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CONCEPTION RAISONNÉE DES ALIMENTS

UNE APPROCHE MULTIDISCIPLINAIRE DE LA FORMULATION

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CONCEPTION RAISONNEE DES ALIMENTS : UNE APPROCHE MULTIDISCIPLINAIRE DE LA FORMULATION

• formulation agroalimentaire • études produit/procédé •

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Sommaire

Préface

Le but des 14es Journées de Formulation de la Société Chimique de France, organisées les 3 et 4 Décembre 2009 à Paris sur le thème « Conception raisonnée des aliments : une approche multidisciplinaire de la formulation », était de rassembler les chercheurs, industriels et étudiants intéressés par la Formulation. A travers des conférences, des ateliers et des posters scientifiques, ces Journées ont présenté les avancées et spécificités de la conception raisonnée des produits dans le domaine alimentaire.

Les interventions ont été organisées autour de trois grands thèmes. Sur le premier, intitulé « Quelles approches disciplinaires pour la formulation des aliments ? », cinq conférenciers se sont appliqués à démontrer que formuler des aliments implique nécessairement de prendre en compte plusieurs approches disciplinaires. Les démarches ainsi défendues ont surpris les habitués des Journées de Formulation par leur ouverture extrêmement large mais les ont passionnés aussi. Le deuxième thème a abordé la question de la prise en compte de la diversité humaine, de la conception à la consommation des produits. De ce point de vue, le domaine de la science des aliments mais également celui des cosmétiques sont précurseurs. Enfin, l'importance des approches multi-échelles pour les études intégrées produit/procédé a été illustrée de façon argumentée et concrète, en s'appuyant sur les résultats d'études menées par les laboratoires de recherche en lien fort avec les industriels du secteur. Une conférence plénière a complété ce panorama des approches avec une touche « gastronomie moléculaire » et ses forces pour la conception et la formulation des mets. Dans un objectif résolument pédagogique, les ateliers à thème ont permis d'offrir aux participants une gamme complémentaire d'illustrations très concrètes et diversifiées d'outils ou de démarches de formulation raisonnée dans le domaine de l'alimentaire.

Ces journées ont réuni 170 personnes dont 90 étudiants, 45 universitaires et 35 industriels. Elles ont été l'occasion de nombreuses et riches discussions à la fin de chaque conférence, au pied des posters, pendant les ateliers ou tout simplement aux pauses café et déjeuner. Deux entreprises ont pu présenter leurs gammes d'appareils pendant ces deux jours : Anton Paar et Formulaction. Le bilan à chaud avec les participants mais également leur retour a posteriori indiquent que chacun a été extrêmement intéressé par les sujets abordés.

Je tiens tout particulièrement à remercier le Comité Scientifique et le Comité d'Organisation AgroParisTech, ainsi que toute l'équipe « Structuration des produits par le Procédé » de l'UMR 1145 Ingénierie Procédé Aliments AgroParisTech-INRA-CNAM dont la majorité des membres ont été mis à contribution d'une façon ou d'une autre dans une ambiance conviviale et efficace.

AgroParisTech et la SCF remercient enfin tout particulièrement l'INRA, l'ACIA, Bel, Kraft Foods, Formulaction, Anton Paar et la Région Ile-de-France (projet Astrea) pour leur soutien financier.

Camille MICHON, Professeur

AgroParisTech

Formalisms and new dishes

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ABSTRACT: Innovation is a keyword in the food industry, but also for cooks. However it is a fact that changes in food are very slow, as we still eat today roast chicken or vegetable soup, as our remote ancestors did. Molecular Cuisine was introduced as a new « culinary trend » in order to promote the use of « new » tools, ingredients and methods. However, innovations are much more important when formalisms are used. In particular, the Complex Disperse System (CDS) formalism is useful to describe colloidal systems that make food and also to make novel colloidal systems useful for food, drugs and other formulated products. The « Non Periodical Organization of Space » (NPOS) formalism takes into account the spatial organization of products. Both formalisms are complementary aspects of the same kind of organization, which leads to the new comprehensive Disperse System Formalism (DSF). Using it, an infinite number of new systems can be invented and later produced. This will be particularly useful for the preparation of « note-by-note » dishes, where pure compounds are used by chefs instead of plant and animal tissues.

KEYWORDS: Innovation, formalism, CDS formalism, NPOS formalism, DSF, « note-by-note » cuisine, molecular gastronomy

1. SCIENCE FOR FORMULATION

Culinary books and cooks always hesitated between tradition and innovation. In the 1970's, the culinary trend called « Nouvelle Cuisine » proposed to modernize culinary practices, avoiding « heavy » gravies, for example… and forgetting that the same name of « Nouvelle Cuisine » was used as early as 1642, where chefs already wanted to get rid of culinary practices of their own past. On the other hand, « innovation » is a motto for the food industry… despite the fact that most food produced by this industry today was already there centuries ago. Most industry innovations are about the production methods, packaging, or new uses (including increasing shelf life), rather than food itself.

The success of « Molecular Cuisine », also called « Molecular Cookery » or « Molecular Cooking » -alas too frequently confused with Molecular Gastronomy (this will be discussed below)- shows that there are many possibilities of real innovation in food or, rather, in « dishes ». Here, we shall address the issue of food innovation, showing why the question is poorly addressed, as formalisms that will be discussed can lead to an infinite number of possibilities.

