Handbook of Molecular Gastronomy
Scientific Foundations, Educational Practices, and Culinary Applications
Róisín M. Burke, Alan L. Kelly, Christophe Lavelle, Hervé This vo Kientza

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Publication details
Hervé This vo Kientza
Published online on: 09 Jun 2021

How to cite: Hervé This vo Kientza. 09 Jun 2021, Cooking: Culinary Precisions and Robustness of Recipes from: Handbook of Molecular Gastronomy, Scientific Foundations, Educational Practices, and Culinary Applications CRC Press
Accessed on: 12 Oct 2023

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Cooking: Culinary Precisions and Robustness of Recipes

Hervé This vo Kientza1,2

1 Université Paris-Saclay, INRAE, AgroParisTech, UMR 0782 SayFood, 75005, Paris, France
2 Group of Molecular Gastronomy, INRAE-AgroParisTech International Centre for Molecular Gastronomy, F-75005, Paris, France

Culinary books include technical descriptions of dishes, artistic prescriptions and “social” advices. Within the technical part, one can distinguish a “definition” and added information, which were named “culinary precisions” (This, 2010). For French cuisine only, more than 25,000 of them were collected, and many were tested over the last decades. A proportion of them are conveying incorrect technical information, and it would be an improvement for culinary education to get rid of them. Because of their huge number, an international collaboration is needed.

This recognition did not occur immediately after the creation of molecular and physical gastronomy, and it calls for an analysis of the history of both culinary practices as well as food science and technology. Indeed, in culinary books of the past (and still today), there are remnants of old magical ideas, such as when it is written that women having periods prevents the making of emulsions such as mayonnaise sauce (Thiebaut, 2017). And in food science and technology, one can remember that, some decades ago, it was suggested that mayonnaise (again!) could be made better in a copper vessel using an iron whisk, because there was a “battery effect” (This, 2010). The fact is that molecular and physical gastronomy was partly based on the investigation of such ideas: culinary circles have been distributing incorrect explanations of phenomena and using out-of-date scientific information.

This view goes back several centuries: since the beginning of the modern natural sciences, their application to phenomena occurring during food preparation (“cooking”) has been considered. For example, in 1560, Ambroise Paré introduced the word “emulsion” (from the Latin word emulgere, “to draw milk”) to describe “thick white products”, as he worked on what we would call today drug formulations (TLFi, 2018). In 1783, the French chemist Antoine-Laurent de Lavoisier published the result of his studies of meat stock (Lavoisier, 1783), quoting the French pharmacist Claude Joseph Geoffroy, also called Geoffroy le Cadet, who scientifically studied such preparations as early as 1730 (Cadet de Vaux, 1818; Geoffroy, 1733; This et al., 2006). Studies of fat by Michel-Eugène Chevreul led him to the discovery of the chemical constitution of triglycerides (Chevreul, 1823). Discussing whether all this was science or technology is not beyond the scope of this chapter (This and Kurti, 1994), because it is related to what is called “culinary precisions”.

Unquestionably, many chemical and physical phenomena occurring during culinary transformations were studied by food science or food technology before 1988, when the concept of molecular and physical gastronomy was introduced (sometimes shortened to “molecular gastronomy”) as a discussion during the preparation of the first International Workshop on Molecular and Physical Gastronomy. However, it is a fact that, in the 1980s, research in food science and technology generally neglected culinary processes.

In France, the microbiologist Edouard Pojersky de Pomiane interpreted (without scientific experiments) culinary practices in the second half of the 20th century, but he also promoted incorrect ideas, such as that you could avoid crying when you peel onions if you bite on a wooden spoon. Japan was also an exception, with articles published (in Japanese) in the Japanese Journal of Home Economics and in the Japanese Journal of Cookery Science, but this work was mostly ignored by the English-speaking scientific community.

In the 1980s, “food chemistry” textbooks, such as the classic Food Chemistry (Belitz and Grosch, 1999), contained almost nothing about culinary transformations; even as late as 1999, most of the chapter on meat described either meat composition and structure, or industrial products (e.g., sausages, meat extracts), but nothing was said about braises, sauté, roasts and all other preparations including meat. Also, less than 0.5% of the text considered “culinary phenomena” (such as meat shrinkage during heating because of collagen denaturation). In addition, nothing was said about the effect of thermal processing on wine, despite the wide use of this beverage in culinary activities; 48% of French classical sauces contain wine (This, 2015).

