

2016

Molecular Gastronomy

Roisin Burke

Technological University Dublin, roisin.burke@tudublin.ie

Herve This

INRA, herve.this@agroparistech.fr

Alan Kelly

UCC, a.kelly@ucc.ie

Follow this and additional works at: <https://arrow.tudublin.ie/tfschafart>



Part of the [Food Science Commons](#)

Recommended Citation

Burke, R., This, H Kelly, A.L. (2016) Molecular Gastronomy. doi:10.1016/B978-0-08-100596-5.03302-3

This Article is brought to you for free and open access by the School of Culinary Arts and Food Technology at ARROW@TU Dublin. It has been accepted for inclusion in Articles by an authorized administrator of ARROW@TU Dublin. For more information, please contact arrow.admin@tudublin.ie, aisling.coyne@tudublin.ie.



This work is licensed under a [Creative Commons Attribution-NonCommercial-Share Alike 4.0 License](#)

Molecular Gastronomy

Róisín Burke, School of Culinary Arts and Food Technology, Dublin Institute of Technology, Dublin, Ireland

Hervé This, Groupe de Gastronomie Moléculaire, INRA-AgroParisTech International Centre for Molecular Gastronomy, Paris, France; and UMR GENIAL, AgroParisTech, INRA, Université Paris-Saclay, Massy, France

Alan L Kelly, School of Food and Nutritional Sciences, University College Cork, Cork, Ireland

© 2016 Elsevier Inc. All rights reserved.

Introduction	1
Why Molecular Gastronomy?	1
Definition of the Discipline	2
An Analysis of Traditional Culinary Practices	2
Categorizing Culinary Precisions	2
The Robustness of Recipes	3
DSF, a Tool for the Description of Colloidal Systems	3
New Applications of Molecular Gastronomy	4
A Case Study of Education in Molecular Gastronomy: Dublin Institute of Technology School of Culinary Arts and Food Technology	5
Conclusions	7
References	7
Relevant Websites	8

Introduction

Molecular gastronomy is the scientific discipline that explores the phenomena occurring during culinary transformations. First articulated in 1988, since then it has been developed in a number of universities, research institutes, companies, and kitchens around the world. The objective of molecular gastronomy is the determination of physical and chemical mechanisms involved in the preparation and processing (including cooking) of food, and ultimately the discovery of new mechanisms and applications. Phenomena are explored which had been previously neglected because of their perception as relating to ‘cooking,’ and thus being perhaps regarded more as an art than a technique, and perhaps also because of the apparent lack of commercial interest.

In this article, we will consider the historical introduction of molecular gastronomy and some examples of the application of its principles. For example the ‘Dispersed Systems Formalism’ (DSF), a formal language analogous to the formalism of chemistry, but which applies to the physical organization of systems, as affected by processing steps and formulation. The DSF approach also opens the possibility of predicting new systems, thus underpinning technical innovation in food formulation.

Why Molecular Gastronomy?

Scientific and technological approaches have been applied for a long time to food products, leading to a complex understanding of how chemistry, physics, and microbiology interplay in transformations from raw materials and ingredients to finished products. These approaches and their applications have been in the context of what can be achieved on an industrial scale, while at the same time underpinning the development of new and innovative food products.

However, an examination of a typical cookbook demonstrates that the range of culinary preparations, i.e., the transformations operated by the professional or domestic cooks, is considerably wider than the range of the transformations practiced by the food industry. For example, while cooks often process wine thermally, in particular, during sauce production, this activity is not supported by research into chemical modifications occurring during such processes. Thus, this important area of food science was neglected as a serious topic of scientific study for a long time, and transformations such as those involved in the preparation of dishes, even if they seem ‘anecdotal’ from a scientific point of view, were arguably regarded as an art more than a science.

This is why, in 1988, Hervé This with Nicholas Kurti (1908–98) extended work which had been started from the eighteenth century and introduced a scientific discipline which was named ‘molecular and physical gastronomy’ (This and Kurti, 1994), a title abbreviated to ‘molecular gastronomy’ in 1998. The term itself has a useful analogy to ‘molecular biology,’ in that just as the former brought a rigorous scientific approach to the discipline of biology, so molecular gastronomy brings a similar approach to the work of the chef.