Let us begin by addressing the question of « food ». As clear ideas lead to better understanding, it is probably useful to define it more clearly. Dictionaries give the definition: « Any substance that can give to living beings the elements necessary for their growth or for their preservation ». According to this definition, raw plant or animal tissues should be considered as food as well as food products obtained by using these tissues, but such a definition is confusing, as human beings very seldom

eat non transformed tissues or natural products; raw materials are transformed, so that chemical and physical changes determine the final composition of all food as well as its bioactivity (sensory effects, nutritional value, possible toxic effects, etc.). For « food production », i.e. dishes making, plant or animal tissues are at least washed, cut, not to mention thermal processing. Generally « cooks » (even in the food industry, as the difference between home, restaurants or food factories is generally a question of scale, not of the nature of products) devote themselves to clean the food ingredients microbiologically, and change their consistence and flavor. Even for a simple carrot salad, for example, there is a big difference between the raw product in the field, and what we eat, i.e. grated carrots in a plate, because cutting the tissue triggers enzymatic reactions such as enzymatic browning due to polyphenol oxidase enzymes (EC 1.14.18.1, PPO), for example,… or because there can be exchanges between the dressing and the plant tissue.

This analysis leads to a first conclusion [1]: reagents and products of « culinary transformations » should not be called « food » indistinctly. Could we call « ingredients » the reactants and « dishes » the products? If the name « dish » is indeed relevant for describing what we eat (rather than just « food »), using the word « ingredients » has no more drawbacks than « reactants », as it can change according to circumstances; just as some particular compound can be a product for one process, and a reactant for another, some foodstuff can be both an ingredient or a dish (for example, blood sausage is a product for the producer, but only a reactant for the cook who does the final thermal process, adding a garnish such as cooked apples, potato purée…). How should culinary transformations be called? As the transformations performed in factories of the food industry or in the kitchen (at home or in restaurants), it is proposed to keep the terminology « culinary transformations ».

Coming now to formulation, in particular in food, it is interesting to recognize that the formulation activity should tackle both the question of the inner constitution of dishes and the processing steps leading to dishes.

Indeed, the culinary trend introduced in 1992 under the name of Molecular Cuisine (given in 1998) was an improvement on both aspects, as its definition is « cooking with new ingredients, new tools, new methods ». Here « new » only means that it was not present in classical culinary practices, such as those described by the French cook Paul Bocuse (Collonges-au-Mont-d'Or, France), for example. Indeed, the use of liquid nitrogen for making sherbets or ice creams is not classic, whereas it was proposed as early as 1907 in London; vacuum distillation is only appearing in the kitchens of the most advanced chefs, whereas it is common practice in chemistry laboratories; and Asian populations use gelling agents such as carraghenans and alginates for millennia, but such products are recent in Occidental kitchens. More generally, it is a fact that such practices were not used by home or restaurant cooks until they were proposed by scientists interested in « Molecular Gastronomy ».

Introduced in 1988 by the late Nicholas Kurti (1908-1998) and one of us (Hervé This), Molecular Gastronomy is no cooking, but rather a scientific discipline whose scope is to look for the mechanisms of phenomena occurring during dish preparation (« cooking ») and consumption. It has three main objectives : (1) exploring the technical component of cooking, (2) exploring scientifically its artistic component, and (3) exploring its social component. From a technical point of view, it is rational to consider that culinary transformations are dynamic processes involving systems with composition and structure, so that it is obvious to make complementary descriptions of the physical state, on the one hand, and of the chemical state, on the other. The bioactivity of such systems can be considered as the result of the two, as there can

be interactions between the physical structure and the release of compounds, with or without modifications of the released compounds and of the physical structure of the system.
As Molecular Gastronomy is not an application of sciences but rather a science itself, it has nothing to do with formulation, except that it is easy to get applications from any discovery about culinary transformation, as will be shown in the next example.

1.1 The color evolution of carrot stocks

The study of an already existing process can help to understand the main parameters and how to control them in order to obtain the desired transformed product. For example, the control parameters to make an aqueous solution by thermal processing of carrot (Daucus carota L.) roots (« carrot stocks ») are the variety of carrot, pH, time and temperature of processing… However these parameters are not sufficient to control the result completely, as we discovered that the same thermal processing applied to two halves of the same carrot root led to solutions of different colors [2].
Having obsverved that the only difference between these two solutions was the exposure to light, we decided to investigate the color evolution (as measured using the CIE L*, a*, b* parameters) of carrots stocks and we processed plant tissues for up to 547 h, time after which no color evolution could be significantly observed (Figs. 1-3). A spiral shape was determined in the (a*,b*) plane.