Probably because culinary transformations are complex, and also because the food industry did not support studies outside its field, food science and technology had drifted slowly toward the science of ingredients and toward technological questions, neglecting phenomena that occur when making home or restaurant dishes, such as cassoulet, goulash, hollandaise sauce, etc. It was even considered a conspicuous eccentricity when an article on bearnaise was published in a scientific journal in the 1970s (Perram et al., 1977).

This is why the late Nicholas Kurti (1908–1998), former professor of physics in Oxford (This, 1999), and I decided in March
Take a dozen pears of middle size, remove the skin and put them immediately in cold water. Then melt 125 g of sugar with some water in a pan at low heat: as soon as the sugar is melted, add the pears, add some lemon juice if you want to keep the pears white; if you prefer them red, do not add lemon juice and cook them in a pan lined with tin.

In this recipe, the words in bold are enough to give the definition of the dish (this definition here is less than 10% of the recipe). The words in italics add “precisions”. Here, there is no “third part” (art, social). However depending on the recipe and the author, the precision ratio of recipes can vary considerably; for example, in some recipes from the French chef Jules Gouffé (Gouffé, 1867), the percentage of culinary precisions is nil.

Making this difference between culinary definition and culinary precisions was the basis for an improved scientific strategy for molecular and physical gastronomy: (1) modelling definitions and (2) exploring precisions. However, this new programme was rapidly discovered to be insufficient, because the main point in culinary practice is to produce “good” dishes; this is art, and not technique, because “good” means “beautiful to eat”. Moreover, even technically successful and artistically well-designed dishes are not appreciated if the guests are neglected or treated poorly, so that the “social component” of culinary practice also needs to be considered. Of course, the natural sciences cannot have the last word on such topics, but evolutionary biology of psychology, for example, can explain a lot about human behaviour and, accordingly, about culinary practice. Today, the scientific programme of molecular and physical gastronomy could be more appropriately stated as: (1) explore scientifically the technical part of cooking (definitions and precisions); (2) explore scientifically the art component of cooking; (3) explore scientifically the “social link” component of cooking.

Now that this scientific programme is clearer, what is the most rational way of exploring the field of culinary phenomena? As culinary transformations are dynamic processes involving systems with structure (Dickinson, 2006), it is natural to make complementary descriptions of the physical state, on one hand, and of the chemical state, on the other. The bioactivity (organoleptic, nutritious or toxic) of such systems is considered later as the result of the two states (This, 2012).

Testing Culinary Precisions

We now see why culinary precisions (in short, “precisions”) are important for molecular and physical gastronomy. Since the 1980s, a lot of precisions have been tested, and the number of precisions now collected from French culinary books alone is more than 25,000. Many have been given online (This, 2019a) or discussed within the framework of a yearly course on molecular and physical gastronomy (This, 2019b); some have been analysed in a book (This, 2010). The open questions are many, and we give some examples in the following.

Is it true that pears (Pyrus communis L.) stay white when lemon (Citrus citrus L.) juice is added, in a pear jam? The answer is yes, and it is well understood that ascorbic acid...
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((R)-5-((S)-1,2-dihydroxyethyl)-3,4-dihydroxyfuran-2(5H)-one) inhibits o-diphenol O2 reductase enzymes (EC 1.10.301, PPO) (Zawistowski et al., 1991). When pears and other fruits are cut, these enzymes transform the released phenolics, such as chlorogenic acid and (+)-epicatechin, into reactive quinones, which can in turn polymerize into dark pigments (Grotte et al., 2000; Goupy et al., 1995).

Is it true that pears turn red when cooked in tin-covered copper pans? During public lectures and laboratory experiments with Valérie Michaud, we performed numerous tests with common pears (Passe Crassane, Williams, Red Williams, Comice, Conference ...) and never observed the expected red colour. Model tests using tin ions did not produce the red colour, but such a colour was obtained for many varieties when the pH was lower than 2 (Figure 24.1).

This is attributed to anthocyanidins from the fruits, which turn red in an acidic medium (UV-visible spectroscopy: $\lambda_{\text{max}} = 522$ nm) (Belitz and Grosch, 1999). Colouration is particularly deep near the pear skin, where anthocyanidins are more concentrated.

Is it true that mayonnaise sauce fails when made by menstruating women? This precision has been tested experimentally and was proved wrong (of course!).

Is it true that mayonnaise sauce fails when made during a full moon? Students at Tours University (MST Le goût et son environnement, promotion 2000–2001) tested this old wives’ tale, and the first mayonnaise that they made failed; i.e., a phase separation occurred after the addition of oil. However, the same students were told to repeat the process and got well-formed emulsions. Indeed, there is no reason why the sauce could fail in all the circumstances described by old wives’ tales, as it is only an emulsion, i.e., a dispersion of oil droplets in the water of the yolk and vinegar, with proteins and phospholipids from the egg stabilizing (it would be more appropriate to write “metastabilizing”, as emulsions are not thermodynamically stable) the droplets.

