When shall we have
‘Comparative Molecular Gastronomy’?
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In a first article in a previous issue of this journal, we considered the CDS/NPOS formalism, which was devised for the description of food colloids and also for description of the spatial organization of such matter in dishes. Here this formalism is applied to the description of the classical French sauces. It is also shown how this formalism is useful for the introduction of new dishes. Finally we consider how “comparative molecular gastronomy” could be achieved, giving one tool for the quantitative determination of the “robustness” of culinary recipes.

**Keywords**: Soft matter, colloids, dispersed system, formalism, food, cooking.

**Introduction**

In a previous article in this journal, we considered the early history of the scientific discipline called Molecular Gastronomy, and the CDS/NPOS formalism was presented. Of course, describing phenomena is useful, but science needs more: it looks (quantitatively) for the mechanisms of phenomena. How is the description useful? Here, we shall consider first this question, before showing how the CDS/NPOS formalism is useful for the description of new colloidal material, leading to the introduction of an infinite number of “new dishes”. In particular, the application to sauces lead to the introduction of a new concept, the “robustness” of recipes, which was useful to understand the evolution of the number of physical categories of sauces. This needed a collection of “culinary precisions”. In this regard, we shall see here that new information could be gathered when scientists from various countries collected culinary precisions from their own culture: “comparative molecular gastronomy” could be performed when this will be done.

**The application to sauces**

Let us first consider how using the CDS formalism was shown to be important both for science and technology. One of the first demonstration of the technological interest of the CDS/NPOS formalism, in particular, is in the description of a new dish named “Chocolate Chantilly”¹,² that was introduced in 1995 as a generalization of whipped cream (called “Chantilly cream” when sucrose is added).³

Milk cream is primarily made of a fat globules dispersed in a water phase (with an appropriate frequency cut, micelles of caseins should not be considered in its formula).⁴ It is sometimes described as “oil-in-water emulsion resulting from the concentration of milk”, but this is not true, as at room temperature part of the fat is solid:⁵ hence a formula such as f (O, S)/W should be preferred to O/W, the expression f (O, S) being today unknown, as it is not established if f (O, S) is equal to S® O or to O/S. Anyway, the making of whipped cream can be described by the equation:

\[ \frac{f(O, S)}{W} + G \rightarrow \frac{[G + f(O, S)]}{W} \]

Looking for formulas is an invitation to changes. O, it was said, can be any liquid fat, W any aqueous solution, and G any gas. This is why “chocolate Chantilly” is obtained when, starting from a chocolate emulsion, whipping is achieved while cooling under 34°C. Alternatively foie gras Chantilly, cheese Chantilly or even “olive oil Chantilly” can be made when cooling is enough.

In practice, making such products is easy. For example, with chocolate: first make a chocolate emulsion O/W by heating chocolate into a water phase (the proportion of chocolate and water has to be chosen so that the final fat/water ratio is about the same as the ratio in ordinary cream). Then whip (G) at room temperature while the emulsion is cooled: after some time (some minutes, depending on the efficiency of the cooling), a “chocolate mousse” [G+f(O, S)]/W is obtained. This mousse contains no eggs, contrary to traditional chocolate mousse,⁶ and the texture can be the same as in whipped
cream. As whipped cream is called “Chantilly cream” when sugar is present, the name “chocolate Chantilly” was given to the new dish. Of course, the same equation holds when chocolate is replaced by cheese or foie gras, or even butter, leading to “cheese Chantilly”, “foie gras Chantilly”, or “butter Chantilly”.

Finally, a new dish called “faraday”, in honor of the great physical chemist, was introduced as a demonstration that physical systems could be done after formulas (here [(G+O+S)/W]/S). The number of possibilities is innumerable. It can be easily calculated that, using four phases and four operators, the number of formulas is 114,688, and more than 10^6 with six phases: there is plenty of room for innovation!

**Testing culinary precisions**

The CDS formalism was also applied in a scientific study, for the description of French classical sauces as compiled from classic or official culinary books.\textsuperscript{7,8,9} 23 categories were found.\textsuperscript{10} Surprisingly some simple types are missing, such as “foamed veloutés”((G+(W/S))/W), which are not difficult to produce practically, and it is a question of why such sauces were not “invented” by cooks of the past. This last question led to a separate study of the number of kinds of sauces in function of time. For this study, traditional French culinary books were used.\textsuperscript{11,12} The increasing number of types of sauces shows that culinary empiricism had probably not enough time to develop all kind of sauces.

One goal of Molecular Gastronomy is to collect and investigate what are now called “precisions”. Since the 80’s, a lot of precisions have been tested, and the number of precision now collected from French culinary books only is more than 25,000. Is it true that pears (Prunus communis, L.) stay white when lemon (Citrus citrinus, L.) juice is added, in a pear jam? Is it true that pears turn red when cooked in tin covered copper pans? Is it true that mayonnaise sauce fails when made by menstruating women? Is it true that mayonnaise sauce fails when made during a full moon?

For some precisions (such as the last two), the answer is obvious, but more generally, tests performed since 1980 show that all possibilities arise: some precisions seem wrong and they are wrong (1): some seem wrong and they are true (2); some seem true and they are wrong (3); and seem true and they are true (4); some precisions are uncertain (5). Sometimes, tests lead to surprising results (what was awaited while creating molecular gastronomy).

