour. But the heat of cooking uncoils the protein, unsheathing the same pigment that keeps flamingos feathers pink. A similar explanation applies to the blue/green to red colour change for cooked lobsters. (And by the way they do not scream when boiled. Placing them directly in boiling water is indeed painful for them, but the sharp sound is from the steam that escapes from their shell.)

Notice how similar astaxanthin is to carotene. But the extra C=O group in astaxanthin increases the alternating single-double bond network, which makes it easier for electrons to get excited to higher energy levels. Compared to carotene, astaxanthin needs less energy or that of a longer wavelength for electronic excitation. This is consistent with the fact that astaxanthin reflects color of a longer wavelength: pink instead of orange. By the way, if you find a flamingo feather, keep it. Astaxanthin sells for $ 7000/kg! Of course a feather will have a negligible fraction of astaxanthin, so look for a lost flamingo instead.

In both cooking and food packaging, there is often a basis behind seemingly arbitrary procedures. For example, in cartons, an egg is stored with its narrow point down. Why? The wider end contains the air pocket, which due to its lower density tends to rise away from the yolk when the egg is stored in this proper position. When the egg is inverted, the air pocket, which contains bacterial and fungal spores, will rise into the yolk and lower its shelf life.

We often distort reality by trying to operate by simple rules of thumb. This certainly applies to vitamins in fruits and vegetables. Cooking certainly reduces the concentration of vitamins in food, but it does not destroy them, as shown in the table below:

Effect of Heat on Vitamins

Source; USDA

Food(100g)	**Vit A in Raw(IU)**	**Vit A in Cooked(IU)**	**Vit C in Raw(mg)**	**Vit C in Cooked(mg)**
carrots	28129	17202	5.9	3.6
red peppers	5700	2760	190	163
broccoli	3000	1967	93	65

And where in the fruit and vegetable are the vitamins located? Does the peel contain a lot of nutrients? The answer varies. In the case of the potato, the peel does have fiber and minerals, and baking with the peel prevents the escape of some vitamin C during the cooking process. I have not been able to verify the claim that most of the vitamin C is in the flesh just underneath the peel. In the case of mangos, vitamin A is distributed evenly throughout the orange pulp, which is coloured by similar beta carotene molecules. But the peel, especially when ripe, has antioxidants, carotenes and vitamin C. Apple peels are not devoid of nutrients either: they contain minerals (K^+, Mg^{+2}), antioxidants and fiber.

Finally a great example of another endothermic reaction in the kitchen: cooking avocados. Some compounds in the avocado will be converted into bitter alkaloids with heat. But if the avocados are added towards the end of a recipe to minimize the amount of heat absorbed, then the amount of bitter-tasting products will be kept to a miniumum.

References

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