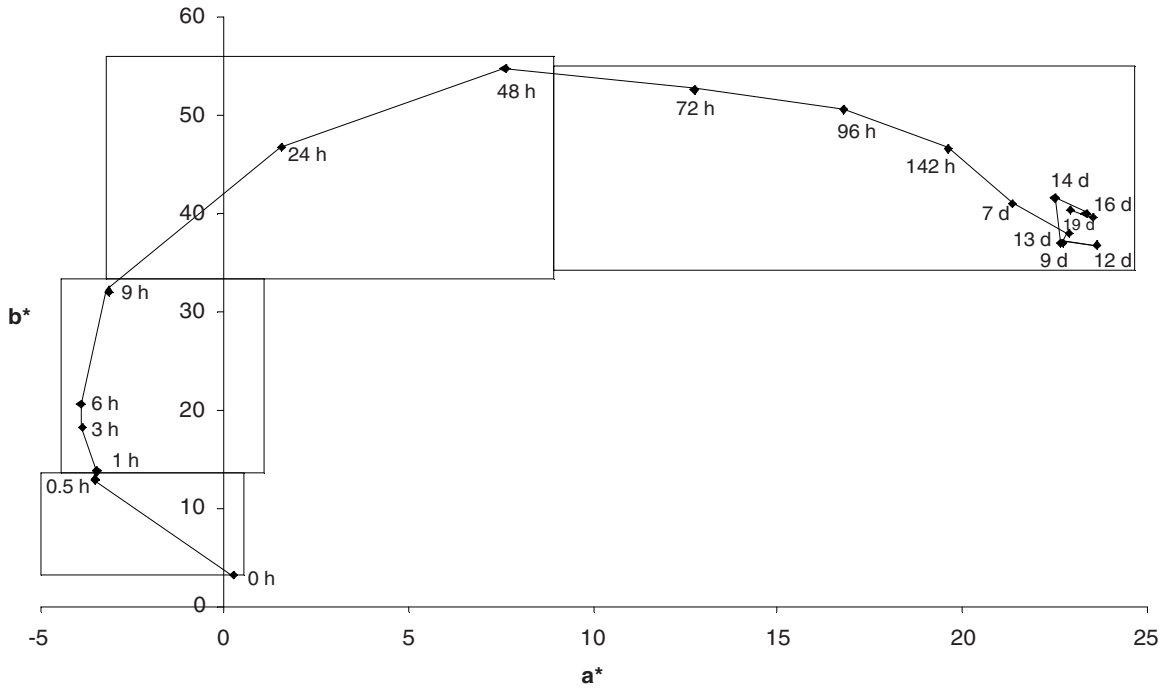


Figure 1. a* and b* variations (between 0 and 19 d of thermal processing)

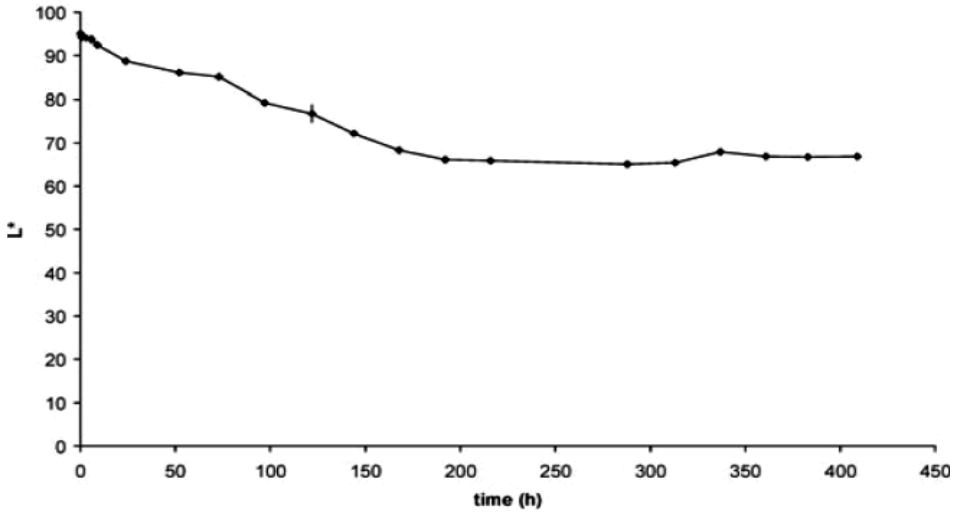


Figure 2. L* variation (between 0 and 19 d)

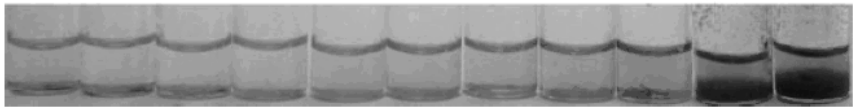


Figure 3. Stock color evolution (from left to right : 0, 0.5, 1, 3, 5, 7, 9, 24, 48, 72, and 142 h)

Then, a comparison of color evolution for stocks prepared with or without exposure to light was studied (Fig. 4,5).

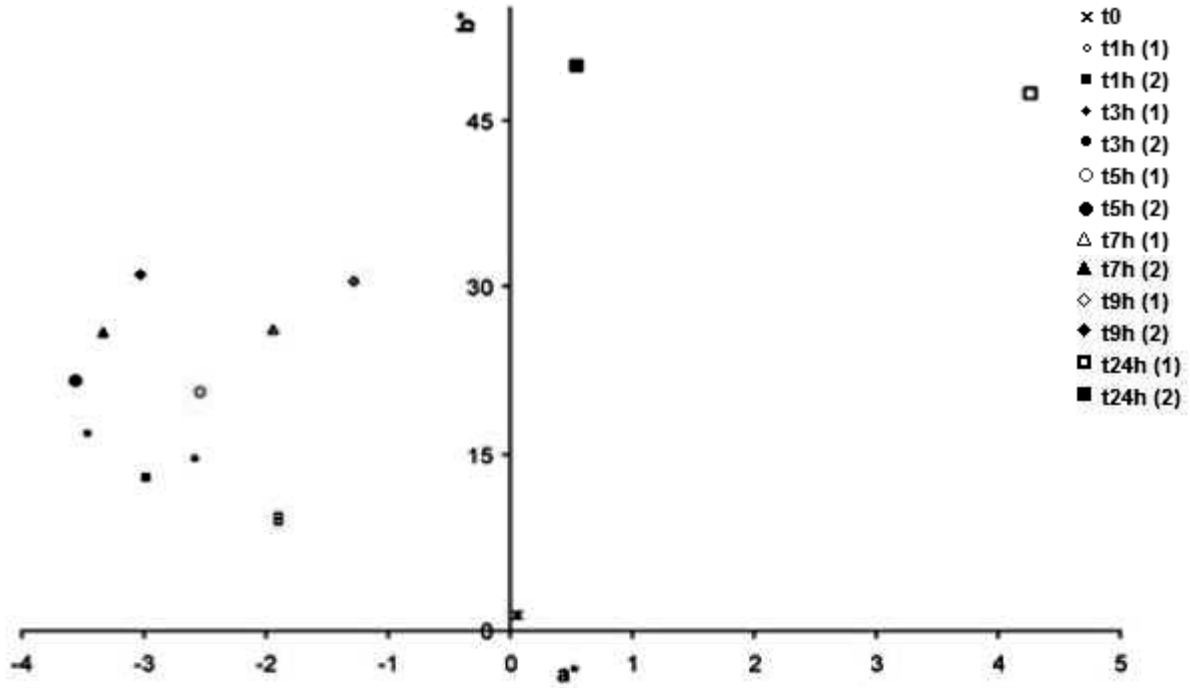


Figure 4. a* and b* variations of stocks prepared in light (1) or dark (2) conditions (between 0 and 24 h).

