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Scientific Foundations, Educational Practices, and Culinary Applications
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Cooking

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Cooking

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Cooking? If it is “the activity or skill of preparing food” or “the process of preparing food by heating it” (Lexico, 2020; Stevenson, 2010), this whole handbook deals with it, and no particular description is needed. However, here, I shall envision a general description of some thermal processes based on thermal transfer, before introducing an innovative method of cooking. Then I shall discuss the chemical basis behind changes triggered by the various thermal processes.

A Table for Innovation

Let us first observe that the definition of cooking that includes heating is debatable, as we would certainly not consider as “cooked” a frozen chicken that was taken out from the deep freeze and put at room temperature: it would be heated, certainly, but the temperature for physical and chemical changes characteristic of what we consider “cooked” would not occur. Also, macerating some animal tissues in an acidic medium (lime juice, for example) gives a result that looks as if these tissues have been heated, but here, there would be no temperature increase (fish à la Tahitienne, ceviche, etc., for which the word “coction” was proposed) (This, 2001).

Before considering the chemical changes occurring during thermal processing of plant or animal tissues, let us begin by observing that the various traditional methods for the processing of food include either thermal processing or another way of changing the chemical state of the tissues (This, 1997). Indeed, we can distinguish between giving energy to the inside of the food ingredients by conduction, and giving energy by radiation. In the former, the hot source can be a solid, a liquid (aqueous solution or oil) or a gas (air, steam). In the latter, it is traditionally infrared, with a limited depth being reached because of radiation absorption by the tissues, but of course, microwave radiation is now also almost traditional (and other sources producing energy in the form of visible light, such as lasers, could be used). For non-thermal processing, one can trigger some coagulation of proteins using acids and bases or ethanol, and also by the application of a high pressure, in “pascalization” or high-pressure processing (Chauhan, 2019).

Of course, a classification such as the one given in the previous paragraph is very crude, because “hot” only means something in relationship with the various phenomena that can occur, as shown in the chapter dealing with eggs at 6X°C of this book, “Let Us Have an Egg” (This, 2009). But it is already useful, as it allows analysis of the various traditional cooking methods (This, 2014). For example:

- grilling means heat transfer by conduction from a hot solid;
- braising means heat transfer from a mildly hot aqueous solution;
- boiling means heat transfer from a hot aqueous solution at 100 °C;
- frying means heat transfer from a hot oil (with differences between deep frying and flat frying, the latter creating a unidirectional gradient);
- baking means heat transfer from a hot gas (air);
- steaming means heat transfer from a hot gas (steam);
- roasting means heat transfer from infrared radiation;
- microwaving means heat transfer from microwave radiation;
- and, as said, transformations of tissues can occur after contact with acids (fruit juices and vinegar, for example), bases (lime in longevity eggs, for example), brandies (as in the “beaumés”; see the chapter on egg coagulation), sugar and salt, all creating “coctions”.

All these processes could be discussed in more detail, but it is proposed now to observe that some of these “elementary”, or “unit”, processes can be applied in a row. For example, in braising, there is (traditionally) first the contact with hot air, and then a processing in a closed vessel, for which the heat transfer occurs from hot humid air at a temperature below 100 °C. Or for some frying processes, potatoes can be boiled before being fried, i.e., receiving heat from hot oil.

What about envisioning a systematic table with the elementary processes in rows and in columns? This creates more than a hundred possibilities with very different results (Table 23.1).

Let us observe that this general idea of coding processes was already put into action when considering the cooking of eggs (see...
In this chapter) in a different manner. More abstractly, this means always having a number for a particular process, creating “formulas” that correspond to particular processes. Alternatively, the ingredients can also be described in this way, as in the “dough tree” that we are going to examine now (Table 23.2).

The idea is to observe that doughs are generally made of flour and water. Some include fat (oil, butter), and some don’t. Some are leavened, and some are not. Some contain eggs, and some don’t. Some are steamed, and some are boiled. This can be arranged systematically as a “tree of doughs” (here from left to right) showing many possibilities that are not practised traditionally. Some names are given in the last column.