The development of and key principles of molecular gastronomy have been described in a number of articles (This, 2002, 2005, 2006a, 2009, 2011a,b; This and Rutledge, 2009; Thomson, 2014; Van Der Linden et al., 2008).

Definition of the Discipline

As the range of culinary transformations is vast, a key initial question in the development of molecular gastronomy concerned which phenomena to explore as a priority. Thus, the first objective was to understand the particular nature of the operations which were most common in kitchens. On this basis, it was recognized that culinary activity had three components which could be the subject of specific studies.

Firstly, the manufacture of some products includes a specific technical operation, which is critical to technical 'success'; for example, a soufflé has to 'inflate,' otherwise it is a cake or a pancake, and not that which was intended. Molecular gastronomy, insofar as it is not technology (it is not inclusive of 'culinary technology'), but rather a science, is less interested in the technical conditions for the preparation of the dishes than in the mechanisms underpinning phenomena such as this inflation, as well as in the phenomena which take place during the eventual consumption of the dishes.

However, culinary activity is not limited to technical activities, as shown by the importance of the quantity of salt (sodium chloride) in the soufflé discussed above: there is no technical difference in practice between putting 5 or 10 g of salt per kg, but there is an essential difference in sensory significance (the salt interacts with receptor cells present in papillae, because, again, the food is a particular physicochemical system as it is eaten. This is named an artistic component, which can be studied scientifically as well).

The third aspect is neither technique nor art; this is the social aspect, the importance of which for the appreciation of food, and thus its consumption, is even higher than the artistic or technical importance.

Thus, 'cooking,' i.e., the human activity consisting of preparing and processing food on a relatively small scale in a kitchen or similar environment, can be explored scientifically from three points of view, i.e., social, artistic, and technical, and is a relevant and rational field of investigation for the scientific discipline named molecular gastronomy.

An Analysis of Traditional Culinary Practices

These three components of the culinary activity having been defined, a key objective in the development of molecular gastronomy was to study more finely the practices of the past. Up to that point, culinary techniques had been passed on in an oral or written way ('recipes'). As these means of transmission describe the transformations and the phenomena which take place during culinary activity, it was of relevance to initially explore them.

Three elements were especially identified in recipes:

1. A 'definition': the minimal technical part of the recipe which leads to the production of the food, often consisting of an operating protocol; for example, the definition of 'marmalade' involves slices of oranges plus sugar plus heat.
2. 'Culinary precisions': these are all the technical additions that are not part of the 'definition'; in the orange jam recipe, it is sometimes 'said' that you have to cook until a drop of the liquid forms a gel on a cold plate.
3. A third part, including information that is not a matter of technique, but has perhaps an artistic or social dimension; again in the case of the orange jam recipe, the fineness of the shredding of the slices is a measure of success.

Another example of the methodical approach to analysis of traditional culinary practice concerns the traditional belief that salt should be added to water when cooking green vegetables. Many reasons are given depending on which cookery book you read, e.g., to fix the color, to make the water 'hotter,' to make the water 'cooler,' to make the water boil faster, and to season the vegetables. In this case, while the color of green vegetables can change during cooking primarily due to changes to the pigment molecules and structural tissue modifications due to beta elimination of pectins, the changes are greatly influenced by pH and calcium content of the water, and pure sodium chloride does not have much of an effect (Valverde, 2007).

Categorizing Culinary Precisions

The collation and analysis of culinary precisions in France began in March 1980. This large project is not yet finished, but after more than 25 000 culinary precisions collected, it is already possible to distinguish categories: judgments, sayings, proverbs, maxims, tricks, proportions, indications, practices, instructions of use, explanations, rules, aphorisms, and processes (This, 2006b). A difference has also been defined between precisions that are related to ingredients (PRI) or to operations (PRO).