Finally, tests of culinary precisions performed since 1980 show that all possibilities arise: (1) some precisions seem wrong, and they are wrong; (2) some seem wrong, and they are true; (3) some seem true, and they are wrong; and (4) some seem true, and they are true. We shall now give a brief example of each, adding a fifth class, of uncertain precisions (5).

(1) As we demonstrated, it does not seem true, and indeed it is not true, that women’s menstruation prevents them from preparing mayonnaise, as has been proposed in France. Indeed, it is strange that this culinary precision is widespread in France yet not in England (on the other hand, in England, menstruating women should not rub meat with salt) (Kurti, 1995) or in other countries. This demonstrates how much cooking is rooted in culture, and why comparative molecular gastronomy across countries and cultures could be an interesting project (This, 2006).

(2) In 1994, the question of whether the skin of suckling pigs crackles more (i.e., becomes more crispy) when the head of the pig is cut off immediately after being roasted was examined (This, 1994). This advice seemed intuitively wrong, but it was proven to be true. The culinary precision was found in L’Almanach des gourmands from the French gastronome Alexandre-Balthazar Grimod La Reynière: “suckling pigs should have the head cut immediately when the pigs are taken out from the oven, otherwise their skin softens”. The same advice is found in many other culinary books. For example, the French chef Marie Antoine Carême indicates that a cut should be made around the neck (“When you are ready to serve, you separate immediately, with the tip of the knife, the skin of the neck, so that the skin says crisp, which makes most of the interest of roasted sucking pigs”). These remarks are strange, as in roasted pigs, no fluid seems to exchange between the head and the skin; it was highly unlikely that the advice was true, but the experiment was performed (public experiment at Saint-Rémy-l’Honoré, Yvelines, France, July 7, 1993) with four suckling pigs from the same parents, reared together on the same farm, weight 7.1–7.3 kilograms, cooked on a large outside fire from 4:00 PM to 9:00 PM, with one head being cut off for each pair of pigs. Blind tasting for 143 people showed that the skin of pigs with head cut was crispier.

The mechanism behind this was easily discovered, as it was observed during cooking that a stream of steam was escaping one pig from a hole made during the preparation. This means that heat is causing water to evaporate from the surface of the meat during cooking, making the crust, and that vapour formed inside the meat is not enough to compensate for the loss of surface water. When the pigs are no longer being heated, the crust softens if vapour goes through; cutting the head prevents vapour perfusion, as it escapes through the opening.

(3) It is said that a pan in which green beans are cooked should not be covered, as this would entrap volatile acids, which would promote pheophytinization of chlorophylls, but tests show that
there is no colour difference. The idea seemed true, but it is wrong (Valverde, 2008).

(4) It is sometimes said that the soufflés should be made from very firm whipped egg whites, added to a viscous preparation. It was demonstrated that this precision holds, as vapor bubbles formed in the bottom part of soufflés during cooking escape less easily through a firmer foam (This, 2002; see also the chapter on Expansion in this book). The advice seemed true, and it is true.

(5) Let us now discuss a fifth class, with culinary precisions having a non-clear-cut status. For example, it was said by the French chef Pierre Gagnaire (This, 2005b) that wine sauces are more “brilliant” (in French, this would mean shiny or luminous) when shaken than when whipped. Such a declaration, even by a famous chef, should be considered with caution, because in many circumstances experiments have shown that cooks were influenced by tradition rather than experiments and facts.

In such cases, one has to carefully define the question, because it would be useless to make tests in conditions different from the ones in which an observation is made; in particular, the production of wine sauces depends both on the authors and on the period in the history of cooking. The “wine sauces” discussed by Gagnaire are made from a veal “fond”, wine and butter. The “fond” is a solution obtained by grilling veal bones until they have a brown (not black) colour. Then, water, carrot (\textit{Daucus carota} L.) roots, onions (\textit{Allium cepa} L.) bulbs and possibly other plant tissues are added. A thermal treatment at a temperature lower than 100 °C for some hours (between 2 and 20, depending on the author, but also on each particular sauce) is achieved. Then, the fond is filtered, and its volume is reduced by boiling to about one-tenth of its initial volume, after which red wine is added. The sauce is reduced again, and red wine is again added, before butter is added while the sauce is heated at a temperature lower than 100 °C, so that there is no boiling (when details are not given here, it has to be understood that the cooks themselves can make changes depending on any particular sauce; e.g., the exact quality of the “red wine” is not considered, and any red wine can be used).