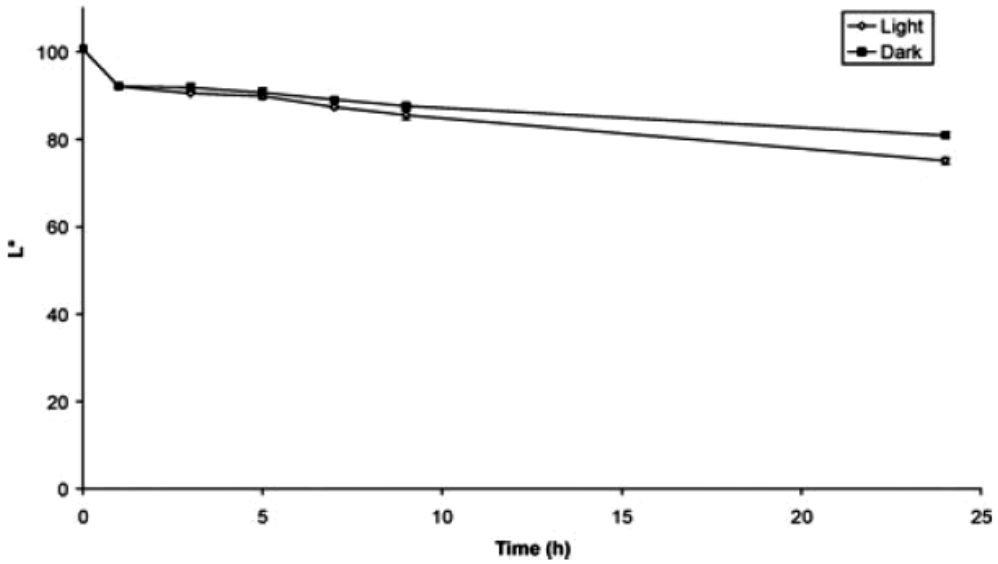


Figure 5. L* variation of stocks prepared in light (o) or dark ( ) conditions (between 0 and 24 h).

Every other parameter was the same for both samples (temperature: 100 °C, processing time: 24h, same plant sample washed to prevent an enzymatic browning, condenser adapted to the heating vessel to prevent losses of water and other compounds, etc.). After thermal processing, the « light exposed stock » was always browner than the « light unexposed solution ». This confirmed the influence of light on the color of the solution. For all treatments, four patterns can be distinguished on these curves:

- Pattern 1 (between 0 and 1 h) where a* decreases and b* increases.
- Pattern 2 (between 1 and 9 h) where a* is constant and b* increases.
- Pattern 3 (between 9 and 72 h), where a* and b* increase.
- Pattern 4 (until the end of the thermal treatment) where a* increases and b* decreases.

The parameters a* and b* evolve more significantly than the parameter L* which similarly decreases for both light exposure conditions in all four patterns. The same result was previously recorded by Loong and Goh on vegetable juice [3]. However, differences appear for the two kinds of stocks, with a faster evolution toward a brown solution in stocks exposed to light.

1.2 Models of color evolution

As all experiments, with or without exposure to light, with a separation of carrots from the stock or not, at any pH, showed the same kind of « spiral shape » variation in the (a*,b*) plane, this spiral shape was chemically investigated and a mathematical model was developed.

Carotenoids and other pigments from carrot tissues being poorly water soluble, we assumed that the main solutes in carrot stocks were produced by pectin modifications. Firstly, galacturonic acid ((2S,3R,4S,5R)-2,3,4,5-tetrahydroxy-6-oxohexanoic acid, GalA) is created from pectins during a thermal treatment of plant tissues through a -elimination [4]. Model solution made of GalA dissolved in water produced a color evolution which is similar to the pattern 1 (Fig. 6).