Why did precisions arise? Considering the way culinary craft developed, it can be easily assumed that failures and successes generated assumptions concerning the experimental protocol used. This observation leads to a prediction: if it is true that precisions come 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 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 ($T_1$, $T_2$, ...), ingredients ($m_1$, $m_2$, ...), 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, lecithin content...), the amount of vinegar (i.e. water at the first order), the rate of oil addition, 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 $P = R(x_i, y_j)$, the $x_i$ being parameters describing the ingredients, and the $y_j$ the parameters describing the process, $i$ and $j$ being integers from 1 to respectively $n$ and $m$.

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 a point inside a hypervolume in the multidimensional space of the parameters.
For each parameter of the recipe, the interval \( x_{i,\text{max}} - x_{i,\text{min}} \) is clearly a measure of the robustness \( \rho \), but in order to get a non-dimensional value that can be compared to others, we need to divide \( x_{i,\text{max}} - x_{i,\text{min}} \) by a number having the same units. We propose to normalize by the uncertainty \( \sigma(x) \) on the considered variable \( x \) : 
\[
\rho_i = \Delta x_i / \sigma(x).
\]
Of course, orders of magnitudes have to be calculated instead of exact values, as the uncertainty is only known as estimation.

For example, mayonnaise can be defined by the mass of yolk \( m(y) \), the mass of vinegar \( m(v) \), the mass of oil \( m(o) \), 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 \( P_w \), the efficiency of dispersion \( E_d \). As the critical parameter is clearly the oil addition, let us focus on robustness related to oil addition : in the beginning of mayonnaise preparation, oil should not be added too fast, because water in oil emulsion is obtained instead of oil in water emulsion. As the quantity of water from one yolk and one teaspoon of vinegar is about \( 15 g+5 g =20 g \) using 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 \( 1 \text{ kg} \), cooked at \( 180^{\circ}\text{C} \) for a time between \( 20 \) and \( 60 \text{ min} \), robustness is equal to \( (60-20)/5=8 \) if the precision of time measurement is chosen equal to \( 5 \text{ min} \). If the cooking temperature is lower (e.g. \( 70^{\circ}\text{C} \), then the cooking time interval would be still bigger, and robustness higher : the time interval could be estimated to be between \( 60 \text{ min} \) and one day, so that the robustness is equal to \( 1.440/5=276 \).

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 do it, let us assume that robustness is inversely related to the number of precisions : 
\[
\rho = 1/n.
\]
If the total number of precisions is the sum of number of precisions \( n_1, n_2, n_3... \) for classes \( i \) of precisions, then for each class : 
\[
\rho_i = 1/n_i.
\]
Hence 
\[
\rho = 1/(n_1 + n_2 + n_3 + ...)
\]
\[
= 1/(1/\rho_1 + 1/\rho_2 + ...)
\]
or 
\[
1/\rho = 1/\rho_1 + 1/\rho_2 + ...
\]

Does the inverse relation hold? In the corpus of precisions that we collected since 1980, there are 105 paragraphs about mayonnaise preparation, compared to 12 paragraphs for roasts.

In Figure 2, we show how robustness \( \rho \) depends on the number of paragraphs containing precisions for grated carrots, stock, soufflé, boiled eggs, gougeres, mayonnaise, beef roast. When stock is included, 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. When stock is excluded, the relationship is more as predicted.

More work has now to be done to test our assumption, using the aggregation relation of partial robustness \( 1/\rho = 1/\rho_1 + 1/\rho_2 + ... \), but also to look for the signification of derivation of the equation defining products : what does mean a high partial derivative \( dR/dx \)?

**Comparative Molecular Gastronomy**

Today, more and more groups of Molecular Gastronomy are created in various countries. Each country can focus its study on the particular definitions and precisions of its culture, so that we can look forward to a time when “Comparative Molecular Gastronomy” will be possible. Of course, some assumptions on the origin of precisions can be made on the basis of “robustness of recipes”, but a more comprehensive collection of culinary precisions associated with periods would help to investigate such cases.

As we said, dozens of thousands of culinary precisions were collected for French culinary books only, but it would be scientifically interesting that other countries than France do the same work, as it would allow some comparative works. The CDS/NPOS formalism also could be useful: in the same was as it was used for studying the evolution of the number of physical categories of sauces, it could be applied for comparing sauces between countries, and understand cultural influences and transfers.

This would also have educational interest, perhaps helpful in view of the current pandemic of obesity.
in Creta, where originated the famous Cretan diet, up to one third of children age 12 years old are now overweighed or obese. Another important data is the increasing concern for environment, and the increasing proportion of the population living in cities. Energy issues are also to be considered. And, finally, there is a growing gap between the world of science and the laypeople, along with the disaffection for scientific studies.

All these data lead toward the idea that children should receive more information about food and food preparation. In particular, health programs promoting healthy diet cannot be successful if people cannot choose cleverly the food they eat. In order to adapt food to particular cases, citizens need to get some clear information about it. But tradition is no guarantee for healthy food, and for rational preparation of food. This is why Ateliers expérimentaux du gout and other programs were introduced in France, linking cooking and science, at school. Some of these programs include field work of children that contribute to the collection of culinary precisions, in order to create a national data base of such precisions. No doubt that others countries could do the same.

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和文抄録
本稿の前稿において、我々は食品コロイドと調理におけるコロイドの空間組織とを表現するために考案された CDS/NPOS（複合分散系/非周期的空間組織）公式論について考察した。本稿ではこの公式論を伝統的フランス料理のソースの説明に適用したい。また、この公式論が新しい料理を紹介するのにいかに役立つかを示す。我々はまた、「比較分子美味学」がどのように实现されるかを考察し、しっかりと作られている料理レシピを定量的に測定する手段にしていきた いと考えている。

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