### TABLE 23.1

<table>
<thead>
<tr>
<th>Heat transferred from</th>
<th>Hot solid</th>
<th>Simmering aqueous solution</th>
<th>Boiling aqueous solution</th>
<th>Hot oil</th>
<th>Hot air</th>
<th>Steam</th>
<th>Infrared</th>
<th>Microwaves</th>
<th>High pressure</th>
<th>Acids</th>
<th>Bases</th>
<th>Ethanol</th>
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<tbody>
<tr>
<td>Hot solid</td>
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</tbody>
</table>

### TABLE 23.2

The Tree of Doughs Is Horizontal, Growing from Left to Right

<table>
<thead>
<tr>
<th>Flour and water</th>
<th>With fat</th>
<th>Not kneaded, but egg added</th>
<th>With yeast</th>
<th>Boiled Steamed</th>
<th>Dampnudel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kneaded, no egg</td>
<td>With yeast</td>
<td>Boiled Steamed</td>
<td>Dampnudel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without fat</td>
<td>Not kneaded, but egg added</td>
<td>With yeast</td>
<td>Boiled Steamed</td>
<td>Dampnudel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kneaded, no egg</td>
<td>With yeast</td>
<td>Boiled Steamed</td>
<td>Dampnudel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Without yeast</td>
<td>Boiled Steamed</td>
<td>Kneple</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not kneaded, but egg added</td>
<td>With yeast</td>
<td>Boiled Steamed</td>
<td>Kneple</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kneaded, no egg</td>
<td>With yeast</td>
<td>Boiled Steamed</td>
<td>Kneple</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Without yeast</td>
<td>Boiled Steamed</td>
<td>Dry noodles</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>With yeast</td>
<td>Boiled Steamed</td>
<td>Cornuau</td>
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</tr>
</tbody>
</table>

### In More Depth: Some Chemistry of Cooking

The diversity of plant and animal tissues, and the diversity of processes applied to them, can appear infinite, but the processes are used because they trigger some particular changes, based on the molecular and physical characteristics of the food ingredients. Animal tissues, on the one hand, and plant tissues, on the other, belong to categories sharing physical and chemical characteristics.

Most animal tissues are muscular tissues, made of grouped bundles of muscular fibres, chemically based primarily on water, proteins and fat (Girard, 1990). For plant tissues, the plant cell wall (with polysaccharides such as cellulose, hemicelluloses and...
pectins) surrounds the inside of cells, which are mainly composed of water and sometimes starch and fat (Bowes, 1988).

For plant tissues, first, low temperature can cause hardening of the tissues through the release of calcium ions that will bridge pectins (Anthon and Barrett, 2006). But at higher temperatures:

- starch will gelatinize (Véchambre et al., 2010);
- amylose and amylopectin will be hydrolysed (Utrilla-Coello et al., 2014);
- pectins will be hydrolysed (Figure 23.1);
- some small saccharides can undergo intramolecular dehydration (Wunderlin et al., 1998; Lewkowski, 2001).

In particular, pectin degradation is a very important phenomenon because of its contribution to the softening of plant tissues. Many studies have shown that this elimination process (E1 mechanism) occurs in two steps involving a carbocation intermediate (Neukom and Deuel, 1958). The process seems to be accelerated by the presence of a methyl group on the C5 of galacturonic acid residues (Albersheim et al., 1960). The more methylated the pectins, the more hydrolysed they are during thermal treatment (Sajjaanantakul, 1989). More generally, \( \beta \)-elimination is the primary process responsible for pectin degradation during thermal treatment at pH 6.1. However pectins can also be degraded by acidic hydrolysis (Krall and McFeeters, 1998). Methyl groups are needed for \( \beta \)-elimination but not for acid hydrolysis. Polypectates (degree of methylation (DM) < 5%) can be degraded in acidic medium. For pH higher than 3.5, \( \beta \)-elimination would be the primary process.