In our studies, the sauce was first modelled by a system containing distilled water (instead of stock and wine), gelatine (because gelatine is extracted in the first steps of fond production) and butter (approximate quantities of 100 mL water, 6 g gelatine and 60 g butter, based on preliminary analyses). The initial mixture of water and gelatine was divided into two parts, and the same quantity of butter was added to each. Then, the model sauce was heated and either shaken (the pan was moved forward and back over a distance of 5 cm, 23 times in 10 s, for 65 s) or whipped using a whisk (four whipping movements per second).

Initial (triangular) visual tests with 52 people did not detect any difference in visual appearance. However, the observation of the model sauces using optical microscopy (microscope Meiji Techno ML Série 2000, Model ML2300) showed clear differences (Figure 24.2) that were characterized.

![Figure 24.2](image-url) Wine sauces with the butter emulsified by whipping with a whisk (left) or by shaking the pan (right). Under each picture, a histogram of the diameters of fat droplets is given.
These differences can be explained by the fact that the energy given to the sauce is very different when the sauce is shaken or whipped. This energy is used to increase the surface energy of the emulsion and, hence, the size of the melted butter droplets dispersed in the water phase.

At that point, it should be concluded that, if there is no difference in “brilliancy” (or shining), there is, however, a difference in flavour, as it was demonstrated for these model emulsions that the composition of odorant molecules above an emulsion differs depending on the microstructure of the emulsion, where composition is constant (Relkin et al., 2004).

### Reasons for Culinary Precisions: The Robustness Assumption

Why did precisions arise in the past? Considering the empirical way culinary technique developed, we assume that failures and successes generated assumptions concerning the experimental protocol used. For example, in the old recipe for emulsion given now (Bernardi et al., 1853), the inverse order of ingredients should have frequently led to failure:

Green Rémolade. Take a handful of chervil, tarragon, you will blanch these herbs that are called Ravigote; press and grind, add salt, pepper, mustard; grind all together, then add half a glass of oil that you amalgamate with the ravigote and mustard; finally you add two or three egg yolks.

Such a process is strange; the authors are describing an emulsion but they add the surfactants (proteins and phospholipids from the yolk) at the end (happily, there are some phospholipids and proteins, as well as water, in the ground herbs!). The frequent failure of such a method could have led them to investigate the causes of the irregularity of the process, and culinary precisions should have arisen naturally. This observation leads to a prediction: if it is true that precisions arise from failures, then an inverse quantitative relationship should exist between the “robustness” of a recipe and the number of precisions written in culinary books.

In order to test experimentally this theoretical prediction, “robustness” has first to be made quantitative. Let us consider that a recipe $R$ is a function of many variables: various times ($t_1$, $t_2$, …), temperatures ($T_1$, $T_2$, …), quantities of ingredients ($m_1$, $m_2$, …) and very general details of process ($p_1$, $p_2$, …).

For example, in a mayonnaise recipe, the process can be described by the amount of egg yolk (a parameter including water content, protein content and phospholipid content), the amount of vinegar (i.e., primarily water), the rate of oil addition and the energy of whipping.

A product $P$ obtained through the recipe using particular conditions is given by the equation:

$$ P = R(t_1, t_2, ..., T_1, T_2, ..., p_1, p_2, ...). $$

Or, more generally, $P = R(x_i, y_j)$, $x_i$ being parameters describing the ingredients, $y_j$ the parameters describing the process, and $i$ and $j$ being integers from 1 to $n$ and $m$, respectively.

As long as the parameters vary within certain limits ($x_{i, \text{min}} < x_i < x_{i, \text{max}}$, $y_{j, \text{min}} < y_j < y_{j, \text{max}}$), the recipe is successful: a product is the result of a successful recipe if it is associated with a point inside a limited hypervolume in the multidimensional space of the parameters; when the representing point is outside the recipe hypervolume, the result is considered as failed. For each parameter of the recipe, the size of the interval $[x_{i, \text{min}}, x_{i, \text{max}}]$ can be a measure of the robustness, but, in order to get a non-dimensional value that can be compared with others, we need to divide $x_{i, \text{max}} - x_{i, \text{min}}$ by a number having the same units. We proposed to normalize by the uncertainty $i(x_i)$ on the considered variable $x_i$:

$$ \rho_i = \frac{\Delta x_i}{i(x_i)} $$

Of course, orders of magnitudes have to be calculated instead of exact values, as the uncertainty is only known by estimation.