One key finding has been that the traditional or even modern culinary precisions are not actually all pertinent. Several have been experimentally shown to be inefficient. For example, it is sometimes taught in culinary schools that strawberries should not be washed, because this would make them lose their flavor. Or it is advised to heat the mixture of whole egg and sugar at 50 °C when preparing a sponge cake. Or, worse, it was proposed that menstruating women were unable to successfully make mayonnaise sauce. While some of these culinary precisions are obviously wrong, others deserve testing. Indeed the 'Parisian Seminars of Molecular Gastronomy,' introduced in September 2000, have presented monthly opportunities to test these precisions. Moreover, these studies are deeply linked to the exploration of the definitions.

To understand why incorrect culinary precisions may have continued to be passed on for many years, it may be useful to consider an analogy between the classification of culinary precisions and that of symptoms of diseases was proposed. In this analogy, molecular gastronomy is at a point which had been reached by medicine in the eighteenth century, when the difference between

nosology (from Greek *nosos*, 'disease'), i.e., the branch of the medicine which looks for the criteria of classification of the diseases, and nosography, which consists of making classifications, began to emerge.

More accurately, precisions whose predictions are confirmed or refuted by experimental tests may be described as 'right' and 'wrong,' respectively. After years of experimental studies of precisions, it appears that all possibilities exist:

- some precisions appear right and are right (e.g., it is proposed that cut pears remain white when lemon juice is added, and indeed ascorbic acid can block the chemical modification of phenolic compounds due to polyphenol oxidase enzymes);
- some appear right but are actually wrong (e.g., that washing strawberries does not make them lose their flavor, as is frequently taught in culinary schools);
- some appear wrong but are correct (it was said that cutting the head off roasted suckling pigs would keep the crispiness of the skin);
- some appear wrong and are indeed wrong (the link between menstruation and mayonnaise sauce); and
- finally, for some precisions, the status is difficult to establish before experiment (for example, it is said that pears will turn red when cooked in a pan lined with tin, and it was shown that the appearance of the red color was indeed a result of processing at low pH).

The fact that some culinary precisions are wrong, as shown by experimental studies, leads to two key questions:

1. Why were wrong ideas transmitted in a technical field?
2. Why were culinary circles so slow to test the knowledge which was being transmitted?

The number of culinary precisions is so large that such questions have to wait for further work, but the group of culinary precisions which are contradicted by experimental tests may be of particular interest for further investigation. Indeed, when a hypothesis regarding the possible result of a particular process is refuted experimentally, this probably means that the theory underlying our judgment can be improved.

Moreover, the study of the transmission of culinary precisions can be the basis of an historical study of such ideas, which leads to a phylum of precisions, including 'comparative molecular gastronomy,' in which culinary practices of various cultures are compared.

Nonetheless, looking for categories is a good starting point, and the analysis of 'failures' (when the result is not correctly described by the recipes) show the great importance of the correspondence between the result and the definition, as given by technical, physiological, and cultural aspects.

To date, the main identified causes for failures included the following:

- poorly understood chemical or physical mechanisms (e.g., when it is advised that whipped egg whites cannot be whipped again after they have drained back to a liquid);
- inappropriate generalization from another scenario (e.g., when it is advised that adding boiling vinegar to a mayonnaise sauce stabilizes it, on the basis of an assumption that acidity has an effect on the coagulation of proteins);
- bad technical generalization (sorrel would dissolve fish bones during long cooking);
- magical thought (mayonnaise sauce would fail when the moon is full);
- poor biological interpretation (crème patisserie would curdle in hot weather with storm conditions);
- generalization from macroscopic to microscopic (cutting the edge of a puff pastry before cooking would improve heat transfer);
- intellectual laziness (pheasants have to be stored hanged by the neck, and they would be ready to cook when they fall), and;
- bad scientific interpretation (for years, it was reported that mayonnaise had to be prepared using an iron whisk and a copper bowl, because of a 'battery effect').

The Robustness of Recipes

On the other hand, it is interesting that, in spite of a lack of scientific knowledge, chefs succeed in making most of their preparation; this shows that the processes they use are 'robust.'

