



# SCIENCE of COOKING

Biochemistry and Biotechnology 100 - Dragon Core Area 4 with Lab



## Caramelization



Carmalization of sucrose



Carmalization of carrots, onions and celery

The Maillard reaction occurs when part of the sugar molecule (the aldehyde group, if you must know) reacts with the nitrogen part of the protein molecule (an amino group). The resulting series of reactions is not well understood even by food scientists, but it leads to the brown color and many flavorful compounds that are yet to be identified.

Caramelization is what happens to pure sugar when it reaches 338° F. A few tablespoons of sugar put in a pan and heated will eventually melt and, at 338° F, start to turn brown. At this temperature, the sugar compounds begin to break down and new compounds form.

As with the Maillard reaction, the details of what happens during caramelization aren't well understood. But the results are appreciated all the same.

**Caramelization** or **caramelisation** (see spelling differences) is the **oxidation** of sugar, a process used extensively in cooking for the resulting nutty flavor and brown color. Caramelization is a type of non-enzymatic browning reaction.

As the process occurs, volatile chemicals are released producing the characteristic caramel flavor.

The reaction involves the removal of water (as steam) and the break down of the sugar. The caramelization reaction depends on the type of sugar. Sucrose and glucose caramelize around 160C (320F) and fructose caramelizes at 110C (230F).

### Caramelization temperatures

Sugar	Temperature
<a href="#">Fructose</a>	110° C, 230° F
Galactose	160° C, 320° F
<a href="#">Glucose</a>	160° C, 320° F
Maltose	180° C, 356° F
<a href="#">Sucrose</a>	160° C, 320° F

The highest rate of the color development is caused by fructose as caramelization of fructose starts at 110C. Baked goods made from honey or fructose syrup will therefore give a darker color.

**Take home point** – Caramelization starts at a relatively high temperature as compared to other browning reactions and the temperature depends on the type of sugar. In foods, often several different carbohydrates and other



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components are present; all these may influence the caramelization temperature as well as the different steps and reactions, and thus the final flavors and colors that are produced.

Caramelization of sucrose starts with the melting of the sugar at high temperatures (see below) followed by foaming (boiling). Sucrose first decomposes into glucose and fructose. This is followed by a condensation step, in which the individual sugars lose water and react with each other. Hundreds of new aromatic compounds are formed having a range of complex flavors.

The highest rate of the colour development is caused by fructose as caramelization of fructose starts at lower temperature. Baked goods made from honey or fructose syrup thus are generally a bit darker than those made with sugar.

In the case of the caramelization of sucrose three main product groups are formed: a dehydration product, caramelan  $C_{12}H_{18}O_9$ ; and two polymers, carmelen  $C_{36}H_{50}O_{25}$  and caramelin  $C_{125}H_{188}O_{80}$ .

During a caramelization reaction, the initial reaction involves a loss of water and forming the polymers into a highly complex polymer.

Caramel color first gained commercial importance as an additive in brewery products (e.g. porter, stout, dark beers and ales) and as a colorant for brandy.

**Flavors of Caramel:** Caramelization reactions also result in the formation of flavors. Diacetyl is an important flavor compound, produced during the first stages of caramelization. Diacetyl is mainly responsible for a buttery or butterscotch flavor. Diacetyl is not only produced by caramelization, it can also be produced by bacteria in fermented products, such as beer and yogurt.

Besides diacetyl hundreds of other flavor compounds are produced for instance furans, esters and maltols.

Hydroxymethylfurfural (HMF) is found in honey, juices, milk but also in cigarettes. Hydroxyacetyl furan (HAF) has a sweet aroma and a low odor threshold. Maltol has a taste reminiscent of freshly baked bread and is used as a flavor enhancer in breads and cakes.

Diacetyl ( 2,3-butanedione) is an important flavor compound, produced during the first stages of caramelization. Diacetyl is mainly responsible for a buttery or butterscotch flavor.

Esters and lactones which have a sweet rum like flavor.

Furans which have a nutty flavor.

Maltol has a toasty flavor.

If caramelization is allowed to proceed to far the taste of the mixture will become less sweet as the original sugar is destroyed. Eventually the flavor will turn bitter.

## Stages of caramelization of saccharose (table sugar)

Step	Temp °C	Description and use	Image
1	Evaporation of water	100	Sugar is melted and impurities rise to the surface;



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4	<i>Small Ball</i>	110 - 115	No colour; semi-soft cooling; no flavour change. Used in cream candy fillings, Italian meringue, fondants, fudge, and marshmallows;	
5	<i>Large Ball</i>	119 - 122	No colour; firm cooling; no flavour change. Used in soft caramels;	
6	<i>Light Crack</i>	129	No colour; firm cooling; no flavour change. Used in semi-hard candies.	
7	<i>Hard Crack</i>	165 - 166	No colour; hard cooling; no flavour change. Used in butterscotch and hard candies;	
8	<i>Extra-hard Crack</i>	168	Slight colour; shatters like glass during cooling; no flavour change. Used in hard candies;	
9	<i>Light Carmel</i>	180	Pale amber to golden brown; rich flavour.	
10	<i>Medium Carmel</i>	180 - 188	Golden brown to chestnut brown; rich flavour;	
11	<i>Dark Carmel</i>	188 - 204	Very dark and bitter; smells burned. Used for colouring, but lack of appropriate sweetness;	
12	Black Jack	210	Also known as "monkey's blood." At this point, the sugar begins to break down to pure carbon. Burning flavour.	



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## Caramelizing high sugar vegetables

Caramelizing onions, by slowly cooking them in a little olive oil until they are richly browned, is a wonderful way to pull flavor out of the simplest of ingredients. Onions are naturally sweet; and as caramel comes from the simple cooking of sugar, when you slowly cook onions over an extended period of time, the natural sugars in the onions caramelize, making the result intensely and wonderfully flavorful. You can use onions prepared this way on top of steak, or for onion soup, tarts, pizza, or onion dip.

### How to Caramelize Onions

*Quantities depend on how much caramelized onions you wish to make. In this example, 5 large raw onions yielded about 2 cups caramelized onions.*

#### INGREDIENTS

- Several medium or large onions, yellow, white, or red
- Olive oil
- Butter (optional)
- Salt
- Sugar (optional)

#### METHOD

1 Slice off the root and top ends of the onions, peel the onions. Cut the onions in half. Lay them cut side down and slice the onions lengthwise to desired thickness.



2 Use a wide, thick-bottomed sauté pan for maximum pan contact with the onions. Coat the bottom of the pan with olive oil, or a mixture of olive oil and butter (about 1 teaspoon per onion). Heat the pan on medium high heat until the oil is shimmering. Add the onion slices and stir to coat the onions with the oil. Spread the onions out evenly over the pan and let cook, stirring occasionally. After 10 minutes, sprinkle some salt over the onions, and if you want, you can add some sugar to help with the caramelization process.

3 Let cook for 30 minutes to an hour more, stirring every few minutes. As soon as the onions start sticking to the pan, let them stick a little and brown, but then stir them before they burn. The trick is to let them alone enough to brown (if you stir them too often, they won't brown), but not so long so that they burn. After the first 20 to 30 minutes you may want to lower the stove temperature a little, and add a little more oil, if you find the onions are verging on burning. A metal spatula will help you scrape up the browned bits from the bottom of the pan as the caramelization proceeds. As the onions cook down, you may find you need to scrape the pan every minute, instead of every few minutes. Continue to cook and scrape, cook and scrape, until the onions are a rich, browned color. At the end of the cooking process you might want to add a little balsamic vinegar or wine to help deglaze the pan and bring some additional flavor to the onions.