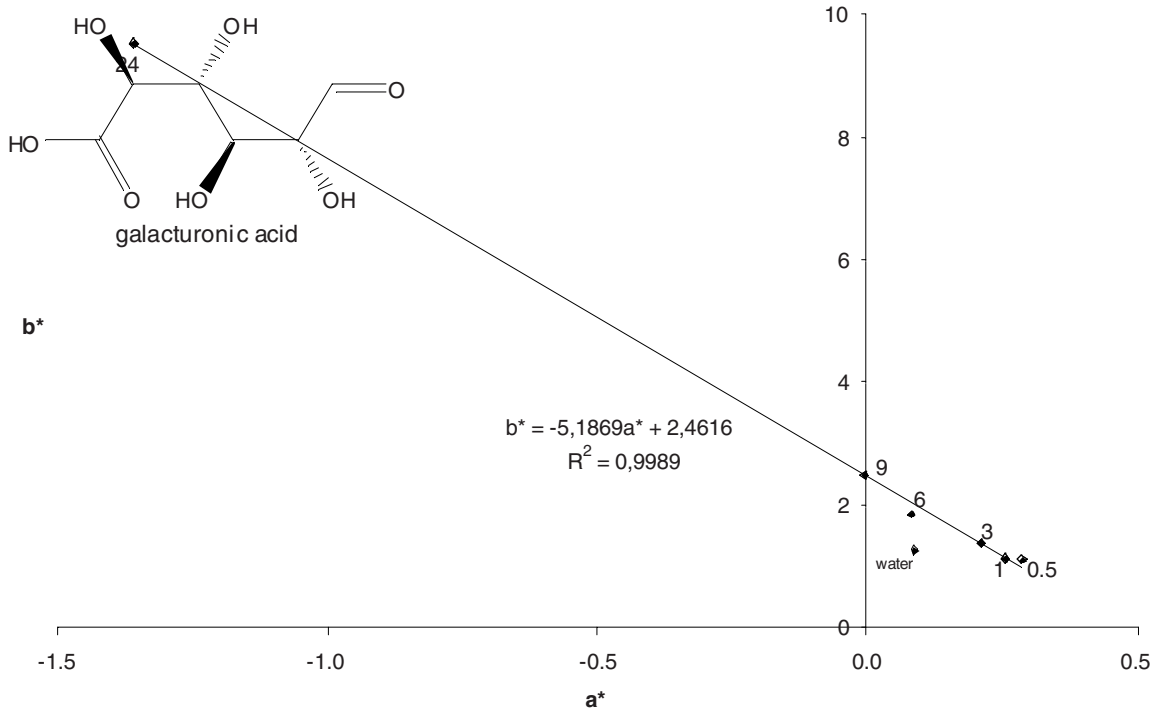


Figure 6. Variation of a* and b* parameters for thermally treated aqueous solutions of GalA.

However, such a behavior is not enough to reproduce the whole spiral shape, and it was calculated that either the compounds formed during GalA modifications are transformed into novel products, or a second compound with different color characteristics is extracted with a different time course evolution.
Indeed let us first remark that, if a compound having a particular light absorption with no saturation effect (i.e. the color is proportional to the concentration) is added in a solution with kinetic v(t) = dm(t) / dt, m(t) being the mass of the compound in the solution at time t, the color of the solution at any time can be represented as a vector **C**(t) with coordinates (a*(t), b*(t)):

$$\mathbf{C}(t) = k \,.\, m(t) \,.\, \mathbf{c},$$

where **c** is a unit vector.
If m(t) is simply proportional to the time (i.e. equal to v . t, where v is a constant), the color curve would be as shown in Figure 6. In such cases, the color point is going to infinity in the **c** direction. However, when saturation effects occur or when a compound is not added with constant rate but instead appears in the solution with a rate decreasing with time, such as when a compound (given initial quantity) is extracted from a solid, the color curve is only a segment. In the first case, the final coordinate is that of a saturated solution, and in the second case, it is determined by the final, extracted, mass.
Now, when two compounds 1 and 2 are added, the color vector is the sum of the two individual color vectors for each compound (again in the limit of no color saturation):

$$\mathbf{C}(t) = \mathbf{C_1}(t) + \mathbf{C_2}(t)$$

In the particular case of equal extraction kinetics (but with different light absorptions of the two compounds), the color evolution is described by a segment in the (a*, b*) plane. However, when the appearance rates of the two compounds are different, various color curves can be obtained, some having a spiral shape. The same color

curves are obtained when a compound 1 is introduced in the solution, this compound 1 being transformed into a compound 2 having different light absorption properties. For example, Figure 7 shows the theoretical color curve obtained when a compound 1 is introduced with a decreasing time-law (either exp(-t) or 1/t) and when a compound 2 is forming from the decomposition of compound 1, at a rate proportional to the quantity of compound 1 already in the solution. This leads to the differential system :

$$\frac{dm_1(t)}{dt} = e^{\ t} \quad \frac{dm_2(t)}{dt}$$

$$\frac{dm_2(t)}{dt} = \quad m_1(t)$$

Solving this system in $m_1(t)$ first gives:

$$m_1(t) = \frac{(\ a_1 + \ a_1)e^{\ t}}{1+} + \frac{e^{\ t}}{1+} \ ,$$

with a condition $m_1(0) = 0$, i.e. $a_1 = -1/(-1+\alpha)$. Then $m_2(t)$ can be calculated as :

$$m_2(t) = \quad \frac{e^{\ t} \quad a_1 e^{\ t} + \ a_1 e^{\ t} + a_2 \quad a_2}{1+} \ .$$

and spiral shapes are obtained:

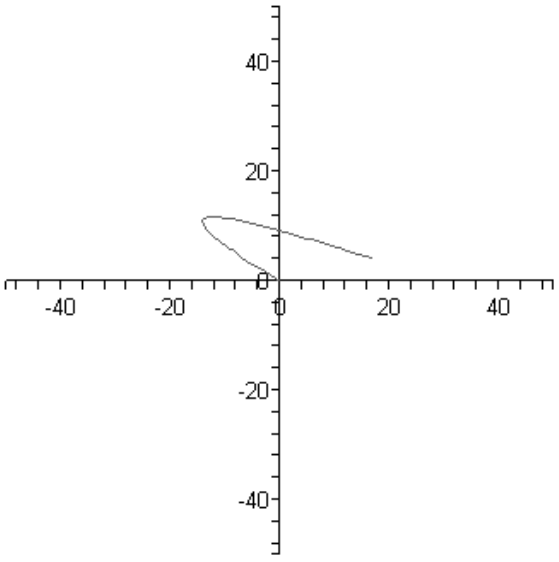


Figure 7. Equation of the model and color curve obtained when a compound 1 is extracted and transformed into a 2nd compound 2, having different color properties.

If such modelling is not useful for cooks or for the food industry, the whole study is important to them, because both communities rely on adding various compounds (such as grilled onion (Allium cepa L.) bulbs) for giving the desired color to stocks. This is « costly » and useless, as we now know that the control of color could be

obtained more easily by light during processing ; also some bitterness could be avoided.