The robustness of a recipe may be defined as the likelihood of it leading to a similar result each time despite variation in the technical parameters; more precisely it is defined as the ratio of the extent of possible variations of a parameter (for example, temperature) to the uncertainty with which this parameter is known. For example, a pear compote is robust, as only a limited number of ingredients and details, i.e., 'pears, sugar, water, and heat,' are sufficient to obtain a compote, and there are a large number of quantities and cooking times that allow a compote to be produced. In contrast, mayonnaise sauce is less robust, as there are several key parameters that cannot be changed too widely for success of the product.

It is possible to quantify the robustness of a recipe by calculating the partial robustness for each parameter that has an influence on the recipe (e.g., temperature, time, speed of mixing). These measures of partial robustness may then be aggregated to obtain a global estimate of robustness, using an equation analogous to that used to model an equivalent resistor in a parallel circuit.

DSF, a Tool for the Description of Colloidal Systems

DSF is a method for describing the structure and organization of dispersed systems, which are commonly found in many food products (This, 2007, 2013b). Within the DSF concept, a particular type of formal language is used to describe colloidal systems, with

Table 1 Examples of the application of the Dispersed Systems Formalism approach to classification of food systems

<i>Formalism</i>	<i>Food example</i>	<i>Description</i>
W	Meat broth	Aqueous solution of soluble ingredients
O	Sage butter	Flavored melted fat
O/W	Mayonnaise	Oil-in-water emulsion
S/W	Apple sauce	Solid particles suspended in an aqueous medium
W/S	Parenchyma of plant tissues	Nonconnected gels
(O + S)/W	Chocolate drink	An emulsion containing solid cocoa particles
(O + W)/S	Butter at room temperature	Dispersion of a water phase and liquid fat in the crystalline network of solid fat
(G + O + S)/S	Chocolate mousse	Foamed emulsion containing solid cocoa particles
(G + O + S)/W	Custard	Emulsion with air bubbles and solid coagulated egg protein in an aqueous medium
(G + O + S)/W	Ice cream	Ice crystals, air, and emulsified fat in a continuous phase of concentrated sugars
(G + O + S)/W	Mousseline	Foam or mousse with added whipped cream
(O + (W/S))/W	Bechamel sauce	Sauce made from butter, flour, and milk
(S + (W/S))/W	Allemande	A white meat-based sauce
(O + S + (W/S))/W	Batarde	A hot butter sauce
((O + (W/S))/W)/S	Chantilly cream	Whipped sweetened cream
(O + (W/S) + (W@S))/W	Aioli	Emulsified sauce made with garlic and olive oil
(O + S + ((G + O)/W))/W	Mousseuse	Whipped sauce made from lemon juice, salt, and cream

letters being used to represent the different phases present (i.e., G for a gas, L for a liquid that can be specified as O for oil, W for water or aqueous phases, and S for solids). This builds on, and considerably extends, the long-standing practice of referring to oil-in-water and water-in-oil emulsions by the shorthand O/W and W/O, respectively.

Numbers are then given for the physical dimensions of the objects (between 0 and 3), relative to a chosen reference size, and operators give the organization between the phases, e.g., / for a random dispersion, @ for inclusion of a phase in another, × for dispersion between two phases, and σ for superposition. For example, if mayonnaise is observed under the optical microscope with a magnification enough to see the droplets of diameter between 0.001 and 0.1 mm, the continuous aqueous phase is given a dimension of 3 (it is of the same order of magnitude as the reference size, this size being here the diameter of the visual field), and the oil droplets have a 0 dimension, as they are smaller by one order of magnitude or more in all three directions of space.

Following analysis by microscopy, it has been possible to describe a range of food systems with DSF, and therefore, to classify them by complexity. One of the initial successes of this approach involved the reclassification of 451 different sauces used in French cuisine into 23 different systems differing in their DSF classification, as shown in [Table 1](#).