For example, mayonnaise can be defined by the mass of yolk, $m(y)$, the mass of vinegar, $m(v)$, the mass of salt, $m(s)$, the mass of pepper, $m(p)$, the mass of oil in each successive addition, $m(d)$, the whipping power, $P_w$, and the efficiency of dispersion, $Ed$.

As the critical parameter is clearly the oil addition, let us focus on robustness related to oil addition: at the beginning of mayonnaise preparation, oil should not be added too fast, or a water-in-oil (W/O) emulsion is obtained instead of an oil-in-water (O/W) emulsion. As the quantity of water from one yolk and one teaspoon of vinegar is about (15 g + 5 g = 20 g), and considering the uncertainty on the oil quantity added each time (estimation based on experiments 7.5 g), robustness related to oil addition is equal to 20/7.5 = 2.7.

In more “robust” recipes, such as beef meat roasted in the oven, the calculated robustness is bigger; for a piece of meat of mass 1 kg, cooked at 180 °C for a time between 20 and 60 min, assuming that the precision on time measurement is 5 min, robustness is equal to (60 − 20)/5 = 8. If the cooking temperature is lower (e.g., 70 °C), then the cooking time interval would be still bigger, and robustness higher; the time interval could be estimated to be between 60 min and 1 day, so that the robustness is equal to 1440/5 = 276.

For some recipes, parameters are not independent, and success is obtained only if more than one condition is simultaneously verified. Particular robustnesses have to be aggregated. In order to consider this, let us assume that robustness is inversely related to the number of precisions:

$$ \rho = 1/n_p $$

If the $n$ is the total number of precisions:

$$ n = n_1 + n_2 + \cdots + n_m. $$

Then

$$ \rho = 1/(n_1 + n_2 + \cdots) = 1/(1/\rho_1 + 1/\rho_2 + \cdots). $$

Does the inverse relation hold? In the corpus of precisions that we have collected since 1980, there are 105 paragraphs about mayonnaise preparation, compared with 12 paragraphs for roasts.
In Figure 24.3, we show how the robustness $\rho$ depends on the number of paragraphs containing precisions for grated carrots, stock, soufflé, gougères, mayonnaise and roast beef. In Figure 24.3a, stock is included, and the curve does not correspond to an inverse relation: stock generated many precisions only because of its culinary importance, even if there is almost no risk of failure. In Figure 24.3b, stock has been excluded, and the relationship is more as expected.

More work now needs to be done to test our assumption, using the aggregation of partial robustness, for example, and also the hyperspace needs to be explored more thoroughly.

**Comparative Molecular Gastronomy**

As we said earlier, molecular and physical gastronomy developed initially through international workshops, but, after 1999, these meetings were complemented with monthly seminars and also courses, numerous lectures, articles and books. Today, more and more associations of molecular and physical gastronomy are in existence in various countries, making an international network of scientists in universities and research centres. Each country can focus its study on its own particular definitions and precisions, so that we can look forward to a time when “comparative molecular and physical gastronomy” will be possible. Of course, some assumptions on the origin of such precisions can be made on the basis of “robustness of recipes”, but a more comprehensive collection of culinary precisions associated with time periods would help to investigate such cases.

As we said, dozens of thousands of culinary precisions were collected for French culinary books alone, but it would be scientifically interesting for other countries than France to do the same work, as it would allow some comparative analysis. The disperse system formalism (DSF, see the chapter on this in this book) also could be useful in this regard; in the same way as it was used for studying the evolution of the number of physical categories of sauces, it could be applied to comparing sauces between countries and thereby understanding cultural influences and transfers.

This would also have educational interest, perhaps helpful in view of the current pandemic of obesity. Even in Crete, where the famous Cretan diet originated, up to one-third of children aged 12 are now overweight or obese (WHO, 2013). Other important factors include the increasing concern for the environment, the increasing proportion of the population living in cities, and energy issues. Finally, there is a growing gap between the world of science and laypeople, along with a disaffection for scientific studies, which could easily be bridged by considering food, the most complex scientific process most people engage in on a daily basis, as a scientific phenomenon.

All these data lead toward the idea that children should receive more information about food and food preparation. In particular, health programmes promoting a healthy diet cannot be successful if people cannot rationally choose the food they eat. In order to adapt food to particular cases, citizens need clear information. However, tradition is no guarantee of healthy food or rational preparation of food. This is why educational activities such as “Ateliers expérimentaux du gout” (This, 2001) and other programmes were introduced in France, linking cooking and science at school. Some of these programmes include fieldwork by children that contributes to the collection of culinary precisions in order to create a national database of such precisions. No doubt, all countries could do the same.

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