2. APPLICATIONS TO FORMULATION: TECHNOLOGICAL TYPOLOGY

In view of making technology transfers more efficient, it was proposed to recognize that there are two kind of technologies that were called « local » (when it is done directly by technicians, or without using new scientific data) and « global » (using new scientific results, as will be shown later with the example of the « pianocktail ») [5]. It is also very important to recognize that any new knowledge is worth the transfer, and only imagination is needed.
In our laboratory, we followed proposals from the French philosopher Abraham Moles (« inventivity matrices »), and we introduced a table system for science/technology transfers (Table 1).

Table 1. A table for promoting technology transfer.

New knowledge obtained by the scientific team (during laboratory studies)	Ideas of technology transfer (discussed during Technology Transfer Meetings)	Technology studies decided, based on column 2 (they have to be done in the industry)	Result of the technology studies	New proposals after the analysis of results

Scientists have the duty to produced new knowledge, concepts, methods…: results are introduced in the first column of the table. Then, during technology transfer meetings, scientists and technologists together can try to find uses of such ideas (column 2). Of course, experimental tests of the proposals have to be done; the results are put in column 3. Either results are in good agreement with the predictions, and the ideas can be used in practice, or the desired results are not obtained, and then either the theory should benefit from this experiment, or modifications of the technological idea should be proposed.
Of course, the question of filling the second column sometimes appears difficult, and this is why general categories of technology transfers were proposed, after the analysis of ten years of innovation in the particular field of Molecular Cuisine (Table 2).
However, it would be too long to consider examples of all « technology types », and we shall later consider only the (probably) most important category, i.e. using formalisms.

2.1 Algebraic notations for formulation

The importance of algebraic notation (technology type 2.5, Table 2) is not new, and it was a big success of René Descartes, Wilhelm Gottfried von Leibniz or Isaac Newton

to use it in mathematics. In a treatise of logic published in 1918, the French logician Edmond Goblot discussed how notation can lead to discovery [6]:
« For the algebra of logic, its inventors probably never thought that it was only a notation of concepts, relationships and elementary operations for logicians, and they had never had any doubt on the difference between discovery of a truth and the invention of a notation for expressing it when it is discovered. Notation can lead to discovery, as it occurred frequently in algebra. To general and abstract concepts,

Table 2. Technology types.

1. Without any use of novel knowledge		**2. Using new data (concepts, information, methods): Fundamental Technology**
1.1. Local Technology	**1.2 Global Technology**	
1.1.1 Using the same tools, methods and ingredients as before to make the same products as before (second order modifications) 1.1.2 Solving technical problems using the same tools, ingredients and methods	1.2.1 Introducing new tools, ingredients and methods to make the same products as before 1.2.2 Introducing new tools, ingredients, methods to make new products 1.2.1 Generalisation (without science) 1.2.3 Transfers between fields (sans science) 1.2.4 Application of general ideas introduced elsewhere	2.1 Using classical laws 2.2. Generalisation (with science) 2.3 Transfers between fields (with science) 2.4 Rationalisation, keeping old ideas 2.5 Using formalisms 2.6 Application of new theoretical ideas, concept creation

untractable without formula, cumbersome to use with words and common language, the algebra of logic, as ordinary algebra, substitutes concrete and regular symbols which can be organized in a wealth of combinations and reduce heavy mind operations to very simple written processes. »
Goblot was indeed not the first one to propose such ideas : in the XVIIIth century, Antoine Laurent de Lavoisier (Paris, 1743 - id., 1794) introduced the formalism of chemistry in order to make chemical reasoning easier, and it was the basis of the introduction of modern chemical notation [7] : « In order to better show the state of the issue, and to present synthetically the result of what is going on during metal dissolutions, I built formulas, that could be confused with algebra, but do not derive

from the same principles; we are very far from the time when the precision of mathematics can be introduced in chemistry, and I invite the reader to consider the formulas that I shall give only as simple annotations, whose aim is to think easier ».

2.2 Using digital notation in trees

One of the simplest choices for making an « algebraic » notation is using binary trees. This was tested for products of the same kind as noodles, but the idea is very general.
Any « recipe » is using several ingredients and processing steps. As ingredients can be added successively, a list of them can be established, and the decision of using them or not can be coded by a binary digit (0, 1). The same idea holds for tools, or for processing steps. For example, a whole set of food products can be made from flour and water (no choice here), using (1) or not (0) fat, yeasts, added gluten, eggs… Such products can be thermally processed in water (0) or with vapour (1)… Using such codes, a particular binary tree is leading to noodles, gnocchis, and all products of the same "technology family".
Of course, other digit systems can be chosen, as can be shown with egg processing. If egg is receiving a code number equal to 1, and parts of eggs are being numbered from 1 to 9, then a codification of the processing possibilities (Table 3) can lead to codes associated to particular results [8].

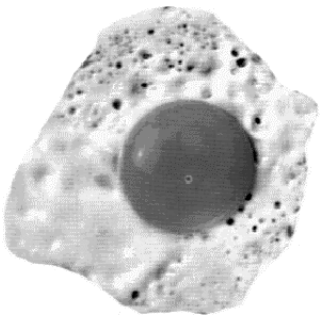
Table 3. "Algebraic" notation for 3 stages of a transformed product

Code number	First ingredient	Process	Add
1	egg	full egg	Nothing
2		shell	Gas
3		non mixed yolk and white	Water
4		mixed yolk and white	Oil
5		yolk alone	Solid
6		white alone	Ethanol
7			Acid
8			Alkali
9			Heat

For example, the sequence 1.1.1. corresponds to a whole raw egg; 1.1.6. corresponds to a "baumé egg", a product to which the name of the French chemist Antoine Baumé was given (Fig. 8a) ; 1.1.8. is a « 100-year-old egg » ; 1.1.9. is an hard-boiled egg (Fig. 8b) ; 1.3.9. is a fried egg (Fig. 8c) ; 1.4.9. corresponds to an omelette (Fig. 8d) ; 1.6.2. is a whipped egg-white ; 1.6.4. leads to a « geoffroy » (Fig. 8e) ; 1.6.6. is a « thenard » (Fig. 8f)… Such a codification is useful to describe a transformed product and to detect innovation possibilities.