Experimentally, the importance of \( \beta \)-elimination for the texture of plant tissues has been studied, but with contradictory results. During thermal treatment, the softening of carrot (Daucus carota L.) tissues was described as a first-order kinetic mechanism (Paulus and Saguy, 1980) or due to two different mechanisms (Huang and Bourne, 1983), the first being the cause of pectin transformation in the middle lamella (responsible for 95–97% of firmness loss). The two-step loss of firmness was later observed again (Huang and Bourne, 1983), with a loss of firmness observed during the first 5–8 min (60%) (Greve et al., 1994). \( \beta \)-elimination is increased by higher temperatures: 1% solutions of lemon

![FIGURE 23.1](image-url)  
Cooking plant tissues (and softening them) is associated, for example, with degradation of pectin (mostly polymers of galacturonic acid, or (2S,3R,4S,5R)-2,3,4,5-tetrahydroxy-6-oxohexanoic acid) through \( \beta \)-elimination, a hydrolysis process due to breaking chemical bonds between galacturonic residues.  
(Keijbets and Pilnik, 1974)
(Citrus citrus) pectins have a viscosity that decreases from 14 to 13 or from 14 to 1 for thermal treatments at 35°C and 95°C, respectively. Moreover, the length of galacturonic acid chains drops from 350 units to 16 or 63 units after 1 h at 95 and 80 °C, respectively.

Of course, pectin is not the only polysaccharide that can be hydrolysed during thermal processing. Whereas cellulose is highly heat resistant, starch (amylose and amylpectin) or proteins dissociate slowly with time, in particular when the environment is acidic, such as in meat or in most dishes (Belitz and Grosch, 1999a). These processes generate saccharides or amino acids, which can then react by processes such as dehydration of hexoses or Streker degradation (Belitz and Grosch, 1999b). For example, 5-(hydroxymethyl)-2-furaldehyde (HMF) is formed by hexose dehydration (Wunderlin et al., 1998; Lewkowsi, 2001).

For animal tissues:

- water is not chemically transformed, but it can evaporate;
- some proteins (actins, myosins) can “coagulate”, i.e., be denatured and link through intermolecular bonds such as disulfide bridges (see the chapter on “uncooking an egg”);
- some other proteins are hydrolysed, such as collagen, which makes up the envelope of the muscular fibres and also creates bundles and superbundles of such fibres; this creates peptides and amino acids;
- fat melts and can be oxidized (see the chapter on fat oxidation in this book).

Of course, such a short description does not include all processes, and many culinary phenomena remain unexplained. For example, the formation of hydrogen sulfide during egg processing is readily observed (from the egg white, or from the yolk) using a piece of filter paper impregnated with a solution of lead acetate; it has been studied (Germs, 1973), but no publication explains why this process does not occur when eggs are thermally processed for more than 12 h at 65 °C.

Also, “pyrolysis” mechanisms seem to be very important during culinary processes, as very high temperatures are obtained at the surface or even inside food products when water is evaporated. For example, the temperature under cubes of meat 5 cm wide was measured to be about 100 °C when the heating power was low, so that the flow of juice expelled because of collagenic contraction (Kopp et al., 1977) is enough to keep the lower surface moist; but the temperature under the meat can reach very high temperatures when the heating power overcomes water evaporation (temperatures as high as 290 °C were measured). Also, during the first step of shrimp viscous production, when shrimp shells are heated in oil, temperatures as high as 320 °C have been measured in a professional kitchen, which is much higher than the temperatures studied in model systems (Mar’in and Shlyapnikov, 1980). We invite the reader to consult the chapter on glycation reactions in this book.

As a conclusion to this chapter, it should also be observed that the “most important” changes in terms of mass are not always the most important in terms of flavour, as exemplified by the evaporation of odorant compounds from a solution.

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