Gels can, for example, be described by DSF, as they are a dispersion of liquids in a solid. They are moreover interesting to study in molecular gastronomy, as many food systems are or include complex gels. For example, gelatin gels have two continuous phases, so their DSF formula is D3(S) × D3(W), but plant tissues are also a form of gel, of a different formula (D0(W)/D3(S)), and potato (*Solanum tuberosum* L.) tubers are even more complex, because the water phase inside the cells contains some starch granules, which are solids.

In addition, DSF can describe transformations during cooking or processing, such as when cream ((O + S)/W) is whipped (turning to G/((O + S)/W)). The DSF approach has also been applied to combinatorial approaches to creation of new food products, as when a pump-based microfluidic desktop unit was used to prepare a wide range of blends, emulsions, foams, and suspensions from a finite number of initial ingredients ([This, 2007](#)); this approach has been shown to be able to produce over 10⁸ different systems from only 11 initial input variables.

New Applications of Molecular Gastronomy

Developments in the field of Molecular Gastronomy in recent years include the emergence of the concepts of ‘Molecular Cooking’ and ‘Note-by-Note cooking’ ([This, 2008, 2013a, 2014](#)). Molecular Cooking is defined as producing food in kitchens using ‘new’ tools, ingredients, and methods (INICON, 2003); examples of this could include use of equipment such as siphons, ingredients such as sodium alginate, and methods such as that used in *sous-vide* cooking.

In the case of ‘Note-by-Note cooking,’ meat, fish, vegetables, or fruits are not used to make dishes, but instead compounds, either pure or in mixtures, are assembled by the chef to design the shapes, colors, tastes, odors, temperatures, trigeminal stimulation, textures, nutritional aspects, and more of the desired dish ([This, 2013a](#)).

A Case Study of Education in Molecular Gastronomy: Dublin Institute of Technology School of Culinary Arts and Food Technology

Molecular Gastronomy and the related disciplines mentioned above represent effectively a new way of examining the nature of food and its preparation. Consequently, there has been recognition internationally of the need to develop education programs to train new generations of graduates with the blends of skill sets and competencies to play a role in this field in the future. Interestingly, internationally, there has been a parallel emergence, particularly in the United States, of a related discipline called Culinology[®] or Culinary Science, which may be defined as being grounded in the world of food science, but applied to culinary situations, whereas Molecular Gastronomy may be regarded as the same discipline but coming from the opposite direction.

In considering the development of the field of Molecular Gastronomy, it is appropriate to consider an example of an innovative program designed to teach students principles of this emergent discipline.

In the Dublin Institute of Technology, both Molecular Cooking and Note-by-Note cuisine are used to stimulate students' interest in and understanding of the chemistry and physics of food and its constituents, and to allow creativity to flourish in the development of novel and highly innovative dishes, drinks, and food products (Burke, 2011; Burke et al., 2012).

In this institution, Molecular Gastronomy is taught through team teaching and blended learning (Figure 1). For a particular topic, e.g., emulsions, a Culinary Science lecturer delivers a lecture which is followed by a practical session in an experimental kitchen taught by both a Culinary Arts and a Culinary Science lecturer. The students, undergraduate or postgraduate, are from Food Science and from Culinary Arts programs, and they learn skills and techniques from each other in a practical environment. As part of the Molecular Gastronomy modules, students are required to produce drinks and/or dishes through 'Molecular Cooking' or 'Note-by-Note cooking.' A number of examples of novel drinks and dishes created through Molecular Cooking in this program are shown in Figures 2a–4.

In the egg-based theme example (Figure 2a), the chemical and physical properties of an egg or its components are exploited in order to substitute it for other usual components and thereby create an innovative drink or dish (Sciences-Cuisine, 2013). In the example shown, the student exploited the properties of egg constituents to create a dairy-free version of Irish coffee for lactose-intolerant consumers. A sabayon is a light sauce traditionally made with egg yolks, sugar, and wine (typically Marsala), and in Italy it is called 'Zabaglione'; the recipe for the egg sabayon included the following ingredients: egg yolk, white refined sugar, water, Irish whiskey, xanthan gum and gellan gum (polysaccharides produced by bacteria), and white coloring. The lightness of the egg-based sauce coupled with the addition of xanthan and gellan gums allowed a stable 'creamlake' layer to remain above the coffee layer during consumption.