(a) “Baumé egg”

(b) Hard-boiled egg



(c) Fried egg

(d) Omelette

(e) “Geoffroy”

(f) “Thenard”

Figure 8. Various results obtained with a codification of part of eggs and processing methods

3. THE DISPERSE SYSTEM FORMALISM

The notation method can also be used to describe transformed products as food, drugs and other formulated products (cosmetics, paintings, coatings...), in order to classify them and to create new ones. As written before, Lavoisier introduced the now classical formulas of chemistry because he wanted to make easier the description of compounds and chemical processes. The same ideas can be adapted to artificial systems... [8].

Such products are frequently colloidal systems or made of such systems [9-13]. For instance, emulsions are known since 1560, when the French surgeon Ambroise Paré (1509-1590) understood that white liquids like milk or cream were often composed of water and fat. However, complex systems such as potatoes (suspensions of starch granules dispersed in the liquid inside of cells, with cells themselves organized into a solid) or ice creams (gas bubbles, fat crystals, ice crystals dispersed in a liquid solution) are complex systems for which only descriptions at the interface were considered [14-15].
Accordingly, a CDS (« complex disperse system ») formalism was introduced at the European Congress on Interface Science (ECIS), in 2002 for the description of the « material » from which the various parts of dishes are made. Later, in 2003, another formalism called NPOS (« non periodical organization of space ») was proposed for the overall description of dishes, and relative distribution of materials described by the CDS formalism, but it was recently recognized that these two formalisms could be mixed into a more comprehensive description called « disperse system formalism » (DSF). These two formalisms can be applied for the description of other formulated products.

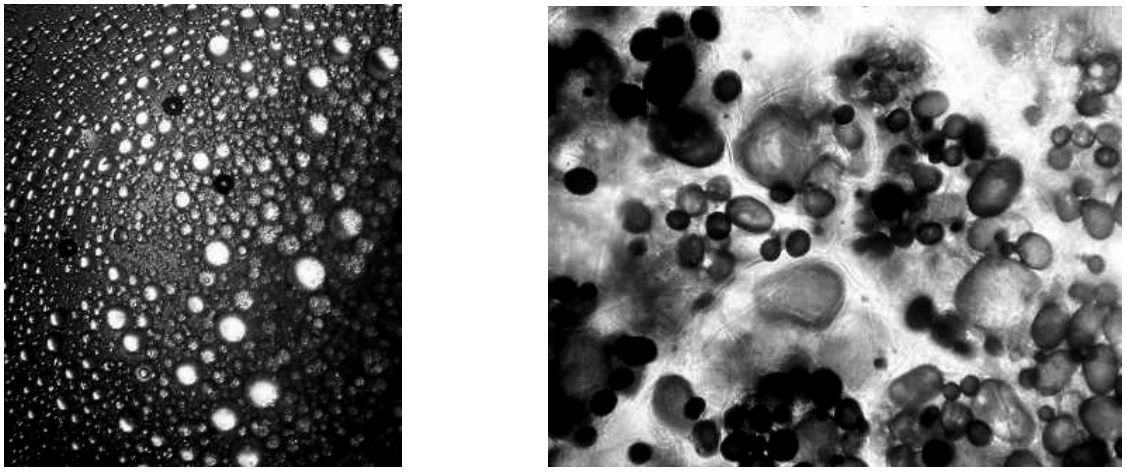
3.1. The Complex Disperse System (CDS) Formalism

In the CDS formalism, the various phases that make up the colloidal systems are considered: symbols G, O, W, S respectively stand for « gas », « oil »" (any hydrophobic phase), « water » (any aqueous solution), « solid » ; other symbols such as E for « ethanol » could be added if necessary ; « operators » are added, to make formulas. In particular, the IUPAC symbol « @ » is used to describe an inclusion ; for example, S@W is an inclusion of a solid in an aqueous solution. The symbol « / » was proposed to describe the random dispersion, such as in emulsions, foams…. For instance, O/W is an oil-in-water emulsion. The symbol « + » is used to describe a mixture of phases that can be dispersed into another one, such as (G+O)/W for an aerated emulsion, where the water solution is the continuous phase and where gas bubbles and oil droplets are dispersed into this solution. The symbol « _ » indicates a superposition. Finally the symbol « x » is used to describe the mixing of two continuous phases, such as in gelatine gels (SxW). Up to now, these connectors could describe all food systems that were considered.
Some rules are useful to give coherence to this formalism:
- The components of a sum have to be written in the alphabetical order, like (G+O+S)/W.
- Repetitions can be described by exponents. For example, egg yolks are made of concentric layers called light and deep yolk [16] deposited respectively during the day and the night ; their number is about 9, as shown on ultrasound scan pictures [17]. In such a case, as each layer is composed of granules (S) dispersed into a plasma (W), the full yolk could be described as $(S/W)^{@9}$.
- The quantity of each phase can be added as a subscript, such as O_{95}/W_5 to describe an emulsion of 95 g oil into 5 g water.
- The size of structures can be given into brackets, such as in:

$$O_{200}[10^{-6} – 10^{-5}]/W_5$$

where the powers of 10 indicate the minimum and maximum radii (expressed in m) of dispersed oil droplets (SI units should be used).