In the seaweed-based example (Figure 3), an aperitif and a main dish were created incorporating one or more marine algae (Sciences-Cuisine, 2012). The aperitif has a crunchy seaweed element and the main dish incorporates a seaweed extract. To create this dish, students explored the functional properties of seaweed and its extracts.

Figure 4 shows an example of a novel dish created through Note-by-Note cooking. Students were asked to incorporate a dilute solution of the pure compound methional into a drink or dish composed entirely of pure compounds or mixtures



Figure 1 Advanced Molecular Gastronomy Module, DIT. Food Science and Culinary Arts students working side by side while being mentored by Dr Róisín Burke (Culinary Science) and Ms Pauline Danaher (Culinary Arts).



Figure 2a Dairy-free Irish-style coffee produced by Aaron Fitzpatrick (final year degree student, Culinary Arts, DIT), containing egg yolk, xanthan gum, coffee, and gellan F. Image: Aaron Fitzpatrick.



Figure 2b The sabayon remains stable throughout the drinking experience. Image: Aaron Fitzpatrick.

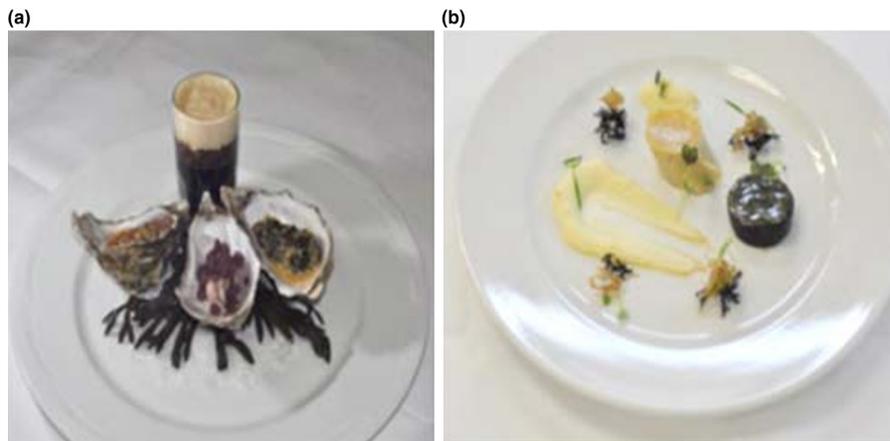


Figure 3 (a) Oysters three ways with Guinness stout and (b) scallop with cauliflower black pudding and scallop purée. Created by Hugh Higgins (final year degree student, Culinary Arts, DIT). Agar was incorporated into elements of both dishes.



Figure 4 'Sunday chicken roast dinner' made from a mixture of pure chemical compounds by Ciarán Doyle (final year degree student, Culinary Arts, DIT).

of pure compounds. As shown in [Figure 4](#), a dish was created which evoked memories of Sunday chicken roast. A meal was created which consisted of roast chicken tiles and carrot tiles with rosemary pearls, and a lemon mash and a potato meringue, both of which included methional. The dish combined structural compounds such as gellan gum with flavor chemicals including 2-methyl-3-furanthiol, which gives the flavor of chicken, and verbenone and borneol to add a hint of rosemary ([Thomson, 2014](#)).

Conclusions

In this article, conceptual tools have been reviewed which can be used to describe and characterize the culinary transformations that occur in many diverse food systems. These tools can be applied to the transformations of animal, plant tissues, or more complex systems, whether in food processing or during cooking. The measurement of the complexity of these transformations is clearly a critical goal of the development of molecular gastronomy: it will be interesting to explore the transformations in the order indicated previously and, if possible, bring complex cases studies back to elementary cases.

The result of such approaches could be the production of physical systems corresponding to a rationally constructed range of formulas, through the physical or chemical characterization of these systems, followed by an exploration of the permutations arising from the formulas and results of these characterizations. For such studies, the modern methods of chemometrics and combinatorial chemistry will doubtless be essential, because of the large amount of data necessary to collect to make this approach successful. It will also be necessary to determine the chemical transformations of the diverse organic compounds present in food, during 'culinary conditions,' e.g., heating at a temperature of 100 °C in water for times up to several hours. It is also noted that this article considers only the technical aspect of culinary activity and that studies about the artistic and social sides remain essential in parallel.

References

- Burke, R., Danaher, P., Traynor, M., 2012. The Development of Molecular Gastronomy as a Subject Discipline at the Dublin Institute of Technology. Available at: <http://arrow.dit.ie/cgi/viewcontent.cgi?article=1143&context=tfschafart>.
- Burke, R., 2011. The EU Erasmus Mundus Program: the Master's Degree in Food Innovation and Product Design (partners: Dublin Institute of Technology, AgroParisTech, University of Naples and University of Lund). *J. Culin. Sci. Technol.* 9 (2), 66–70.
- This, H., Kurti, N., 1994. Physics and chemistry in the kitchen. *Sci. Am.* 270 (4), 44–50.
- This, H., Rutledge, D., 2009. Analytical methods for molecular gastronomy. *Anal. Biol. Chem.* 394, 659–661.
- This, H., 2002. Molecular gastronomy. *Angew. Chem. Int. Ed.* 41 (1), 83–88.
- This, H., 2005. Molecular gastronomy. *Nat. Mater.* 4, 5–7.
- This, H., 2006a. Food for tomorrow? How the scientific discipline of molecular gastronomy could change the way we eat. *EMBO Rep.* 7, 1062–1066.
- This, H., 2006b. Modelling dishes and exploring culinary 'precisions': the two issues of molecular gastronomy. *Br. J. Nutr.* 93, S139–S146.
- This, H., 2007. Formal descriptions for formulation. *Int. J. Pharm.* 344 (1–2), 4–8.
- This, H., 2008. Molecular gastronomy vs molecular cooking. *Food Technol.* 62 (12), 108.
- This, H., 2009. Molecular gastronomy, a scientific look at cooking. *Acc. Chem. Res.* 42, 575–583.
- This, H., 2011a. Molecular gastronomy in France. *J. Culin. Sci. Technol.* 9 (3), 140–149.

- This, H., 2011b. The last ten years of molecular gastronomy. *Actual. Chim.* 353–354, 111–118.
- This, H., 2013a. Molecular gastronomy is a scientific discipline and note-by-note cuisine is the next culinary trend. *Flavour* 2, 1.
- This, H., 2013b. Solutions are solutions, and gels are almost solutions. *Pure Appl. Chem.* 85, 257–276.
- This, H., 2014. *Note by Note Cooking: The Future of Food* (M.B. DeBevoise, Trans.). Columbia University Press, New York.
- Thomson, H., 2014. Chemical Cuisine Poised to Shake up Food Chain. Available at: <https://www.newscientist.com/article/mg22229722-900-chemical-cuisine-poised-to-shake-up-food-chain/>.
- Valverde, J., October, 2007. Study of the Modifications Induced by Various Culinary and Industrial Treatments of Pigment Systems from Immature Pods of Green Beans (*Phaseolus vulgaris* L.); Introduction of New Analytical Methods for the Study of Such Systems (Ph.D. thesis), University Paris VI.
- Van Der Linden, E., McClements, D.J., Ubbink, J., 2008. Molecular gastronomy: a food fad or an interface for science-based cooking? *Food Biophys.* 3, 246–254.

Relevant Websites

- <http://www.ttz-bremerhaven.de/en/research/food/research-projects/893-inicon.html> – INICON, 2003. Introduction of Innovative Technologies in Modern Gastronomy for Modernisation of Cooking.
- <http://sciences-cuisine.fr/evenements/concours/concours2013> – Sciences-Cuisine, 2013. Concours 2013 (last accessed 24.05.16.).
- http://www.sciences-cuisine.fr/images/evenements/Concours_2012/Hug_Higgins_-_Dublin_Institute.pdf – Sciences-Cuisine, 2012. Concours 2012 (last accessed 24.05.16.).