- To take into account the various scales in systems, the size of the smallest structures considered can be given in brackets, as a “reference size” at the end of formula.
For example, $O[10^{-5} – 10^{-4}]/W$ $[d > 10^{-5}]$ indicates that the structures considered are larger than 10^{-5} m, i.e. smaller granules are not taken into account.
- Some simplifications can be done. For instance, G/G is equal to G.
Kinetic parameters such as time or energy can be added to describe the evolution of the system. The equation O/W + G → (G+O)/W can be replaced by the following formula : $G_{t=0…50}+O_{30(100-t)/100})/W_{70(100-t)/100}$, where the time t is in seconds), the gas would be introduced at regular pace and indexes give volumes instead of mass.
Up to now, no food system escaped a description by this formalism. But do all formulas correspond to possible systems ? Many dispersed systems are metastable and not thermodynamically stable. Indeed, they evolve, depending on the size of their structures or on the nature or quantity of stabilizing elements like surfactants in emulsion. It is also a question of kinetics, not of thermodynamics.
This CDS formalism has the advantage to clearly show the physical structure of matter described and primarily to limit the description to a pertinent order of magnitude for sizes, using the reference size. For instance, mayonnaise sauce can be represented by the formula O/W $[10^{-6} - 10^{-4}]$ and potato (Solanum tuberosum L.) tissues by (S1/W)/S2 $[R < 10^{-6}]$, assuming that the cytosol inside plant cells is a liquid (indeed it could be considered as a gel, but this would not change much the description (Fig 9).



(a) (b)

Figure 9. (a) Optical microscopy of a mayonnaise: oil droplets with a diameter between 10^{-6} m and 10^{-4} m are dispersed into an aqueous solution ; (b) Optical microscopy of a potato tissue : starch granules with a diameter smaller than 10^{-6} m are dispersed in the aqueous solution (cytosol) inside cells, this solution being itself dispersed in the solid system of the potato tuber.

3.2. Using formulas for innovation

The CDS formalism is an important tool for innovation. In 1995, a new dish named « Chocolate Chantilly » was based on the equation O/W + G → (G + O)W [18]. First, a chocolate dispersion ((O+S)/W) is made by heating chocolate (the formula can be written f(O,S), because it is not well known today) into water with the same final fat/water ratio as in ordinary cream. Then, this dispersion is whipped (+G) at room temperature while cooling. The very unstable hot (G+O)/W system is slowly

Société Chimique de France

Groupe Formulation

Présentation de la Société Chimique de France

La Société Chimique de France (SCF) est une association régie par la loi du 1er Juillet 1901, fondée en 1857 et reconnue d'utilité publique. Son objectif est la promotion de la Chimie dans ses aspects scientifiques, éducatifs et appliqués. La Société Française de Chimie, résultant de la fusion de la SCF avec la Société de Chimie Physique en 1984, a repris en 2008 le nom originel de Société Chimique de France. La SCF est organisée en Divisions, en Groupes thématiques, en Sections régionales et en Clubs de jeunes. Le Groupe Formulation constitue l'un des Groupes thématiques pluridisciplinaires.

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GROUPE FORMULATION

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La formulation, considérée auparavant comme un art, est devenue une démarche scientifique pluridisciplinaire et multi-sectorielle. Elle consiste à associer une ou plusieurs " matières actives" à une série "d'auxiliaires de formulation" pour conduire à un mélange répondant à un cahier des charges précis et capable de satisfaire un besoin d'un client (industriel ou consommateur final). Deux types d'industries sont plus particulièrement concernées par la formulation : les industries de spécialités chimiques, qui conçoivent les ingrédients de base des formules (tensioactifs, pigments, composés filmogènes, parfums, huiles, stabilisants, épaississants,…) et les industries de formulation, qui fabriquent des produits prêts à l'emploi possédant les propriétés d'usage requises (médicaments, cosmétiques, produits phytosanitaires, détergents, peintures, adhésifs,…). En fait, toutes les autres industries de transformation de la matière font aussi appel à la formulation (produits agroalimentaires, carburants, textiles, caoutchouc, plastiques, verres, ciments,…).

Le **Groupe Formulation** a pour ambition de contribuer au développement d'une approche raisonnée de la formulation qui éclaire la démarche empirique traditionnelle fondée sur un savoir-faire acquis « sur le terrain ». Pour atteindre cet objectif, le Groupe favorise la mise en place d'enseignements dédiés à la formulation et facilite les échanges entre les acteurs industriels cités plus haut et les universitaires oeuvrant dans toutes les disciplines scientifiques concernées : synthèse de produits de performance, physicochimle des interfaces et des systèmes dispersés, génie des mélanges, rhéologie des fluides complexes et des poudres, chimiométrie, déformulation, méthodes de caractérisation,…

Ses principales activités sont :

- L'organisation des **Journées de Formulation**, focalisées sur des thèmes transversaux correspondant à des préoccupations communes à plusieurs industries de formulation. Les conférenciers universitaires sont chargés de faire le point sur les concepts et les méthodes et les intervenants industriels présentent des études de cas choisies dans différents domaines d'application de la formulation.

- La publication des **Cahiers de Formulation**, qui rassemblent des articles originaux rédigés par les membres du Groupe ou par les conférenciers et auteurs de communications aux Journées de Formulation.

- L'organisation des grands congrès internationaux **"Formula ®"** (Nice, 1987 ; Toulouse, 1990 ; La Grande-Motte, 2001 ; Londres, 005 ; Potsdam, 2007 ; Stocholm, 2010 ; Mulhouse, annoncé pour 2013). Ce sont des lieux de rencontre pour tous les universitaires et les industriels intéressés par la formulation au-delà de leurs domaines particuliers.

- Des **réunions trimestrielles** du "noyau dur" du Groupe (15–20 personnes) destinées à faire le point sur les actions en cours.

Site web : www.societechimiquedefrance.fr/fr/formulation.html